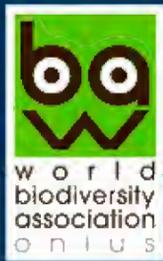


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*Carabus (Megodontus) imperialis* Fischer, 1822 - Russia, SW Altay, Kalbinskiy range

**The Genus *Carabus* Linnaeus, 1758 (Coleoptera Carabidae).** *Carabus* Linnaeus, 1758 is a genus of beetles of the Family Carabidae. It contains about 100 subgenera and is highly differentiated in about 1000 species and a very large number of subspecies. Terrestrial and carnivorous *Carabus* are nocturnal predators that feed on snails, earthworms and caterpillars. The genus is widespread in the Oloartic Region but nearly all the species are native to the Palearctic. *Carabus* are adapted to live from the sea level up to 5000 m in the mountains, they can be easily found in all kinds of habitats except the deserts and the areas permanently covered by ice. Unable to fly they usually have reduced to rudimental wings, a very few species occasionally have individuals capable of flying: *C. clatratus*, *C. granulatus* and, probably, *C. maurus*, which makes them excellent biogeographical indicators. *Carabus* are of medium to large size (12 mm to 65 mm) with developed mandibles and long and strong legs; the dorsal surface of the body frequently has a sculpture formed of three kinds of longitudinal parallel and symmetrical arranged striae and deep points; often the sculpture is very diversified and shows conspicuously morphological variations: totally erased, irregular, protruding ribs, with large and deep fovea, etc. Very often *Carabus* are colorful and of fascinating beauty. For these reasons they are so attractive and notable items for collections, in fact they have been collected and studied since, at least, 200 years. *Carabus* is one of the most deeply studied groups of Coleoptera, with a huge literature on their taxonomy, biology, phylogeny, ecology and biogeography. Nevertheless, the genus is still far to be completely known, in fact a number of new taxa are described every year especially from the most remote areas of Asia and many taxonomic problems are far to be solved.

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Cover photo by A. Plutenko



1. *Carabus (Megodontus) schoenherri sajanus* Breuning, 1927 - Russia, Siberia, W Sajjan Mts., A. Plutenko.



2. *Carabus (Megodontus) leachi panzeri* Dejean, 1829 - Russia, SW Altay, Kalbinskiy range, A. Plutenko.



3. *Carabus (Limnocarabus) clatratus auranensis* Müller, 1902 - Serbia, Vojvodina, Ruma, Sava river, I. Rapuzzi.

## First record of *Mesophylax aspersus* (Rambur, 1842) from the Republic of Kosovo (Trichoptera Limnephilidae)

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### ABSTRACT

The distribution of *Mesophylax aspersus* Curtis, 1834 (Trichoptera Limnephilidae) ranges from Western Europe, Mediterranean region, Madeira, Canary Islands and up to South-western Asia. According to the present knowledge it is however almost absent from South-eastern Europe. In this paper we present first record of *M. aspersus* from the Republic of Kosovo. This is at the same time first country record of the genus. Unlike many countries where this species is present abundantly in our case it is extremely rare. A single adult male specimen of *M. aspersus* was found in an ultraviolet light trap at the Blinajë Hunting Reserve on August 23rd 2013. This has been a single specimen of this species caught at this locality during a one year monthly sampling of caddisflies with UV light traps and entomological net. Another male specimen has been caught on September 24th 2014 at the same locality. Streams and rivers in all parts of Kosovo were surveyed during the period 2009-2014 for Trichoptera species and currently the Blinajë Hunting Reserve is the only locality where this species has been found. The distributional area of this species has been considerably expanded by this record. The closest country where this species has been recorded is Bosnia and Herzegovina.

### KEY WORDS

*Mesophylax aspersus*; Kosovo; Trichoptera; Balkan Peninsula.

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### INTRODUCTION

The genus *Mesophylax* McLachlan 1882 (Trichoptera Limnephilidae) is classified according to Schmid (1955, 1957) in Stenophylacini tribus close to genera *Stenophylax* Kolenati, 1848 and *Micropterna* Stein, 1874; this genus consists by only six species in the European fauna (Malicky, 1998; 2004).

Species of genus *Mesophylax* are mainly distributed in the Mediterranean area and radiate quite far to the West, North, East, South-west and South-east (Malicky, 1998).

*Mesophylax aspersus* Curtis, 1834 has a distribution mostly limited in countries surrounding the Mediterranean Sea, occurring from the Canary Islands to the Near East (e.g. Schmid, 1957; Botosaneanu, 1974; Dakki, 1987; Bonada, 2004).

From the biological point of view, adults of *M. aspersus* emerge in spring and undergo a summer diapause in caves (Bouvet & Ginet, 1969; Botosaneanu, 1974; Salavert et al., 2011). They do not feed during the adult stage, surviving most probably on the reserves of the adipose tissue accumulated during the larval phase (Bournaud, 1971).

## MATERIAL AND METHODS

### *Data sampling and processing*

Adult caddisfly specimens were collected with entomological net and ultraviolet light trap. The sampling was carried out monthly between March and December 2013 and only casually during the autumn of 2014. Ultraviolet light was placed above the white pan of 60 cm in diameter filled 10 cm with water with a few drops of detergent. The trap was placed on stream bank and operated from dusk until next morning. Collected samples were preserved in 80 % ethanol. The specimens were identified under a stereomicroscope with determination keys from Malicky (2004) and Kumanski (1985, 1988). Specimens were collected by Halil Ibrahim and were determined by Halil Ibrahim. Specimens of *M. aspersus* were verified by Professor Hans Malicky. The collection is deposited at the Laboratory of Zoology of the Faculty of Natural and Mathematical Sciences, University of Prishtina, Kosovo.

### *Study area*

The territory of Blinajë Hunting area designated as special reserve zone is located in central part of Kosovo, 15 km on the western side of Lypjan town. The total surface of Blinajë special reserve is 5500 ha and stretches in the territory of three municipalities: Lypjan, Shtime and Glllogoc. The altitude within this territory ranges from 670 to 860 m above sea level. There are 33 artificial lakes present inside Blinajë special reserve.

The sampling site (Fig. 1) is located at the spring area of the only stream inside this area which is adjacent to the biggest lake inside Blinajë special reserve (42.5185°N, 20.9788°E, and 721 m above sea level).

## RESULTS

Family LIMNEPHILIDAE

*Mesophylax* McLachlan, 1882

*Mesophylax aspersus* Curtis, 1834

A single adult male specimen of *Mesophylax*

*aspersus* was found in an ultraviolet light trap at the Blinajë Hunting Reserve on August 23rd 2013. This has been a single specimen of this species caught at this locality during a one year monthly sampling of caddisflies with UV light traps and entomological net.

Other species associated with *M. aspersus* in this sample are: *Potamophylax pallidus* (Klapalek, 1899) (10 males, 3 females), *Micropterna nycterobia* McLachlan, 1875 (4 male, 1 female), *Wormaldia occipitalis* (Pictet, 1834) (1 male), *Hydropsyche saxonica* McLachlan, 1884 (2 males) and *Hydropsyche* sp. (5 females); leg. Halil Ibrahim.

Another male specimen of *M. aspersus* has been caught on September 24th 2014 at the same locality with ultraviolet light trap.

Other species associated with *M. aspersus* in this sample are: *Potamophylax pallidus* (5 males, 2 females), *Micropterna nycterobia* (1 male, 1 female) and *Hydropsyche* sp. (2 females); leg. Halil Ibrahim.

## DISCUSSION AND CONCLUSIONS

In this paper we present first record of *Mesophylax aspersus* from the Republic of Kosovo. This is at the same time first country record of the genus. The distribution of *M. aspersus* ranges from Western Europe, Mediterranean region, Madeira, Canary Islands and up to southwestern Asia (until Cachemira) (Malicky, 1998; Bonada et al., 2004). In the Balkan Peninsula the species is however rare. It has been previously reported from Bulgaria (Kumanski, 1988) but after a revision of this genus (Malicky, 1998), the eastern part of the Balkan Peninsula seems to be inhabited by *M. impunctantus* McLachlan, 1884 and not *M. aspersus* (Kumanski, 1997, 2007).

The distributional area of *M. aspersus* has been considerably expanded by this record. The closest country where this species has been recorded is Bosnia and Herzegovina (Radovanović, 1935). This record is almost eight decades old and in meantime despite detailed investigations in Bosnia and Hercegovina (eg. Marinković-Gospodnetić, 1966, 1970, 1971, 1978; Stanić-Koštroman, 2009), this species hasn't been found any more. In Macedonia, a neighboring country to Kosovo, as in the rest of the eastern part of the Balkan Penin-

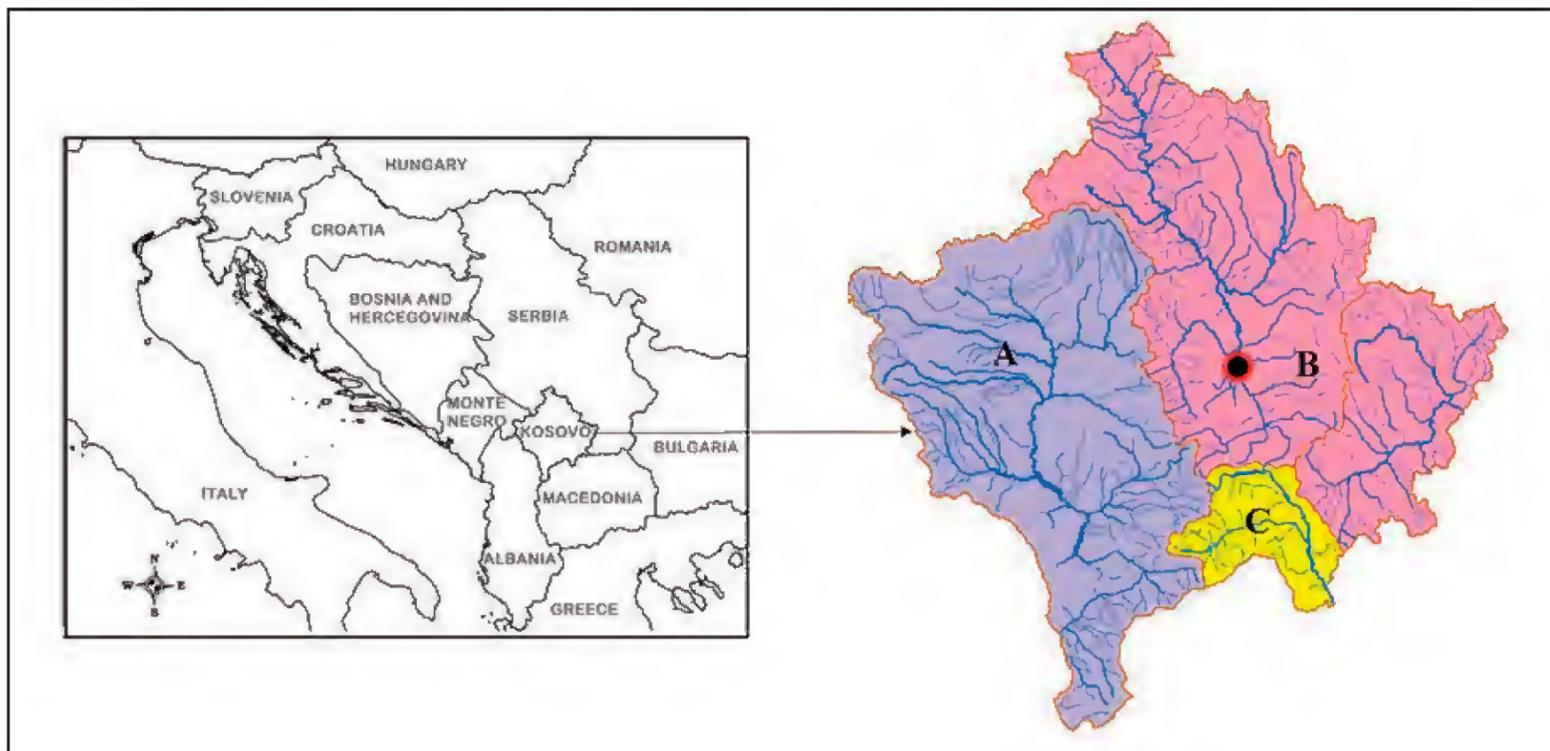


Figure 1. Sampling site in Blinajë Hunting Reserve: A) Adriatic Sea Basin, B) Black Sea Basin, C) Aegean Sea Basin.

sula up to the Western Anatolia is present a subspecies *M. impunctatus aduncus* Navas, 1923 (Kumanski, 1997). Thus, in the continental part of the Balkan Peninsula, Kosovo seems to be the border line between the distribution of *M. aspersus* and *M. impunctatus*.

The species seems to be very rare in Kosovo. More than 100 localities (Ibrahimi, 2011; Ibrahimi et al. 2012 a, 2012 b, 2013) in streams and rivers in all parts of Kosovo were surveyed during the period 2009–2014 for Trichoptera species and currently the Blinajë Hunting Reserve is the only locality where this species has been found. The abundance of *M. aspersus* found in Kosovo also seems to be low. Out of nearly 1100 caddisfly specimens caught during 2013 and 2014 in Blinajë Hunting Reserve, only two specimens belong to *M. aspersus*. This is not the case in other areas around the Mediterranean Sea where this species is present. For example in the Iberian Peninsula the species is quiet abundant (Bonada, 2004).

This record is a further contribution to the inventory of the caddisfly fauna of the Republic of Kosovo which is one of the poorest investigated areas in Europe (Pongrácz, 1923; Marinković-Gospodnetić, 1975, 1980; Malicky, 1986, 1999; Ibrahimi, 2007; Ibrahimi & Gashi, 2008; Ibrahimi et al., 2012 a; Ibrahimi et al., 2012 b; Ibrahimi et al., 2013; Oláh, 2010; Oláh et al., 2013a; Oláh et al., 2013b).

## ACKNOWLEDGEMENTS

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# About the presence of the snow vole, *Chionomys nivalis* (Martins, 1842) (Mammalia Rodentia Cricetidae), in Calabria, Southern Italy: data review and critical considerations

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## ABSTRACT

The presence of *Chionomys nivalis* (Martins, 1842) (Mammalia Rodentia Cricetidae) in Calabria, the southern tip of the Italian peninsula, is reported in different literature sources, but the only Calabrian specimen, from Lago Cecita, Cosenza district, is preserved into Museo Zoologico “La Specola”, Firenze. A recent examination of this specimen, moreover, has shown that it is an *Arvicola amphibius* (Linnaeus, 1758) juvenile. The distribution of *C. nivalis* along the Apennines, requires adequate insights and critical reviews.

## KEY WORDS

Apennines; Calabria; *Chionomys nivalis*; distribution.

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## INTRODUCTION

The snow vole *Chionomys nivalis* (Martins, 1842) (Rodentia Cricetidae), is a species widespread from south-western Europe through south-eastern Europe to the W Caucasus, east to Turkey, Israel, Lebanon, W Syria, W and N Iran and S Turkmenistan (Musser & Carleton, 2005). In Italy it is present continuously along the Alps, while the distribution area of the Apennines is more fragmented (A Mori, 2008). Moreover, on the latter portion, some bibliographic data, such as few Abruzzo mountains as well as the Matese Massif, between Molise and Campania, should be confirmed by more recent research (Nappi et al., 2007). Further south, always along the Apennines, the question about the snow vole presence in the Calabria region, in the southern tip of the Italian peninsula, subject of this note, is of particular interest. The presence of the species in this region, in fact, was considered uncertain and debated for nearly half a century.

From the literature search, the first value found is contained in a generic work on mammals, where snow vole is reported in Italy “*sulle Alpi e sull’Appennino, sino alla Calabria*” (“on the Alps and on the Apennines, until Calabria”), without further details (Scortecci, 1953). However, this species is absent in other publications concerning Calabrian mammals (Costa, 1839, 1845, 1847, for a correct dating of the issues of “Fauna del Regno di Napoli” written by O. G. Costa, see D’Erasmus, 1949; Moschella, 1900; Lucifero, 1909; Pasa, 1955) and Toschi (1965), expresses some doubts about its presence in the region.

Afterwards, in a study about some birds of prey from Sila Grande, Cosenza, is reported the discovery of the predation remains near a nest of buzzard *Buteo buteo* Linnaeus, 1758, 25.V.1971, consisting of “*cranio frammentario, denti e peli di Microtino, quasi certamente Microtus nivalis*” (fragmentary skull, teeth and hair of Microtine, almost certainly *Microtus nivalis*), now synonymous with *Chionomys*

*nivalis* (Dessi Fulgheri et al., 1972). This material is now lost and is no longer verifiable (P. Mirabelli, pers. com.).

Afterwards, the presence of the species in the region, based on a museal specimen, is reported by Amori et al. (1986). According to Amori (1993), “*these sporadic records could be confirmed by further and more specific research*” and in another review, Amori (1999) indicate the species distribution, in Italy, from the Alps until the central Apennines. More recently, the presence of the snow vole in Calabria, is reported in a mammals volume of “Fauna d’Italia” series (Amori, 2008) and in the section of this species of the IUCN Red List (Kryštufek & Amori, 2008).

## MATERIAL AND METHODS

In this paper, all literature data, that it was possible to find, were considered. In addition, the only Calabrian specimen, known by writers, was analysed. This consist in a liquid preserved body, with relative skull, into Museo Zoologico “La Specola”, Firenze, n. MZUF-7448 (Cosenza, Lago Cecita, 18.VIII.1970, Piero Mannucci legit; head-body: 89 mm, tail: 57 mm; ear: 10 mm; hind foot: 22 mm).

Of this specimen, skull and teeth morphologies were analyzed. Third upper molar and first lower molar, in particular, were compared with the molar morphotypes, identified by Nadachowski (1991), just in the genus *Chionomys* Miller, 1908.

## RESULTS

A recent analysis of the specimen above mentioned, has shown that the tooth morphology (Fig. 1) is that typical of water vole *Arvicola amphibius*, (Linnaeus, 1758) as well as the skull morphology, relatable to a young specimen of this species (Figs. 2, 3). As confirmed, moreover, by comparison with skulls of juvenile specimens of water vole (Museo Civico di Storia Naturale di Milano, nn. 1855, 1863, 1869, 1875, 4134; Museo di Storia Naturale, Università della Calabria: nn. SG35, SG147, AS164; Coll. Teriologica G. Aloise: n 615).

## DISCUSSION

It seems that the snow vole has colonized the southern areas of the Italian peninsula already during

very ancient times, perhaps the early middle Pleistocene. This is suggested by a finding at the site of Notarchirico, within Venosa Basin, Potenza district, characterized by the presence of archaic elements such as *Sorex* cfr. *runtonensis* Hinton 1911, *Pliomys episcopalis* Bartolomei, 1970 and *Arvicola cantianus* (Koenigswald 1973) (Sala, 1999). It is also useful to remember, in this context, the fact that among the small mammals, in Italy, Calabria is the southern distribution limit of different species (see Amori et al., 2008) some of which, of mountain environment, with disjoint areal as *Driomys nitedula* Pallas, 1778 (Capizzi & Filippucci, 2008), or fragmented areal as *Talpa caeca* Savi, 1822 (Aloise & Cagnin, 2003) and *Neomys fodiens* Pennant, 1771 (Aloise et al., 2005). *T. caeca* and *N. fodiens*, previously considered distributed along the central and northern Italy, but absent in the southern regions, were found only recently. Taking into account these assumptions, the presence of the snow vole, in Calabria, cannot be excluded, even for the lack of research in potentially suitable areas, such as, for example, Pollino Massif and Orsomarso Mountains.

Based on the results of the present work, and in the absence of some objective evidence, snow vole must be currently considered to be absent from this region. On the other hand, until now, all research related to small mammal fauna, have not yielded positive results regarding the presence of the species in Calabria (Lehmann, 1961, 1964, 1973, 1977; Aloise et al., 1985; Cagnin et al., 1986; Aloise & Cagnin, 1987) and on the basis of more than 3.000 specimens of small mammals, collected over the entire territory of Calabria during 1983-2013 (Coll. Teriologica of the Museo di Storia Naturale of the Università della Calabria and Coll. Teriologica G. Aloise), snow vole has never been found. With regard to Lago Cecita area, although it was also the subject of several investigations that have provided more than 300 specimens from traps and 84 specimens from raptors pellets, *C. nivalis* has never been found. It should also be noted that in this area there are no environments suitable for the snow vole.

Moreover, the presence of water vole, just around Lago Cecita, is supported by a liquid preserved specimen (n. SG147, Cosenza district, Spezzano Sila, Valle Capra, 18.VII.1991) and by a 6 specimen from raptor pellets into Collezione Teriologica of the Museo di Storia Naturale, Università della Calabria, by a stuffed skin (n. 4020,

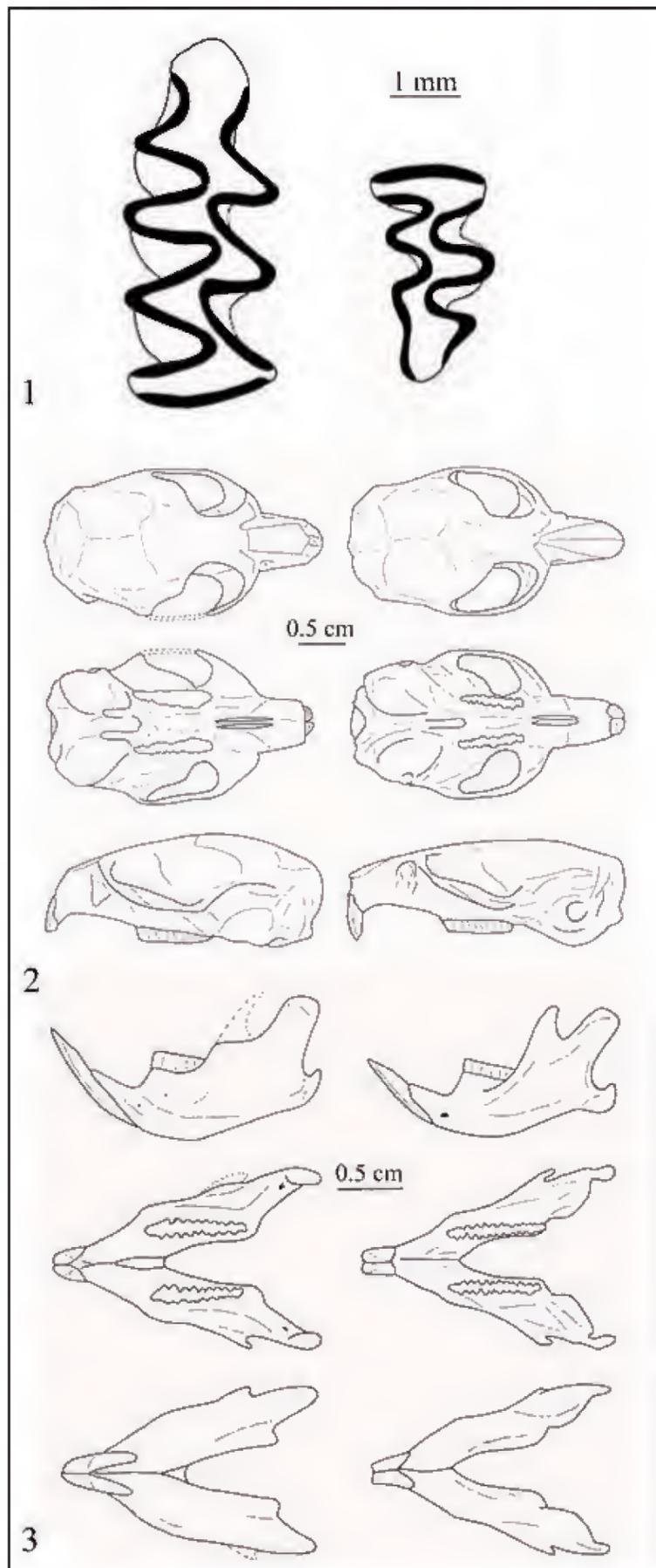


Fig. 1. Right first lower molar (left) and right third upper molar (right) of the specimen MZUF-7448 determined in this paper as *Arvicola amphibius* (see Fig. 2 for details). Figure 2, 3. Skulls (Fig. 2) and jaws (Fig. 3) in different view of juvenile of *Arvicola amphibius* (left) (Calabria, Cosenza, Lago Cecita, 18.VIII.1970, P. Mannucci leg., Museo Zoologico "La Specola", Firenze, n. MZUF-7448) and *Chionomys nivalis* (right) (Emilia Romagna, Modena, Monte Cimone, 19.IX.1990, C. Bertarelli leg., Museo Civico di Ecologia e Storia Naturale, Marano sul Panaro, n. 296).

14.VII.1963) into Museo Civico di Storia Naturale di Milano and by some observations (F. Pellegrino, 2012, pers. com.). The distribution of the snow vole, in central-southern Italy, certainly requires adequate deepening but data about water vole, a very decreasing species in Italy, recently no longer found in different historical localities, are equally interesting (Cagnin, 2008).

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# Species composition of carabid communities (Coleoptera Carabidae) in apple orchards and vineyards in Val d'Agri (Basilicata, Italy)

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## ABSTRACT

An entomological investigation was carried out in an agricultural area, mainly apple orchards, of the Agri river plain, located in some municipalities of Basilicata, Italy. Between 2012 and 2014, species richness and composition of carabid assemblages were investigated on the ground surface of differently managed (abandoned, organic, commercial and IPM) apple orchards and vineyards. Ground beetles (Coleoptera Carabidae) were sampled by means of pitfall traps. 1288 individuals belonging to 40 species were collected, representing two-thirds of the carabid fauna of this area found in our and earlier studies. The species richness varied between 4 and 20 in the different orchards. The common species, occurring with high relative abundance in the individual orchards in decreasing order were: *Pterostichus (Feronidius) melas* (Creutzer, 1799), *Pseudoophonus (Pseudoophonus) rufipes* (De Geer, 1774), *Brachinus crepitans* (Linnaeus, 1758), *Harpalus (Harpalus) dimidiatus* (P. Rossi, 1790) and *Poecilus (Poecilus) cupreus* (Linnaeus, 1758). Most of the collected ground beetles were species with a wide distribution in the Palearctic region, eurytopic and common in European agroecosystems. The assemblages were dominated by small-medium, macropterous species, with summer larvae. No endemic species were found.

## KEY WORDS

ground beetle; pitfall trapping; bioindicators; conservation; agro-ecosystem management.

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## INTRODUCTION

In the frame of the ENEA project AGRIVAL (aree AGRICole ad alto VALore naturalistico dell'alta val d'Agri = high nature value farmland in upper Val d'Agri) (Menegoni et al., 2012, 2014), an entomological investigation was carried out in an agricultural area, apple orchards and vineyards, of the Agri river plain, located in the municipalities of Marsico V., Tramutola, Grumento N. and Viggiano (Potenza, Basilicata, Italy).

The aim of this research was to investigate the Carabid assemblages. In Europe several studies

gave faunal data on similar agro-ecosystems inhabiting carabids (Kutasi et al., 2004); these studies indicate that variations in cultivation management leads to variations in carabid beetle assemblages. Although the spatial distribution of carabid beetles may be primarily determined by microhabitat conditions and biotic interactions at the local scale, identifying general patterns of carabid responses to different agro-ecosystem managements may help to understand how species, functional groups and assemblages effectively distribute, and to predict how they will cope with current and future land-use and climatic changes (Brandmayr et al., 2011; Kotze et

al., 2011). In previous studies in Europe the following species were mentioned as common (Kutasi et al., 2004): *Pseudoophonus rufipes* (De Geer, 1774), *Harpalus distinguendus* (Duftschmid, 1812), *Harpalus tardus* (Panzer, 1796), *Nebria brevicollis* (Fabricius 1792), *Pterostichus melanarius* (Illiger, 1798), *Poecilus cupreus* (Linnaeus, 1758), *Harpalus affinis* (Schrank, 1781).

## MATERIAL AND METHODS

Five traps were activated for a week every month in 12 sampling locations, from May until October. Sampling started on July, 2012 and ended on October, 2014. Locations have been selected according to the type of crop (10 apple orchards and 2 vineyards) and the managing practices (traditional, integrated and organic) (Fig. 1, Table 1). Due to logistic unpredictable problems, some of the locations selected at the beginning of the experiment (samples Aa, Ab and Ac) were not suitable anymore, and since 2013 were displaced with analogous locations, respectively samples G, H and L.

Ground beetles were sampled using plastic pit-fall traps (500 ml and 100 mm the diameter of the top) buried in the soil and filled with 50 ml salt water. Pitfalls were covered with a 10 × 10 cm plastic roof to prevent flooding.

The qualitative and quantitative data of the carabid assemblages, recorded in the orchards of the selected areas of Val d'Agri, were analyzed in three different ways: 1) the weighted average of different species in the total catch of the 12 samples; 2) the sum of the scores was calculated (where the most abundant species collected in an orchard were placed in decreasing order, and the dominant species, with highest relative abundance scored 8, the second one 7 etc.; the scores from different orchards were summarised by species: the highest possible score, if a species was dominant in all orchards, was  $[12 \times 8] 96$ ); 3) the presence or absence of the species in the orchards was also investigated. The most widely distributed species (which were found in 12 of the 12 investigated orchards) got 100%; the species, which was collected in 9 orchards, got 75% etc.

Carabids were identified to the species level, if possible, following the nomenclature of Fauna

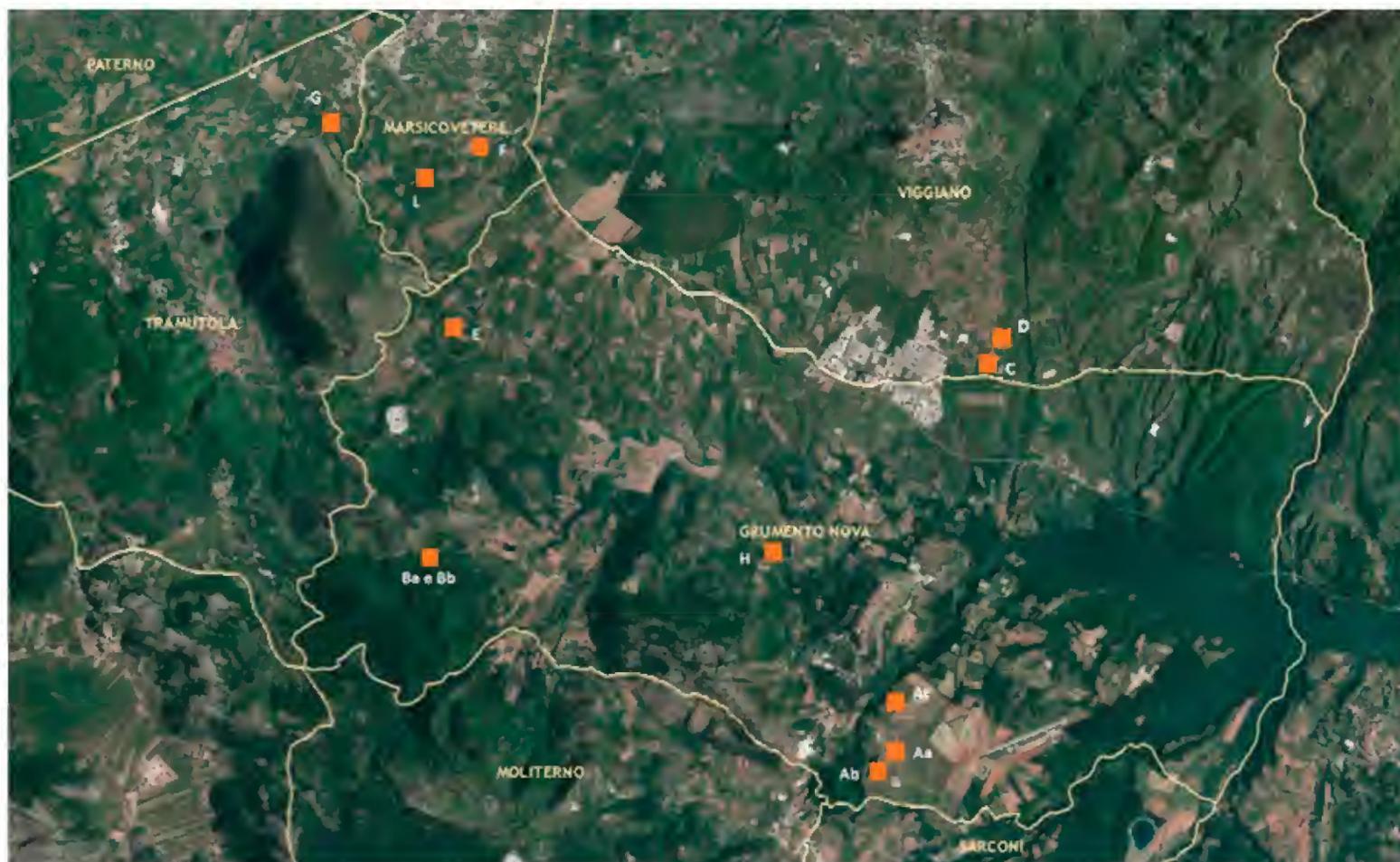


Figure 1. Locations of sampled farms: Val d'Agri (Basilicata, Italy). Modified from AGEA 2011.

FARM	code	Lat. N	Long. E	destination	management	environment
New Ager	A a	40° 16'	15° 53'	apple orchard	conventional	agro-ecosystem
New Ager	A b	40° 15'	15° 53'	apple orchard	IPM	agro-ecosystem
New Ager	A c	40° 16'	15° 53'	apple orchard	IPM	ecosystem
Caputi	B a	40° 17'	15° 49'	apple orchard	conventional	agro-ecosystem
Caputi	B b	40° 17'	15° 49'	apple orchard	conventional	near a ditch
Fiorenti	C	40° 18'	15° 54'	apple orchard	abandoned	industrial zone
Fiorenti	D	40° 18'	15° 54'	vineyard	conventional	agro-ecosystem
Donza	E	40° 19'	15° 49'	apple and pear orchard	abandoned	agro-ecosystem
Pisani	F	40° 20'	15° 50'	vineyard	organic	agro-ecosystem
Tropiano	G	40° 21'	15° 49'	apple orchard	conventional	agro-ecosystem
Padula	H	40° 17'	15° 52'	apple orchard	abandoned	agro-ecosystem
Bosco Galdo	L	40° 20'	15° 50'	apple orchard	IPM	agro-ecosystem

Table 1. Localization of farms samples and some their characteristics (Val d'Agri, Basilicata, Italy).

Europaea (Vigna-Taglianti, 2013). Specimens, preserved in alcohol, are stored in the collection of the ENEA Casaccia research centre.

## RESULTS

Overall, 1,288 individuals have been collected belonging to 40 carabid species which represent, according to our elaboration of the available data (Casale et al., 2006; Letardi et al., 2014a,b), two thirds of the total carabid fauna reported for this geographic area. The species richness of the investigated carabid assemblages ranged between 4 and 20 in the different orchards: the weighted averages of different species in each samples were not statistically significantly different, nevertheless they show an evident tendency to increase in terms of biodiversity moving from conventional management farms towards organic and semi-abandoned, re-naturalized ones (Table 2). The relatively high biodiversity value in the conventional managed farm New Ager (Aa) could be an exception due to the very few number of samples (just 4, all during 2012) collected: in 2013 and 2014 it was not possible to sample inside the New Ager farm, due to technical logistic impediments.

Qualitative and quantitative data analyses have been performed among the collected carabid species following 3 methods: their proportion in the total catch of the investigated orchards; the scoring of the seven commonest species in the different orchards (total scores) and their presence in the orchards (distribution).

The most abundant species was *Pterostichus melas* (33%) followed by *Pseudoophonus rufipes* (20%), *Brachinus crepitans* (14%), *Harpalus dimidiatus* (8%) and *Poecilus cupreus* (6%). The species which dominated the carabid assemblages (with the total scores) were *Pterostichus melas* (80), *Pseudoophonus rufipes* (79), *Harpalus dimidiatus* (45), *Poecilus cupreus* (18), *Brachinus crepitans* (14), *Carabus rossii* Dejean, 1826 (11) and *Calathus fuscipes* (Goeze, 1777) (10) (Table 3). *Pterostichus melas* and *Pseudoophonus rufipes* were found in all investigated samples (100%), *Harpalus dimidiatus* was found in the 75% of the different habitats, *Poecilus cupreus* was found in the 67%, *Anchomenus dorsalis* (Pontoppidan, 1763) and *Calathus* sp. pr. *montivagus* Dejean, 1831 were found in the 58%, while *Amara* sp. pr. *aenea* (De Geer, 1774) and *Nebria brevicollis* (Fabricius, 1792) were also quite common (50%).

FARM	code	sam- ples	average	stan- dard dev.	species num- ber
New Ager	A a	4	3.00	±1.83	6
New Ager	A b	4	1.50	±1.29	4
New Ager	A c	4	2.25	±1.26	5
Caputi	B a	17	1.65	±1.27	13
Caputi	B b	16	1.75	±1.39	13
Fiorenti	C	14	2.93	±1.69	16
Fiorenti	D	17	2.00	±1.84	18
Donza	E	15	4.60	±2.32	18
Pisani	F	17	3.18	±1.70	20
Tropiano	G	12	1.00	±1.28	10
Padula	H	13	2.92	±1.98	17
Bosco Galdo	L	13	1.38	±1.12	10

Table 2. Weighted average of species biodiversity.

It can be concluded that four species *Pterostichus melas*, *Pseudoophonus rufipes*, *Harpalus dimidiatus* and *Poecilus cupreus* were among the commonest species in the investigated samples in respect of all three approaches.

## DISCUSSION

Altogether, as a result of our investigations, 40 carabid species, representing about two-thirds of the whole carabid fauna reported in this area in our and previous studies (Casale et al., 2006), were found in apple orchards and vineyards of the medium area of the Agri river plain.

Most of the collected carabids, both in the whole area and in each sample, were species with a wide distribution in the Palearctic region, eurytopic and common in European agroecosystems.

The assemblages were dominated by small-medium, macropterous species, with summer larvae; we didn't find any endemism (Table 4).

species	Aa	Ab	Ac	Ba	Bb	C	D	E	F	G	H	L	Total score
<i>P. melas</i>	+	14.3	7.3	41	6.2	21.2	62.6	41.2	18.8	52.3	15.9	57.8	80
<i>P. rufipes</i>	46.2	28.6	87.8	6.4	87.7	50	10.1	7.4	12.5	8.1	5.7	15.6	79
<i>H. dimidiatus</i>		37.1		5.1	+	14.4	13.1	23.5	+		8.1	6.3	45
<i>P. cupreus</i>	43.1	+			+	+		10.3		+	7.2	+	18
<i>B. crepitans</i>	+			6.4					+	+	50.5		14
<i>C. rossii</i>				9		+	+		28.1		+		11
<i>C. fuscipes</i>		+	+						5.2	10.5		+	10
<i>A. aenea</i>		+		+			+			5.8	+	+	5
<i>C. convexus</i>									10.4				5
<i>D. clypeatus</i>				5.1							+		4
<i>O. cribricollis</i>		+		5.1						+			4
<i>C. preslii</i>				+		+			5.2		+		3
specimen n°	65	35	41	78	65	52	99	68	96	86	333	270	
species n°	6	10	4	17	5	10	13	13	16	18	18	20	

Table 3. Relative abundance (%) and the total scores of the most abundant carabid species. Relative abundance lower than 5% were marked with +.

<p style="text-align: center;"><b>Aa</b></p> <p><i>Brachinus crepitans</i> <i>Calathus circumseptus</i> <i>Nebria brevicollis</i> <i>Poecilus cupreus</i> <i>Pseudoophonus rufipes</i> <i>Pterostichus melas</i></p> <p style="text-align: center;"><b>Ab</b></p> <p><i>Calathus fuscipes</i> <i>Harpalus serripes</i> <i>Pseudoophonus rufipes</i> <i>Pterostichus melas</i></p> <p style="text-align: center;"><b>Ac</b></p> <p><i>Acinopus megacephalus</i> <i>Harpalus dimidiatus</i> <i>Poecilus cupreus</i> <i>Pseudoophonus rufipes</i> <i>Pterostichus melas</i></p> <p style="text-align: center;"><b>Ba</b></p> <p><i>Agonum sordidum</i> <i>Amara sp.pr. aenea</i> <i>Anchomenus dorsalis</i> <i>Calathus sp.pr. montivagus</i> <i>Carabus rossii</i> <i>Cryptophonus tenebrosus</i> <i>Cymindis miliaris</i> <i>Harpalus dimidiatus</i> <i>Harpalus sp.</i> <i>Nebria brevicollis</i> <i>Pseudoophonus rufipes</i> <i>Pterostichus melas</i> <i>Pterostichus cfr. nigrita</i></p> <p style="text-align: center;"><b>Bb</b></p> <p><i>Agonum sordidum</i> <i>Anchomenus dorsalis</i> <i>Brachinus sclopeta</i> <i>Cychrus italicus</i> <i>Harpalus dimidiatus</i> <i>Harpalus serripes</i> <i>Harpalus sp.</i></p>	<p style="text-align: center;"><b>Bb</b></p> <p><i>Nebria brevicollis</i> <i>Poecilus cupreus</i> <i>Pseudoophonus rufipes</i> <i>Pterostichus melas</i> <i>Pterostichus cfr. nigrita</i> <i>Trechus quadristriatus</i></p> <p style="text-align: center;"><b>C</b></p> <p><i>Acinopus megacephalus</i> <i>Anchomenus dorsalis</i> <i>Brachinus crepitans</i> <i>Calathus cinctus</i> <i>Calathus circumseptus</i> <i>Calathus fuscipes</i> <i>Calathus sp. pr. montivagus</i> <i>Carabus convexus</i> <i>Carabus preslii</i> <i>Carabus rossii</i> <i>Cychrus italicus</i> <i>Harpalus dimidiatus</i> <i>Pseudoophonus rufipes</i> <i>Pterostichus melas</i> <i>Pterostichus cfr. nigrita</i> Carabidae sp. 1</p> <p style="text-align: center;"><b>D</b></p> <p><i>Amara sp. pr. aenea</i> <i>Anchomenus dorsalis</i> <i>Brachinus crepitans</i> <i>Bradycellus cfr. verbasci</i> <i>Calathus cinctus</i> <i>Calathus fuscipes</i> <i>Calathus sp. pr. montivagus</i> <i>Carterus cfr. fulvipes</i> <i>Cryptophonus tenebrosus</i> <i>Cymindis miliaris</i> <i>Harpalus serripes</i> <i>Nebria brevicollis</i> <i>Olisthopus cfr. fuscatus</i> <i>Ophonus cribricollis</i> <i>Poecilus cupreus</i> <i>Pseudoophonus rufipes</i> <i>Pterostichus melas</i></p>	<p style="text-align: center;"><b>D</b></p> <p><i>Trechus quadristriatus</i></p> <p style="text-align: center;"><b>E</b></p> <p><i>Amara sp.pr. aenea</i> <i>Anchomenus dorsalis</i> <i>Brachinus crepitans</i> <i>Calathus circumseptus</i> <i>Calathus sp. pr. montivagus</i> <i>Carabus preslii</i> <i>Carabus rossii</i> <i>Carterus cfr. fulvipes</i> <i>Chlaenius chrysocephalus</i> <i>Ditomus clypeatus</i> <i>Drypta dentata</i> <i>Harpalus dimidiatus</i> <i>Harpalus distinguendus</i> <i>Nebria brevicollis</i> <i>Ophonus sp.</i> <i>Poecilus cupreus</i> <i>Pseudoophonus rufipes</i> <i>Pterostichus melas</i></p> <p style="text-align: center;"><b>F</b></p> <p><i>Agonum sordidum</i> <i>Amara sp.pr. aenea</i> <i>Anchomenus dorsalis</i> <i>Brachinus sclopeta</i> <i>Calathus cinctus</i> <i>Calathus fuscipes</i> <i>Calathus sp. pr. montivagus</i> <i>Carterus cfr. fulvipes</i> <i>Harpalus dimidiatus</i> <i>Harpalus distinguendus</i> <i>Harpalus sp.</i> <i>Harpalus sp.pr. affinis</i> <i>Lebia sp.</i> <i>Nebria brevicollis</i> <i>Olisthopus cfr. fuscatus</i> <i>Poecilus cupreus</i> <i>Pseudoophonus rufipes</i> <i>Pterostichus melas</i> <i>Trechus quadristriatus</i> Carabidae sp. 2</p>	<p style="text-align: center;"><b>G</b></p> <p><i>Amara sp. pr. aenea</i> <i>Calathus fuscipes</i> <i>Egadroma cfr. marginatum</i> <i>Harpalus dimidiatus</i> <i>Harpalus distinguendus</i> <i>Ophonus cribricollis</i> <i>Poecilus cupreus</i> <i>Pseudoophonus rufipes</i> <i>Pterostichus melas</i> <i>Pterostichus cfr. nigrita</i></p> <p style="text-align: center;"><b>H</b></p> <p><i>Amara sp.pr. aenea</i> <i>Brachinus crepitans</i> <i>Calathus cinctus</i> <i>Calathus circumseptus</i> <i>Calathus sp. pr. montivagus</i> <i>Carabus preslii</i> <i>Carabus rossii</i> <i>Cryptophonus tenebrosus</i> <i>Ditomus clypeatus</i> <i>Harpalus dimidiatus</i> <i>Harpalus distinguendus</i> <i>Harpalus serripes</i> <i>Harpalus sp.</i> <i>Ophonus cribricollis</i> <i>Ophonus (Metophonus) sp.</i> <i>Pseudoophonus rufipes</i> <i>Pterostichus melas</i></p> <p style="text-align: center;"><b>L</b></p> <p><i>Anchomenus dorsalis</i> <i>Calathus circumseptus</i> <i>Calathus sp. pr. montivagus</i> <i>Carabus preslii</i> <i>Carabus rossii</i> <i>Harpalus dimidiatus</i> <i>Poecilus cupreus</i> <i>Pseudoophonus rufipes</i> <i>Pterostichus melas</i> Carabidae sp. 2</p>
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Table 3. Species collected in each locality (Val d'Agri, Basilicata, Italy).

The common species in agro-environments investigated were the same as those usually found in field crops and which can be considered as "disturbance-tolerant" species.

The number of captures, qualitative and quantitative data here reported have shown a clear

tendency to be more abundant moving from conventional towards to organic managements, not supported by a solid statistical analysis; therefore sampling more distributed in terms of time and replicates would be necessary to provide more suitable data.

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# Paleontologic and stratigraphic data from Quaternary deposits of Leghorn subsoil (Italy)

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## ABSTRACT

The Authors describe two malacofauna fossils attributable, on biostratigraphic and stratigraphic base, to Pleistocene and Late Pleistocene, observed by a drilling carried out in the east of the city of Leghorn, Italy. The malacological fossil association of Pleistocene was low in number of individuals but well characterized in the number of species; the one attributable to the Upper Pleistocene is related to contemporary associations already known in literature for Leghorn subsoil, and shows two species not previously reported. The malacofauna of the Lower Pleistocene is characteristic of the current coastal muddy debris; Tyrrhenian malacofauna mainly consists of allochthonous elements, from a “*Posidonia* meadows” and the depositional environment is attributable to the Mediterranean current seabeds. The stratigraphy of the subsoil of the area differs from that known in literature, as it shows a single level of “Panchina” that rests directly above clay sediments of the Lower Pleistocene.

## KEY WORDS

Malacofauna; Stratigraphy; Pleistocene; Leghorn.

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## INTRODUCTION

The present study is part of a project examining the malacofauna found in sediments forming the substrate of the city of Leghorn (Italy) which is not always investigable directly. This is mainly because of the closure, at the end of the nineteenth century, of all the quarries, and the rapid development, during the last century, of the city itself, which resulted in the obliteration of the last outcrops. In the second half of 1900 were published a few papers of malacology, including one related to the excavation of the dry dock of the “Torre del Fanale” (Barsotti et al., 1974). Therefore, the study of the malacofauna of Leghorn subsoil can be carried out

only by analysing new successions, even within the town limits, to refine the knowledge on biotic fossils and compare them with those already known.

Recently, have been published data on two new sections, one at the immediate northeast outskirts of the town in locality “Vallin Buio” (Ciampalini et al., 2014a), where the Tyrrhenian sediments rest directly on those of the Pliocene, and the other one from an excavation inside the town, near the section studied herein, and called section “via Gramsci” from its location (Ciampalini et al., 2014b), in which is highlighted a malacofauna contained in the top level of the “Panchina” formation.

The present paper describes the discovery of two unpublished fossil malacofauna in deposits attrib-

uted to Lower Pleistocene and the Upper Pleistocene.

These deposits were brought to light during the execution of a geological drilling for the geotechnical characterization of the subsoil and herein named, section “via Manasse” (Figs. 1, 2). Within the sediments, in addition to molluscs, were recovered ostracods and foraminifera, whose study was carried out to assess the chronostratigraphic framework of the sediments and their paleoenvironmental characterization.

### Geological framework

In the subsoil of Leghorn, in a modest layer of reddish sands (“Sabbie di Donoratico”), there are up to two calcarenitic sands (Panchina) which, on the basis of stratigraphic and faunal evidence, are generally attributable to the Tyrrhenian (Malatesta, 1942; Barsotti et al., 1974; Ciampalini et al., 2006).

The levels of “Panchina” belong to a morphological element known in the literature as “Terrazzo di Livorno” (Barsotti et al., 1974; Lazzarotto et al., 1990), interpreted as a polycyclic marine terrace (Federici & Mazzanti, 1995) that developed during

the stage 5 of the marine isotope stratigraphy (“marine isotope stage 5”) (Chen et al., 1991; Antonioli et al., 1999). The substrate of this terrace consists of sediments related to the Lower Pleistocene that, based on fossil remains found on several occasions, were attributed to the “Formazione di Morrone” (Bossio et al., 1981; Dall’Antonia et al., 2004; Boschian et al., 2006).

### MATERIAL AND METHODS

The sediments analyzed originate from a drilling, the location of which is shown in figure 1, carried out for the geological and geotechnical assessment of the subsoil (Fig. 2). The fossil shells were collected directly from sediments or after washing them. Considering the small amount of sedimentary material available, it has not been possible to recover a large number of complete specimens of large dimensions.

For measures of shells we used the following abbreviations: d = maximum diameter; l = maximum

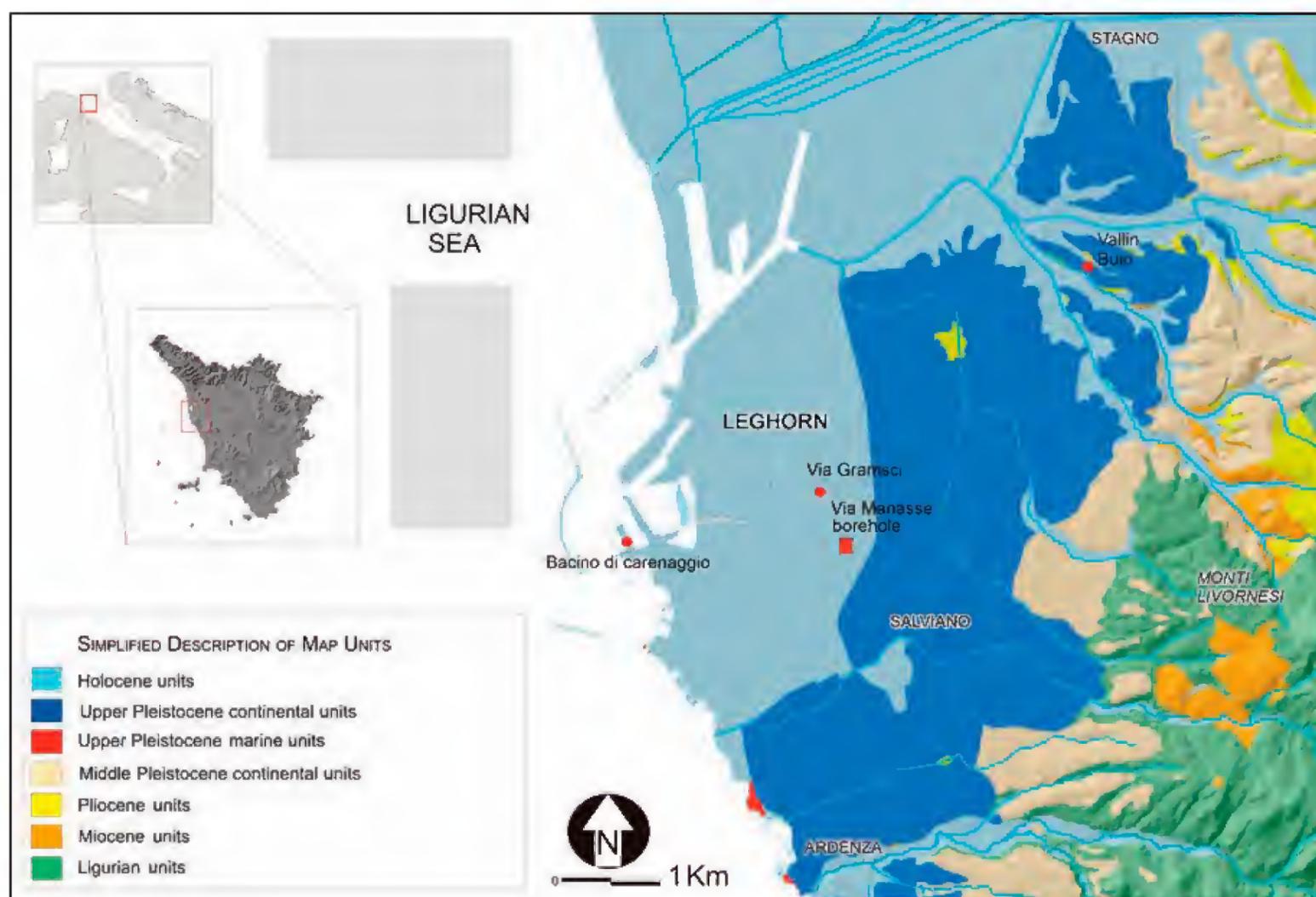


Figure 1. Geological sketch map and location of the investigated borehole from “Via Manasse” (43°33’01” N-10°19’16” E).

width; h = maximum height. The measurements are in millimeters and the specimens figured are numbered in Table 1.

Abbreviations used to indicate the marine biotic communities are according to Pérès & Picard (1964): HP, biocenosis of photophilic algae; SGCF, biocenosis of coarse sands with influence of bottom currents; VTC, biocenosis of coastal terrigenous muds. The list of Tyrrhenian molluscs found in this study, reported in Table 1, is compared with those of other locations recently studied, i.e. “Vallin Buio” and “via Gramsci” (Ciampalini et al., 2014a, 2014b), and with that of the careening basin of the “Torre del Fanale” which is, to date, the largest excavation (Barsotti et al., 1974).

The studied material is deposited, with the catalog number MSNM 827, at the Museum of Natural History of the Mediterranean in Leghorn.

Were weighed 150 g of anhydrous material, employed for the micropalaeontological analysis. The samples were disgregated in water at 100 °C, filtered in sieves with meshes net of 74 µm and then dried in oven at 70 °C. The micropalaeontological analysis was conducted primarily on foraminifera and ostracods. As for the biostratigraphic and palaeoecological appearance of identified taxa, reference is made to the main available papers (Ruggieri, 1973; Dall'Antonia et al., 2004; Guernet, 2005; Faranda & Gliozzi, 2008).

## RESULTS

In the sequence under consideration, starting from ground level, have been recognized seven lithological intervals listed below, from which three samples, indicated with the abbreviations MAN1, MAN2 and MAN3, respectively, were collected, at different elevations (Fig. 3), for micropalaeontological analysis.

Interval 1 (0-0.80 m): dark brown sands, with nodules of Mn. In the first 10-15 cm, dark in color due to the presence of coal, are visible brick fragments that indicate a very recent age;

Interval 2 (0.80-1.10 m): sand with fragments of wood and sand with gravel;

Interval 3 (1.10-3.80 m): ocher sandy silt with Fe-Mn nodules and rare levels of gravel. This level becomes darker in the upper part;



Fig. 2. Core photograph, showing the first 5 meters from ground level; the arrow indicates the portion of the borehole where it was found the Tyrrhenian malacofauna described

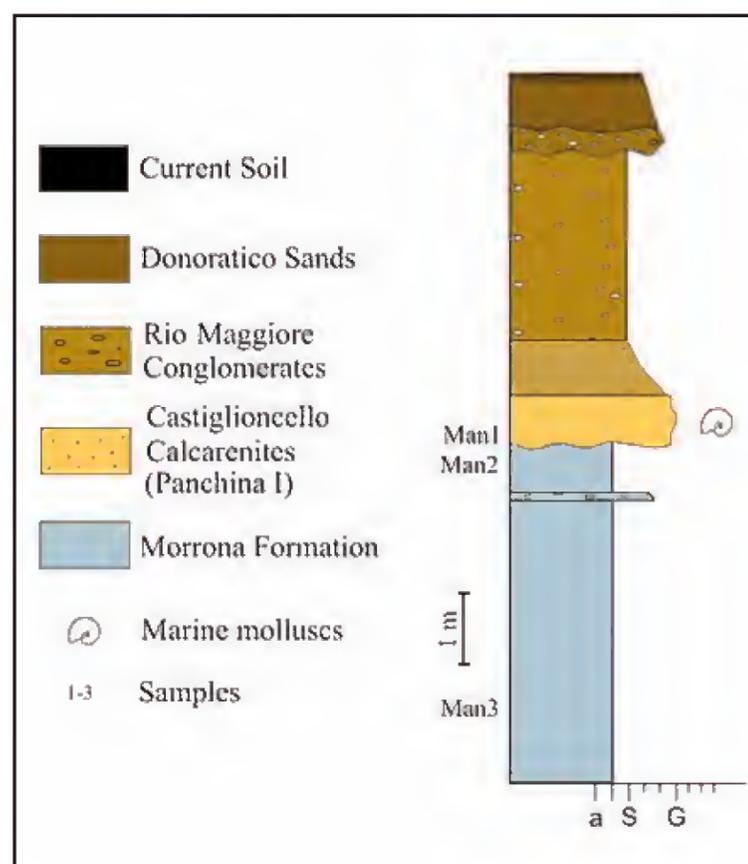


Figure 3. Stratigraphic column of the borehole from “Via Manasse”; sample position is shown; a - Shales, S - Sands, G - Gravels

Interval 4 (3.80-4.50 m): beige calcareous sand, fossiliferous. From this level the sample MAN1 was taken;

Interval 5 (4.5-4.7 m): gray-blue sand. From it the sample MAN2 was taken;

Interval 6 (4.7-10 m): gray blue clayish silt with sandy fossiliferous levels; at 6 m of depth is present a decimeters level of gravel ocher in color. From this range the sample MAN3 was taken;

Interval 7 (10-20 m): gray bluish clay silt with rare fossils.

By micropalaeontological analysis conducted on the sample MAN1, taken within the interval 4, it was observed a malacofauna consisting of few individuals, in good conditions, representing fifteen species of gastropods and four bivalves; the full list is shown in Table 1. By comparison of the species observed with those reported for coeval sections recently described, and those listed for the larger "Bacino di Carenaggio" (see Barsotti et al., 1974; Ciampalini et al., 2014a, 2014b), it appears the presence of two species not previously reported, i.e. *Gibbula turbinoides* (Deshayes, 1835) and *Fusinus pulchellus* (Philippi, 1844).

Within Foraminifera, the conservation status varies widely, from good to bad; frequently, individuals of *Elphidium crispum* (Linnaeus, 1758) were found associated with common representatives of *Elphidium* spp., *Ammonia parkinsoniana* (d'Orbigny, 1839), *Ammonia beccarii* (Linnaeus, 1758), *Ammonia* spp. The residue of the washing consists of a medium coarse sand, white in color. Granules are formed by lithics, quartz and fossil fragments (molluscs, echinoids, foraminifera) very elaborate, subspherical and with traces of erosion. Noteworthy, part of the components of the sand are cemented forming agglomerates.

The analysis conducted on the sample MAN2, from interval 5, allowed to recognize a rich and diversified association of frequent specimens of *Loxoconcha subrugosa* (Ruggieri, 1977), with specimens of *Aurila lanceaeformis* (Uliczny, 1969), *A. convexa* (Baird, 1850), *Pterigo cythereis*, *Cytheropteron sulcatum* (Bonaduce, Ciampo et Masoli, 1976), *C. latum* (Müller, 1894), *Paracytheridea* cf. *hexalpha* (Doruk, 1980), and representatives of the rare species *Cimbourila cimbaeformis* (Seguenza, 1883), among the ostracods. Moreover, specimens belonging to the Foraminifera genera *Elphidium*, *Ammonia*, *Dorothia*, *Cassidulina* have been collected. The residue of washing is made up of a sand with a grain size ranging from fine to coarse and gray in color. The granules are complex, mainly made of lithics.

The sample MAN3, from the interval 6, comprises a fossil association rich either in number of specimens or in number of species. Were found numerous specimens of *Loxoconcha subrugosa*, and valves belonging to the genera *Aurila*, *Pterigo cythereis*, *Cytheropteron*, *Bosquetina*, *Buntonia* (Ostracoda); specimens belonging to the genera

*Elphidium*, *Ammonia*, *Dorothia*, *Cassidulina* and to the species *Hyalinea baltica* (Schroeter, 1783) (Foraminifera) were collected. In addition, frequent remains of echinoids, bryozoans and molluscs were observed. Among these have been identified the species *Turritella tricarinata* (Brocchi, 1814) (Fig. 48), *Nassarius gigantulus* (Bellardi, 1882) (Figs. 49, 50) and *Corbula gibba* (Olivi, 1792) (Figs. 51, 52).

The residue of washing is a gray sand with a particle size ranging from fine to coarse. Sand grains are mainly composed of lithics and fossil remains.

## DISCUSSION

The result of the micropalaeontological analysis of the samples MAN2 and MAN3, from the intervals 5 and 6, indicate associations typical of a marine environment of the shallower part of the internal platform. Furthermore, the discovery of significant species as *Aurila lanceaeformis*, *Cimbourila cimbaeformis*, *Loxoconcha subrugosa*, *Hyalinea baltica* allow to attribute the lower part of the succession to the lower Pleistocene, in particular to the "Calabriano p.p. (Emiliano)", in agreement with the presence of the gastropod *Nassarius gigantulus* that disappears at the top of the "Emiliano" (Ragaini et al., 2007).

In levels 5 and 6 have been identified, as the most significant species, *Turritella tricarinata*, *Nassarius gigantulus* and *Corbula gibba* which form a common association in sediments of the Lower Pleistocene attributable to the VTC biocenosis.

Lithological characteristics and micro-macropalaeontologic associations, allow to report the lithological interval 4 to the formation known as "Panchina", widespread in the area, and attributed to the Late Pleistocene (Tyrrhenian). Fossil Mollusca referable to the Tyrrhenian, as *Persististrombus latus* (Gmelin, 1791) and *Conus emineus* (Born, 1778), have been reported by Malatesta (1942) in a sand from the bottom of a well dug in the Hospital of Leghorn, in the vicinity of the succession under study.

The small number of bivalves (only four species) found in this interval is not significant itself, but, taking into account the fifteen species of gastropods in common with the other sections already known in literature, and considering their sediments, the Tyrrhenian fossil association is

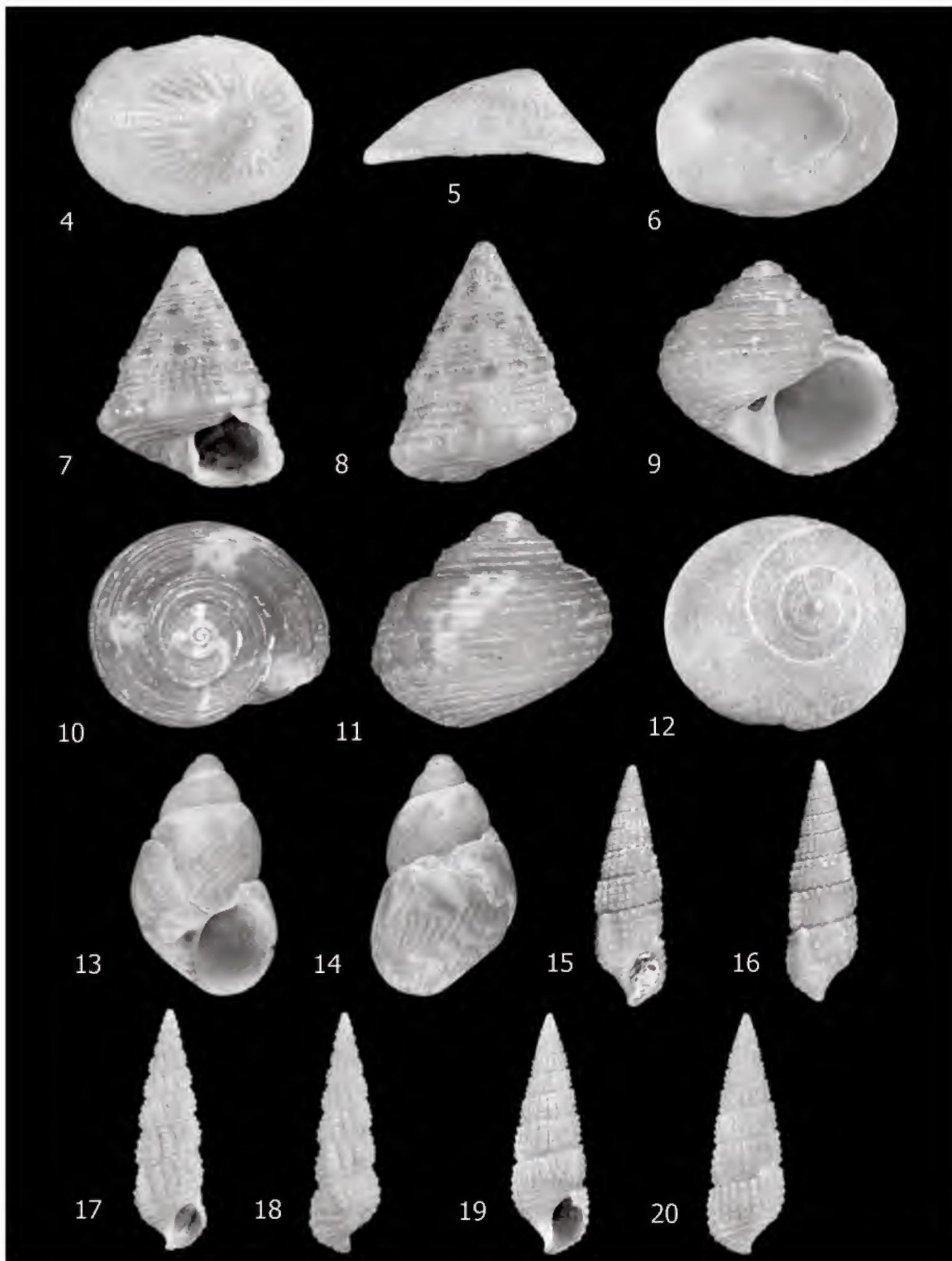
	via Manasse	via Gramsci (Ciampalini et al., 2014a)	Vallin Buio (Ciampalini et al., 2014a)	Bacino carenaggio (Barsotti et al., 1974)	Figures
GASTROPODA Cuvier, 1795					
<i>Tectura virginea</i> (O. F. Müller, 1776)	*		*		4–6
<i>Jujubinus exasperatus</i> (Pennant, 1777)	*	*	*	*	7, 8
<i>Gibbula turbinoides</i> (Deshayes, 1832)	*				9–11
<i>Bolma rugosa</i> (Linné, 1767)	*	*	*	*	12
<i>Tricolia tenuis</i> (Michaud, 1829)	*		*	*	13, 14
<i>Bittium reticulatum</i> (Da Costa, 1778)	*	*	*	*	15–18
<i>Bittium latreillii</i> (Payraudeau, 1826)	*	*			19, 20
<i>Cerithium vulgatum</i> Bruguière, 1792	*	*	*	*	
<i>Rissoa variabilis</i> (Von Mühlfeldt, 1824)	*			*	21, 22
<i>Rissoa</i> sp.	*				23
<i>Alvania mamillata</i> Risso, 1826	*	*	*		24, 25
<i>Alvania discors</i> (Allan, 1818)	*	*	*	*	26, 27
<i>Alvania cimex</i> (Linnaeus, 1758)	*			*	28, 29
<i>Rissoina bruguieri</i> (Payraudeau, 1826)	*	*			30, 31
<i>Columbella rustica</i> (Linnaeus, 1758)	*		*	*	32, 33
<i>Fusinus pulchellus</i> (Philippi, 1844)	*				34–36
<i>Vexillum ebenus</i> (Lamarck, 1811)	*			*	37, 38
BIVALVIA Linnaeus, 1758					
<i>Striarca lactea</i> (Linnaeus, 1758)	*	*	*	*	39–42
<i>Glycymeris</i> sp.	*	*	*	*	43, 44
<i>Chama gryphoides</i> (Linnaeus, 1758)	*			*	46, 47
<i>Parvicardium exiguum</i> (Gmelin, 1791)	*	*	*	*	45

Table 1. List of fossil molluscs from Tyrrhenian found in the survey of “via Manasse”, compared with those found in sections of “via Gramsci”, “Vallin Buio” and “Bacino di Carenaggio”.

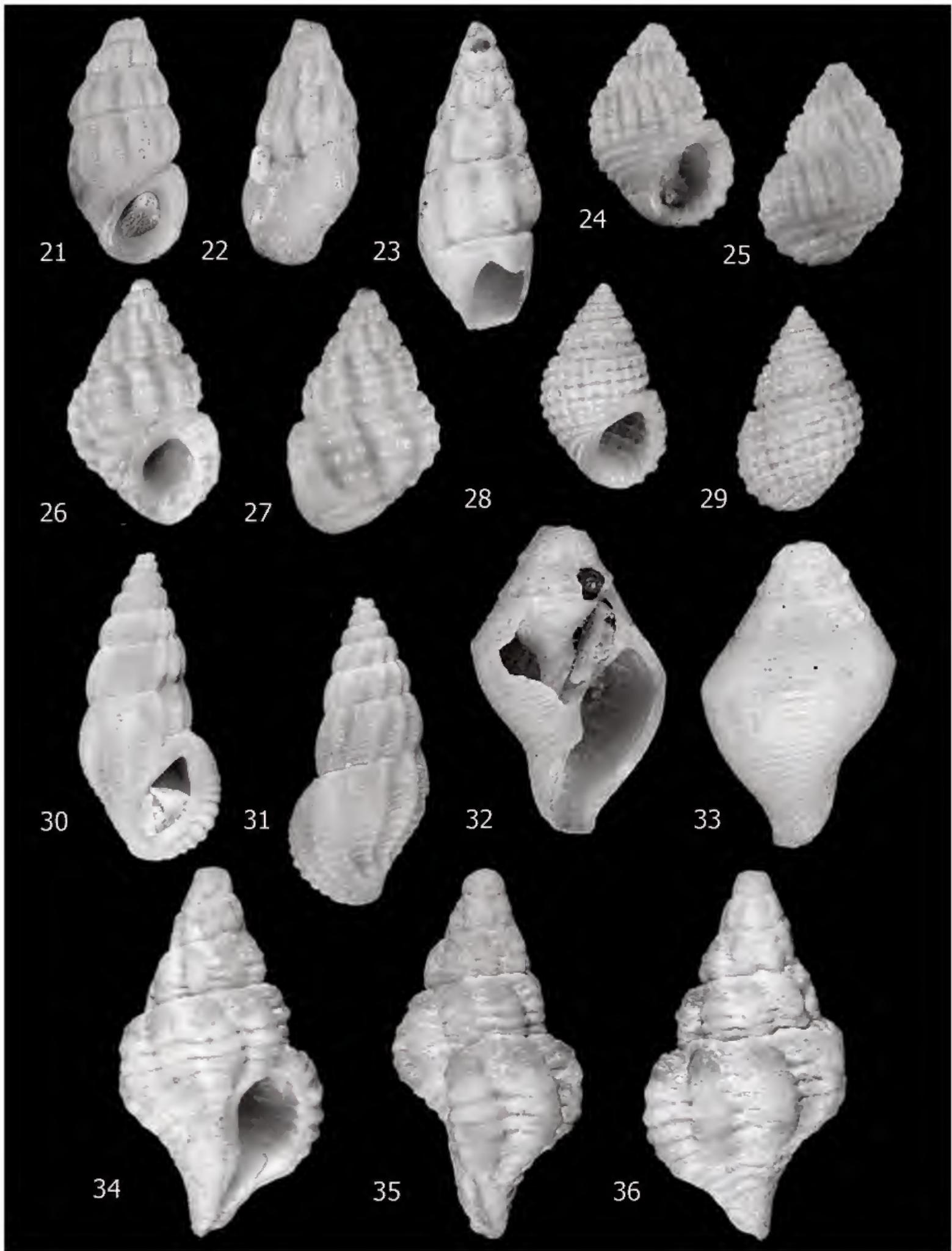
compatible with a biocenosis of the SGCF type, with specimens from the HP biocenosis. These data confirm those already found in previous studies on similar samples (Barsotti et al., 1974; Ciampalini et al., 2014a; Ciampalini et al. 2014b) and what reported by Corselli (1981) for the current seabed of the Gulf of Baratti (LI).

By comparing the lists of molluscs of the Upper Pleistocene, relative to the locations of the territory of Leghorn and reported in the above mentioned papers (Table 1), it can be seen that the species in

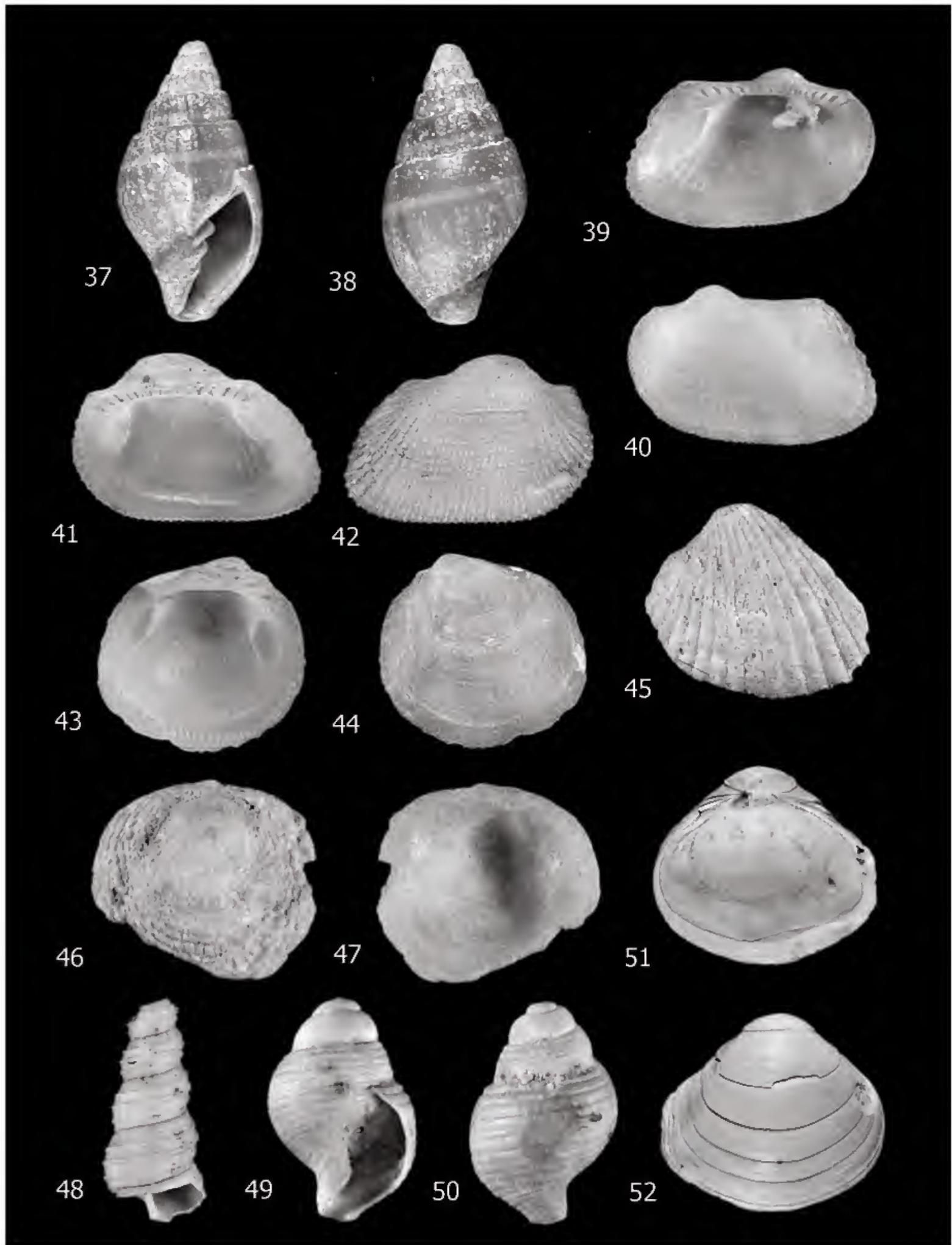
common are nearly all, with the exception of *Rissoa variabilis* (Von Mühlfeldt, 1824) and *Vexillum ebenus* (Lamarck, 1811), which are absent in the deposits of “via Gramsci” and “Vallin Buio”, but present at the “Bacino di carenaggio”; *Rissoina bruguieri* (Payraudeau, 1826) present in “via Gramsci”, but absent in “Vallin Buio” and the “Bacino di carenaggio” and, finally, *Gibbula turbinoides* and *Fusinus pulchellus* absent in all other locations. As for the failure of a previous report of *Bittium latreillii* (Payraudeau, 1826), we assumed that the



Figs. 4–6. *Tectura virginea* (O. F. Müller, 1776) d = 3.3, h = 1.7. Figs. 7, 8. *Jujubinus exasperatus* (Pennant, 1777) d = 4.8, h = 6.5. Figs. 9–11. *Gibbula turbinoides* (Deshayes, 1835) d = 3.9, h = 3.6. Fig. 12. *Bolma rugosa* (Linnaeus, 1767) operculum d = 6. Figs. 13, 14. *Tricolia tenuis* (Michaud, 1829) d = 4, h = 7.1. Figs. 15–18. *Bittium reticulatum* (Da Costa, 1778), Figs. 15, 16: d = 3.2, h = 10.8; Figs. 17, 18: d = 2.6, h = 7.3. Figs. 19, 20. *Bittium latreillii* (Payraudeau, 1826) d = 2.4, h = 7.9.



Figs. 21, 22. *Rissoa variabilis* (Von Mühlfeldt, 1824) d = 2, h = 3.9. Fig. 23. *Rissoa* sp. d = 1.6, h = 4.2. Figs. 24, 25. *Alvania mamillata* Risso, 1826 d = 3.2, h = 5. Figs. 26, 27. *Alvania discors* (Allan, 1818) d = 2.5, h = 4; Figs. 28, 29. *Alvania cimex* (Linnaeus, 1758) d = 2.3, h = 4.4; Figs. 30, 31. *Rissoina bruguieri* (Payraudeau, 1826) d = 2.6, h = 6.8. Figs. 32, 33. *Columbella rustica* (Linnaeus, 1758) d = 3.3, h = 4.9. Figs. 34-36. *Fusinus pulchellus* (Philippi, 1844) d = 2.0 mm, h = 5.5 mm.



Figs. 37, 38. *Vexillum ebenus* (Lamarck, 1811)  $d = 4$ ,  $h = 8.2$ . Figs. 39–42 *Striarca lactea* (Linnaeus, 1758), Figs. 39, 40:  $l = 4.9$ ,  $h = 3.5$ ; Figs. 41, 42:  $l = 6.2$ ,  $h = 3.9$ . Figs. 43, 44. *Glycymeris* sp.  $l = 4.1$ ,  $h = 3.9$ ; Fig. 45. *Parvicardium exiguum* (Gmelin, 1791)  $l = 7.3$ ,  $h = 6.3$ ; Figs. 46, 47. *Chama gryphoides* (Linnaeus, 1758)  $l = 5.3$ ,  $h = 4.7$ ; Fig. 48. *Turritella tricarinata* (Brocchi, 1814)  $d = 4.8$ ,  $h = 11$ ; Figs. 49, 50. *Nassarius gigantulus* (Bellardi, 1882)  $d = 1.3$ ,  $h = 2.5$ . Figs. 51, 52. *Corbula gibba* (Olivieri, 1792)  $l = 9.4$ ,  $h = 8.3$ .

species may have been confused with *B. reticulatum* (Da Costa, 1778). *Gibbula turbinoides* and *Fusinus pulchellus*, exclusive of the succession of "via Manasse", are compatible with the habitat of "posidonieto" as one lives at low depth under the rocks and on seagrass, and the other between the *Posidonia oceanica* (L.) Delile rhizomes.

The overall available data and micropalaeontological analysis confirm, for the level of "Panchina", a shallow marine habitat at high energy, with rocky substrates alternating to sandy ones, in proximity of or mixed to seagrass meadows. Even for the micropalaeontological association of the sample collected in the limestone (interval 4), the conservation status of the fossils and the structure of the granules of sand confirm the hypothesis of the occurrence of a marine environment at high energy.

Contrary to other Tyrrhenian fossil malacofauna found in the Leghorn area and at the same stratigraphic level, which are generally poorly preserved (Ciampalini et al., 2014a, 2014b), the association of "via Manasse" is composed of specimens little eroded and often with traces of original coloring. This, combined with the finer grain size of the sediments, although still corroborating the hypothesis of a marine environment at high energy, may indicate a lower transport and consequently a marine environment more stable and little deeper than that assumed for the neighboring area of "via Gramsci", characterized, instead, by shoals of "Panchina" quite compact.

The lithological study of the drilling revealed peculiar stratigraphic characteristics partly different from those previously reported (Barsotti et al. 1974; Ciampalini et al., 2006; Ciampalini et al., 2014b). The drilling of "via Manasse" shows, in fact, only one level of "Panchina" (lithological interval 4), whereas former studies have often described two levels, separated by a layer of clay and silt of continental environment (Barsotti et al. 1974; Zanchetta et al., 2004; Ciampalini et al., 2006). On the other hand, only one level has been observed in the successions close to the ancient cliffs and at higher altitudes. The presence of the Lower Pleistocene, at the bottom of the drilling, enriches our knowledge on the stratigraphy of the area that, today, is still poorly known. As already reported, in stratigraphic levels below the "Panchina" it is possible to find sediments of both Pliocene and Lower or Middle Pleistocene.

## CONCLUSIONS

The lithological study of the drilling revealed seven major lithological intervals. Micropalaeontological and lithostratigraphic analyses allowed to attribute the intervals 7-5 to the Formation of Morrone (Lower Pleistocene, Calabrian) and the lithological interval 4 to the Formation of the "Calcareni di Castiglione" (Upper Pleistocene), also known as "Panchina".

The intervals 3 and 2 are attributed, on the basis of observations on site, to the formation of conglomerates of Rio Maggiore, while interval 1 refers to the "Sabbie di Donoratico", present throughout the Terrace of Leghorn. On the top of the drilling was identified a soil rich in coal.

In the drilling analysed in this work, was observed only one level of "Panchina" just above the clay sediments of the Lower Pleistocene.

The analysis of malacofauna present in the "Panchina" confirms data already known for an advanced part of the Tyrrhenian cycle. Conversely, no tropical molluscs, typical of the coasts of NW-Centre Africa, and characteristic of the Tyrrhenian baseline (MIS 5e), have been found. Since their discovery was reported by Malatesta (1942) at a depth of about 6 meters (about 12 meters above sea level), in a well near the present hospital and less than one km away from "via Manasse", this result raises some questions. If for the section of "via Gramsci", adjacent to the hospital we could hypothesize the failure in finding the African species due to the shallow depth of the drilling, little more than three meters, the same cannot be said for the drilling of "via Manasse", up to 20 meters above the ground. At the depth of 6 meters from ground level "via Manasse" sediments and malacofauna are attributable to the Lower Pleistocene, sample MAN3, while in the hospital area both sediments and malacofauna are Tyrrhenian (Malatesta, 1942).

The scantiness of recovered materials due to the nature itself of the sampling carried out, i.e. only a single drilling, could be the cause of the failure in finding or recognizing the Tyrrhenian level MIS 5e. Nevertheless, it is also possible that this level is not always present in the subsoil of Leghorn.

On the other hand, the lack of the second calcarenitic level, probably eroded and replaced by sediments of the river-type (Conglomerates of Rio Maggiore), currently occurring above the fossil level,

attests the possibility that important variations in the stratigraphy of the terrace Leghorn have occurred.

In conclusion, it is not easy to find in the subsoil of Leghorn the initial part of the transgressive Tyrrenian cycle and, consequently, to establish its relationship with the underlying lithological units.

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## Stream's water quality and description of some aquatic species of Coleoptera and Hemiptera (Insecta) in Littoral Region of Cameroon

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### ABSTRACT

Aquatic insects are the dominant taxon group in most freshwater ecosystems and are particularly suitable for large scale and comparative studies of freshwater community responses to human-induced perturbations. Understanding these responses is crucial for establishing conservation goals. In this study, we used three families of aquatic insects (Coleoptera Gyrinidae, Hemiptera Gerridae and Veliidae) as surrogates to measure the aquatic health of urban streams in the city of Douala, and we described eight characteristic species. Aquatic insects were sampled monthly over a 13-month period in two forested sites and ten urbanized sites. Meanwhile, measurements of the environmental variables were taken. Overall, 20 species were identified; the family Gerridae was the most diversified with 11 species, followed by Veliidae (5 species), and Gyrinidae (4 species). All these species were present only at the two forested sites; no species was found in the urbanized area all over the study period. Morphological description of the eight best indicator species (*Orectogyrus specularis* Aubé, 1838, *Orectogyrus* sp.1, *Orectogyrus* sp. 2, *Eurymetra manengolensis* Hoberlandt, 1952, *Eurymetra* sp. 1, *Eurymetra* sp. 2, *Rhagovelia reitteri* Reuter, 1884 and *Rhagovelia* sp.) revealed not described characteristic features and potentially new species. This testified that in Cameroon, biodiversity of aquatic insects is yet entirely to be investigated, and that there is an urgent need in their taxonomic revision. Physicochemical analyses revealed the very poor health status of urban streams with highly polluted water, while suburban streams have unpolluted water. The results of redundancy analysis revealed that the presence of Gyrinidae, Gerridae and Veliidae species is undoubtedly favored by the high rate of dissolved oxygen, important canopy coverage and very low organic matter input. It is thus clear that polluted status of urban streams due to human activities is the primary cause of the extinction of aquatic insect species.

### KEY WORDS

Aquatic Coleoptera and Hemiptera; morphological features; sensitive species; water pollution.

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### INTRODUCTION

Climate change, loss of biodiversity and the growth of an increasingly urban world population

are main challenges of this century (Müller et al., 2010). In developing countries, urban population and anarchic urban land use have dramatically increased over the past few decades. Such population

growth and urban expansion are placing greater stresses on the natural environment (Cohen, 2003), leading to a strong variability on the physical and chemical features of lotic ecosystems by clearing riparian vegetation and opening canopy, increasing inputs of sediments, nutrients, organic matter and pollutants (i.e., heavy metals), altering flows and reducing habitat heterogeneity (Xu et al., 2013; Zhang et al., 2013). Such modifications result into drastic changes in the biological component and the ecological functioning of urban streams, with a deterioration of water quality and loss of sensitive aquatic biota (Tchakonté et al., 2014). There is therefore a growing need to better understand and predict how biotic communities respond to these disturbances.

As an important functional group in stream ecosystems that sustains the stability and complexity of aquatic communities, insects have frequently been used to indicate changes in the composition of stream communities that respond to anthropogenic disturbances since they are sensitive indicators of long-term environmental changes in water and habitat quality (Rosenberg & Resh, 1993; Song et al., 2009; Zhang et al., 2013). Within the insects, Ephemeroptera, Plecoptera and Trichoptera are well known as good bioindicators in stream ecosystems (Rosenberg & Resh, 1993; Foto Menbohan et al., 2013; Nyamsi Tchatcho et al., 2014), whereas the use of aquatic Coleoptera and Hemiptera in biomonitoring studies is rare. Despite their limited use in stream biomonitoring, some aquatic Coleoptera and Hemiptera taxa have been shown as being sensitive to increase in sediment and organic pollution (e.g., Hauer & Resh, 1996; Zettel & Tran, 2004). Furthermore, most Hemipteran's species are endemic to particular islands or continental regions and often have extremely limited distributions, issuing them a bioindicator identity.

In the city of Douala which is the most densely populated and industrialized area of Cameroon, urbanization is anarchical with precarious sanitation systems in shanty quarters; household disposals, municipal and industrial wastewater and solid wastes are discharged directly in the environment without preliminary or adequate treatment (Tening et al., 2013; Tchakonté et al., 2014). To our knowledge, no study has so far dealt with diversity, morphological description and ecological requirement conditions of aquatic insect of the families Gyrinidae, Gerridae

and Veliidae in Douala rivers. Indeed, these Coleoptera and Hemiptera accomplish their entire live cycle in aquatic milieu (except pupal stage of Gyrinidae); they are therefore in permanent contact with the aquatic environment and might reflect even the most subtle changes occurring in the medium.

This study aimed thus to inventory and to describe characteristic species of Gyrinidae, Gerridae and Veliidae in urban and forest streams of Douala city, in order to provide further information on the systematic of these families and to offer hypotheses as to how the species are distributed.

## MATERIAL AND METHODS

### *Study area and sampling stations*

Douala city is located at the bottom of the Gulf of Guinea, along the estuary of the Wouri River. This city extends between 3°58' - 4°07' of latitude North and between 9°34' - 9°49' of longitude East, and presents a flat topography with altitudes varying between 1.6 and 39 m (Olivry, 1986). The climate of this region was classified by Suchel (1972) as a wet tropical type, characterized by a short dry season (December to February) and a long rainy season (March to November). Rainfalls are abundant and regular with the annual average values varying between 2596 mm and 5328 mm. The air temperature is relatively high with a monthly average of approximately 28 °C (Suchel, 1972). Samplings were carried out monthly, from September 2012 to September 2013 in 12 stations located in the three larger contiguous watersheds (Nsapè, Tongo'a-Bassa and Mgoua) situated at the left bank of the Wouri River (Fig. 1).

The watershed of Nsapè is located in a peri-urban area situated at about 30 km away from the urban centre. This watershed is particularly covered by vegetation of a secondary dense forest type, composed of high trees, shrubs and tall grasses (undergrowth) which alternate with some cleared spaces used for traditional farming purposes. This forested area is uninhabited and sheltered of any urban/industrial activity. Two stations identified as N<sub>1</sub> and N<sub>2</sub> were selected in this forested area. Inversely, Tongo'a-Bassa and Mgoua basins are located in industrialized areas and are highly polluted by human activities. Five sampling stations (T<sub>1</sub>, T<sub>2</sub>,

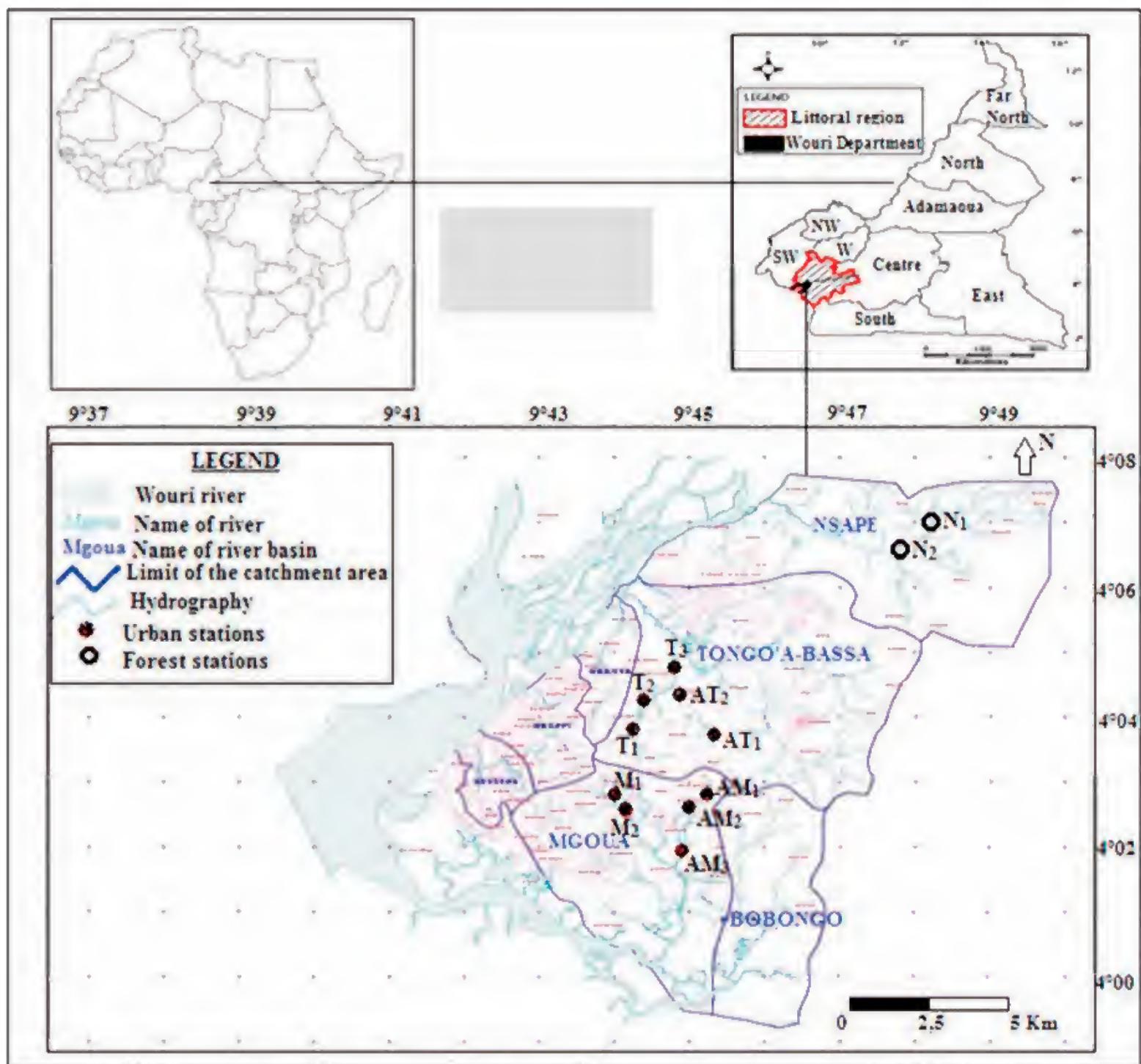


Figure 1. Hydrographic map of the study sites showing sampling stations.

T<sub>3</sub>, AT<sub>1</sub>, and AT<sub>2</sub>) were selected in the Tongo' a-Bassa catchment. The stations T<sub>1</sub> and T<sub>2</sub> are localized respectively at 350 m upstream and 200 m downstream from the outlet of the effluent of an industry of chocolate factory and confectionery. Stations AT<sub>1</sub> and AT<sub>2</sub> are located respectively at 100 m and 3.5 km downstream from the outlet of effluents coming from a brewery industry, a textile industry and an industry of manufacture of glasses. While station T<sub>3</sub> is situated at 500 m downstream from the junction of the two preceding arms. The five other stations (M<sub>1</sub>, M<sub>2</sub>, AM<sub>1</sub>, AM<sub>2</sub> and AM<sub>3</sub>) were chosen in Mgooua river basin. The stations M<sub>1</sub> and M<sub>2</sub> are respectively localized at 350 m upstream

and 250 m downstream from the outlet of effluents coming from the great Industrial Centre of Bassa. Stations AM<sub>1</sub> and AM<sub>2</sub> are located respectively at 300 m upstream and 150 m downstream from the outlet of the effluent of a soap and cosmetic factory, while station AM<sub>3</sub> is situated at approximately 2.4 km downstream of this effluent.

#### *Measurement of environmental variables*

At each sampling station, 15 environmental variables were taken into account. Three physical parameters were determined to characterize the habitat. The mean water depth (WD) was measured

on transects with equal distance interval across the river sections (Song et al., 2009). Current velocity (CV) was measured by timing the front of a neutral non-pollutant dye (blue of methylene) over a calibrated distance. At each sampling station, canopy coverage (%) was estimated visually (Rios & Bailey, 2006).

The measurements of physicochemical parameters of water at each sampling station were done following APHA (2009) and Rodier et al. (2009) standard methods. Water temperature, pH, and dissolved oxygen (DO) were measured *in situ* using an alcohol thermometer, a HACH HQ11d pH-meter, and a HACH HQ14d oxymeter, respectively. Likewise, electrical conductivity (EC) was measured *in situ* using a HACH HQ 14d conductimeter. Suspended solids (SS), turbidity, ammonium ( $\text{NH}_4^+$ ), nitrites ( $\text{NO}_2^-$ ), nitrates ( $\text{NO}_3^-$ ), and phosphates ( $\text{PO}_4^{3-}$ ) were measured in the laboratory using HACH DR/2800 spectrophotometer. The Biochemical Oxygen Demand (BOD5) was measured using a Liebherr BOD analyzer. In order to assess the organic pollution level at each sampling station, the Organic Pollution Index (OPI) was calculated according to the protocol described by Leclercq (2001). OPI is based on three ions concentrations resulting from organic pollution ( $\text{NH}_4^+$ ,  $\text{NO}_2^-$ , and  $\text{PO}_4^{3-}$ ) and one synthetic parameter (BOD5).

### ***Sampling, identification and representation of aquatic insect species***

Insect samples were collected at each station using a long-handled kick net (30 cm x 30 cm side, 400  $\mu\text{m}$  mesh-size, 50 cm depth). For each station, samplings were done in a 100 m stretch following protocol described by Stark et al. (2001). At each station, 20 drags of the kick net were done in different micro-habitat, each corresponding to a surface of 0.15  $\text{m}^2$  (30 cm x 50 cm). The materials that were collected in the sampling net were rinsed through a 400  $\mu\text{m}$  sieve bucket and all macroinvertebrate individuals were sorted and preserved in plastics sampling bottles with 70% ethanol. In the laboratory, all aquatic insects belonging to the families Gyrinidae (Coleoptera), Gerridae and Veliidae (Hemiptera) were identified under a stereomicroscope using appropriate taxonomic keys (Dejoux et al., 1981; Durand & Levêque, 1981; De Moor et al., 2003; Stals & De Moor, 2007; Tachet et al., 2010), and counted.

The specimens intended for representation were prior immersed in 10% sodium hydroxide overnight, so as to soften their chitin and lighten their body. The drawings of general morphology of characteristic species were carried out under a stereomicroscope equipped with a drawing tube. Details of key appendages were drawn using an optical microscope 100 $\times$  magnification, equipped with a drawing tube.

### ***Data analyses***

Insect richness, abundances and occurrence frequencies were used to classify species according to Dajoz (2000). In order to study the relationships between environmental variables and the distribution and dynamic of the eight characteristic insect species, Canonical Redundancy Analysis (RDA) was performed based on the data matrix of species abundances and physicochemical parameters. RDA is a constrained ordination method, efficient in directly revealing relationships between the spatial structure of communities and environmental factors that might be responsible for that structure (Legendre et al., 2011). Monte Carlo permutations (499 permutations) were done so as to identify a subset of measured environmental variables, which exerted significant and independent influences on insect species distribution at  $p < 0.05$ . CANOCO for Windows 4.5 software (Ter Braak & Smilauer, 2002) was used for this analysis.

## **RESULTS**

### ***Environmental variables***

The mean values and standard deviation (SD) of environmental variables measured at each sampling station are shown in Table 1. The lower mean values of water temperature were observed at forested sites (25.9° C), whereas at urbanized sites, higher values were recorded, especially downstream from the outlet of industrial effluents. The mean values of pH varied between 6.10 ( $\text{N}_1$ ) and 8.16 ( $\text{AM}_2$ ). The percentage of dissolved oxygen was overall higher at suburban sites (>75%) compared to urban sites, where waters were closed to the hypoxic condition, with mean values oscillating between 2.95% ( $\text{T}_3$ ) and 21.3% ( $\text{AM}_1$ ). Mean values of electrical conductivity ranged between 13.1  $\mu\text{S}/\text{cm}$  ( $\text{N}_2$ ) and

1559  $\mu\text{S}/\text{cm}$  ( $\text{AT}_1$ ). Turbidity and suspended solids were globally very low at forested sites, with mean values ranging from 14 to 26 NTU and from 4.2 to 7.7 mg/L, respectively. Whereas in urban zone, mean values of these parameters varied between 94.2 NTU ( $\text{AM}_1$ ) and 259.7 NTU ( $\text{AT}_1$ ), and between 47.9 mg/L ( $\text{AM}_1$ ) and 163.5 mg/L ( $\text{AT}_1$ ), respectively for turbidity and suspended solids. The lowest mean values of nitrates (0.11 mg/L), nitrites (0.006 mg/L), ammonium (0.09 mg/L) and phosphates (0.08 mg/L) were recorded at suburban station  $\text{N}_1$ , whereas the highest were registered at the urban stations  $\text{AT}_1$  (6.98 mg/L),  $\text{AM}_2$  (0.26 mg/L),  $\text{M}_1$  (5.19 mg/L) and  $\text{AT}_1$  (2.2 mg/L), respectively. Concerning BOD, the lowest value (13.08 mg/L) was observed in station  $\text{N}_1$ , while the highest values (218.1 mg/L) were obtained at station  $\text{AT}_1$ . Mean values of water's depth and current velocity fluctuated between 0.22 m ( $\text{M}_1$ ) and 0.75 m ( $\text{AM}_3$ ), and between 0.22 m/s ( $\text{AM}_3$ ) and 0.89 m/s ( $\text{AT}_1$ ), respectively. At the level of all the sampling stations situated in urban area, canopy was absent; mean-

while it was estimated to 69% and 73% respectively at the level of stations  $\text{N}_1$  and  $\text{N}_2$  located in forested sites. The organic pollution index (OPI) revealed that organic pollution ranged from low to null at the forested sites; whereas in urban streams, organic pollution level was very high.

### Composition and distribution of species

Overall, 20 species were identified for the three studied aquatic insect families (Table 2). The family Gerridae (Hemiptera) was the most diversified with 11 species, followed by the family Veliidae (Hemiptera) with 5 species, and the family Gyrinidae (Coleoptera) which accounted 4 species. All these species were caught only at the two forested sites ( $\text{N}_1$  and  $\text{N}_2$ ); no species were found at any of the ten sampling stations located in urban streams, all over the study period. Among the taxa identified 3 species of Gyrinidae (*Orectogyrus specularis* Aubé, 1838, *Orectogyrus* sp. 1 and *Orectogyrus* sp.2), 5

Variables	Forested sites		Urbanized sites										
	$\text{N}_1$	$\text{N}_2$	$\text{T}_1$	$\text{T}_2$	$\text{T}_3$	$\text{AT}_1$	$\text{AT}_2$	$\text{M}_1$	$\text{M}_2$	$\text{AM}_1$	$\text{AM}_2$	$\text{AM}_3$	
Temperature ( $^{\circ}\text{C}$ )	Mean	25.9	25.9	29.4	29.2	30.1	32.7	30.54	29.1	29.54	28.8	29.23	29.4
	SD	0.79	0.98	1.7	1.61	2.36	2.24	2.12	2.63	2.23	1.78	1.73	2.28
pH (UC)	Mean	6.10	6.19	7.01	6.98	6.72	7.93	6.71	6.92	6.79	6.75	8.16	7.01
	SD	0.71	0.93	0.52	0.53	0.73	1.11	0.84	0.63	0.72	0.66	0.91	0.86
DO (%)	Mean	75.4	80.3	14.6	17.7	2.95	4.65	5.5	6.32	5.7	21.3	10.51	5.64
	SD	8.3	10.9	10.1	11.8	1.66	2.47	3	8.73	5.89	12	7.86	6.62
EC ( $\mu\text{S}/\text{cm}$ )	Mean	13.2	13.1	397.9	401.1	475.3	1559	624.2	403.1	677.5	291.3	478.9	443.7
	SD	6.82	3.09	115	117	152	1159	277.5	148	636.6	79	417.1	170
Turbidity (NTU)	Mean	14	26	102.2	116.3	131.6	259.7	173	125.1	119.9	94.2	122.6	106.9
	SD	10.5	17.2	108	71	66	187.4	100.6	40	69.6	18.7	86.59	60
SS (mg/L)	Mean	4.2	7.7	62.9	54.9	100.5	163.5	99.2	77	71.62	47.9	72.69	86.9
	SD	3.8	4.09	101	85.5	84	112.3	66.1	39.7	27.3	25.9	41.72	72.7
$\text{NO}_3^-$ (mg/L)	Mean	0.11	0.2	2.79	1.53	3.7	6.98	4.43	2.24	3.22	1.91	3.24	3.1
	SD	0.16	0.17	5.26	0.58	2.92	4.9	3.32	2.14	1.49	1.18	3.99	1.3
$\text{NO}_2^-$ (mg/L)	Mean	0.006	0.008	0.23	0.21	0.13	0.21	0.041	0.04	0.08	0.12	0.26	0.2
	SD	0.0	0.0	0.46	0.39	0.26	0.31	0.025	0.06	0.1	0.15	0.65	0.29
$\text{NH}_4^+$ (mg/L)	Mean	0.09	0.1	4.5	4.56	4.4	4.04	3.12	5.19	4.15	3.1	2.49	3.29
	SD	0.07	0.08	2.53	2.73	2.31	2.93	1.04	3.16	0.32	2.39	1.86	1.52
$\text{PO}_4^{3-}$ (mg/L)	Mean	0.08	0.14	1.21	1.06	1.3	2.2	1.4	1.53	1.17	0.9	0.88	1.39
	SD	0.13	0.2	0.41	0.38	0.58	1.73	0.69	0.91	0.73	0.43	0.37	0.45
$\text{BOD}_5$ (mg/L)	Mean	13.08	16.2	96.9	156.2	158.5	218.1	176.2	89.6	105	94.6	121.15	139.6
	SD	6.9	10.2	50	53	67	63.23	46.24	31.3	27.39	29	22	33
WD (m)	Mean	0.31	0.66	0.37	0.48	0.65	0.26	0.62	0.22	0.43	0.35	0.26	0.75
	SD	0.07	0.05	0.07	0.06	0.04	0.04	0.05	0.03	0.05	0.06	0.05	0.03
CV (m/s)	Mean	0.64	0.48	0.75	0.78	0.57	0.89	0.71	0.38	0.37	0.46	0.45	0.22
	SD	0.04	0.05	0.04	0.05	0.04	0.03	0.03	0.03	0.05	0.05	0.04	0.05
OPI Values	Mean	4.63	4.14	1.67	1.73	1.69	1.48	1.81	1.81	1.87	1.98	1.94	1.77
	SD	0.53	0.55	0.30	0.26	0.31	0.37	0.25	0.37	0.32	0.31	0.34	0.40
Pollution level		Null	Low										Very high

Table 1. Mean values and standard deviation (SD) of environmental variables measured at each sampling station during the study period.

species of Gerridae (*Eurymetra manengolensis* Hoberlandt, 1952, *Eurymetra* sp. 1, *Eurymetra* sp. 2, *Limnogonus chopardi* Poisson, 1941 and *Limnogonus* sp.) and 3 species of Veliidae (*Microvelia* sp., *Rhagovelia reitteri* Reuter, 1884 and *Rhagovelia* sp.) were present simultaneously at the two suburban stations and are considered as characteristic species. Each of the other species was caught either at the station N<sub>1</sub> or at the station N<sub>2</sub>, exclusively.

### *Morphological description of some characteristic species*

DESCRIPTION OF SPECIES OF THE GENUS *ORECTO-GYRUS* RÉGIMBART, 1884 (COLEOPTERA GYRINIDAE). The aquatic insects of the family Gyrinidae are all holometabolous. Adult Gyrinidae (whirligig beetles) are highly adapted to the aquatic environment, being the only beetles that normally use the water surface film for support. They are, however, equally at home under the water. Both adults and larvae of

all Gyrinidae are strictly aquatic. The adult gyrenids are true water beetles with medium-sized to moderately large, ranging from 4–17 mm in length. The body shape of the adults is ovate or elongate-ovate, convex, with a sharp lateral edge around the whole body. This edge separates the hydrofuge dorsal surface of the insect from its wettable ventral surface. The lateral edge divides the compound eyes into dorsal and ventral halves (Fig. 7), with the dorsal part looking up out of the water, whereas the ventral part looks down into the water. The antennae of adult gyrenids are short, stout and highly sensitive (Fig. 5). The front legs of gyrenids are long and adapted for seizing prey. The middle and hind legs are adapted for swimming: they are short and dorsoventrally compressed, with fringes of swimming hairs (Fig. 6).

The adult specimens of the genus *Orectogyrus* are recognized with their elongate-ovate-convex body and their last abdominal segment elongate extending beyond the elytra edge. The upper side of

ORDERS/FAMILIES	SPECIES	N <sub>1</sub>	N <sub>2</sub>	All urban stations
COLEOPTERA GYRINIDAE	<i>Aulonogyrus</i> sp.	3*	-	-
	<i>Orectogyrus specularis</i> Aubé, 1838	9*	6*	-
	<i>Orectogyrus</i> sp.1	8*	15*	-
	<i>Orectogyrus</i> sp.2	27**	19*	-
HEMIPTERA GERRIDAE	<i>Aquarius distanti</i> Horvath 1899	-	2*	-
	<i>Eurymetra manengolensis</i> Hoberlandt, 1952	64***	69**	-
	<i>Eurymetra</i> sp.1	18*	13*	-
	<i>Eurymetra</i> sp.2	4*	6*	-
	<i>Gerris swakopensis</i> Stål, 1858	-	3*	-
	<i>Gerris</i> sp.	-	2*	-
	<i>Hynesionella aethiopica</i> Poisson, 1949	-	2*	-
	<i>Limnogonus chopardi</i> Poisson, 1941	9**	7*	-
	<i>Limnogonus</i> sp.	2*	8**	-
	<i>Neogerris</i> sp.	3*	-	-
HEMIPTERA VELIIDAE	<i>Tenagogonus</i> sp.	-	5*	-
	<i>Carayonella hutchinsoni</i> Poisson, 1948	1*	-	-
	<i>Microvelia gracillima</i> Reuter, 1882	2*	-	-
	<i>Microvelia</i> sp.	12**	6*	-
	<i>Rhagovelia reitteri</i> Reuter, 1884	162***	90**	-
<i>Rhagovelia</i> sp.	31**	42**	-	

Table 2. Distribution, abundances and occurrence frequencies of insect species of the families Gyrinidae, Gerridae and Veliidae in different sampling stations; \* = rare, \*\* = accessory, \*\*\* = frequent, (-) = absent. For undefined species, the descriptor author's name of the genus is given.

elytra is glabrous or (partly) pubescent, black in color, with distinct metallic shiny portions used as systematic character. The specimens that we recorded have a pale yellow lateral border on the pronotum and elytra. The hindmost two abdominal sternites are more-or-less laterally compressed and movable, with a ventral median row of long hairs used as a rudder for swimming. Three species, *Orectogyrus specularis* Aubé, 1838, *Orectogyrus* sp. 1 and *Orectogyrus* sp. 2 were identified. In *O.* sp. 1 (Fig. 4), only the last abdominal segment is extended beyond the elytra, whereas in *O. specularis* and *O.* sp. 2 (Figs. 2, 3), it is the two last ones. Moreover, the ornateness of elytra permitted to clearly separate these three species. The specimens of *O. specularis* measure  $9.4 \pm 0.1$  mm in length and  $4.16 \pm 0.02$  mm in width; the inter-ocular space measures  $1.6 \pm 0.001$  mm and the pronotum is  $1.2 \pm 0.02$  mm in length. For *O.* sp.1, the body is  $7.08 \pm 0.11$  mm in length and  $3.6 \pm 0.01$  mm in width; the inter-ocular space measures  $1.12 \pm 0.002$  mm and the pronotum is  $0.92 \pm 0.08$  mm in length. Concerning *O.* sp. 2, the specimens caught measure  $9.54 \pm 0.26$  mm in length and  $4.2 \pm 0.02$  mm in width; the mean length of the inter-ocular space is  $1.4 \pm 0.01$  mm and the pronotum is  $1.2 \pm 0.04$  mm in length. The median silky swimming hairs of the last abdominal sternite are longer in *O. specularis* and *O.* sp. 2 (800 - 850  $\mu$ m) as compared to *O.* sp. 1 (520-680  $\mu$ m).

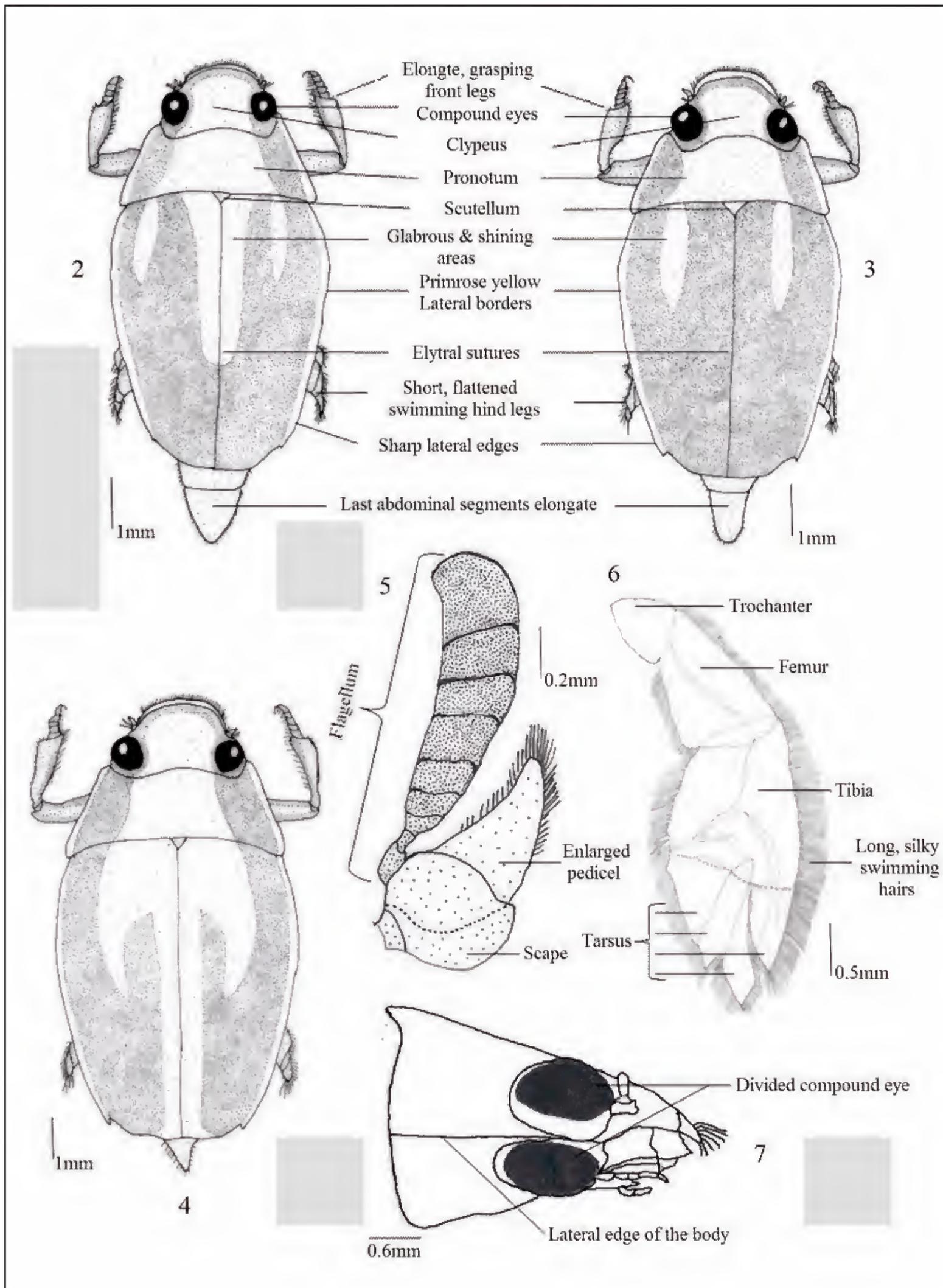
DESCRIPTION OF SPECIES OF THE GENUS *RHAGOVELIA* MAYR, 1865 (HEMIPTERA VELIIDAE). The Veliidae are hemimetabolous insects gliding or treading on the surface of the water. They are typically characterized by their jointed mouthparts, modified to form a rostrum or "beak", which is adapted for piercing and sucking. The head is short, less than two times longer than wide, bent downward, and triangular. It has a distinct longitudinal sulcus mid-dorsally, a jointed rostrum with 3 segments, a pair of four-segmented antennae longer than the head, and no ocellus. The legs are nearly equidistant and the hind-coxae are distinctly moved apart from each other, with mid-femora not exceeding or very slightly the end of the abdomen. The tarsal claws are subapical.

The adult specimens of the genus *Rhagovelia* Mayr, 1865 are distinguishable with their body surface matt and blackish or brownish; all tarsi three-segmented with the basal segment very short;

mid-tarsi deeply cleft with leaf like claws and hairy swimming fans arising from the base of the cleft (Fig. 10). The mesoscutellum is not exposed, covered by posteriorly-extended pronotal lobe. Two species, *Rhagovelia reitteri* Reuter, 1884 and *Rhagovelia* sp. were identified for this study.

Adult specimens of *R. reitteri* collected are macropterous and their fore-wings (hemelytra) are not divided into corium and membrane (Fig. 8). However, these hemelytra can detach during sampling or identification processes. The specimens of *R. reitteri* measure  $4.15 \pm 0.15$  mm in length and  $1.05 \pm 0.002$  mm in width; the inter-ocular space measures  $0.24 \pm 0.001$  mm and the pronotum is  $0.82 \pm 0.02$  mm in length. Inversely, the individuals of *Rhagovelia* sp. are apterous, with stout hind femora bearing small distinct spines on the inner margins (Fig. 9). Their body is  $4.12 \pm 0.2$  mm in length and  $1.2 \pm 0.01$  mm in width; the inter-ocular space measures  $0.23 \pm 0.01$  mm. The lengths of the pro-, meso- and metanotum are  $0.81 \pm 0.03$  mm,  $0.24 \pm 0.001$  mm and  $0.24 \pm 0.004$  mm, respectively. The body is mainly black; pronotum anteriorly completely yellow, posteriorly variably colored, usually black, but in some specimens with yellowish hind margin, and in smallest specimens uniformly light reddish brown; connexiva (most lateral areas of sternites and laterotergites) usually brown, in smaller specimens yellow; anteclypeus, rostrum, and proepisterna mainly yellowish; antenna and legs mainly black, basal half of first antennomere, all coxae and trochanters, basal half of all femora, inner margins of hind femora yellow.

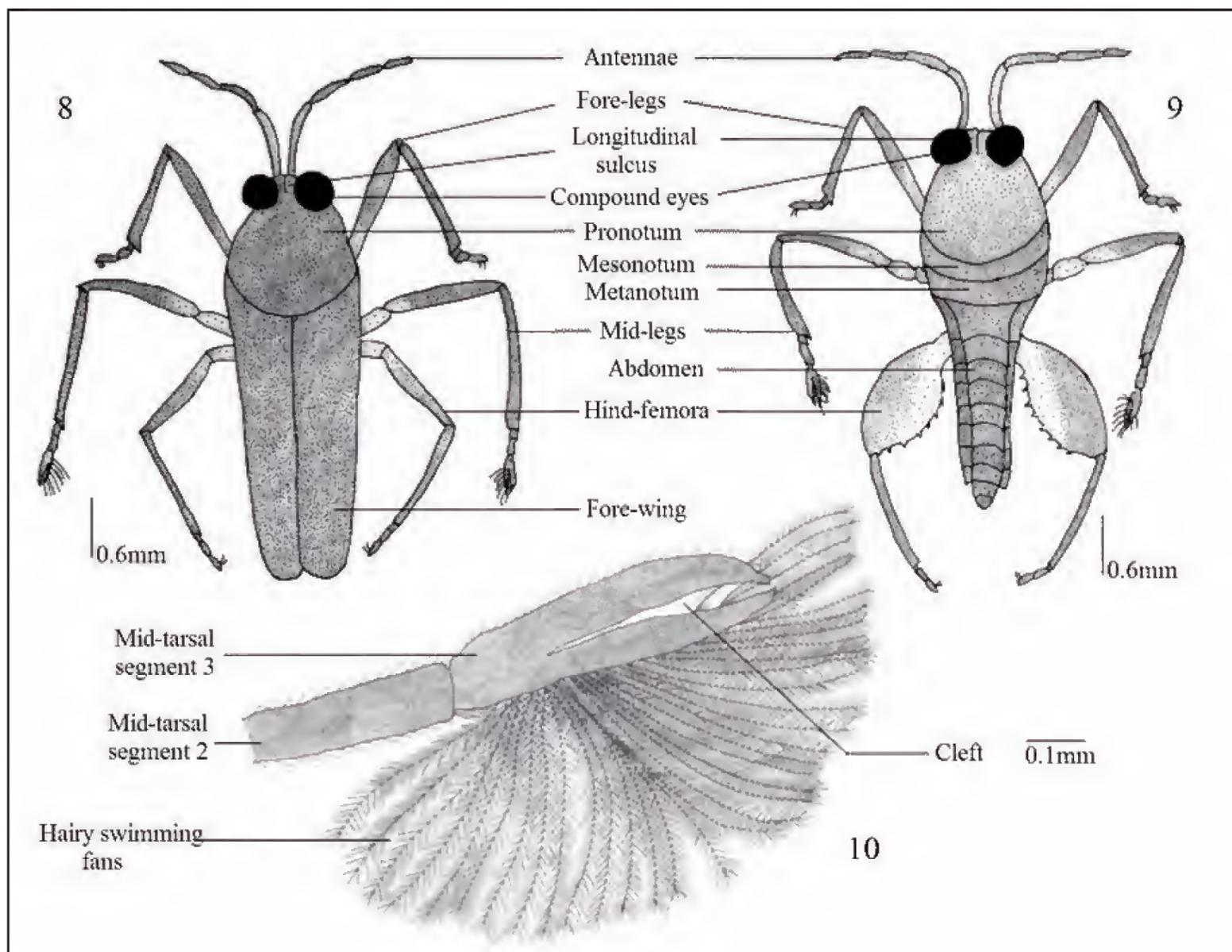
DESCRIPTION OF SPECIES OF THE GENUS *EURYMETRA* ESAKI, 1926 (HEMIPTERA GERRIDAE). The Gerridae are hemimetabolous insects gliding or treading on the surface of the water. They are typically characterized by their jointed mouth parts, modified to form a rostrum or 'beak', which is adapted for piercing and sucking. The head is short, less than two times longer than wide, bent downward, and triangular; it has no longitudinal sulcus, a jointed rostrum with 4 segments, a pair of four-segmented antennae longer than the head, and no ocellus. The mid and hind-legs are distant from fore-legs and longer than these formers, and their femora are clearly extended beyond the abdomen. The hind-coxae are distinctly moved apart from each other.



Figures 2–7. *Orectogyrus* adult. Morphology in dorsal view of *O. specularis* (Fig. 2), *O. sp. 2* (Fig. 3) and *O. sp. 1* (Fig. 4); Fig. 5, antenna; Fig. 6, hind leg; Fig. 7, lateral view of the head showing divided compound eye.

The adult specimens of the genus *Eurymetra* Esaki, 1926 are apterous and distinguishable with their short, stout and rounded abdomen. Their body is shiny and rounded, and generally does not exceed 4.5 mm in length. The meso and metanotum are well distinct and separated by a lateral suture, whereas the metasternum is reduced to a small triangular plaque. All tarsi are two-segmented and the tarsal claws are modified (straight or 'S'-shaped) in some specimens. At the level of fore-tarsi, segment 1 is shorter than segment 2 (Fig. 15), whereas in the mid- and hind-tarsi, segment 1 is 3 to 4 times longer than segment 2 (Fig. 14). Three species, *Eurymetra manengolensis* Hoberlandt, 1952, *Eurymetra* sp. 1 and *Eurymetra* sp. 2 were identified for this study (Figs. 11–13). The specimens of *E. manengolensis* and *E. sp.1* measure  $4.1 \pm 0.1$  mm in length over  $2.48 \pm 0.04$  mm in width, and  $4.04 \pm 0.12$  mm in length over  $2.76 \pm 0.07$  mm in width,

respectively. For *E. manengolensis*, the lengths of the pro-, meso- and metanotum are  $0.23 \pm 0.01$  mm,  $0.94 \pm 0.006$  mm and  $0.24 \pm 0.02$  mm, respectively. Whereas in *E. sp. 1*, the pro-, meso- and metanotum are  $0.25 \pm 0.02$  mm,  $0.94 \pm 0.01$  mm and  $0.22 \pm 0.04$  mm in length, respectively. For these two species, 8 abdominal segments are visible in dorsal view; the edges of thoracic and abdominal tergites are black in color; a mid-dorsal longitudinal band is observed on the thoracic and the first two abdominal tergites. Abdominal pleura are well developed in *E. manengolensis* as compared to *E. sp. 1*. Concerning *E. sp. 2*, the individuals caught measure  $3.11 \pm 0.41$  mm in length and  $2.17 \pm 0.02$  mm in width; 9 abdominal segments are visible in dorsal view. Their pro-, meso- and metanotum measure  $0.22 \pm 0.02$  mm,  $0.97 \pm 0.04$  mm and  $0.23 \pm 0.02$  mm in length, respectively. Their body is pale yellow with median sulcus on thoracic tergites.



Figures 8–10. *Rhagovelia* adult. Morphology in dorsal view of *R. reitteri* (Fig. 8), *R. sp.* (Fig. 9) and detail of mid-tarsal fan (Fig. 10).



### Relationships between environmental variables and insect species

The results of redundancy analysis (RDA) revealed that the relationships between the 8 characteristic aquatic insect species and their habitat conditions follow mainly the first two axes (F1=94.9 %; F2=3.6 %) which accounted for 98.5 % of the total variance expressed (Fig. 16). Following the first axis (F1) in positive coordinates the presence and abundances of the 8 characteristic insect species (*Orectogyrus specularis*, *Orectogyrus* sp. 1, *Orectogyrus* sp. 2, *Rhagovelia reitteri*, *Rhagovelia* sp., *Eurymetra manengolensis*, *Eurymetra* sp. 1 and *Eurymetra* sp. 2) are positively and significantly influenced by water depth, high dissolved oxygen content, important canopy coverage and higher values of OPI (i.e., very low organic matter input). *Rhagovelia* sp. seems to quite appreciate moderate water flow. Inversely, in negative coordinates, the presence of these sensitive aquatic insects is impeded by the polluted status of water with high values of temperature, pH, turbidity, electrical conductivity, suspended solids, ammonium, nitrites, nitrates, phosphates and BOD.

### DISCUSSION

This study achieved in Douala watershed permitted to identify 20 species, all present only at the two forested sites (N1 and N2); no species being found in urban streams. The absence of these

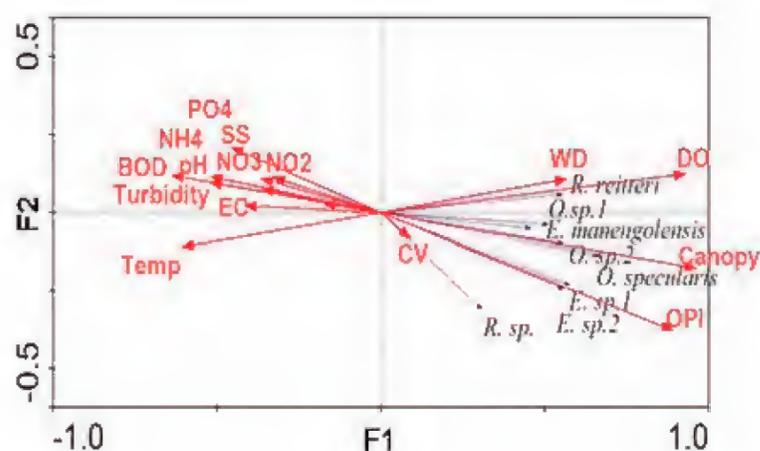


Figure 16. Redundancy analysis biplot showing gathering of characteristic aquatic insect species in response to environmental variables; NH4 = ammonium, NO2 = nitrites, NO3 = nitrates, and PO4 = phosphates. See "Materials and methods" section for other abbreviations.

Hemiptera (Gerridae Veliidae) and Coleoptera (Gyrinidae) families in Douala's urban waterways is undoubtedly due to their polluted status caused by the uncontrolled discharge of domestic, municipal and industrial wastes and sewages in the rivers.

Indeed, the hypoxic condition of water, the very high values of water temperature, conductivity, turbidity, suspended solids, diverse ions ( $\text{NO}_3^-$ ,  $\text{NH}_4^+$ ,  $\text{PO}_4^{3-}$ ), organic matter input and BOD were registered at urban stations, and could have been responsible for the extinction of these aquatic insects. These observations allowed us to assume that species of these families might be sensitive to water pollution and in-stream habitat degradation, since we hypothesized that these taxa would have historically been present at these streams before urbanization, as they do in suburban streams. Similarly, Foto Menbohan (2012) reported that species of these aquatic insect families were absent (or very rare) in the most of urban streams of the Mfoundi river basin in Yaoundé (Cameroon). Our results are consistent with those of Compin & Céréghino (2003) and Song et al. (2009) who showed that a decrease in Coleoptera species richness in human-impacted streams is clearly related to changes in water quality and habitat suitability. Moreover, aquatic Coleoptera species, especially those belonging to Elmidae, Gyrinidae, and Haliplidae have also been recognized as good water quality indicators (Hilsenhoff, 1988; Bote et al., 2002; Sánchez-Fernández et al., 2006). Hauer & Resh (1996) added that many species of these Coleoptera families have been shown to be sensitive to increase in sediment and organic pollution. Concerning the aquatic Hemipteran's families (Gerridae Veliidae), their use in stream biomonitoring programs is still worldwide limited.

In this study, these aquatic bugs occurred only at forested sites and presented high diversity; we believe that these Hemiptera could be sensitive to water pollution and their use as bioindicators might enhance the accuracy of water quality assessments in urban impaired streams. Our results are in line with those of Zettel & Tran (2004) who found that in Vietnam, *Rhagovelia polymorpha* a congener species of *R. reitteri* and *Rhagovelia* sp. identified in Douala forested stream, also inhabit small stream in a forested area, with a moderate to slow water flow, in partial shade, bottom with rock or sand. Moreover, the canonical redundancy analysis

(RDA) revealed that the presence and abundance of the most characteristic species of these aquatic bugs are positively and significantly influenced by high dissolved oxygen content, important canopy coverage, low mineralization, very low organic matter input and current velocity.

Concerning morphological features of the Gyrinidae, this study revealed that *Orectogyrus* sp.1 and *Orectogyrus* sp. 2 differ from the Afrotropical *Orectogyrus specularis* Aubé, 1838 and *O. camerunensis* Ochs, 1924 known to occur in Cameroon, particularly by the distinct metallic shiny ornateness of the elytra. However, these species are to be compared to other Afrotropical allotype or paratype occurring elsewhere, to know whether we are face to new records or new species. As for the Veliidae, *Rhagovelia* sp. described here differs drastically from *R. reitteri*, as it lacks wings. Additionally, *Rhagovelia* sp. has stout hind femora bearing short distinct spines on the inner margins. This former character makes *Rhagovelia* sp. to be closer to *R. polymorpha* describe by Zettel & Tran (2004), but in *R. polymorpha* the body including legs is silky, with numerous black, semi-erect setae and with short, appressed yellow pubescence; legs with very long black setae. Moreover, *R. polymorpha* is smaller in size (body length 3.2-3.6 mm) as compared to our specimen (body length  $4.12 \pm 0.2$  mm). The specimens of *Eurymetra* sp.1 and *Eurymetra* sp.2 that we recorded in this study differ significantly from the typical *E. manengolensis* described by Hoberlandt (1952) in Cameroon Manengouba mount. Abdominal connexiva (pleura) are well developed in *E. manengolensis* as compared to *E. sp. 1*.

In addition, mid- and hind-coxae are larger in *E. sp. 1* than in *E. manengolensis*. As for *E. sp. 2*, the specimen described here shows some similarities with the genus *Eurymetropsis* examined by Poisson (1965) in terms of morphology (especially size and color). However, in *Eurymetropsis* body is more flattened and often lustrous above, the lateral suture between the meso- and metanotum is not so keeled, all tarsal segments are also nearly equal in length, what distinguish it from our specimen.

## CONCLUSIONS

This biological assessment permitted to identify 20 species, all present only at the forested sites; no

species being found in urban streams. This study highlights that species richness and distribution of aquatic insect of the families Gyrinidae, Gerridae and Veliidae in Douala watershed are highly and negatively influence by polluted status of its urban streams due to anthropogenic activities which cause the extinction of the sensitive taxa. We thus believe that these aquatic Coleoptera and Hemiptera species are sensitive to water pollution and we suggest that their use as bioindicators might enhance the accuracy of water quality assessments in Cameroon.

Morphological description of our specimens revealed many undescribed taxa which are probably new records or new species. This testified that in Cameroon, biodiversity of aquatic insects is yet entirely to be investigated, and that there is an urgent need for a modern taxonomic revision and establishment of a complete key to the Cameroonian species.

## ACKNOWLEDGEMENTS

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# High frequency components of the songs of two Cicadas (Hemiptera Cicadidae) from Sardinia (Italy) investigated by a low-cost USB microphone

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## ABSTRACT

During August 2013, a low-cost ultrasonic USB microphone (Ultramic 250 by Dodotronic), was field-tested for its first application ever in Cicadomorph bioacoustics studies. Two different species were recorded in the ultrasonic domain, with 250 kHz sampling frequency, one of them also with 96kHz audio recordings for comparison purposes. Ultramic 250 proved suitable for field use, while the recording campaign provided the opportunity to confirm the presence in South-Western Sardinia of two species (Hemiptera Cicadidae), *Tibicina corsica corsica* Boulard, 1983, endemic to Sardinia and Corse, and the widespread *Cicada orni* Linnaeus, 1758. To the best knowledge of the author, those reported are the first field recordings of Cicadidae songs encompassing the ultrasonic domain up to 125 kHz and, in particular for *C. orni*, display sound emissions at frequencies above those previously reported in literature. Even though conceived for the study of Chiropterans, self-contained, low-cost USB ultrasonic microphones proved useful in insect bioacoustics investigations.

## KEY WORDS

Cicadomorpha; ultrasound; bioacoustics.

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## INTRODUCTION

It has been known for several years that many insects species do hear ultrasounds, as for example in the papers by Conner (1999), Barber & Conner (2007), Pollack (2007), Nakano et al. (2008), Sueur et al. (2008), Corcoran et al. (2009), Nakano et al. (2009), Takanashi et al. (2010) and Yager (2012), that successfully demonstrate that ultrasounds play a significant role in many contexts, including prey-predator interaction and male-female communication. Despite this widely acknowledged fact, spectral components well above human hearing are seldom included in field studies about insect songs, although investigations and description of animal

sounds restrained to a specific frequency window (such as the human hearing range), may result in an incomplete or improper representation of their actual harmonic structure, leading to disputable conclusions.

Generally speaking, with the notable exception of the study of Chiropterans, bioacoustics of the sub-aerial fauna, including insect sounds, has been field-studied mainly within the human hearing range (conventionally ranging from 20 Hz to 20 kHz - herein under, “audio range”), both for comparability with published materials, that we may deem as “historical anthropocentrism”, and for technical reasons including high cost and complex handling of the equipment for ultrasound recording,

that may require a specific technological stack including dedicated microphones, preamplifiers, power sources and recorders, that may prove unsuitable for field use.

A recent field expedition of the author to SW Sardinia, Fluminimaggiore (Carbonia-Iglesias Province), provided the opportunity to field-test an innovative, low cost USB microphone, Dodotronic Ultramic 250, and resulted in the ultrasound recordings here presented to improve bioacoustic knowledge on local Cicadomorpha, as well as to document what appears, to the best knowledge of the author, as the first application of a new class of cheap, self-contained USB microphones with ultrasonic threshold, epitomized by Ultramic 250, in the field of Hemiptera scientific bioacoustics. As a further note of interest, the cicada fauna of Sardinia is still not particularly well studied (J. Sueur, pers. comm.), and the recordings themselves may contribute to filling this gap.

## MATERIAL AND METHODS

Brizio & Buzzetti (2014) reported about the successful usage of Ultramic 250 (Fig. 1) in the field of Orthopteran bioacoustic studies. To test whether Ultramic application to Cicadomorphan bioacoustics would prove equally valid, in August 2013 two species of cicada from Sardinia were recorded.

All the species reported were recorded within a 15 km range from Fluminimaggiore (Carbonia-Iglesias Province, Sardinia, Italy) (Fig. 2), although additional recordings of *Cicada orni* Linnaeus, 1758 were subsequently taken in mainland Italy. All the audio material was obtained by field recording. Specimens were not captured nor recorded in constrained conditions.

The capability of Ultramic 250 to deliver accurate recordings of Orthopteran songs was demonstrated in a separate study (Brizio & Buzzetti, 2014), also by collecting 96 kHz, 16 bit stereo recordings for comparison purposes. Available equipment for audio recordings included a Zoom H1 handheld digital Micro-SD recorder, coupled with a self-built stick stereo microphone using Panasonic WM-64 capsules from an Edirol R-09 digital recorder. Acoustic recordings were taken in stereo, 16 bit, with 96 kHz sampling frequency, and thus capable of covering frequencies up to 48 kHz.



Figure 1. Ultrasound USB recording set: Asus Eee PC 1225B notebook personal computer, USB cable and Dodotronic Ultramic 250. On the display, SeaWave software by the University of Pavia's Interdisciplinary Center for Bioacoustics.

Ultrasound monophonic recording at 250 kHz sampling frequency was performed via a Dodotronic Ultramic 250 microphone connected via USB cable to an Asus Eee PC 1225B notebook personal computer, using SeaWave software by CIBRA - University of Pavia's "Centro Interdisciplinare di Bioacustica e Ricerche Ambientali" (<http://www-3.unipv.it/cibra/>). Originally received as amplitude data (mV) by the recording apparatus, software-normalized spectral energy is expressed in decibels. Sound pressure is expressed in dB Full Scale, even though the dB symbol will be used.

Oscillograms, spectrograms and frequency analysis diagrams were generated by Adobe Audition 1.0 software. All the illustrations refer to Ultramic 250 monophonic recordings unless otherwise noted.

In the recent paper by Brizio & Buzzetti (2014), some technical requirements of Ultramic 250 (such as the need to keep the USB cable length under 1 m) are addressed in more detail. The same paper proposes a specific operating protocol to ensure comparability between Ultramic recordings and audio range recordings available in literature, and supports the consistency of recordings obtained by Ultramic and by conventional microphones, while some cautions are needed due to the poorer frequency response of the ultrasonic-threshold microphone capsule if compared to ordinary microphones.

In day time condition unaffected by Chiropteran or Orthopteran sounds, background noise floor level in the ultrasonic domain can be empirically deter-

ined from frequency analyses as the average level of the spectral components not attributable to the sounds emitted by the recorded specimen, and can easily be measured by recording environmental sounds in quiet, no wind conditions, pointing the microphone towards the specimen during silence pauses. For the recordings here analysed, and for a “medium gain” setting of Ultramic 250 (see Brizio & Buzzetti, 2014), noise floor level in spectral frequency analyses can be placed at around -80 dB for the entire inaudible range.

In the recording station of Capo Pecora, a 71 kHz, very narrow band continuous emission up to -65 dB was recorded even in silent conditions and, being unrelated with the animal sounds here described, shall be reported but excluded from any kind of analysis and will be considered as part of the background noise, its plausible origin being telecommunication antennas in the vicinities that may directly originate the noise, or may induce a spurious harmonic component in the Ultramic circuitry.

When using Ultramic in the field, it is particularly uneasy to find the ideal recording distance from a singing specimen (even more so when, as in the case of the recordings presented here, the

specimen was out of sight) for reasons that include the incapacity of the human ear to take into account the volume of the inaudible components (as a consequence, volumes perceived as relatively low by the unaided ear may saturate the recording) and the variable intensity of inaudible components during song emission. As a consequence, even the smallest variation in the direction of the handheld microphone pointing towards an unseen specimen may result in more or less sharp volume changes, that compose with the natural pattern of volume variations. Consistent with the scope of this study, the author strived to attain the closest possible range and the most precise and constant microphone heading that could provide a high volume input, as near as possible to 0 dBfs, from which even the faintest high frequency harmonics, the most directional and prone to attenuation even at relatively short distance - could be extracted and analyzed.

For those reasons, although the oscillogram, generated in real time by SeaWave, was constantly monitored during the recording, small oscillations in volume can be observed.

Adobe Audition software settings, such as resolution in bands, windowing function and

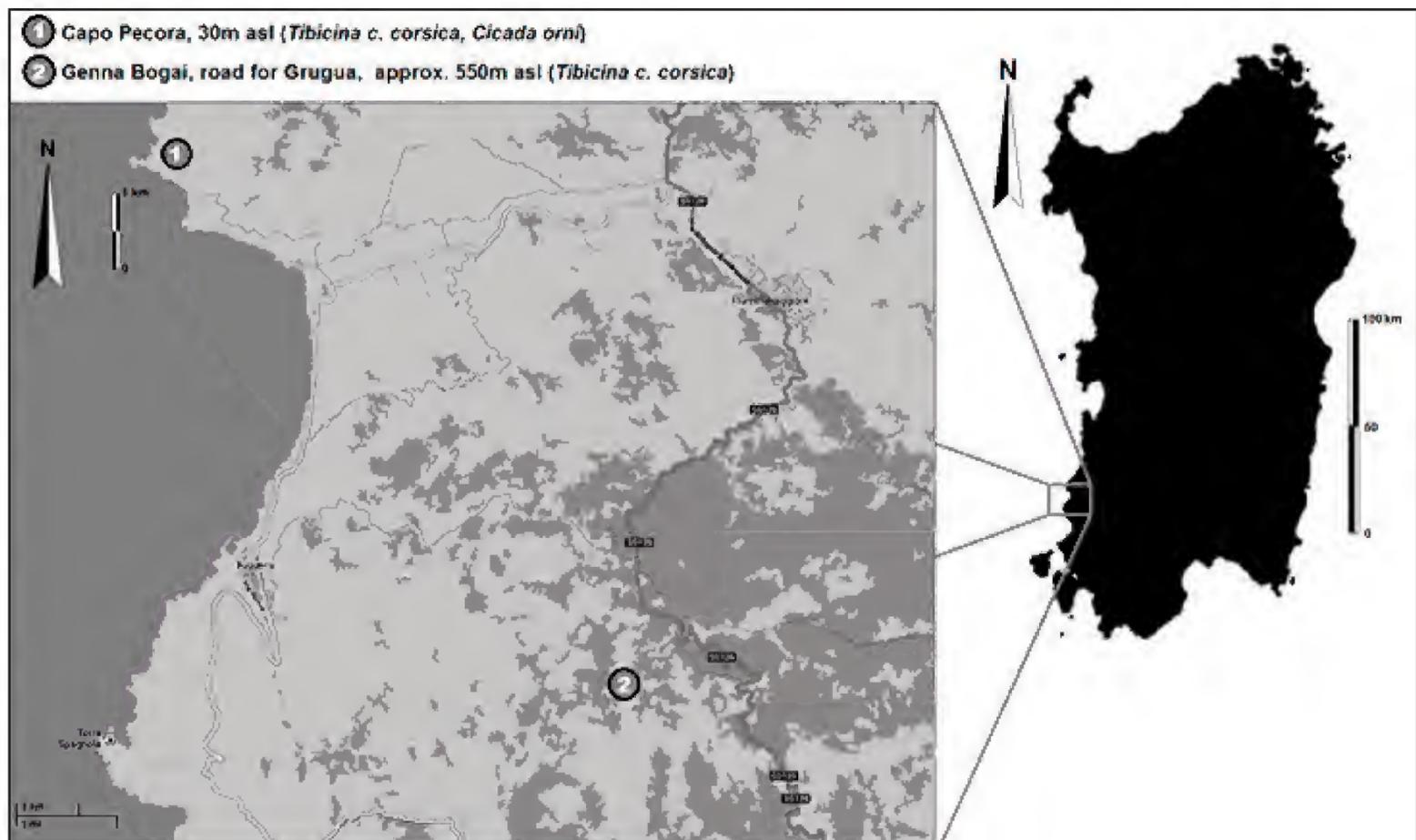


Figure 2. Recording stations in southwestern Sardinia, in the territory of the Communes of Arbus (Capo Pecora) and Fluminimaggiore (Grugua).

logarithmic energy plot range (in our case, respectively 16384, Welch Gaussian and 100 dB) used to generate time-frequency spectrograms were selected as the best compromise for an accurate graphical rendition unaffected by over-representation of background noise. As a consequence of the settings chosen, the lowest significant energy level visualized in the time-frequency spectrograms generated by Adobe Audition is around -70 dB. In all the frequency analyses, a heavy line was superimposed to the illustration at the -70 dB level (Figs. 7, 11-14), marking the level above which spectral components emerge in the time-frequency spectrograms, and constituting a very conservative threshold for the safe attribution of those components, well above the background ultrasonic noise, to the singing animal.

To give more evidence even to the faintest significant spectral components, screenshots from time-frequency spectrograms (Figs. 8, 12, 13) were contrast-enhanced with Adobe Photoshop by a procedure involving in sequence: color removal, image inversion, brightness and contrast adjustment, shadows/highlights adjustment. Those interventions did not affect the accuracy of time-frequency rendering, and allowed to highlight the 95 kHz "tail" (see below) to *C. orni* sound units.

## RESULTS AND DISCUSSION

### *Tibicina corsica corsica* Boulard, 1983

EVIDENCE COLLECTED. Bioacoustical and photographic.



Figure 3. One of the recorded specimens of *Tibicina corsica corsica*, Genna Bogai, 16.VIII.2013.

EXAMINED MATERIAL. Italy, Sardinia, Genna Bogai (Carbonia-Iglesias Province), Latitude 39.37373, Longitude 8.49732, 549 m asl and Capo Pecora (Medio Campidano Province), Latitude 39.450908, Longitude 8.396298, 20 m asl.

DISTRIBUTION. This subspecies (Fig. 3) is distributed in Sardinia and Corse (its type locality), while in mainland Europe (Southern France) it's substituted by *T. corsica farmairei* Boulard, 1984.

REMARKS. Identification of this species, based also on visual recognition supported by photographic evidence, posed no doubt.

Ultrasound recordings took place near Capo Pecora, in the low shrubs (garrigue) with air temperatures in the range of 27 °C at around 16.00. 96 kHz recordings collected around 11 a.m., in comparable air temperature, along the road from the Genna Bogai pass to the locality called Grugua, allowed to verify the consistency between Ultramic and ordinary recordings also in the case of Cicadomorphan songs (Figs. 4, 5). It's noteworthy that the latter samples include an acoustic aggression behaviour as reported by Sueur & Aubin (2003) for the same species in Corse: the loud, competitive interaction between two male specimens, one of them "clicking" and the other "buzzing" in answer to the "clicks".

The male calling song (oscillogram, Figs. 4-6) is typical of *T. corsica*. It's currently believed that the two subspecies, *T. corsica corsica* and *T. corsica farmairei* can not be separated based on their songs, that show no appreciable differences between the insular and the continental subspecies (J. Sueur pers. comm.).

The whole frequency scope spectrum analysis (Fig. 7) allows to observe that, besides the cluster of audible frequency peaks centred around 10 kHz, the sound pattern can be quite clearly made out up to around half of the spectrogram, before hitting the background noise floor observed at around -78 dB. As explained above, the intensity peak at around 71 kHz is a peculiar noise component to be ignored. To give evidence of the song's spectral structure, figure 7 includes five brackets, C1/C5, corresponding each to a specific frequency band limited by a sharp decrease in sound pressure. Within each cluster (with the exception of C4) two main sub-clusters can be made out, with the lower frequency sub-cluster containing the highest sound pressure

peaks. Components above the background noise and attributable to the singing specimen can be made out with sufficient clarity up to 56 kHz.

Although the complexity and peculiarities of the Cicadomorpha sound apparatus do not allow for a song with clearly outstanding fundamental frequencies, as those observed in Orthopteran songs in Brizio & Buzzetti (2014), it can be easily recognized how the song acoustic signature, in frequency bands if not in clearly observable high-order harmonic frequencies, is observable well above the audible range.

The time-frequency spectrogram (Fig. 8) gives further evidence of the presence of ultrasonic, structured higher-order components replicating the main audible band centered around 11 kHz.

### *Cicada orni* Linnaeus, 1758

EVIDENCE COLLECTED. Bioacoustical evidence.

EXAMINED MATERIAL. Italy, Sardinia, Capo Pecora (Medio Campidano Province), Latitude 39.450908, Longitude 8.396298, 30 m asl, approximate nearest recording distance 15 m. Italy, Emilia Romagna, Poggio Renatico (Ferrara Province), Latitude 44.761475, Longitude 11.473074, 10 m asl, approximate nearest recording distance 20-25 m.

DISTRIBUTION. This species is distributed in all the Italian territory.

REMARKS. The ultrasound recordings took place near Capo Pecora, collecting the sound of specimens singing from the pine trees and from the highest shrubs. The following year, further recordings for comparison purposes were obtained in Poggio Renatico, in the Padan Plain of mainland Italy, from specimens singing from English Oaks, Laurel Oaks, Tree of Heaven *Ailanthus altissima* (Mill.) Swingle in an urban private park.

The unmistakable calling song (oscillogram, Figs. 9, 10) of *C. orni*, based on repetitive echemes and well described in literature (for example by Sueur et al. (2008)) substantially differs from the more or less continuous, hissing and higher pitched emission by *T. corsica corsica*.

The frequency analysis of the whole spectral range of a single echeme (Fig. 11), shows a song whose conventional subdivision in "bands", here proposed as an aid in the observation of the song

structure, isn't as evident as in the song of *T. corsica corsica*. Apart showing a less defined pattern, components above the background noise and attributable to the singing specimen can be clearly made out up to approximately 80 kHz. By rescaling the illustration above, one can find a substantial agreement with Figure 2C in Sueur et al. (2008), with vibration spectra displaying an higher relative amplitude around 50 kHz and an increase towards 80 kHz. As reported by Sueur et al. (2008), in the high frequency domain the tympanal membrane (TM) of the female *C. orni* is driven at its best resonance frequency at 50 kHz, a frequency domain represented by bands C4 and C5 in Fig. 11 and Table 2.

Two excerpts from *C. orni* songs Ultrasonic recordings were compared with frequency analyses from Sueur et al. (2008), as illustrated in Fig. 12. Although obtained in different ambient conditions, the two examined excerpts show some consistent features with the sample of *C. orni* tympanal membrane vibration spectra obtained by Sueur et al. (2008)

- two or three "humps" between 40 kHz and 50 kHz, consistent with some of the male specimens (faint blue lines)

- sharp energy increase at around 50 kHz

- three "humps" between 50 and 60 kHz, consistent with several of the female specimens (faint red lines)

- gradual energy increase towards 80 kHz

Frequencies above 80 kHz were not reported in Sueur et al. (2008)

Time-Frequency spectrogram (Fig. 13), allows to observe the synchronicity in the emission of the high-frequency and the audible frequency components of the song. Components attributable to the singing specimen can be made out with sufficient clarity up to 80 kHz.

As a novelty from an higher frequency range than that explored by Sueur et al. (2008), a faint "tail" (a frequency cluster roughly centred at 95 kHz) lasting around 300 msec was observed immediately following some of the better defined emissions (lasting around 100 msec) in the 80 kHz band. By further contrast enhancement of the time-frequency spectrogram, and by extending the spectral analysis to a lapse of time of around 300 msec, encompassing the "tail", the presence of this further emission band can be observed in Fig. 14 and in Fig. 15, emerging

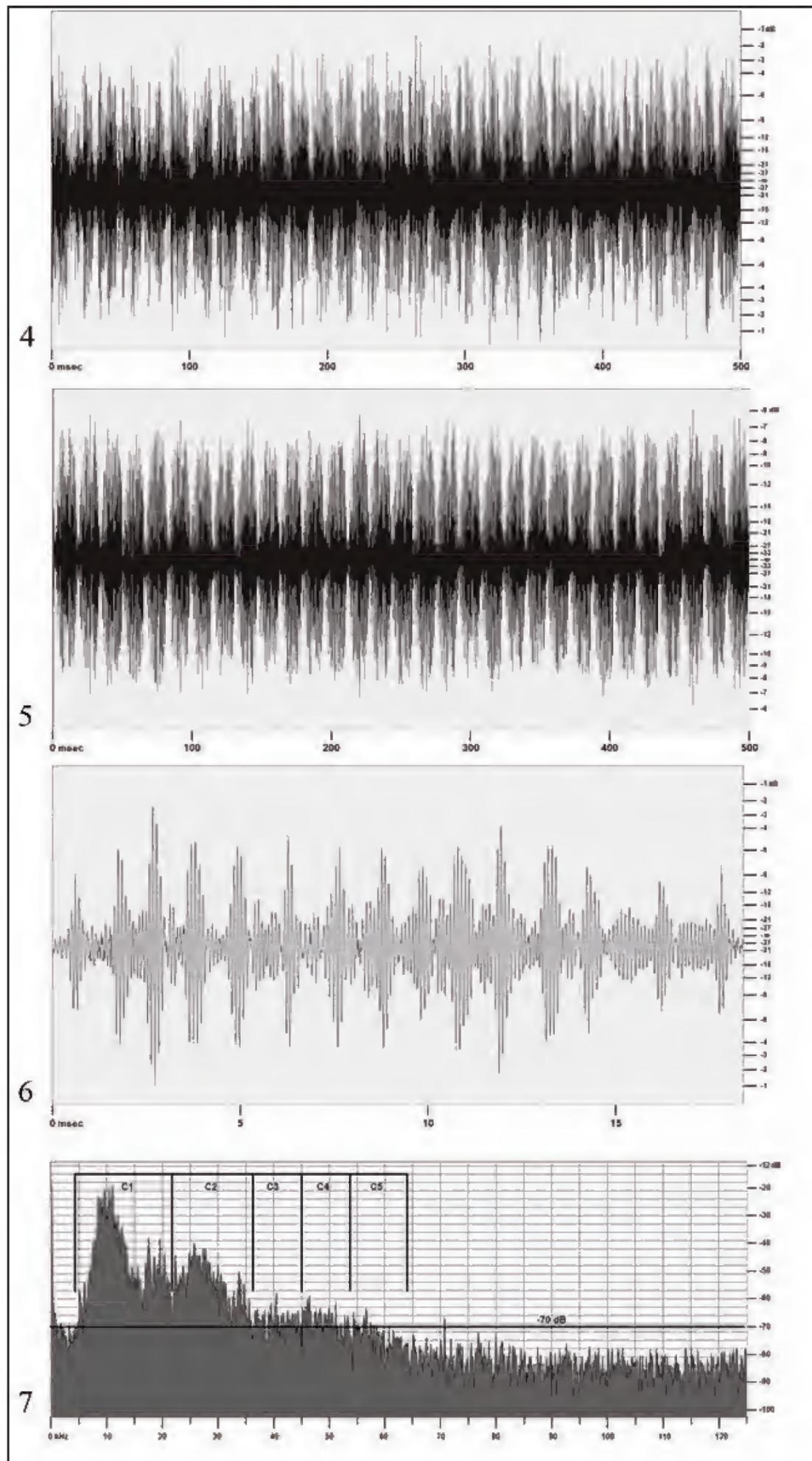


Figure 4. Song of *Tibicina corsica corsica*. Oscillogram, calling song -500 msec. Figure 5. Song of *T. corsica corsica*. Calling song -500 msec. This oscillogram from a 96 kHz recording of another specimen, obtained by a non-ultrasonic microphone based on Panasonic WM-64 capsules, is very similar to Fig. 4, and shows an overall good oscillogram consistency between Ultramic and ordinary recordings. Figure 6. Song of *T. corsica corsica*. Oscillogram, calling song: Sound unit (echeme) -19 msec. Figure 7. Song of *T. corsica corsica*. Frequency spectrum analysis of the calling song, Blackmann-Harris window type, FFT size 4096 bytes, 0-125kHz. Volume window -12dB / -100dB. C1/C5: main "bands" or "frequency clusters" observed.

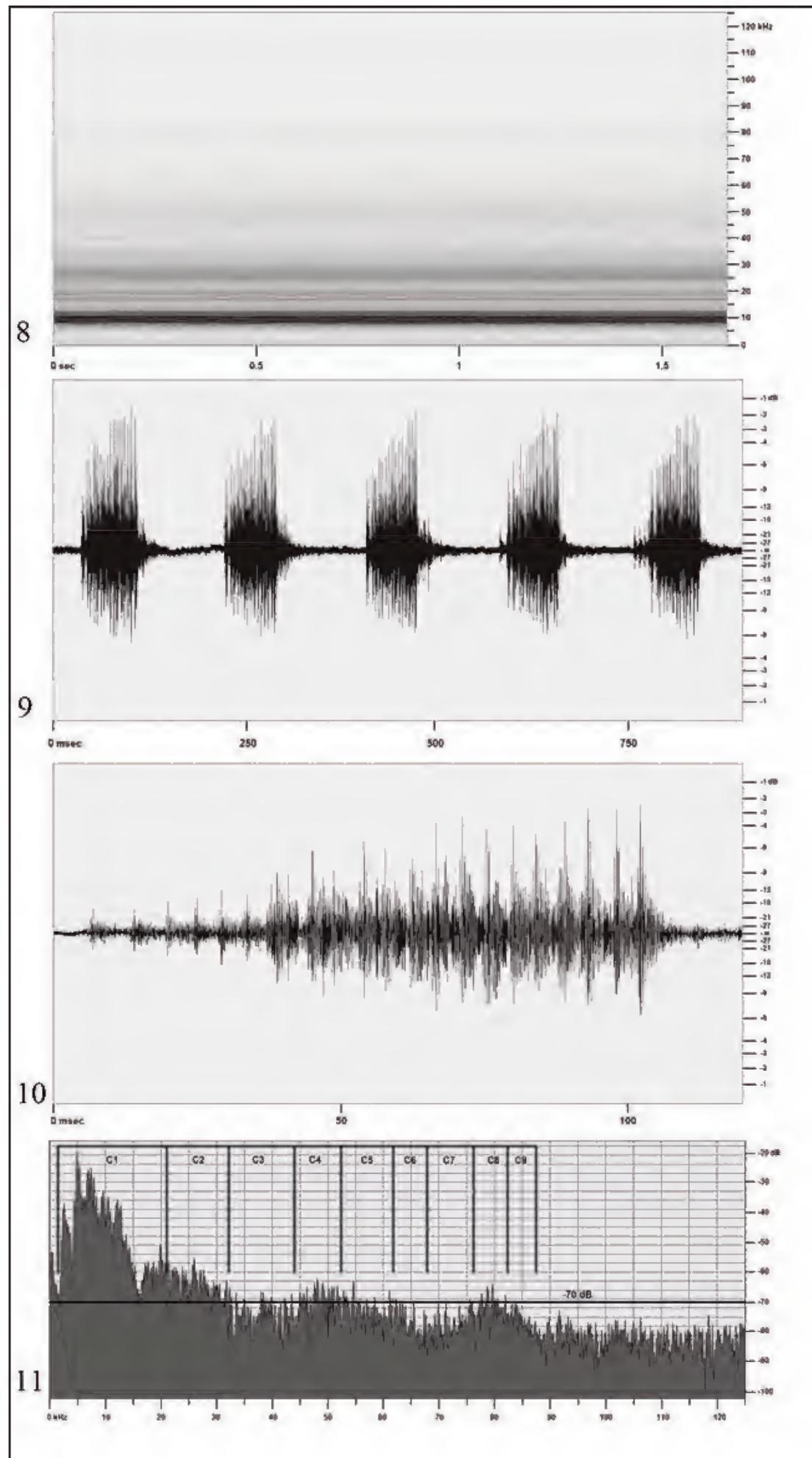


Figure 8. Song of *Tibicina corsica corsica*. Time-frequency spectrogram, 0-125kHz. The faint peak at 71 kHz is a spurious artifact from an unidentified external source. Figure 9. Song of *Cicada orni*. Oscillogram, calling song -870 msec. Figure 10. Song of *C. orni*. Oscillogram, calling song: Sound unit (echeme) -120 msec. Figure 11. Song of *C. orni*. Frequency spectrum analysis of a single song unit, Blackmann-Harris window type, FFT size 4096 bytes, 0-125kHz. Volume range below -20dB. Volume window -12dB / -100dB. C1/C9: main “bands” or “frequency clusters” observed.

Band	Frequency Hz	Volume dB	Band	Frequency Hz	Volume dB	Band	Frequency Hz	Volume dB
C1	8483	-23.24	C1	19470	-38.24	C3	40460	-57.98
C1	9582	-20.58	C1	20320	-43.16	C3	44250	-65.95
C1	10310	-19.98	C2	22270	-44.30	C4	46380	-58.94
C1	10980	-19.18	C2	25690	-39.33	C4	51080	-60.76
C1	11960	-29.91	C2	27280	-41.60	C5	54320	-64.69
C1	12690	-33.94	C2	33690	-50.17	C5	56510	-63.45
C1	17510	-37.67	C3	39420	-61.36	C5	56430	-68.53

Table 1. Song of *Tibicina corsica corsica*. Frequency spectrum analysis of the calling song, a selection of the main observed frequency peaks above -70 dB and their sound pressures from the Ultramic 250 recording.

Band	Frequency Hz	Volume dB	Band	Frequency Hz	Volume dB	Band	Frequency Hz	Volume dB
C1	2563	-36.98	C1	19770	-50.64	C5	54500	-63.30
C1	4882	-19.53	C2	25930	-55.13	C5	61090	-66.48
C1	7385	-24.84	C3	37900	-66.48	C7	71280	-68.45
C1	9521	-33.42	C4	48090	-63.05	C8	78730	-65.22
C1	10490	-35.22	C4	49010	-63.78	C8	79580	-64.11

Table 2. Song of *Cicada orni*. Frequency spectrum analysis of the calling song, a selection of the main observed frequency peaks above -70 dB and their sound pressures from the Ultramic 250 recording.

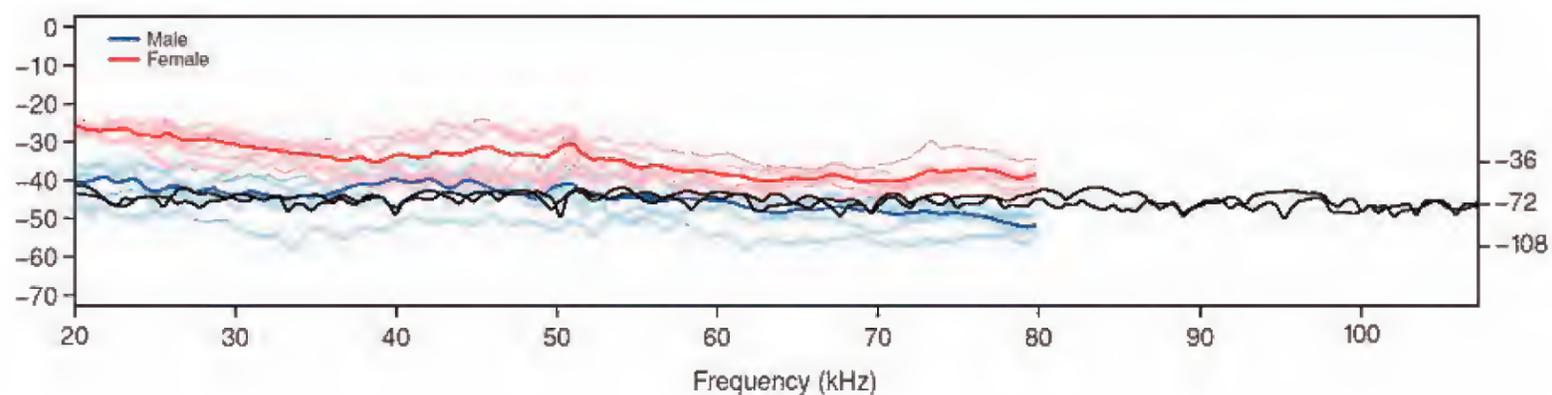


Figure 12. Song of *Cicada orni*. Two frequency analyses of 300 msec excerpts, centered at -72 dB, from *C. orni* Ultramic recordings (solid black lines) are superimposed to average *C. orni* male tympanal membrane vibration spectra (blue lines: male songs, red lines: female songs) measured in laboratory conditions. Illustration modified from Fig. 2 C from Sueur et al. (2008) - frequency range 20 kHz- 110 kHz ca.

above the limit of -70 dB and thus becoming observable in the time-frequency spectrogram.

The 80 kHz components do not appear regularly. Similarly, the 95 kHz band does not follow every echeme containing the 80 kHz band. Having not observed any of the following:

- a total decoupling of the 80 kHz and 95 kHz components from the *C. orni* echemes,
- 80 kHz and 95 kHz components in other Ultramic recordings,
- 80 kHz and 95 kHz components in Ultramic recordings from the same stations during the pauses

between *C. orni* song bouts, the author finds much more probable that those components are an integral, although occasional, part of *C. orni* song units rather than software artefacts emerging at spectrogram rendering level, or artefacts from Ultramic.

The synchronicity of the 80 kHz emission with some of the echemes, and the appearance of the highest frequency emissions here reported both in the frequency analysis mode and in time-frequency spectrograms corroborate this preliminary conclusion.

In August 2014, recordings of *C. orni* song, including the highest frequency components, were obtained in Poggio Renatico (mainland Italy, Padan Plain) for comparison purposes, in particular to investigate the high frequency “tail”. Specimens were recorded from a slightly higher distance (around 20 m) than the previous year in Sardinia. The recordings showed frequent occurrences of the same pattern of irregular high frequency “tails” observed in August 2013 in Sardinia, affecting a band of about 20 kHz from around 75 kHz to around 95 kHz.

For comparison purposes, in the subsequent night and morning the acoustic/ultrasound background was recorded in the same location (Poggio Renatico) of the recordings described above, with the same settings used during the day, avoiding the lapse of time from around 9 a.m. to around 9 p.m. when *C. orni* sings. Screenshots from Adobe Audition were contrast-enhanced with the same procedure as in figures 16 and 17 for comparison purposes.

Background recordings taken at around midnight (Fig. 19) and morning recordings taken at around 8 a.m. (Fig. 20) were examined for any occurrence of the discontinuous yet well recognizable pattern observed in the 75 kHz-95 kHz band of *C. orni* recordings. The author observed that:

- none of the background ultrasound components above 70 kHz exceeded the -70 dB threshold
- the 70 kHz-100 kHz band from the background recordings doesn't bear any resemblance to the same band in *C. orni* recordings. At the same time, *C. orni* recordings seem unaffected by the features appearing in the background recordings.

Background night recordings displayed Chiropteran echolocation calls and Orthopteran songs, with singing species including *Eumodicogryllus burdigalensis burdigalensis* (Latreille, 1804),

*Eupholidoptera schmidti* (Fieber, 1861), *Oecanthus pellucens* (Scopoli, 1763). Ultrasounds from passing bats can be made out at around 30 kHz, while the regular pattern of Orthopteran songs can be made out under 30kHz. Frequencies around 68 kHz and 98 kHz display feeble regular pulses of different duration whose probably anthropogenic origin was not investigated.

The ultrasound background above 70 kHz recorded in the morning resembled quite closely the night recording from the same location, with a persistence of the feeble pulses at around 68 kHz and 98 kHz. Their regularity in the 8 p.m.-8 a.m. period may hint at a non-biological source.

Surely, a more detailed investigation beyond the scope of this paper may corroborate or disprove the author's findings.

## CONCLUSIONS

The songs by two cicadas from Sardinia have been recorded in the field, by a low-cost USB microphone capable of generating very wide band (0 to 125 kHz) monophonic recordings, including both audible and inaudible frequencies. This device, Ultramic 250, by generating results consistent with other recording methods and by providing useful information about the high-frequency components above 20 kHz and up to 125 kHz, proved as useful for the investigation of Cicadomorph songs, as it proved to be in the study of Orthopteran songs.

The song by *T. corsica corsica* showed harmonic components (bands) up to 56 kHz, while the song by *C. orni* seems to exceed the limit of 80 kHz previously explored in literature, and may include frequencies in the 100 kHz range.

Getting a full grasp of the intraspecific and interspecific significance of the ultrasound components is beyond the scope of this contribution: it is reasonable to suppose that the species whose song is here described may have a sound generating and receiving capability even in ranges above those previously reported in literature. Questions that can be addressed include a possible role of ultrasound components in the evaluation of song direction and distance by conspecifics: a sound source may be considered omnidirectional when it emits wavelengths longer than its biggest linear dimension, while directivity is inversely proportional to

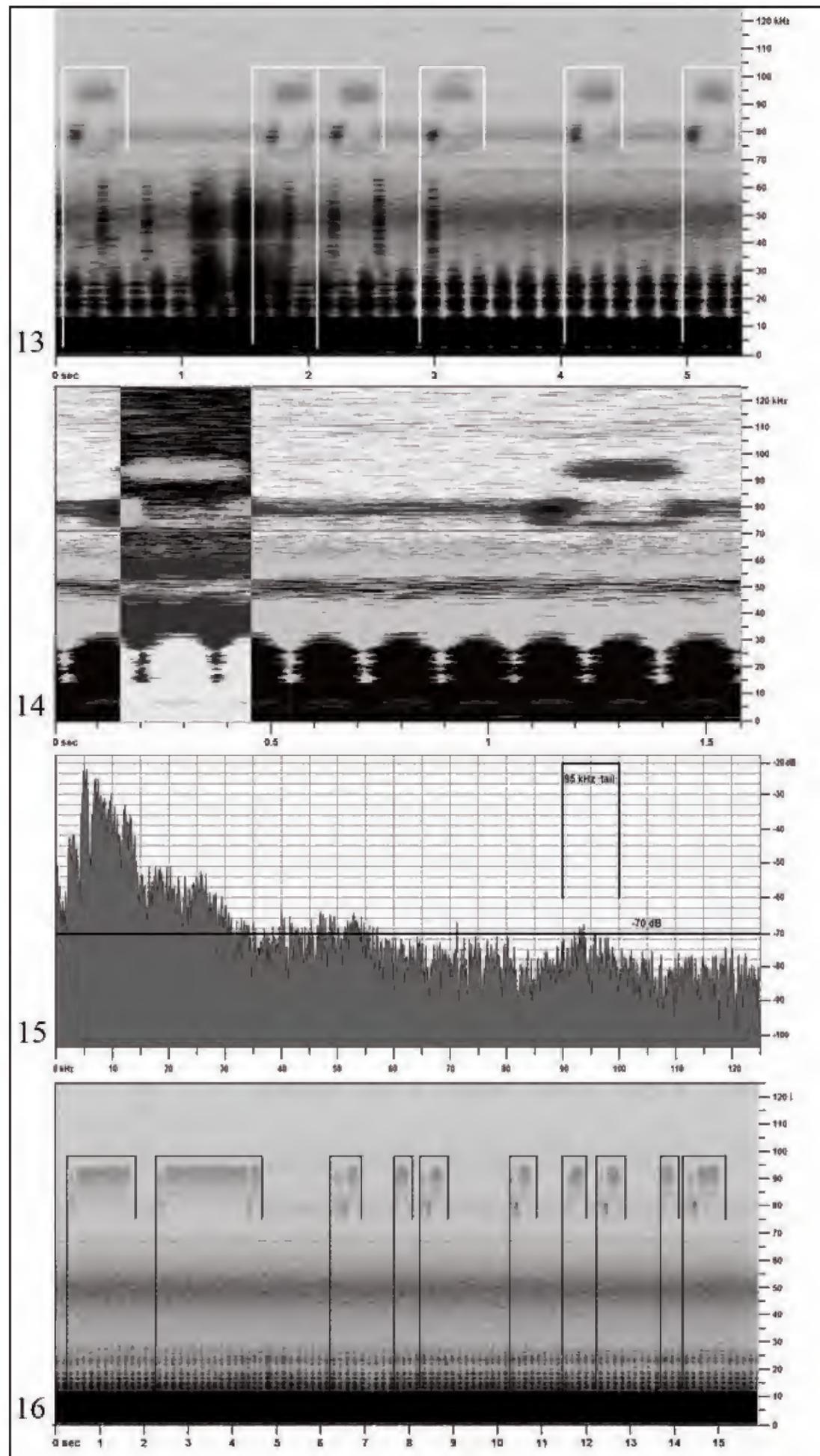
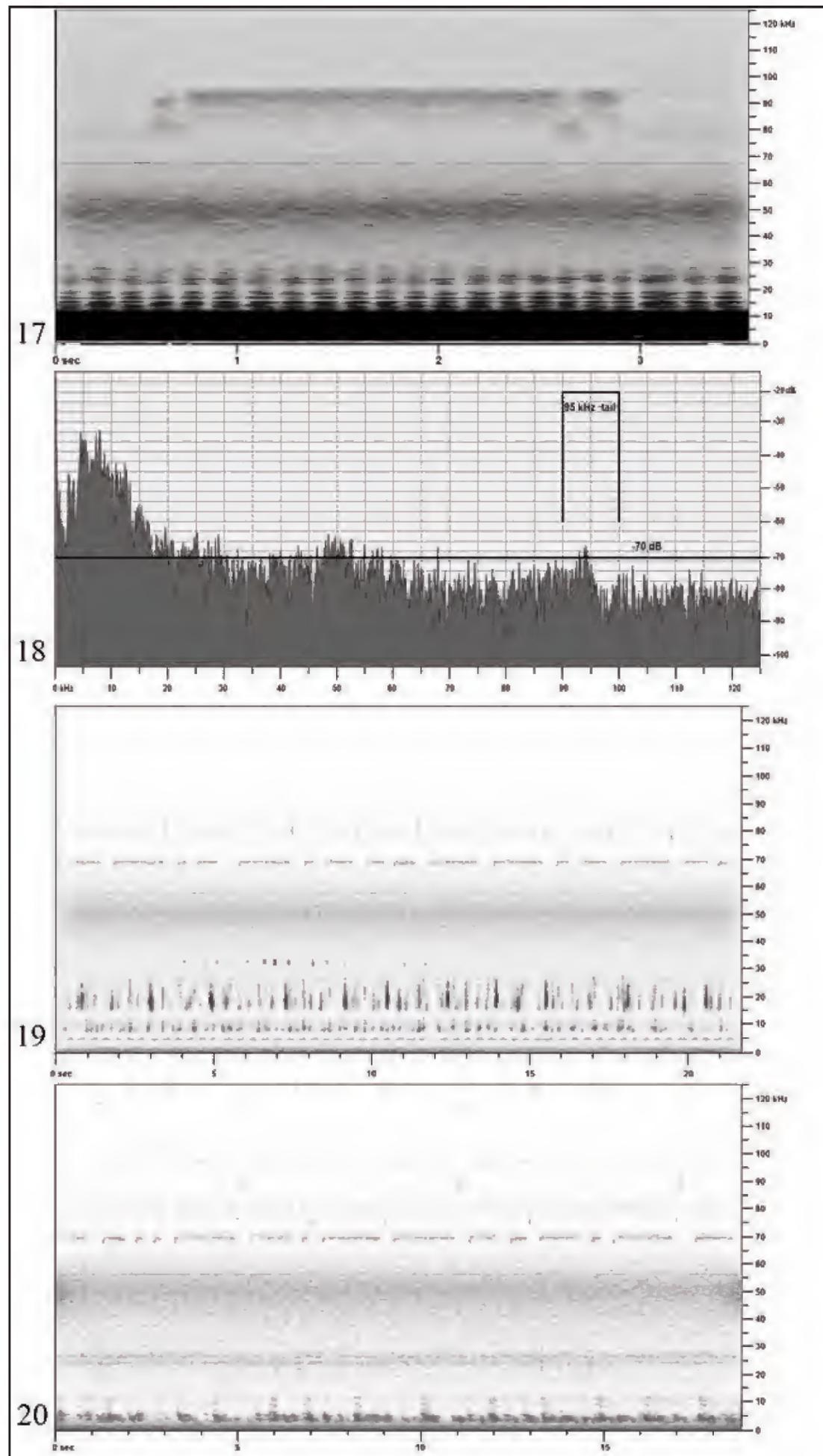


Figure 13. Song of *Cicada orni*. Enhanced contrast picture of a time-frequency spectrogram, 0-125kHz. White lines give evidence to the synchronicity of audible and inaudible spectral components, up to the frequency cluster centered at around 79 kHz and including a very faint 300 msec "tail" in the 95 kHz range. Figures 14-15. Enhanced contrast spectrogram and frequency spectrum analysis of 300 msec including the 95 kHz "tail" band, Blackmann-Harris window type, FFT size 4096 bytes, 0-125kHz. Volume range below -20 dB. Volume window -19 dB / -102dB. Figure 16. Song of *C. orni*, comparison specimen from Poggio Renatico, Padan Plain. Enhanced contrast picture of a time-frequency spectrogram, 0-125 kHz. Black lines border the frequency cluster centered at around 79 kHz and including a very faint 300 msec "tail" in the 95 kHz range.



Figures 17-18. Song of *Cicada orni* from Padan Plain. Enhanced contrast spectrogram and frequency spectrum analysis of 1800 msec including the 95 kHz “tail” band, Blackmann-Harris window type, FFT size 4096 bytes, 0-125 kHz. Volume range below -20 dB. Volume window -15dB/-102 dB. Figure 19. Ultrasound background recording taken at 11:55 p.m. in the night following the recordings in Poggio Renatico, Padan Plain. Enhanced contrast picture of a time-frequency spectrogram, 0-125 kHz. See text for comments. Figure 20. Ultrasound background recording taken at 7:55 a.m. in the morning following the recordings in Poggio Renatico, Padan Plain. Enhanced contrast picture of a time-frequency spectrogram, 0-125 kHz. See text for comments.

wavelength. As reported for example by Miller (2000, 2002) in the case of Killer Whales *Orcinus orca* Linnaeus, 1758 (Mammalia Cetacea), as well as by Jakobsen et al. (2013) for echolocating bats, for a constant energy and emitter size, an increase in frequency, that is decrease in wavelengths, focuses the energy in a beam that is narrower (thus, more directional) but longer, which at short distances counteracts the decrease in range due to increased atmospheric attenuation at higher frequencies. Unfortunately, field recording condition and uncontrollable specimen position in the wild did not allow to draw any conclusion about the orientation of the singing specimen relative to the microphone axis, neither to measure the different relevance of ultrasound components at different angles between the singing specimen and the microphone.

## ACKNOWLEDGMENTS

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## A multi-year survey of the butterflies (Lepidoptera Rhopalocera) of a defined area of the Triestine karst, Italy

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### ABSTRACT

A photographic survey of butterflies (Lepidoptera Rhopalocera) was carried out over a period of three years (2011, 2012 and 2013) in an area around the villages of Malchina, Ceroglie and Slivia, the municipality of Duino-Aurisina near Trieste, in the Friuli Venezia-Giulia region, northeast Italy. Historically, this area of the Triestine karst has been influenced by human activities. Grazing intensity, however, has declined over the past 50-100 years, leading to encroachment of the forested areas over previously more open grasslands. During the three-year survey period, sampling intensity, measured as the number of days during which butterflies were observed and/or photographed, increased from year to year. In 2012 and 2013, especially surveys began in February and continued into December. During the three years, a total of 79 species (Papilionidae, 3; Pieridae, 11; Lycaenidae, 17; Riodinidae, 1; Nymphalidae, 37, including 15 Satyrinae; and Hesperidae, 10), including seven listed as either endangered or near-threatened in Europe, were identified. Among the species of European conservation value recorded were: *Scolitantides orion*, *Melitaea aurelia*, *Melitaea trivia*, *Argynnis niobe*, *Hipparchia statilinus*, *Coenonympha oedippus* and *Carcharodus floccifera*. Strong local populations of the following regionally threatened, declining and/or protected species were also recorded: *Euphydryas aurinia*, *Brintesia circe*, *Arethusana arethusana*, *Hipparchia fagi*, *Pyronia tithonus* and *Coenonympha arcania*. Such intensive surveys covering several months of each year provide in-depth knowledge of butterfly fauna in an area of changing land use, and can provide a benchmark for future surveys against a background of continued land-use change, as well as other pressures such as climate change.

### KEY WORDS

Butterflies; Rhopalocera; Triestine karst; environmental change; biodiversity.

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### INTRODUCTION

The character of the Triestine karst is determined by its climate and geology. Climatically, it represents a transitional area between the Mediterranean and Continental/pre-alpine zones. Geologically, the underlying limestone rocks contribute to features such as exposed rocky outcrops, dolinas (depressions caused by the collapse of underground caves), thin soils and little surface water (although

some artificial ponds have been created) (Poldini, 1989).

These physical conditions have combined with historic land-use changes to create the patchwork of habitats for which the Triestine karst is known today. The original oak forest was felled in historic times and for many years the area was heavily grazed. With a general cessation in grazing, regrowth has occurred and currently mixed woodlands dominated by *Ostrya carpinifolia* Scop., while *Carpinus*

*betulus* L., *Fraxinus ornus* L., *Quercus petraea* (Matt.) Liebl. and *Q. pubescens* Willd. are also widespread. Many areas of open grassland exist, including some considered as Mediterranean maquis and some cut for hay. Other areas are decreasing in size, however, as bushes and trees, including *Cotinus coggygria* Scop. and *Prunus mahaleb* L., encroach on formerly grazed or cultivated areas. The grassy areas that remain contain a mixture of xerothermic herbaceous species with a peak flowering period between mid May and mid June (Poldini, 1989). Naturalised areas of *Pinus nigra* J.F. Arnold, introduced for timber in the 1850s, also survive in pockets.

In the dolinas, where temperature inversions mean that a depth of 60 m is equivalent to an elevation of 1,500 to 1,600 m above sea level in winter and 500 m in summer (Touring Club Italiano, 1999), tree species other than *O. carpini-folia* dominate and the microclimate ensures the survival of glacial relict plant communities.

Meanwhile, close to the villages, small-scale vineyards and vegetable plots provide mainly for local consumption. The combination of these physical and biological conditions has created a unique, biodiverse environment. Paolucci (2010), for example, includes 214 species in his guide to the butterflies of northeast Italy, including the regions of Trentino Alto Adige, Veneto and Friuli Venezia Giulia (the Triveneto) - or some 44% of the 482 European species, the karst playing host to well over a hundred species.

The encroachment of woodland into open grassy areas due to the abandonment of formerly grazed areas, however, continues to change the character of the Triestine karst, impacting on the fauna and flora. Van Swaay & Warren (2001), for example, have noted that the abandonment of agricultural land and/or changing habitat management affects some 65% of threatened butterfly species in Europe, while widespread loss and reduction in size of breeding habitats resulting in habitat isolation and fragmentation affects 83% of Europe's threatened species. Many species listed by Paolucci (2010) thus exist in fragmented habitats or at the edge of their ranges.

Overlaid across such biological and anthropogenic influences, climate change is also having noticeable effects on the distribution of many European butterfly species (Roy & Sparks, 2000; Roy et al., 2001; Warren et al., 2001; Stefanescu et

al., 2003), and will continue to do so for the foreseeable future (Settele et al., 2008).

Given the importance of several Italian locations for butterfly diversity and conservation (van Swaay & Warren, 2006), alongside the lack of any systematic recording scheme in the country (van Swaay et al., 2012a), this study set out, through surveying the butterfly fauna of a restricted area of the Triestine karst, to establish a benchmark against which future surveys to determine the ongoing impacts of local land-use and/or climate-induced changes can be compared.

## MATERIAL AND METHODS

### *Study area*

A photographic survey of butterflies (Lepidoptera Rhopalocera) was carried out over a period of three years in an area around the villages of Malchina, Ceroglie and Slivia, the municipality of Duino-Aurisina near Trieste, in the Friuli Venezia-Giulia region, northeast Italy, close to the border with Slovenia (Fig. 1). The highest elevation in the region is Monte Ermada (323 m) to the west of the surveyed zone, which is crossed by several rough tracks and paths. The main paths included in the surveys described herein mostly either start from or pass through Malchina, and include parts of the Gemina path, the Vertikala, CAI 31 and other marked paths (Fig. 1; Anonymous, 2005), and pass through various habitats, including vegetable plots, vineyards, woodlands, dolinas, and grassland that may or may not be cut for hay. There are also several ponds in the study area, in particular one at Malchina and two close to Slivia.

In Malchina itself, many gardens have nectariferous plants such as *Lavandula* L., *Mentha* L. and *Origanum* L. that flower especially in July and attract butterflies from the surrounding areas. The author's south-facing garden is one such example.

### *Equipment*

During sampling sessions, pictures were taken of as many butterflies encountered as possible - if possible including both upper- and under-wing views to assist with accurate identification. For the most part, a Pentax K-k digital camera (typically set

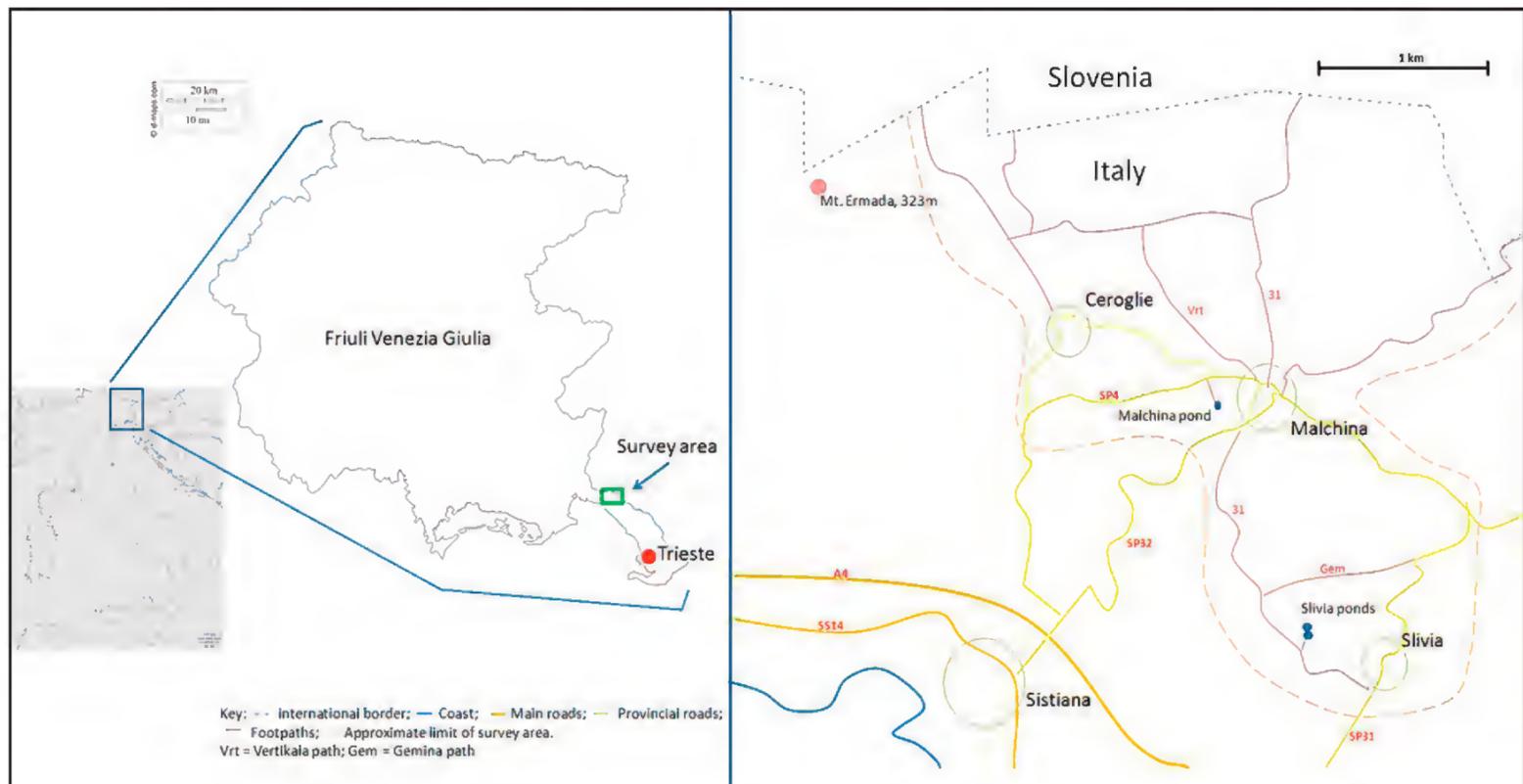


Figure 1. Study area. Left: location of the area surveyed in this study in relation to the rest of Italy, the Friuli Venezia Giulia region and the city of Trieste. The area highlighted in green is shown in more detail to the right. (Outline maps courtesy of d-maps.com). Right: details of roads plus key tracks and paths and other features of the survey area between Ceroglie, Malchina and Slivia north to the border between Italy and Slovenia.

to 200 ASA) was used in tandem with a Sigma 105 mm macro lens. On other occasions, other digital devices such as a compact camera or smartphone were used to record specimens. In addition, especially in 2013 and for those species that are easier to identify definitively (e.g. *Iphiclides podalirius*, male *Anthocharis cardamines*, male *Colias croceus* or *Vanessa atalanta*), butterflies identified without being photographed were recorded as ‘observed’.

### Sampling technique/intensity

Surveys were undertaken over three consecutive years by following the rough tracks, footpaths and field margins in the survey area. No attempt was made to quantify the numbers of a given species observed.

Sampling intensity increased during the course of the three years, as outlined in Table 1. In most cases, surveys were carried out for at least 30 minutes and usually for between 60 to 120 minutes. Surveys were also typically carried out on hot (for the time of year), sunny days with minimal cloud cover.

In 2011, photographs were taken ad hoc, with no attempt to systematically record all sightings, rather just a few notable occurrences. In addition, in most cases, the actual sampling actual dates were

not precisely recorded, just the month. In nine sampling instances, the month is recorded only as either June or July (Table 1).

In 2012, more intense efforts were made to photograph or identify all butterflies observed. Survey dates (59 in total) were accurately recorded (Table 1).

In 2013, attempts were made to photograph or identify all butterflies observed. As in 2012, sampling occasions noted in Table 1 as being undertaken in the author’s garden often lasted just a few minutes and tended to be limited to the period of flowering of the *Lavandula*, *Mentha* and *Origanum* plants. In other cases, butterflies observed during days when no specific (photographic) survey was undertaken were also recorded (12 such occasions). In 2013, including sampling occasions when either only observations were recorded or when no butterflies were seen (despite favourable conditions), a total of 61 sampling sessions were undertaken (Table 1).

### Identification and analysis

To identify the species recorded, various guide books were consulted, especially Paolucci (2010)

and Tolman & Lewington (1997). In cases of uncertainty, experts belonging to the Forum Entomologi Italiani (<http://www.entomologiitaliani.net>) were consulted by posting suitable photographs online. The author also gratefully acknowledges the assistance of Lucio Morin, a local butterfly expert, for help with either the identification or confirmation of the identification of a number of specimens.

Among those species that can be difficult to distinguish from photographs, L. Morin (pers. comm.) also confirms that the species found in the sampling area are *Leptidea sinapis*, not *L. reali*, *Colias alfacariensis* Ribbe, 1905, not *C. hyale* (Linnaeus, 1758), and *Plebejus argus*, not *Pl. idas* (Linnaeus, 1761). In the case of white Pieridae, especially when no suitable photograph was obtained, individuals could often only be identified to the genus level (*Pieris*). In 2011 or 2012, *Pieris* spp. were not regularly recorded, either as photographs or as 'observed'. Species names are valid as per the listing on Fauna Europea ([www.faunaeur.org](http://www.faunaeur.org)). It should be noted, however, that Fauna Europea considers *Hamearis lucina* (Linnaeus, 1758) as a member of the family Riodinidae, whereas it is now included among the Lycaenidae by many authors. The conservation status of the species observed is based on the European Red List of Butterflies (van Swaay et al., 2010), the list provided by van Swaay et al. (2012b) for the European Habitats Directive, and the list for the Triveneto region provided by Paolucci (2010).

## RESULTS

### *Environmental variables*

A total of 482, 1,208 and 1,657 photographs were retained from sampling surveys carried out in 2011, 2012 and 2013, respectively. These photographs accounted for 156, 479 and 738 individual butterflies in each of the three years, respectively. In addition, in 2013, some 128 individuals were recorded as 'observed' but not photographed.

During these three years, 79 butterfly species were recorded. Of these, 45 were recorded in 2011 when sampling was less intensive, 63 in 2012, and 70 in 2013 (Tables 2, 3 and 4).

Of the 79 species recorded, 3 belonged to the family Papilionidae; 11 to the Pieridae; 17 to the Lycaenidae; one to the Riodinidae; 37 to the

Nymphalidae, of which 15 were Satyrinae; and 10 to the Hesperidae.

In early 2012, no butterflies were observed or photographed during the single sampling date in February (12th), although they were on two of three dates in March (on 11th and 24th, but not on 26th). Likewise, in 2013, no butterflies were observed or photographed on the February sampling date (16th), while they were recorded on one of the two sampling dates in March (on 3rd, but not on 22nd), and on nine of 10 dates in April (not on 15th). Among the early-season (up to mid April) species recorded were *Pieris rapae*, *P. napi*, *Gonepteryx rhamni*, *Libythea celtis*, *Nymphalis polychloros*, *Pararge aegeria* and *Erynnis tages*.

In the second half of April, 15 species were recorded in 2012 (including one specimen of *Zerynthia polyxena* on 30 April) and 16 in 2013 (Tables 3 and 4). Among these in 2013 was *V. atalanta*, which was also regularly recorded in early March 2014.

With regard to late-season records, in 2012, butterflies were recorded on 2 and 3 November, but not 22nd. No sampling was undertaken in December 2012. In 2013, butterflies were recorded on three of four dates in November (1, 10 and 17th, but not on 24th), and on one of two dates in December (on 14th but not on 7th). These late-season species (observed in November and into early December), included *C. crocea*, *L. celtis*, *V. atalanta* and *Cacyreus marshalli*.

The highest number of species recorded in a single day was 24 (on 24 August 2013), with more than 20 species also being recorded on six other occasions in 2013 (22 June, 13 and 20 July, 16 and 18 August and 9 September). In 2012, the maximum number of species recorded in a single day was 17 (on 17 July).

Comparing the number of species observed during half-month periods (Tables 2, 3 and 4), 37 species were recorded in the second half of July 2013, with 50 species recorded for the month as a whole (Table 4). Similarly, in 2012, more species were recorded in July than any other month (37), although the diversity was greater in the first half of the month (29 species compared to 19 in the second half of the month) (Table 3).

Among the species most commonly recorded (depending on their respective flight periods) were *I. podalirius*, *P. rapae* and *P. manni*, *Pl. argus*, *Polyommatus icarus*, *Po. bellargus*, *V. atalanta*,

*Melanargia galathea* f. *procida*, *Maniola jurtina* and *Coenonympha pamphilus*. Among the most commonly recorded HesperIIDae were *E. tages*, *Hesperia comma* and *Ochlodes sylvanus*.

Other species were relatively common in some years, but not recorded in other years. *Aporia crataegi*, for example, was recorded in 2011 and 2013 but not in 2012. Likewise, *Hipparchia statilinus* and *Coenonympha oedippus* were recorded only in 2012, and *Aricia agestis* and *Pontia edusa* only in 2013 (Tables 2, 3 and 4).

Also of note were variant forms of some species. *M. galathea* was always present as *M. galathea* f. *procida*, along with a small percentage of f. *leucomelas*. Likewise, a small percentage of *Argynnis paphia*, were f. *valesina*.

Species recorded rarely (i.e. no more than two individuals recorded in any one year) in the area surveyed include *Z. polyxena*, *Callophrys rubi*, *Leptotes pirithous*, *Cupido argiades*, *Cyaniris semiargus*, *Po. daphnis*, *Scolitantides orion*, *Nymphalis antiopa*, *Aglais io*, *Polygonia c-album*, *Melitaea aurelia*, *Brenthis hecate*, *Argynnis adippe*, *A. niobe*, *C. oedippus*, *Carcharodus alceae*, *Carcharodus floccifera* and *Spialia serorius*. Among these, *Z. polyxena*, *S. orion*, *N. antiopa*, *M. aurelia*, *B. hecate* and *C. oedippus* are notable owing to their conservation status (see below).

Of particular interest are seven species recorded in the survey area that are included in the European Red List of Butterflies (van Swaay et al., 2010). The conservation status of these species is outlined in Table 5. In addition, van Swaay et al. (2010) also note that *Euphydryas aurinia*, *C. oedippus* and *Z. polyxena* are listed in 16, 2 and 1 European LIFE projects (see <http://ec.europa.eu/environment/life/>), respectively, with special efforts being made towards their conservation.

A number of other species recorded in the three-year survey are also of regional conservation interest (Table 6). Other than species such as *Callophrys rubi*, *N. antiopa* and *Melitaea trivialis* that were recorded infrequently, healthy populations of vulnerable and locally protected species (including *L. celtis*, *E. aurinia*, *Brintesia circe*, *Arethusana arethusana*, *Hipparchia fagi* and *Coenonympha arcania*) were recorded in the survey area.

The case of *E. aurinia* is interesting in that no individuals were recorded south of the road that bisects the village of Malchina (SS4); although

never abundant, it was observed in reasonable numbers in localized areas north of SS4, but never far (no more than 500 m) from Malchina itself. Likewise, all individuals of *C. oedippus* were recorded within an area of radius no more than 150 m, also to the north of Malchina.

In addition to those species highlighted in Table 6, a further five species found in the survey area are recorded by Paolucci (2010) as being lower risk/near threatened (LR/NT) in the Triveneto region: *Cupido alceas*, *S. orion*, *Hamearis lucina*, *Melitaea athalia* and *Minois dryas*. Of these, *H. lucina* and *M. dryas* are also relatively common and well distributed throughout most of the survey area (Tables 2, 3 and 4).

Likewise, Paolucci (2010) records the following species as data deficient (DD) in the Triveneto region: *P. manni*, *Favonius quercus*, *C. argiades*, *N. polychloros*, *M. aurelia*, *A. niobe* and *C. floccifera*. Of these, *P. manni* and, early in the season, *N. polychloros* both maintain reasonable populations in the survey area (Tables 3 and 4). Thus, the three-year survey undertaken by the author helps to fill some of these data gaps.

## DISCUSSION

The total of 79 species recorded during the three-year survey period compares favorably with other areas of Europe. In the whole of the United Kingdom, for example, there are just 57 resident plus two regular migrant species (Asher et al., 2001). Wagner et al. (2013) recorded 49 butterfly species from 27 sites along an altitude gradient in Bavaria, Germany; while Veronivnik et al. (2011a) recorded between 42 and 61 species each year during a five-year survey (2007-2011) of a disused army base at Mlake in Slovenia, recording a total of 95 species overall. In northern Italy, Marini et al. (2009) recorded 60 butterfly species through sampling 44 hay meadow parcels during a single year (2007) in the Trento region, while Boriani et al. (2005) sampled nine sites of three different rural habitat types in Emilia-Romagna in 2002 and 2003, identifying 39 species. The total also compares well with the 91 butterfly species recorded by Carrara (1926) following many years of collection and study in the area around Trieste (immediately to the east of the area that is the focus of this study and covering a much larger area).

Month-Dates/ Year	Feb 16-28	Mar 1-15	Mar 16-31	Apr 1-15	Apr 16-30	May 1-15	May 16-31	Jun 1-15	Jun 16-30	Jul 1-15	Jul 16-31
2011	0	0	0	1	1	5 <sup>1</sup>	5 <sup>1</sup>	3 <sup>2</sup>	3 <sup>2</sup>	9 <sup>3</sup>	9 <sup>3</sup>
2012	1 <sup>4</sup>	1	2	1	6 <sup>5</sup>	4	3	1	7 <sup>1</sup>	9 <sup>1</sup>	8 <sup>6</sup>
2013	1 <sup>4</sup>	1	1 <sup>4</sup>	2	8 <sup>10</sup>	5 <sup>11</sup>	3 <sup>11</sup>	6 <sup>11</sup>	4 <sup>11</sup>	5 <sup>11</sup>	7 <sup>7, 11</sup>
Month-Dates/ Year	Aug 1-15	Aug 16-31	Sept 1-15	Sept 16-30	Oct 1-15	Oct 16-31	Nov 1-15	Nov 16-30	Dec 1-15	Total	
2011	5	5	3	3	2	2	0	0	0	28	
2012	4 <sup>7</sup>	4	3	2	0 <sup>8</sup>	0 <sup>8</sup>	2	1	0	59	
2013	1 <sup>7, 11</sup>	3 <sup>4</sup>	2	2 <sup>11</sup>	3	1	2 <sup>11</sup>	2 <sup>9</sup>	2 <sup>12</sup>	61	

Table 1. Sampling intensity broken down into half-month intervals. Sampling occasions marked as ‘in author’s garden’ or ‘observations only’ (see footnotes) were less intense than other occasions that involved excursions along the various paths highlighted in Fig. 1. <sup>1</sup> Of which 3 occasions in author’s garden, Malchina. <sup>2</sup> Of which 2 occasions in author’s garden, Malchina. <sup>3</sup> Refers to June and July together, of which 7 occasions in author’s garden, Malchina. <sup>4</sup> No butterflies observed. <sup>5</sup> One sampling date included two periods (30 April, a.m. and p.m.). <sup>6</sup> Of which 6 in author’s garden, Malchina. <sup>7</sup> Of which 1 occasion in author’s garden, Malchina. <sup>8</sup> Owing to other commitments, no surveys were undertaken during October 2012. <sup>9</sup> No butterflies observed. Sampling carried out in evening (17:50-18:20) after warm sunny day. <sup>10</sup> Of which 2 occasions: ‘observations’ only (no photographs) - within Malchina itself. <sup>11</sup> Of which 1 occasion: ‘observations’ only (no photographs) - within Malchina itself. <sup>12</sup> Of which 1 occasion: ‘observations’ only (no photographs) (14 December) within Malchina itself. No butterflies recorded on other sampling date (7 December).

TOTAL SPECIES 45	April (1) <sup>1</sup>	May (5)	June (3)	June- July (9)	Aug (5)	Sept (3)	Oct (2)
<b>PAPILIONIDAE</b>							
<i>Ipichlides podalirius</i> (Linnaeus, 1758)		__x__	__X	x_x__			
<i>Papilio machaon</i> Linnaeus, 1758			__x	x_x__			
<b>PIERIDAE</b>							
<i>Anthocharis cardamines</i> (Linnaeus, 1758)	o						
<i>Aporia crataegi</i> (Linnaeus, 1758)		__X_					
<i>Pieris mannii</i> (Mayer, 1851)						__x_	
<i>Pieris rapae</i> (Linnaeus, 1758)			__x_				
<i>Leptidea sinapis</i> (Linnaeus, 1758)	x	__x__					
<i>Colias croceus</i> (Fourcroy, 1785)		__x_				x__	x_
<i>Gonepteryx rhamni</i> (Linnaeus, 1758)			__x_				
<b>LYCAENIDAE</b>							
<i>Favonius quercus</i> (Linnaeus, 1758)						__x	
<i>Satyrrium ilicis</i> (Esper, 1779)		__x__					
<i>Lycaena phlaeas</i> (Linnaeus, 1761)						__x_	
<i>Cacyreus marshalli</i> Butler, 1898							x_
<i>Cupido argiades</i> (Pallas, 1771)				__x__			

Table 2 (1/2). Summary of butterfly species recorded and observed in the study area in 2011. <sup>1</sup> Figures in brackets indicate no. of sampling sessions per month (or June/July period). <sup>2</sup> Actual sampling session not recorded. x = Either one or two individuals photographed during a sampling session; X = 3 or more individuals photographed during a sampling session; o = Observed (but not photographed) during a sampling session; \_ (or blank) = Neither photographed nor observed during a sampling session.

Species	April (1) <sup>1</sup>	May (5)	June (3)	June- July (9)	Aug (5)	Sept (3)	Oct (2)
<i>Plebejus argus</i> (Linnaeus, 1758)		__x	x__	__X_Xx			x__
<i>Plebejus argyrognomon</i> (Bergsträsser, 1779)		__x__					
<i>Polyommatus bellargus</i> (Rottemburg, 1775)		__X__		x_____	__xx_	Xxx	
<i>Polyommatus icarus</i> (Rottemburg, 1775)		__X__			__xx_	__x	__x
<b>RIODINIDAE</b>							
<i>Hamearis lucina</i> (Linnaeus, 1758)		x__		__x_	__x		
<b>NYMPHALIDAE</b>							
<i>Vanessa atalanta</i> (Linnaeus, 1758)						__x	
<i>Vanessa cardui</i> (Linnaeus, 1758)						__x_	
<i>Limenitis reducta</i> Staudinger, 1901				__x_____		x__	
<i>Melitaea aurelia</i> Nickerl, 1850					__x		
<i>Melitaea didyma</i> (Esper, 1778)						xx_	
<i>Euphydryas aurinia</i> (Rottemburg, 1775)	X	__x_					
<i>Issoria lathonia</i> (Linnaeus, 1758)						x_x	
<i>Argynnis paphia</i> (Linnaeus, 1758)					x_x__		
<i>Argynnis adippe</i> (Denis et Schiffmüller, 1775)			x__				
<i>Boloria dia</i> (Linnaeus, 1767)					x <sup>2</sup>		
<i>Brenthis hecate</i> (Denis et Schiffmüller, 1775)			x__				
<i>Melanargia galathea procida</i> (Linnaeus, 1758)			x__				
<b>NYMPHALIDAE, Satyrinae</b>							
<i>Minois dryas</i> (Scopoli, 1763)					xxx_x	x__	
<i>Brintesia circe</i> (Linnaeus, 1775)						__x_	
<i>Arethusana arethusia</i> (Denis et Schiffmüller, 1775)					xxx_x	__x_	
<i>Hipparchia fagi</i> (Scopoli, 1763)				__xx__	xxx_x	x__	
<i>Hipparchia semele</i> (Linnaeus, 1758)						__X	__x
<i>Lasiommata maera</i> (Linnaeus, 1758)		__x__		__x_____		__x_	
<i>Pararge aegeria</i> (Linnaeus, 1758)						__x	
<i>Pyronia tithonus</i> (Linnaeus, 1767)						__x_	
<i>Maniola jurtina</i> (Linnaeus, 1758)			x__		__x__	__x_	
<i>Coenonympha arcania</i> (Linnaeus, 1761)		__X__					
<i>Coenonympha pamphilus</i> (Linnaeus, 1758)	x	__xx_	xx_		__xXx_	__xx	__x
<b>HESPERIIDAE</b>							
<i>Erynnis tages</i> (Linnaeus, 1758)					__x		
<i>Hesperia comma</i> (Linnaeus, 1758)					__xx_		
<i>Ochlodes sylvanus</i> (Esper, 1777)			x__	x_____	__x_		
<b>No . of species/month</b>	<b>3</b>	<b>14</b>	<b>11</b>	<b>10</b>	<b>14</b>	<b>21</b>	<b>6</b>

Table 2 (2/2). Summary of butterfly species recorded and observed in the study area in 2011. <sup>1</sup> Figures in brackets indicate no. of sampling sessions per month (or June/July period). <sup>2</sup> Actual sampling session not recorded. x = Either one or two individuals photographed during a sampling session; X = 3 or more individuals photographed during a sampling session; o = Observed (but not photographed) during a sampling session; \_ (or blank) = Neither photographed nor observed during a sampling session.

TOTAL SPECIES 63	Feb (1) <sup>1</sup>	March 1-15(1)	March 16-31(2)	April 1-15(1)	April 16-30(6)	May 1-15(4)	May 16-31(3)	June 1-15(1)	June 16-30(6)
<b>PAPILIONIDAE</b>									
<i>Iphiclides podalirius</i>					x____		__x		__xx
<i>Zerynthia polyxena</i> (Denis et Schiffermüller, 1775) <sup>2</sup>					____x				
<b>PIERIDAE</b>									
<i>Anthocharis cardamines</i>					__x__				
<i>Pieris mannii</i>									
<i>Pieris napi</i> Linnaeus, 1758				x					x____
<i>Pieris rapae</i>			x__		x____			x	x_x_xx
<i>Pieris</i> sp.									
<i>Leptidea sinapis</i>					__xx__				
<i>Colias alfacariensis</i> Ribbe, 1905					__xx__				
<i>Colias croceus</i>									____x__
<i>Colias</i> sp.									
<i>Gonepteryx rhamni</i>					x____				
<b>LYCAENIDAE</b>									
<i>Favonius quercus</i>									____x__
<i>Satyrrium ilicis</i>									__xx__
<i>Callophrys rubi</i> (Linnaeus, 1758)					__x__				
<i>Lycaena phlaeas</i>									
<i>Leptotes pirithous</i> (Linnaeus, 1767)									
<i>Cacyreus marshalli</i>									
<i>Celastrina argiolus</i> (Linnaeus, 1758)									
<i>Cupido alcetas</i> (Hoffmannsegg, 1804)					__x_x	xx__			
<i>Scolitantides orion</i> (Pallas, 1771)					____x				
<i>Plebejus argus</i>						__X	X__	X	__xx__
<i>Plebejus argyrognomon</i>									
<i>Polyommatus bellargus</i>						__x	_x_		xx__
<i>Polyommatus icarus</i>						__Xx		x	x____
<i>Polyommatus</i> sp.									
<b>RIODINIDAE</b>									
<i>Hamearis lucina</i>					__xx__	xxx__			
<b>NYMPHALIDAE</b>									
<i>Libythea celtis</i> (Laicharting, 1782)		x		x	x____				
<i>Vanessa atalanta</i>									
<i>Vanessa cardui</i>									
<i>Nymphalis polychloros</i> (Linnaeus, 1758)		X		x					

Table 3 (1/4). Summary of butterfly species recorded and observed in the study area in II-VI.2012. Legend: <sup>1</sup> Figures in brackets indicate no. of sampling sessions per month. <sup>2</sup> Author provided only for those species not recorded in 2011 (Table 2). x = Either one or two individuals photographed during a sampling session; X = 3 or more individuals photographed during a sampling session; o = Observed (but not photographed) during a sampling session; \_ (or blank) = Neither photographed nor observed during a sampling session.

Species	Feb (1) <sup>1</sup>	March 1-15(1)	March 16-31(2)	April 1-15(1)	April 16-30(6)	May 1-15(4)	May 16-31(3)	June 1-15(1)	June 16-30(6)
<i>Polygonia c-album</i> (Linnaeus, 1758)								x	
<i>Limenitis reducta</i>							_x_		
<i>Melitaea athalia</i> (Rottemburg, 1775)						__x			__x__
<i>Melitaea aurelia</i>								x	
<i>Melitaea cinxia</i> (Linnaeus, 1758)					_x_x_	_x_			
<i>Melitaea didyma</i>									X_x__
<i>Melitaea trivia</i> (Denis et Schiffemüller, 1775)								x	_x_x__
<i>Euphydryas aurinia</i>					__xxx_	_xx_			
<i>Issoria lathonia</i>									x_____
<i>Argynnis paphia</i>									_x_x__
<i>Boloria dia</i>					xxxx__				
<i>Brenthis daphne</i> (Bergsträsser, 1780)								x	
<i>Brenthis hecate</i>									x_____
<i>Melanargia galathea procida</i>								x	xx_xx__
<i>Minois dryas</i>									
<i>Brintesia circe</i>									_x_____
<i>Arethusana arethusa</i>									
<i>Hipparchia fagi</i>									
<i>Hipparchia statilinus</i> (Hufnagel, 1766)									
<i>Hipparchia semele</i>									
<i>Lasiommata maera</i>							__x	x	x_x_x__
<i>Lasiommata megera</i> (Linnaeus, 1767)									
<i>Pararge aegeria</i>				x	__x_				xx_____
<i>Pyronia tithonus</i>									
<i>Maniola jurtina</i>								X	xx_xx__
<i>Coenonympha arcania</i>							_X_	x	_x_____
<i>Coenonympha oedippus</i> (Fabricius 1787)									
<i>Coenonympha pamphilus</i>					xxx_x_	__xx		x	xX_x__
<b>HESPERIIDAE</b>									
<i>Carcharodus alceae</i> (Esper, 1780)						x__			
<i>Erynnis tages</i>				x	xx__	_x_			
<i>Hesperia comma</i>									
<i>Ochlodes sylvanus</i>									__x__
<i>Spialia sertorius</i> (Hoffmannsegg, 1804)							x__		
<i>Thymelicus lineola</i> (Ochsenheimer, 1808)								x	_x_____
<i>Thymelicus sylvestris</i> (Poda, 1761)									_x_____
<b>Total spp. for period</b>	<b>0</b>	<b>2</b>	<b>1</b>	<b>5</b>	<b>18</b>	<b>11</b>	<b>7</b>	<b>13</b>	<b>25</b>
<b>Total spp. for month</b>	<b>0</b>		<b>3</b>		<b>20</b>		<b>16</b>		<b>28</b>

Table 3 (2/4). Summary of butterfly species recorded and observed in the study area in II-VI.2012. Legend: <sup>1</sup> Figures in brackets indicate no. of sampling sessions per month. <sup>2</sup> Author provided only for those species not recorded in 2011 (Table 2). x = Either one or two individuals photographed during a sampling session; X = 3 or more individuals photographed during a sampling session; o = Observed (but not photographed) during a sampling session; \_ (or blank) = Neither photographed nor observed during a sampling session.

Species	July 1-15(9) <sup>1</sup>	July 16-31(8)	Aug 1-15(4)	Aug 16-31(4)	Sept 1-15(3)	Sept 16-30(2)	Oct (0)	Nov 1-15(2)	Nov 16-30(1)
<b>PAPILIONIDAE</b>									
<i>Iphiclides podalirius</i>	_x_x_								
<i>Zerynthia polyxena</i> (Denis et Schiffmüller, 1775) <sup>2</sup>									
<b>PIERIDAE</b>									
<i>Anthocharis cardamines</i>									
<i>Pieris mannii</i>		_x__X			__x	_x			
<i>Pieris napi</i>									
<i>Pieris rapae</i>	__x_xx			_x_		_x			
<i>Pieris</i> sp.		_x_x_							
<i>Leptidea sinapis</i>		_x__x							
<i>Colias alfacariensis</i> Ribbe, 1905	_x__				x__				
<i>Colias croceus</i>					__x	_x		Xx	
<i>Colias</i> sp.				_x_					
<i>Gonepteryx rhamni</i>									
<b>LYCAENIDAE</b>									
<i>Favonius quercus</i>	_x__	_x__	_x__						
<i>Satyrrium ilicis</i>	_x__								
<i>Callophrys rubi</i> (Linnaeus, 1758)									
<i>Lycaena phlaeas</i>		__xx_							
<i>Leptotes pirithous</i> (Linnaeus, 1767)						_x			
<i>Cacyreus marshalli</i>			__x	x__	_x_				
<i>Celastrina argiolus</i> (Linnaeus, 1758)	_x__	_xxxx	x_x_						
<i>Cupido alcetas</i> (Hoffmannsegg, 1804)	_x__	_x__x							
<i>Scolitantides orion</i> (Pallas, 1771)									
<i>Plebejus argus</i>	_X_Xx	_Xx_xXxx	_X_		__X				
<i>Plebejus argyrognomon</i>	_x__								
<i>Polyommatus bellargus</i>		__x_	_xx_	_xXx	X_				
<i>Polyommatus icarus</i>	_x_	_x_x_x	__Xx	xx_x	x_X	_X			
<i>Polyommatus</i> sp.						x_			
<b>RIODINIDAE</b>									
<i>Hamearis lucina</i>	_x__	_x__x							
<b>NYMPHALIDAE</b>									
<i>Libythea celtis</i> (Laicharting, 1782)								x_	
<i>Vanessa atalanta</i>					__x	_x		x_	
<i>Vanessa cardui</i>	x__								
<i>Nymphalis polychloros</i> (Linnaeus, 1758)									

Table 3 (3/4). Summary of butterfly species recorded and observed in the study area in VII-XI.2012. Legend: <sup>1</sup> Figures in brackets indicate no. of sampling sessions per month. <sup>2</sup> Author provided only for those species not recorded in 2011 (Table 2). x = Either one or two individuals photographed during a sampling session; X = 3 or more individuals photographed during a sampling session; o = Observed (but not photographed) during a sampling session; \_ (or blank) = Neither photographed nor observed during a sampling session.

Species	July 1-15(9) <sup>1</sup>	July 16-31(8)	Aug 1-15(4)	Aug 16-31(4)	Sept 1-15(3)	Sept 16-30(2)	Oct (0)	Nov 1-15(2)	Nov 16-30(1)
<i>Polygonia c-album</i> (Linnaeus, 1758)									
<i>Limenitis reducta</i>	_x_	_x_x_			x_x				
<i>Melitaea athalia</i> (Rottemburg, 1775)			_x_						
<i>Melitaea aurelia</i>		___x							
<i>Melitaea cinxia</i> (Linnaeus, 1758)									
<i>Melitaea didyma</i>			__x_	x__					
<i>Melitaea trivialis</i> (Denis et Schiffmüller, 1775)									
<i>Euphydryas aurinia</i>									
<i>Issoria lathonia</i>	__x__								
<i>Argynnis paphia</i>	xx_x__					_x			
<i>Boloria dia</i>	__x__		_x__						
<i>Brenthis daphne</i> (Bergsträsser, 1780)									
<i>Brenthis hecate</i>	__x__								
<i>Melanargia galathea procida</i>	_xxX_xx								
<i>Minois dryas</i>		_x__	xxx_	x__	x__				
<i>Brintesia circe</i>	_x_x__	_x__	_x__		x_x				
<i>Arethusana arethusa</i>			_Xxx	xx_					
<i>Hipparchia fagi</i>	_x__	_X__	xx__						
<i>Hipparchia statilinus</i> (Hufnagel, 1766)			_x__	_x__	x__				
<i>Hipparchia semele</i>						_X			
<i>Lasiommata maera</i>			_x_x	__xx	X__				
<i>Lasiommata megera</i> (Linnaeus, 1767)	x__								
<i>Pararge aegeria</i>	__x__		_x__						
<i>Pyronia tithonus</i>		x__xxxx	xxx_						
<i>Maniola jurtina</i>	x_xxx_	_x__xx	__xx	XXx_	x_x	_X			
<i>Coenonympha arcania</i>	_x_x__								
<i>Coenonympha oedippus</i> (Fabricius 1787)	_xx__								
<i>Coenonympha pamphilus</i>	__x__	_x__	_xx_	__x	X_x	xx			
<b>HESPERIIDAE</b>									
<i>Carcharodus alceae</i> (Esper, 1780)									
<i>Erynnis tages</i>	__x__								
<i>Hesperia comma</i>				Xx__	X__				
<i>Ochlodes sylvanus</i>	xx_xx_x_			x__					
<i>Spialia sertorius</i> (Hoffmannsegg, 1804)									
<i>Thymelicus lineola</i> (Ochsenheimer, 1808)									
<i>Thymelicus sylvestris</i> (Poda, 1761)	_x__								
<b>Total spp. for period</b>	<b>29</b>	<b>19</b>	<b>19</b>	<b>14</b>	<b>16</b>	<b>11</b>	<b>-</b>	<b>3</b>	<b>0</b>
<b>Total spp. for month</b>		<b>37</b>		<b>23</b>		<b>21</b>	<b>-</b>		<b>3</b>

Table 3 (4/4). Summary of butterfly species recorded and observed in the study area in VII-XI.2012. Legend: <sup>1</sup> Figures in brackets indicate no. of sampling sessions per month. <sup>2</sup> Author provided only for those species not recorded in 2011 (Table 2). x = Either one or two individuals photographed during a sampling session; X = 3 or more individuals photographed during a sampling session; o = Observed (but not photographed) during a sampling session; \_ (or blank) = Neither photographed nor observed during a sampling session.

TOTAL SPECIES 70	Feb 16-28(1) <sup>1</sup>	March 1-15(1)	March 16-31(1)	April 1-15(2)	April 16-30(8)	May 1-15(5)	May 16-31(3)	June 1-15(6)	June 16-30(4)	July 1-15(5)
<b>PAPILIONIDAE</b>										
<i>Iphiclides podalirius</i>					_x_oo_	xO_xo	o_x	__o__		oXxXx
<i>Papilio machaon</i>										__o
<b>PIERIDAE</b>										
<i>Anthocharis cardamines</i>					__xx__	x__				
<i>Aporia crataegi</i>							__x	xOxxOo		_x__
<i>Pieris brassicae</i> (Linnaeus, 1758)										__o_
<i>Pieris mannii</i>								__x_	__x_	__Xxo_
<i>Pieris napi</i>						__x				__x
<i>Pieris rapae</i>					x_xxO_	xO__	__o			__X
<i>Pieris</i> sp.						__o_		__ox_o		
<i>Pontia edusa</i> (Fabricius, 1777)										
<i>Leptidea sinapis</i>					_oo_ox	x_xox	__xx		__xx	__x_x
<i>Colias alfacariensis</i>										__o_x
<i>Colias croceus</i>							o_x	__ooo		oxx_o
<i>Colias</i> sp.										
<i>Gonepteryx rhamni</i>		o			__x__	oo__		__o_		
<b>LYCAENIDAE</b>										
<i>Favonius quercus</i>										
<i>Satyrrium ilicis</i>								__xxXx	o_xx	_x__
<i>Callophrys rubi</i>						x__				
<i>Lycaena phlaeas</i>					__x_	_o__				
<i>Cacyreus marshalli</i>										__o_
<i>Celastrina argiolus</i>					_x__				__xx	__xxxx
<i>Cupido alcetas</i>									__x	
<i>Scolitantides orion</i>								__x__	__x_	
<i>Aricia agestis</i> (Denis et Schiffermüller, 1775)										__xx
<i>Plebejus argus</i>						_ox_	oXx	X_XxX	__xX	
<i>Plebejus argyronomon</i>										__X
<i>Plebejus</i> sp.										
<i>Cyaniris semiargus</i> (Rottemburg, 1775)						__x				
<i>Polyommatus bellargus</i>							__Xx	_oxxx_	o_xx	
<i>Polyommatus daphnis</i> (Denis et Schiffermüller, 1775)										
<i>Polyommatus icarus</i>							__xx	x_xX_x		__xxx
<i>Polyommatus</i> sp.								__x	__x	__x_

Table 4 (1/6). Summary of butterfly species recorded and observed in the study area in II-15.VII.2013. Legend: <sup>1</sup> Figures in brackets indicate no. of sampling sessions per month. <sup>2</sup> Author provided only for those species not recorded in 2011 or 2012 (Tables 2 and 3). x = Either one or two individuals photographed during a sampling session; X = 3 or more individuals photographed during a sampling session; o = Observed (but not photographed) during a sampling session; \_ (or blank) = Neither photographed nor observed during a sampling session.

Species	Feb 16-28(1) <sup>1</sup>	March 1-15(1)	March 16-31(1)	April 1-15(2)	April 16-30(8)	May 1-15(5)	May 16-31(3)	June 1-15(6)	June 16-30(4)	July 1-15(5)
<b>RIODINIDAE</b>										
<i>Hamearis lucina</i>					__X__	oo__X				
<b>NYMPHALIDAE</b>										
<i>Libythea celtis</i>					_x__	o__		__x	o__	
<i>Vanessa atalanta</i>					__o_			__o_o_		_X_oo
<i>Vanessa cardui</i>								__x_		_xx_
<i>Agalais io</i> (Linnaeus, 1758)						__x_				
<i>Aglais urticae</i> (Linnaeus, 1758)					__o	x__	_x_			
<i>Nymphalis antiopa</i> (Linnaeus, 1758)										
<i>Nymphalis polychloros</i>		X		x_	x__					
<i>Polygonia c-album</i>						_o__			_x_	
<i>Limenitis reducta</i>						__x	__x	__xxx	__o_	__o_
<i>Melitaea athalia</i>								__xx_	_x_	
<i>Melitaea cinxia</i>							_xX			
<i>Melitaea didyma</i>								__x_x	__xx	_x_x_
<i>Melitaea trivia</i>								__x_		
<i>Euphydryas aurinia</i>						__x_x	_xx			
<i>Issoria lathonia</i>										__x
<i>Argynnis paphia</i>									__x_	
<i>Argynnis niobe</i> (Linnaeus, 1758)								__x_		
<i>Argynnis</i> sp.										
<i>Boloria dia</i>					__x_					
<i>Brenthis daphne</i>								__x	__xx	__x_
<i>Melanarga galathea procida</i>								__Xxx	__XX	oxXxX
<i>Minois dryas</i>										
<i>Brintesia circe</i>								__oX	__xxxX	
<i>Arethusana arethusa</i>										
<i>Hipparchia fagi</i>										_x__
<i>Hipparchia semele</i>										_x__
<i>Lasiommata maera</i>							_xx	xoXXxx	__xx	
<i>Lasiommata megera</i>					__x	x_x_				o_xxX
<i>Pararge aegeria</i>					x_xx_oo_	x__	o_	__xx	__x	__x
<i>Pyronia tithonus</i>										
<i>Maniola jurtina</i>							_xX	x_Xxxx	__XX	_xXxo
<i>Coenonympha arcania</i>							_xx	x_XxXx	o_xx	o_xo
<i>Coenonympha pamphilus</i>						__x_X	_Xx	x_xxxx	__xx	_xx_x

Table 4 (2/6). Summary of butterfly species recorded and observed in the study area in II-15.VII.2013. Legend: <sup>1</sup> Figures in brackets indicate no. of sampling sessions per month (or June/July period). <sup>2</sup> Author provided only for those species not recorded in 2011 or 2012 (Tables 2 and 3). x = Either one or two individuals photographed during a sampling session; X = 3 or more individuals photographed during a sampling session; o = Observed (but not photographed) during a sampling session; \_ (or blank) = Neither photographed nor observed during a sampling session.

Species	Feb 16-28(1) <sup>1</sup>	March 1-15(1)	March 16-31(1)	April 1-15(2)	April 16-30(8)	May 1-15(5)	May 16-31(3)	June 1-15(6)	June 16-30(4)	July 1-15(5)
<b>HESPERIIDAE</b>										
<i>Carcharodus floccifera</i> (Zeller, 1847)										
<i>Erynnis tages</i>						XOX_X	o__			__o
<i>Hesperia comma</i>										
<i>Ochlodes sylvanus</i>								__xx__	__xX	oXxxx
<i>Pyrgus amERICANUS</i> (Oberthür, 1910)										
<i>Pyrgus malvoides</i> (Elwes et Edwards, 1897)										
<i>Spialia sertorius</i>								__x__		
<i>Thymelicus lineola</i>								__Xxx	__x__	
<i>Thymelicus sylvestris</i>									__xx	
<b>Total spp. for period</b>	<b>0</b>	<b>2</b>	<b>0</b>	<b>1</b>	<b>16</b>	<b>22</b>	<b>18</b>	<b>30</b>	<b>26</b>	<b>33</b>
<b>Total spp. for month</b>	<b>0</b>		<b>2</b>		<b>16</b>		<b>30</b>		<b>37</b>	

Table 4 (3/6). Summary of butterfly species recorded and observed in the study area in II-15.VII.2013. Legend: <sup>1</sup> Figures in brackets indicate no. of sampling sessions per month. <sup>2</sup> Author provided only for those species not recorded in 2011 or 2012 (Tables 2 and 3). x = Either one or two individuals photographed during a sampling session; X = 3 or more individuals photographed during a sampling session; o = Observed (but not photographed) during a sampling session; \_ (or blank) = Neither photographed nor observed during a sampling session.

Species	July 16-31(7) <sup>1</sup>	Aug 1-15(1)	Aug 16-31(3)	Sept 1-15(2)	Sept 16-30(2)	Oct 1-15(3)	Oct 16-31(1)	Nov 1-15(2)	Nov 16-30(2)	Dec 1-15(2)
<b>PAPILIONIDAE</b>										
<i>Iphiclides podalirius</i>	oX_Xx_x									
<i>Papilio machaon</i>	__X__		__x__	o						
<b>PIERIDAE</b>										
<i>Anthocharis cardamines</i>										
<i>Aporia crataegi</i>										
<i>Pieris brassicae</i> (Linnaeus, 1758)										
<i>Pieris mannii</i>	__xxxx_x	o			__x					
<i>Pieris napi</i>	__x__			__x						
<i>Pieris rapae</i>		o		x__						
<i>Pieris</i> sp.	o__		oox	__o	o__	__o	o			
<i>Pontia edusa</i> (Fabricius, 1777)			__x	__o	o__					
<i>Leptidea sinapis</i>	__xx__		x_x	x__	__o					
<i>Colias alfacariensis</i>	__x_x__									

Table 4 (4/6). Summary of butterfly species recorded and observed in the study area in 16.VII-XII.2013. Legend: <sup>1</sup> Figures in brackets indicate no. of sampling sessions per month (or June/July period). <sup>2</sup> Author provided only for those species not recorded in 2011 or 2012 (Tables 2 and 3). x = Either one or two individuals photographed during a sampling session; X = 3 or more individuals photographed during a sampling session; o = Observed (but not photographed) during a sampling session; \_ (or blank) = Neither photographed nor observed during a sampling session.

Species	July 16-31(7) <sup>1</sup>	Aug 1-15(1)	Aug 16-31(3)	Sept 1-15(2)	Sept 16-30(2)	Oct 1-15(3)	Oct 16-31(1)	Nov 1-15(2)	Nov 16-30(2)	Dec 1-15(2)
<b>PIERIDAE</b>										
<i>Colias croceus</i>				xx			x	xo	x	o
<i>Colias</i> sp.	__x__									
<i>Gonepteryx rhamni</i>	__x__									
<b>LYCAENIDAE</b>										
<i>Favonius quercus</i>	o__									
<i>Satyrrium ilicis</i>										
<i>Callophrys rubi</i>										
<i>Lycaena phlaeas</i>	__x_			x_		__o		x_		
<i>Cacyreus marshalli</i>			_x_						x	
<i>Celastrina argiolus</i>		o	xx_	x_						
<i>Cupido alcetas</i>										
<i>Scolitantides orion</i>										
<i>Aricia agestis</i> (Denis et Schiffmüller, 1775)	__X__	o	x_x	x_						
<i>Plebejus argus</i>	_x_XxXx	o	xxX					_o		
<i>Plebejus argyronomon</i>	__X__		__x							
<i>Plebejus</i> sp.	__x									
<i>Cyaniris semiargus</i> (Rottemburg, 1775)										
<i>Polyommatus bellargus</i>		o	XXX	Xx	_x					
<i>Polyommatus daphnis</i> (Denis et Schiffmüller, 1775)	__x__									
<i>Polyommatus icarus</i>	__XXx		XXX	Xx	_x	__x	x			
<i>Polyommatus</i> sp.										
<b>RIODINIDAE</b>										
<i>Hamearis lucina</i>	o_x__									
<b>NYMPHALIDAE</b>										
<i>Libythea celtis</i>									x	
<i>Vanessa atalanta</i>	__x__		x_o		o_	oxx	x	xo	X	o
<i>Vanessa cardui</i>										
<i>Agalais io</i> (Linnaeus, 1758)										
<i>Aglais urticae</i> (Linnaeus, 1758)			xx_							
<i>Nymphalis antiopa</i> (Linnaeus, 1758)	__o__									
<i>Nymphalis polychloros</i>										
<i>Polygonia c-album</i>										
<i>Limenitis reducta</i>	oo_xx_x	o	xxx	_x	ox	__x				
<i>Melitaea athalia</i>										

Table 4 (5/6). Summary of butterfly species recorded and observed in the study area in 16.VII-XII.2013. Legend: <sup>1</sup> Figures in brackets indicate no. of sampling sessions per month. <sup>2</sup> Author provided only for those species not recorded in 2011 or 2012 (Tables 2 and 3). x = Either one or two individuals photographed during a sampling session; X = 3 or more individuals photographed during a sampling session; o = Observed (but not photographed) during a sampling session; \_ (or blank) = Neither photographed nor observed during a sampling session.

Species	July 16-31(7) <sup>1</sup>	Aug 1-15(1)	Aug 16-31(3)	Sept 1-15(2)	Sept 16-30(2)	Oct 1-15(3)	Oct 16-31(1)	Nov 1-15(2)	Nov 16-30(2)	Dec 1-15(2)
<i>Melitaea cinxia</i>										
<i>Melitaea didyma</i>			x_x	x_						
<i>Melitaea trivia</i>										
<i>Euphydryas aurinia</i>										
<i>Issoria lathonia</i>	_o_x_						x			
<i>Argynnis paphia</i>	__ox			xo						
<i>Argynnis niobe</i> (Linnaeus, 1758)										
<i>Argynnis</i> sp.			_o_							
<i>Boloria dia</i>			__x							
<i>Brenthis daphne</i>										
<i>Melanarga galathea procida</i>	ox_xx_									
<i>Minois dryas</i>			xxx	x_	_x					
<i>Brintesia circe</i>	ox_xx_x		xx_	x_	_x					
<i>Arethusana arethusa</i>			XxX							
<i>Hipparchia fagi</i>	__x		Xox	Xx	ox					
<i>Hipparchia semele</i>				xx	_X	x_x				
<i>Lasiommata maera</i>			_x	xX	_X					
<i>Lasiommata megera</i>	__xx_		xxX	x_	_x					
<i>Pararge aegeria</i>	_x__		xxx	xx	oX	o_o	x			
<i>Pyronia tithonus</i>	__Xx_	o	x_x	x_						
<i>Maniola jurtina</i>		o	xxX	xX						
<i>Coenonympha arcania</i>	__o__									
<i>Coenonympha pamphilus</i>	__xx_x		XXX	Xx	_x	_xx	x			
<b>HESPERIIDAE</b>										
<i>Carcharodus floccifera</i> (Zeller, 1847)	__x									
<i>Erynnis tages</i>	_xXXx_		_x_							
<i>Hesperia comma</i>			XXX	xX	_x					
<i>Ochlodes sylvanus</i>	ooxXx_									
<i>Pyrgus amERICANUS</i> (Oberthür, 1910)	__x		__x		ox					
<i>Pyrgus malvoides</i> (Elwes et Edwards, 1897)	__o__		__x	x_						
<i>Spialia sertorius</i>										
<i>Thymelicus lineola</i>										
<i>Thymelicus sylvestris</i>	__x__									
<b>Total spp. for period</b>	<b>37</b>	<b>9</b>	<b>31</b>	<b>27</b>	<b>18</b>	<b>8</b>	<b>7</b>	<b>4</b>	<b>4</b>	<b>2</b>
<b>Total spp. for month</b>	<b>50</b>		<b>33</b>		<b>30</b>		<b>10</b>		<b>6</b>	<b>2</b>

Table 4 (6/6). Summary of butterfly species recorded and observed in the study area in 16.VII-XII.2013. Legend: <sup>1</sup> Figures in brackets indicate no. of sampling sessions per month. <sup>2</sup> Author provided only for those species not recorded in 2011 or 2012 (Tables 2 and 3). x = Either one or two individuals photographed during a sampling session; X = 3 or more individuals photographed during a sampling session; o = Observed (but not photographed) during a sampling session; \_ (or blank) = Neither photographed nor observed during a sampling session.

Among the species not recorded by Carrara (1926) is *C. marshalli*, a South African species introduced into Italy in 1997 via horticultural trade in its host plant, *Pelargonium* (Balletto et al., 2005). *C. marshalli* has been recorded from nearby Udine and Tarcento as well as Slovenia since 2008 (Bernardinelli, 2008; Verovnik et al., 2011b) and thus is likely to have arrived in the province of Trieste around the same time.

Some 13 European countries, including France, Germany, the Netherlands, Sweden and the UK, are implementing butterfly recording schemes in attempts to build long-term data sets on species abundance. To date, however, Italy is not among these countries (van Swaay et al., 2012a, Butterfly Conservation Europe: <http://www.bc-europe.eu/index.php?id=339>, accessed 14 March 2014). Such schemes, which also record abundance, are valuable for detecting population changes over the long-term, including those influenced by climate change (Roy & Sparks, 2000; Roy et al., 2001; Warren et al., 2001; Stefanescu et al., 2003). However, a case has also been made for recording schemes that measure presence rather than abundance (Casner et al., 2014), as is the case in the current study (although some inferences on abundance can perhaps be made based on repeated sightings over a short time period). This study has also identified several species-rich 1 km transects that could be used as standard transects in a regular recording scheme for the area as per current guidelines (van Swaay et al., 2012a).

Among the 79 species recorded in this survey, some 14 are of conservation concern either in the region or more widely in Europe (Tables 5 and 6). Of particular note are *E. aurinia* and *C. oedippus*. In the case of *E. aurinia*, a number of individuals were recorded in each of the three years of the survey, indicating a stable, healthy population, even if it did not cover the whole of the survey area. While *C. oedippus* was recorded only in 2012, several individuals were found, indicating a relatively small but potentially healthy population that appears, however, to be isolated from any other local populations. Both species were found in patches of rough vegetation and field margins of the cultivated area close to Malchina. It can also be noted that neither species was recorded from the Trieste area in the early 20th century (Carrara, 1926). Targeted surveys timed to coincide with peak flight periods of these two species and across a wider area than the areas identified by the author in this survey would

provide useful additional information on the importance of the location for these two species.

These two species are also among the 34 species considered by van Swaay & Warren (2006) when developing a list of Prime Butterfly Areas (PBAs) for conservation priority in Europe. When selecting their 431 PBAs, van Swaay & Warren (2006) took into account two types of area: discrete sites that support one or more target species; and wider areas (such as mountain ranges or valley systems) where a target species occurs as scattered populations that may well be connected as a single metapopulation. Indeed, a possible *C. oedippus* metapopulation has been recorded at sites around Komen, some 8 km from Malchina across the border in Slovenia (Čelik & Verovnik, 2010). In Italy, *C. oedippus* is known from around 100 sites, although many are considered under threat, mostly by natural reforestation (Bonelli et al., 2010). Further studies in and around the survey area would also help to confirm if other species recorded only rarely in the area were part of other significant metapopulations.

Given the presence of both *E. aurinia* and *C. oedippus* in the survey area, the area of the Triestine karst around Malchina could be considered for possible inclusion as a PBA. This would add to the cluster of PBAs already identified in the Friuli Venezia Giulia/Slovenia/Istria region. The fact that the area also harbours a number of other species at risk regionally, including strong populations of *L. celtis*, *B. circe*, *Ar. arethusa*, *H. fagi* and *C. arcania*, as well as populations of other species such as *H. statilinus* and *Pyronia tithonus* (Tables 2, 3, 4, and 6) adds to the value of the area.

Species	European (EU25) status	EU27 status <sup>1</sup>
<i>Scolitantides orion</i>	LC	NT
<i>Melitaea aurelia</i>	NT	LC
<i>Melitaea trivia</i>	LC	NT
<i>Argynnis niobe</i>	LC	NT
<i>Hipparchia statilinus</i>	NT	NT
<i>Coenonympha oedippus</i>	EN	LC
<i>Carcharodus floccifera</i>	NT	LC

Table 5. European-level conservation status of endangered and threatened butterfly species recorded in the survey area (from van Swaay et al., 2010 and 2012b). LC = Least concern; NT = Near threatened; EN = Endangered. <sup>1</sup> EU27 includes also Bulgaria and Romania

As a designated Natura 2000 site (see Natura Network Viewer: <http://natura2000.eea.europa.eu/#>), much of the survey area is theoretically protected from development. In practice, however, the ongoing abandonment of agricultural fields and succession to more overgrown/wooded areas (Poldini, 1989) or other threats such as construction of new housing continue to erode suitable butterfly habitats. As mentioned earlier, the abandonment of agricultural land and/or changing habitat management affects many of Europe's threatened butterfly species, while other important threats include climate change, increased frequency and intensity of fires and tourism development (van Swaay et al., 2010). Indeed, in 2012, several areas close to the survey area were affected by fire (Tosques, 2012a; 2012b).

Habitat loss is, however, regarded as the greatest threat to butterflies. Van Swaay & Warren (2006), for example, highlight that even species targeted for conservation are declining not only within PBAs, but also within protected areas. Likewise, in the UK, Warren et al. (2001) demonstrated that, despite the positive effects of climate change on range expansion, for three-quarters of 46 species considered, these gains were outweighed by the negative effects of habitat loss.

Van Swaay & Warren (2006) conclude that legislation alone is not enough to maintain threatened populations, but that practical conservation measures are also urgently needed. Such measures should include sound habitat management of key sites allied with sympathetic management of surrounding areas, such as the continuation of traditional agriculture and forestry practices. They also recommend that populations of target species are monitored and that research is conducted to identify appropriate habitat management techniques - with appropriate financial support. In contrast, Navarro & Pereira (2012) argue that 'rewilding' (defined as "the passive management of ecological succession with the goal of restoring natural ecosystem processes and reducing human control of landscapes") of abandoned farmland should be considered as a possible land management option in Europe, particularly on marginal areas. However, they also recognize that such passive forest regeneration will cause some species to decline in abundance while others would increase, i.e. there would be both 'winner' and 'loser' species.

In the survey area considered here, the greatest

Species	Status in Triveneto region	Comments re: area surveyed <sup>1</sup>
<i>Zerynthia polyxena</i>	Very local, EN, protected at EU level	One individual photographed in 2012
<i>Callophrys rubi</i>	LR but in decline	Rare. Recorded once in 2012 and once in 2013
<i>Libythea celtis</i>	Scarce, VU	Good local populations
<i>Nymphalis antiopa</i>	DD/EN - population at lower altitudes EN	One individual observed in 2013
<i>Melitaea trivia</i>	VU, protected in FVG <sup>2</sup>	Never common. Recorded twice in 2012 and once in 2013
<i>Euphydryas aurinia</i>	NT, protected in FVG at EU level	Reasonable population localized to parts of survey area
<i>Brenthis hecate</i>	VU	Very rare. Recorded twice in 2012 only
<i>Brintesia circe</i>	EN, threatened, very local	Good local population
<i>Arethusana arethusa</i>	NT, protected in FVG	Good local population
<i>Hipparchia fagi</i>	VU, locally common, EN in Alto Adige	Good local population
<i>Hipparchia statilinus</i>	DD/LR, can be locally common	A few individuals recorded in 2012 only
<i>Pyronia tithonus</i>	Very local distribution, VU/EN	Found regularly, but never more than one or two individuals
<i>Coenonympha arcania</i>	LR/NT, common - populations in hill/mountain areas of FVG less threatened	Good local population
<i>Coenonympha oedippus</i>	VU, protected at EU level	A few individuals recorded in 2012 only
<i>Pyrgus amoricanus</i>	NT, only local populations	Recorded intermittently in 2013 only

Table 6. Triveneto-level conservation status of protected, endangered, threatened and vulnerable butterfly species recorded in the survey area (from Paolucci, 2010). LR = Lower risk; NT = Near threatened; VU = Vulnerable; EN = Endangered; DD = Data deficient. <sup>1</sup> For additional details, refer to Tables 2, 3 and 4. <sup>2</sup>FVG = Friuli Venezia Giulia

threat to local butterfly populations and diversity of species remains the natural reforestation that is ongoing since the decline of grazing in the area. Similar effects are occurring to local bird communities, with specialist grassland species such as the rock partridge *Alectoris graeca* (Meisner, 1804), grey partridge *Perdix perdix* (Linnaeus, 1758) and ortolan bunting (*Emberiza hortulana* Linnaeus, 1758) having gone locally extinct, populations of skylark (*Alauda arvensis* Linnaeus, 1758) and tawny pipit *Anthus campestris* (Linnaeus, 1758) under threat, and numbers of corn bunting (*Emberiza calandra* Linnaeus, 1758), red-backed shrike (*Lanius collurio* Linnaeus, 1758) and nightjar (*Caprimulgus europaeus* Linnaeus, 1758) much reduced. Concomitantly there have been increases in species frequenting scrub and woodland, such as the nightingale, blackcap, blackbird, chaffinch and melodious warbler (Parodi, 1999). However, exactly which type of management practices are most suited for maintaining both faunal and floral diversity in the area, is unknown.

Based on research in Germany on a comparable grassland site with shallow soil in a warm, dry temperate climate, Romermann et al. (2009) concluded that neither mowing nor various mulching regimes properly conserved the structure of wildflower populations developed over many years of grazing in species-rich semi-natural grasslands. However, they did recommend mulching twice per year, as this generated the most similar floristic and functional plant community compared to the original grazing regime.

In contrast, regarding the conservation of another endangered grassland-specialist insect species, *Saga pedo* (Pallas, 1771) (Orthoptera, Tettigoniidae) that is also present in the survey area (Fontana & Cussigh, 1996; author's observations), from their studies in the Czech Republic, Holuša et al. (2013) recommended either extensive rotational grazing or using scythes to cut grass in a traditional way to maintain open areas of natural grassland. Alternatively, partial machine mowing (one-third to one-half of specific areas) each September could be considered.

Unfortunately it is more than likely that the current situation of abandonment and neglect of once grazed and cultivated areas is likely to continue in the survey area for the foreseeable future. Similarly, Bonelli et al. (2010), discussing the conservation of *C. oedippus* populations across Italy, note that natural reforestation is best prevented by developing suitable, but costly, management plans, "which for the moment remain only on paper, in the best of cases."

The same is likely true for large parts of the Triestine karst, despite the undoubted conservation value for butterfly species, as reported here.

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# First observations on the herpetological and theriological fauna of Alimia Island (Rhodes Archipelago, Aegean Sea)

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## ABSTRACT

This note is a preliminary study on the herpetological and theriological fauna of Alimia Island (Rhodes Archipelago, Aegean Sea). Are described seven species of reptiles and three of micromammals. Is also provided a short botanical characterization of the island.

## KEY WORDS

Alimia; Dodecanese; Aegean island; Rhodes.

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## INTRODUCTION

Currently there is no scientific literature regarding herpetological and theriological fauna of Alimia Island (Rhodes Archipelago, Aegean Sea), and the following reported data are completely new.

## MATERIAL AND METHODS

Alimia Island has been the subject of a partial survey in August 2014. Since this island is uninhabited, the authors stayed in the nearby island of Chalki.

Due to the great difficulties in reaching Alimia, surveys were carried out only in two days, and, for the discontinuity and precariousness of the connections, the authors of this paper, in the study of theriological fauna, could not use live-traps (Sherman) and photo-traps. Therefore were carried out exclusively field research, by examining osteological remains and inspecting glass bottles found *in situ*.

## Study area

Alimia is a small island essentially calcareous, located in the Aegean Sea, north of Chalki and west of Rhodes and is one of the 163 islands that compose the Dodecanese Archipelago (Sokratis, 2006). It is part of Peripheral Unit of Rhodes and administratively belongs to the Municipality of Chalki. Its geographical coordinates are: longitude 27°42'24.11" E; latitude 36°16'26.26" N. The island has an area of 7.42 km<sup>2</sup>, a coastline of 21 km and a maximum height of 274 m above sea level (Fig. 1). Alimia is provided of two large creeks: Imborios and Agios Georgios. Just for the presence of these two natural harbors, in ancient times Alimia was called Eulimna (from Greek limen = harbor) (Blackman et al., 2014).

The island is split in two unequal parts by a fail (Stefanini & Desio, 1928). In southern part a narrow strip of land connects the peninsula of Tigani to the rest of the island (Rackham & Vernicos, 1991). Alimia lacks superficial hydrography; there's only a small retrodunal pond of brackish water in

the bay of Agios Georgios (Fig. 2). Together with the surrounding small islands and Chalki, it's included in the European Network "Natura 2000" as SPA, Special Protection Area, with GR4210026 code. Moreover, with the Official Gazette 991 GG/B of 27 May 1999, Alimia was officially declared archaeological site of national interest for the presence of remains belonging to the Neolithic, such as the Paleochristian Basilica in the bay of Imborios and the Post-Byzantine church of Agios Georgios. The uncontaminated nature of the coasts is testified by the presence in this island of the now rare monk seal, *Monachus monachus* (Di Turo, 1984; Marchessaux & Duguay, 1977). Currently the island is uninhabited and is used by the inhabitants of Chalki, as in the past, for sheep and goats grazing (Iliadis, 1950). Regular connections either with Chalki or with Rhodes are not provided, indeed, Alimia knows only a sporadic tourism made by private boats.

**Botanical aspects.** Alimia is characterized by wide low shrubs in which *Juniperus phoenicea* L. and *Pistacia lentiscus* L. are the most distinctive elements. These species have pulvinated aspect, especially near the coast. In places where shrubs becomes more thin and open, thrives a phrygana almost exclusively characterized by *Thymra capitata* (L.) Cav., to which sometimes is associated *Teucrium capitatum* L. and more sporadically *Salvia fruticosa* Mill.; *Origanum onites* L. and *Sarcopoterium spinosum* (L.) Spach were infrequently observed. The scarcity of the arboreal element is highlighted by the presence of scarce and localized clusters of *Pinus brutia* Ten. The steepest zones of Alimia have terraces once used for olive growing, now hardly visible as covered by the current vegetation. Iliadis (1950) informs that once this island was used not only as grazing land, but also for the production of fodder plants, grain, oil and figs (Cattaneo & Grano, in press).

## RESULTS

### REPTILIA

#### *Hemidactylus turcicus turcicus* (Linnaeus, 1758)

This gecko has a Mediterranean chorotype (Sindaco & Jeremčenko, 2008). Populations intro-

duced by humans are also known for some states in United States and South America. Essentially nocturnal species, is often visible in trophic activity during evening hours. The few individuals observed at Alimia were found among the ruins of Ag. Georgios village, under wood planks in shaded sites with relative humidity. Due to the lack of electricity in the island, the species could not be observed near light sources.

#### *Mediodactylus kotschy* (Steindachner, 1870)

This species, until a short time ago known as *Cyrtopodion kotschy*, has been recently subject of taxonomic review (Rösler, 2000). It has an E-Mediterranean chorotype (Sindaco & Jeremčenko, 2008). Are currently recognized 27 subspecies and in Chalki and Alimia should be present *Mediodactylus kotschy beutleri* (Baran et Gruber, 1981). This subspecies is typical of southwest Turkey and eastern Aegean islands. However, the validity of such subspecies could be under discussion by modern molecular genetic studies (Kasapidis et al., 2005). This gecko carries out semidiurnal activities, choosing stony and arid habitats. It is usually found on soil and on dry-stones walls (Beutler, 1981). At Alimia *Mediodactylus kotschy* was observed into Ag. Georgios village, on dry-stone walls used as enclosures for sheep and goats grazing.

#### *Stellagama stellio daani* (Beutler et Frör, 1980)

The chorotype of this reptile is Mediterranean/Arabian (Sindaco & Jeremčenko, 2008). The recent genus *Stellagama* is considered monospecific and includes the only species *S. stellio* (Baig et al., 2012). Seven subspecies are currently acknowledged, two of which are present in Greece: *S. stellio stellio* (Linnaeus, 1758) and *S. stellio daani*. The first one has been found in five Cyclades islands (Delos, Mikro Rhematiaris, Mykonos, Rinia and Tinos) and in the Ionian islands of Corfù and Paxi (Spaneli & Lymberakis, 2014); the second one was found in other Cyclades islands (Paros, Naxos, Despotico e Antiparos), in most of the eastern Aegean islands and in Thessaloniki, in the north of mainland Greece (Spaneli & Lymberakis, 2014). In Alimia *S. stellio daani* (Fig. 3) was found relatively frequent. Adult and young specimens have been observed during activity and thermoregulation

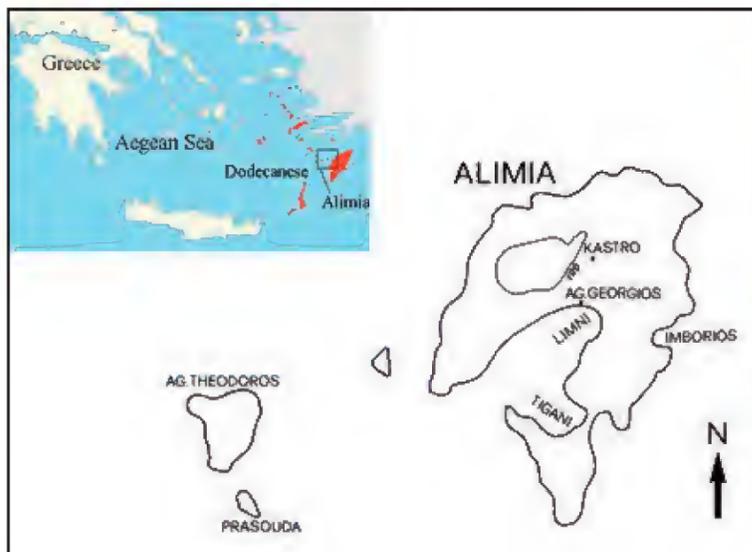


Figure 1. Alimia Island, Rhodes Archipelago, Aegean Sea.



Figure 2. Ag. Georgios village, Alimia Island.

between rocks and among the ruins of Ag. Georgios village.

***Ablepharus kitaibelii kitaibelii*** (Bibron et Bory, 1833)

A single specimen of this lizard, with a Balcanic and W-Anatolic chorotype (Sindaco & Jeremčenko, 2008), was observed near a dry-stone wall, close Ag. Georgios beach. *Ablepharus kitaibelii* appears to be a mainly hygrophilous species (Cattaneo, 1998), as generally lives on wet soil and in under-wood bedding of conifers forest (Broggi, 2002; Wilson & Grillitsch, 2009). However, both to Alimia and to nearby Chalki island, *A. kitaibelii* has been found in extreme aridity. In Chalki indeed it has been very often observed on rocky and arid soil and also on stone walls inside Imborios village. In this latter case, however, the research by the above mentioned species of a degree of humidity inside the village is plausible.

***Anatololacerta oertzeni pelasgiana*** (Mertens, 1959)

*Anatololacerta oertzeni* (Werner, 1904) is a lizard with a Mediterranean chorotype (Sindaco & Jeremčenko, 2008). It consists of six subspecies. At Rhodes and in the adjacent islands there's the subspecies *A. oertzeni pelasgiana* (Fig. 4). Like most Mediterranean reptiles, this lizard is particularly active in springtime, while in summer exposes oneself less frequently. However the young, very typical for the blue color of the tail (Fig. 5), are also

active in the summertime and in the hottest hours (Wilson & Grillitsch, 2009). Indeed, in Alimia the young specimens have been seen more frequently, especially observed up on the walls of the houses of Ag. Georgios village and on dry stone walls. On the contrary adults not exposed oneself to direct sunlight, but stayed inside abandoned houses in conditions of light and shadow.

***Ophisops elegans*** (Ménétries, 1832)

Small lizard with Mediterranean/Iranian chorotype (Sindaco & Jeremčenko, 2008). Eight subspecies are currently recognized including one for Greece: *O. elegans macrodactylus* (Berthold, 1842). *Ophisops elegans* (Fig. 6) resulted the most common reptile in Alimia, generally observed on soil and especially at the basis of juniper bushes.

***Dolichophis* sp.**

Regarding snakes only a partial exuvia was found at the basis of a dry stone wall bordering the abandoned Ag. Georgios village. Structural and chromatic features of the specimen (dark scales with a light middle strip) assign it unequivocally to the genus *Dolichophis* Gistel, 1868. Even if was impossible to make a more detailed meristic examination of the specimen (being the exuvia incomplete), however, for exclusive biogeographic considerations, we can assume that the exuvia is attributable to *D. jugularis* and more precisely to *D. jugularis zinneri* Cattaneo, 2012. This subspecies is indeed present in Rhodes and in the islands of its ar-

chipelago, such as Chalki, Simi and Tilos (Cattaneo, 2012). Therefore the presence of *D. jugularis zinneri* also at Alimia could be argued with good probability.

## MAMMALIA

### *Rattus* sp.

In the immediate surroundings of the big boulders which form the basis of Kastro (180 m s.l.m.) have been found two long bones of *Rattus* sp.: a femur and a tibia. The failure to find other osteological remains didn't allow the distinction between *Rattus*

*rattus* Linnaeus, 1758 and *R. norvegicus* Berkenhout, 1769. Both species live in Rhodes and *R. rattus* is present also in the nearby islands of Chalki (Masseti, 2012). In the Dodecanese area is reported the presence of *R. norvegicus* for Kos and *R. rattus* for Tilos, Karpathos, Kos and Astypalaia (Angelici et al., 1992; Masseti & Sarà, 2002).

### *Mus musculus* Schwarz et Schwarz, 1943

*Mus musculus* commonly called house mouse, is an anthropocore and highly invasive regarded species. This species native of Asia, is present in all continents, except Antarctica (Masseti, 2012).



Figures 3–6. Reptiles from Alimia Island. Figure 3. *Stellagama stellio daani*. Figure 4. *Anatololacerta oertzeni pelasgiana* (adult). Figure 5. *A. oertzeni pelasgiana* (young). Figure 6. *Ophisops elegans*.

*Mus musculus* is included in the list, compiled by IUCN, of 100 world's worst invasive alien species (Lowe et al., 2000). This small rodent can live in very diversified habitat due to the presence of human's commensals populations so-called "indoor" and wild populations called "outdoor" (Amori et al., 2008). The osteological remains related to this species, which consist of the skull, a hemimandible, a scapula, some vertebrae and some ribs, were found inside a dark glass bottle of beer among the ruins of the Ag. Georgios village. Some peculiar features, such as the presence of the notch on the external side of the upper incisors, the presence of only two rows of tubercles on the molars of the hemimandible and of a single root in the upper molar and, moreover, the dimension of various finds, the appearance and the reduced sizes of the braincase, have allowed the attribution of these finds to the species *M. musculus* (Toschi, 1965; Amori et al., 2008).

#### *Suncus etruscus* Savi, 1822

*Suncus etruscus* is the smallest living terrestrial mammal, characterized by a weight of about 2 g and by a length which rarely reaches to 5 cm (excluding tail). It is a typical species of Mediterranean bio-climatic zones, where it lives in environments characterized by dry stone walls and rocks (Amori et al., 2008), situation which moreover has also been found at Alimia. The distribution range of this species includes countries of the Mediterranean basin and extends to Pakistan and India. In the African continent reaches Natal and Tanzania. Has been found a single find of this small mammal, a hemimandible, in the same bottle where the remains relating to *Mus musculus* were found. The shape and size of hemimandible and the height mandibular coronoid, less than 3.2 mm, were the distinctive features for the attribution to the species *S. etruscus* (Amori et al., 2008).

#### CONCLUSIONS

As already noted, due to difficulties in reaching Alimia, the survey on the island may not have been capillary. It seems that because the arid nature and lack of active watercourses of this island, Amphibians are totally absent. A comparable situation is also in the nearby island of Chalki, which has very

similar environmental features (Buttle, 1995; Cattaneo, 2009). All specimens of various species of reptiles were found in Ag. Georgios bay, among the ruins of the abandoned village. Some specimens of *S. stellio* and *A. oertzeni* have also been observed in close proximity of a group of military buildings abandoned in the peninsula of Tigani. The herpetofauna of Alimia has proved to be interesting anyway and, considering the small size of the island, substantially consistent. The species that hosts are clearly of Rhodian matrix; includes two taxa more than the nearby and much bigger (about six times) island of Chalki (*A. oertzeni* and *Ophisops elegans*) (Buttle, 1995; Cattaneo, 2007, 2009), but the latter is more distant from Rhodes. The coexistence of seven species of reptiles in this small island, dry and without human presence, represents a perfect model of sympatry and of optimal utilization of resources.

It is also worth noting that the dense interactive network of the island (to whom contribute four species of lizard and at least three of micromammals) could also allow the survival to a second ophidic species. In this regard is worth remembering that Boettger (1888) reported the news, provided by von Oertzen, about the possibility of the existence of *Montivipera xanthina* in Chalki. Researches carried by us and by others (Joger & Nilson, 2005) have ruled out this possibility, but fact remains that the indication of von Oertzen could refer to another nearby island (in this instance Alimia), assimilated to Chalki or confused with this, following a *lapsus linguae*. Besides the authority and reliability of the German author don't put doubts about the authenticity of the news. So that's why is desirable in the future that researches are carried out in this direction, in order to clarify the enigma.

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# First record of *Rugulina fragilis* (Sars G.O., 1878) from the Mediterranean Sea (Mollusca Gastropoda Pendromidae)

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## ABSTRACT

Several shells of *Rugulina fragilis* (Sars G.O., 1878) (Mollusca Gastropoda Pendromidae) are reported from the Tuscan Archipelago. This is the first record of the species from the Mediterranean Sea.

## KEY WORDS

Mediterranean Sea; new records; Pendromidae; *Rugulina fragilis*; Tuscan Archipelago.

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## INTRODUCTION

Pendromidae Warén, 1991 is a small family of vetigastropods whose systematic position is not yet well understood (Bouchet P. & Rocroi J.P., 2005). It includes two genera, *Pendroma* Dall, 1927 and *Rugulina* Palazzi, 1988. The latter comprises few species (Gofas, 2014), only two of them belong to the European fauna: *Rugulina fragilis* (Sars G.O., 1878) and *R. monterosatoi* (van Aartsen & Bogi, 1987). Their troubled nomenclatural and taxonomic histories are well documented by Warén (1991). Only *R. monterosatoi* has previously been found in the Mediterranean Sea.

## MATERIAL AND METHODS

All material was picked up from bottom samples trawled by local fishermen. Shells were studied with a stereomicroscope. Photos were taken with a digital photocopier. The protoconch whorls are counted according to the method of Verduin (1977).

ABBREVIATIONS AND ACRONYMS. Dp: total diameter of the protoconch (in  $\mu\text{m}$ ); H: maximum height (in mm); Nwp: number of whorls of the protoconch; Nwt: number of whorls of the teleoconch; W: maximum width (in mm); APC: Attilio Pagli collection (Lari, Italy); CBC: Cesare Bogi collection (Leghorn, Italy); CSC: Carlo Sbrana collection (Leghorn, Italy); FCC: Francesco Chiriaco collection (Leghorn, Italy); FGC: Francesco Giusti collection (Leghorn, Italy); RRC: Romualdo Rocchini collection (Pistoia, Italy).

## RESULTS AND DISCUSSION

### *Taxonomy*

Class Gastropoda Cuvier, 1795

Subclass Vetigastropoda Salvini-Plawen, 1980

Family Pendromidae Warén, 1991

Genus *Rugulina* Palazzi, 1988

***Rugulina fragilis*** (Sars G.O., 1878) (Figs. 1–3, 5)

*Adeorbis fragilis* G.O. Sars, 1878: 213, tab. 22, figs. 19a–c (Fig. 4)

*Rugulina fragilis*: Warén, 1991: 71–73, figs 11A–E, 13A, B

*Rugulina fragilis*: Beck et al., 2006: 47

*Rugulina fragilis*: Hoffman et al., 2010: 49, figs. 1–3

ORIGINAL DESCRIPTION. "*Testa tenuis et fragilis, albida, leviter rufescens, exacte trochiformis, spira elevata, anfractibus 4 convexis, ultimo permagno et amplo basi leviter applanata, sutura profunda, apertura patula, oblique expansa, forma ovato-elliptica, labro externo tenuissimo, obliquo, columella aequaliter incurvata, umbilico magno et profundo crista nulla a basi difinito. Superficies vix nitida, lineis spiralibus, elevatis, regularibus obducta. Diam. basis 2,0 mm; altit. 1,7 mm.*"

[The shell is thin and fragile, whitish, slightly reddish, perfectly trochiform, with elevated spire, 4 convex whorls, the last is large and wide with the base slightly flattened, suture deep, aperture wide, obliquely expanded, ovate-elliptic, the external lip is very thin, oblique, the columella is regularly curved, the umbilicus is large and deep, there is no keel on the base. Surface barely shining, regularly covered with raised spiral lines. Diameter at the base 2.0 mm; height 1.7 mm.]

EXAMINED MATERIAL. *Rugulina fragilis*: off Capo Corso (Corsica, France) 600 m, 2 shells in CSC, 6 shells in FGC, 1 shell in APC. *Rugulina* cf. *fragilis*: off Capo Corso (Corsica, France) 600 m, 1 shell in CSC. *Rugulina monterosatoi*: off Gorgona Island (Leghorn, Italy) 400 m, 4 shells in RRC, 1 shell in CSC, 1 shell in FCC; 3 shells off Gorgona Island (Leghorn, Italy) 300 m, in APC; 13 shells, Alboran Sea (Spain) 160 m, in CBC; 4 shells off Giglio Island (Grosseto, Italy) 400 m, in CBC; 4 shells off Capraia Island (Leghorn, Italy) 500 m, in FGC.

DESCRIPTION OF THE EXAMINED SHELLS. Small, thin and fragile, broadly conical (height: 1.00–1.65 mm; width: 1.15–2.05 mm), whitish and semitransparent. Protoconch (0.5–0.6 whorls; diameter about 185  $\mu$ m) protruding, paucispiral, smooth, tilted, border with the teleoconch clear. Teleoconch whorls (2.2–2.6) convex, fairly expanding, suture deep. Aperture broad, ovate, prosocline (seen laterally).

Outer lip sharp. Columella curved, simple. Base quite flattened. Umbilicus wide. Sculpture of subtle spiral threads (9–14 on the last whorl), more close-set in the periumbilical zone. Shell surface further ornamented with a somewhat net-shaped microsculpture of irregular discontinuous lines.

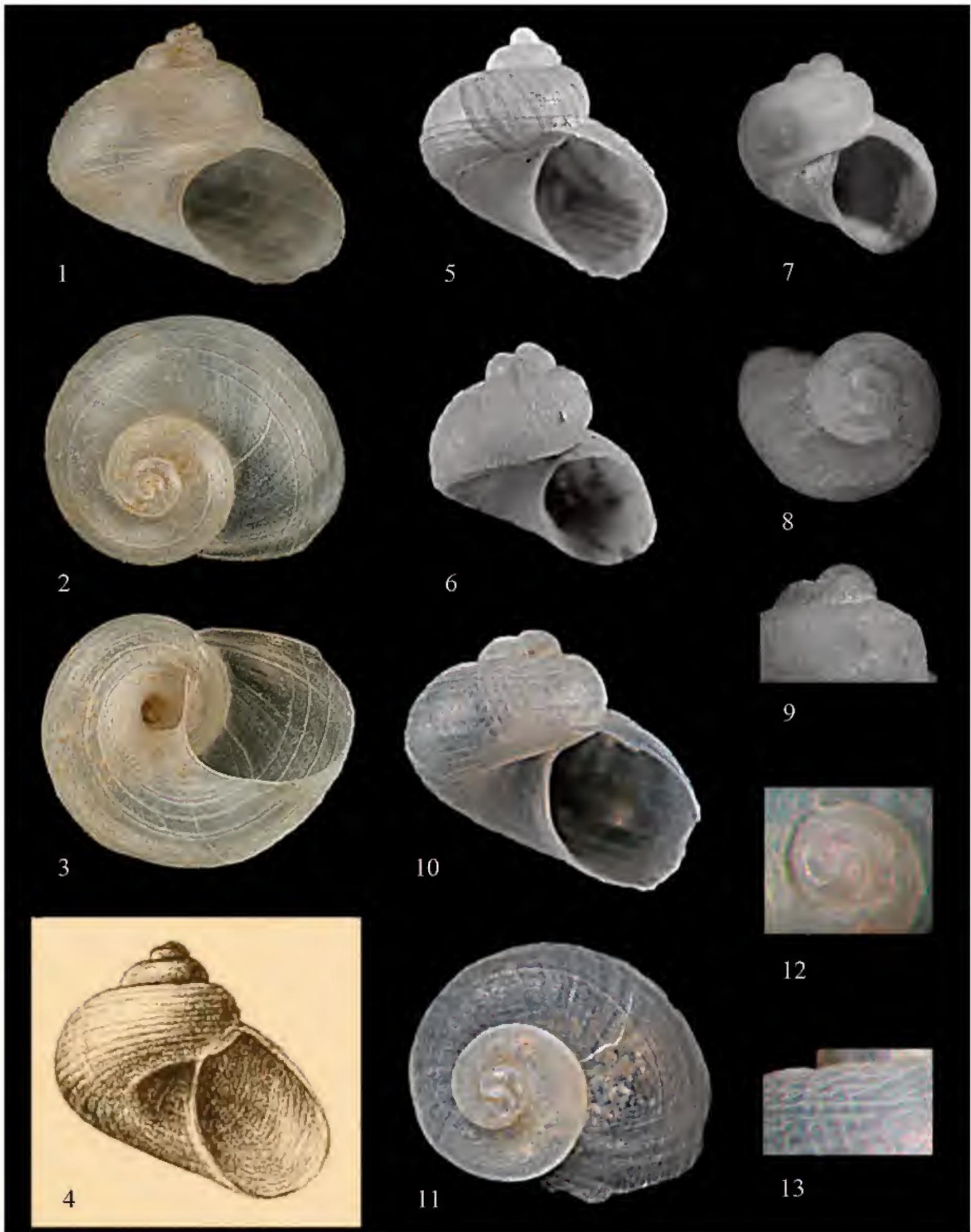
REMARKS. The mediterranean shells match *R. fragilis* in all respects. The only similar species is the cogeneric *R. monterosatoi*, which is constantly smaller (maximum W: 0.85 mm; maximum H: 0.80 mm). Its spiral sculpture has only 2 strong periumbilical cords forming a sort of keel and 1 adapical thread. The protoconch are comparable in size (Dp: about 185  $\mu$ m) (Aartsen van & Bogi, 1987; Warén, 1991; pers. obs.) (Figs. 7–9). Comparing similar-sized shells of *R. fragilis* and *R. monterosatoi*, the latter has a more globular outline, a more depressed spire, less expanded whorls, the outline of the last whorl appears more squarish due to the spiral sculpture, the umbilicus is smaller, and the protoconch less tilted (Figs. 5–6). Note that the shell in fig. 6 is gerontic, being larger for the species and having the last whorl slightly loose. It is nevertheless clearly different from *R. fragilis*.

A shell similar to *R. fragilis* (Figs. 10–13) was found in the same bottom sample (H: 1.20 mm; W: 1.40 mm; Nwt: 1.7). It differs from the latter in having a less conical outline, a stronger microsculpture, a protoconch not tilted, larger in diameter (Nwp: 0.6; Dp: about 270  $\mu$ m). Being a unique specimen, we prefer to leave its status open.

*Rugulina fragilis* is previously known from the Northern Atlantic Ocean, ranging from E Greenland to Norway (Warén, 1991; Hoffman et al., 2010), and the Seine seamount, off the morroccan coasts (Beck et al., 2006). This is the first record from the Mediterranean Sea. Although no living specimens were found, the shells are in good conditions. *Rugulina fragilis* should be added to the recent mediterranean malacofauna.

## ACKNOWLEDGMENTS

The authors are grateful to Cesare Bogi (Leghorn, Italy), Romina Rocchini (Pistoia, Italy), Attilio Pagli (Lari, Italy), Alessandro Raveggi (Florence, Italy), Francesco Chiriaco (Leghorn, Italy), Stefano Bartolini (Florence, Italy) for the



Figures 1–3: *Rugulina fragilis*, off Capo Corso, 600 m, 1.90 mm x 1.50 mm; Fig. 1: frontal view; Fig. 2: apical view; Fig. 3: basal view. Fig. 4: *Adeorbis fragilis* (from Sars, 1878, pl. 22, figs. 19a, modified). Fig. 5: *R. fragilis*, off Capo Corso, 600 m, 1.15 mm x 1.00 mm. Fig. 6: *R. monterosatoi*, off Giglio Island, 400 m, 1.00 mm x 1.00 mm. Figs. 7–9: *R. monterosatoi*, off Gorgona Island, 400 m, 0.77 mm x 0.77 mm; Fig. 7: frontal view; Fig. 8: apical view; Fig. 9: protoconch. Figs. 10–13: *R. cf. fragilis*, same locality as Figs. 1–3, 1.40 mm x 1.20 mm; Fig. 10: frontal view; Fig. 11: apical view; Fig. 12: protoconch; Fig. 13: details of the sculpture.

loan of material. Sincere thanks are due to Cesare Bogi for useful advices, to Stefano Bartolini for digital photographs and to Enzo Campani (Leghorn, Italy) for reading the manuscript. Thanks to Patrick LaFollette (Cathedral City, U.S.A.) for editing the English manuscript.

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## **Colinatys Ortea, Moro et Espinosa, 2013 from Eastern Mediterranean Sea (Opisthobranchia Haminoeidae)**

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### **ABSTRACT**

Two shells of the genus *Colinatys* Ortea, Moro et Espinosa, 2013 (Opisthobranchia Haminoeidae), similar to *Colinatys alayoi* (Espinosa et Ortea, 2004), type species of the genus, are reported from Larnaca, Cyprus. The presence of the species in the Mediterranean Sea is discussed.

### **KEY WORDS**

*Colinatys*; Haminoeidae; new records; Mediterranean Sea.

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### ***Colinatys* sp.**

**EXAMINED MATERIAL.** 2 shells from Larnaca, Cyprus, depth 43 m, May, 2011, picked from bioclastic bottom samples collected by SCUBA near wreck of ferry MS Zenobia, 34°53'52"N 33°39'25"E. Specimen 1, H = 1.35 mm, W = 0.85 mm. (Figs. 1–4), in Alessandro Raveggi collection; specimen 2, H = 1.60 mm, W = 1.20 (Figs. 1–6), in Stefano Bartolini collection.

**DESCRIPTION.** Shell small, translucent, colorless, involutely coiled, subcylindrical-pyriform, truncated, periphery below center of the smoothly rounded body whorl. Aperture longer than spire, narrow posteriorly, widening anteriorly. Umbilicus narrow, partially obscured by the slightly flared columellar lip. Spire concave, nearly covered by final whorl, leaving a narrow opening through which the protoconch can be seen. Outer lip sharp, straight to slightly concave above periphery, convex below. Sculpture of weakly encised, whitish spiral bands of irregular widths, interrupted by stronger closely

packed orthocone axial growth lines, dividing the bands into of rows of squared to elongated pits. Within the apical depression only axial sculpture is evident. The shell surface has a wrinkled, weakly reticulated appearance. The whitish appearing spiral bands are visible within the aperture through the translucent shell (Figs. 1–6).

### **DISCUSSION**

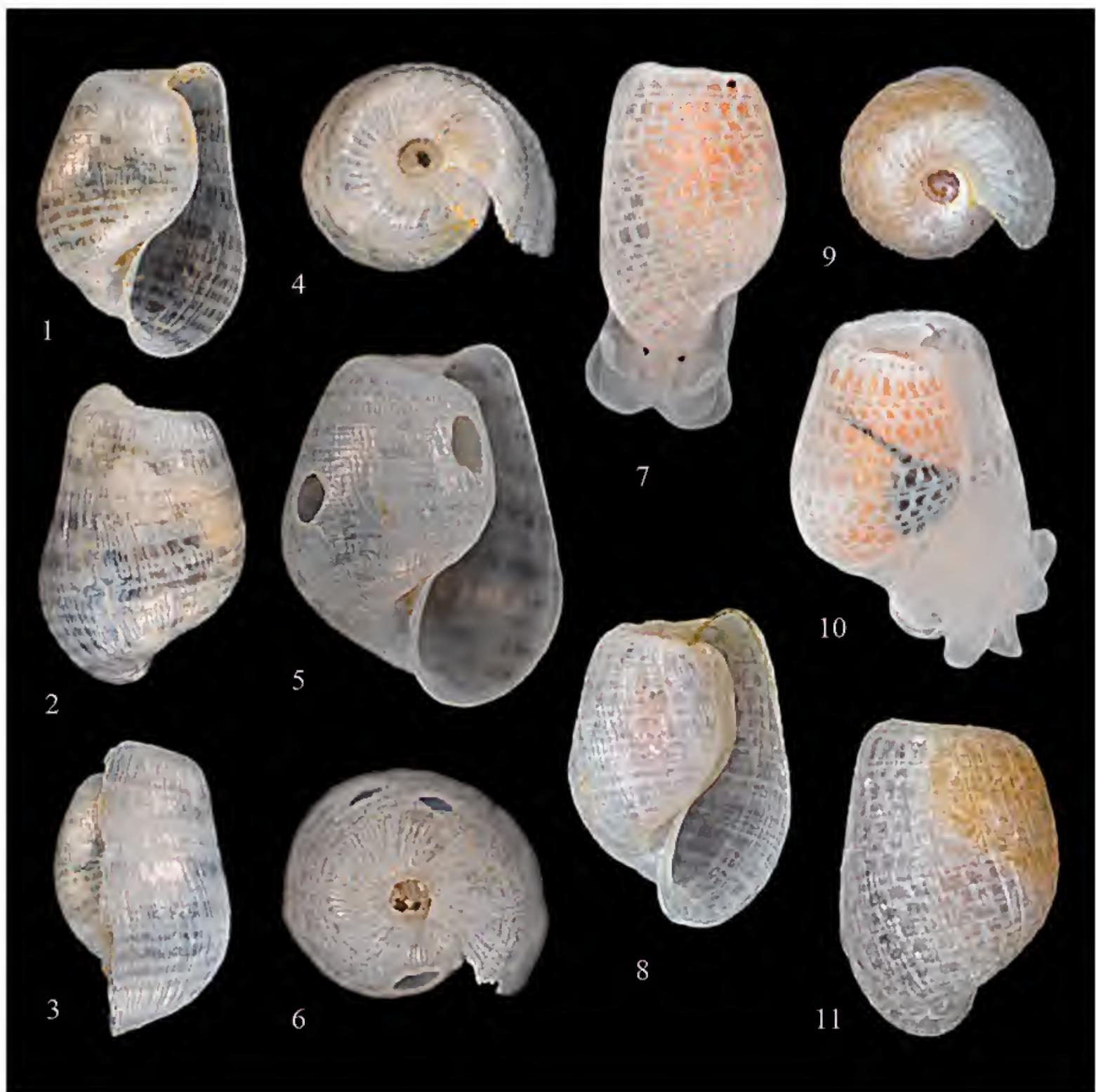
No European Opisthobranchs nor alien Indo-Pacific species recorded from Cyprus (Öztürk et al., 2004; Tsiakkios & Zenetos, 2011) have similar shells.

Considering that many alien marine organisms have settled in the Eastern Mediterranean during recent years (Zenetos et al., 2010), an extensive bibliographic survey was carried out of shelled opisthobranchs of the Indo-Pacific and neighboring areas but was unsuccessful in finding similar species (Issel, 1869; Hedley, 1899a-c; Habe, 1964;

Maes, 1967; Keen, 1971; Kay, 1979; Powell, 1979; Kilburn & Rippey, 1982; Sharabati, 1984; Lin & Qi, 1985; Springsteen & Leobrera, 1986; Kay & Schoenberg-Dole, 1991; Higo et al., 1999, 2001; Jansen, 2000; Okutani, 2000; Hasegawa, 2001, 2005; Hasegawa et al., 2001a-b; Qi, 2004; Dharma, 2005; Thach, 2005; Poppe, 2008; Sasaki, 2008; Valdés, 2008; Yonow, 2008, 2012; Zenetos et al., 2010).

Surprisingly, we found that our shell most closely

resemble *Colinatys alayoi* (Espinosa et Ortea, 2004) (Figs. 7–11), known from Cuba, Florida and Bahamas (Espinosa & Ortea, 2004; Ortea et al., 2013; Redfern, 2013). The genus *Colinatys* Ortea, Moro et Espinosa, 2013 was erected for this species on anatomical grounds, which was originally assigned to *Atys* Montfort, 1810, then transferred to *Retusa* T. Brown, 1827 (Valdés et al., 2006; Rosenberg et al., 2009). No other species have been assigned to the genus.



Figures 1–6. *Colinatys* sp., Larnaca (Cyprus), Figs. 1–4: 1.35 mm, Figs. 5, 6: 1.60 mm; Figs. 7–11. *Colinatys alayoi* (Espinosa et Ortea, 2004), Bahamas, Figs. 7, 8: 1.50 mm, Figs. 9, 10: 1.00 mm, Figs. 11: 2.00 mm (from Redfern, 2013, modified).

Our shells match agree with the conchological characters of *Colinatys*, but we prefer not to assign them to *alayo* as doubts on conspecificity remain due to differences of the shell colour pattern (*C. alayo* has a more marked “checkerboard” pattern), absence of anatomical information and very long distance from typical range. Additional material, particularly live collected specimens for anatomical comparison, are needed to establish the presence of an established population and to clarify its status and relationships. Whether the present species is Mediterranean, Lessepsian, or of other origin is unknown, so we prefer to consider *Colinatys* sp. a cryptogenic species (Carlton, 1996).

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## Reports of *Haliotis* Linnaeus, 1758 (Mollusca Vetigastropoda) from the Middle Miocene of Ukraine

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### ABSTRACT

Two species of Haliotidae are described and illustrated from the Maksymivka quarry near Ternopil (Ukraine), a site characterized by its peculiar Middle Miocene (Badenian) coralgall facies. The first species, *Haliotis volhynica* Eichwald, 1829, has a wide geographical distribution that extends from the Paratethys of Central Europe to the Ukraine, and is quite common in the Maksymivka site. Another different species of *Haliotis* Linnaeus, 1758 was recently found at Maksymivka, only two specimens in several years of research. This species was already reported by Krach (1981) from Poland as *Haliotis tuberculata tauroplanata* Sacco, 1897, a species from the Burdigalian of Piedmont that differs from the Maksymivka species by several characters. We leave this rare species indeterminate at specific level because of the scarcity of material known to date.

### KEY WORDS

Gastropoda; Haliotidae; *Haliotis*; Miocene; Ukraine.

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### INTRODUCTION

Haliotidae Rafinesque, 1815 is a family of marine gastropods consisting of 56 living species and at least 35 fossil ones (Geiger & Groves, 1999; Geiger, 2000). The genus *Haliotis* Linnaeus, 1758 is the only one for the family and is known from Upper Cretaceous (Maastrichtian) (Sohl, 1992) to Recent. Strausz (1966) and Geiger & Groves (1999) proposed to refer all the 11 fossil European taxa known at that time (*Haliotis anomiaeformis* Sacco, 1896; *H. benoisti* Cossmann, 1895; *H. lamellosa* Lamarck, 1822; *H. lamellosoides* Sacco, 1896; *H. monilifera* Bonelli, 1827; *H. neuvillei* Bial de Bell, 1909; *H. ovata* Bonelli, 1827; *H. tauroplanata* Sacco, 1897; *H. torrei* Ruggieri, 1989; *H. tuberculata* Linnaeus, 1758; *H. volhynica*

Eichwald, 1829) to *H. tuberculata volhynica*, because the Recent species (*H. tuberculata tuberculata*) with its Atlantic and Mediterranean populations is known to be extremely plastic in its shell morphology, and most material of European fossil specimens fall within the range of variation within the Recent species.

Aim of the present work is to illustrate some specimens of *Haliotis* recently found at the Maksymivka quarry (Ukraine) from the Middle Miocene (Badenian). A revision of the fossil cited species of *Haliotis* is needed to define the status of the described taxa. The reports of *Haliotis* from the Miocene of Ukraine are scarce, relating to *H. volhynica* or *H. tuberculata volhynica* (Zelinskaya et al., 1968; Krach, 1981) and *H. tuberculata tauroplanata* (Krach, 1981).

## MATERIAL AND METHODS

The Maksymivka quarry near Ternopil (Ukraine) (Fig. 1) is well known in literature for its peculiar Middle Miocene (Badenian) coralgal facies and its fauna (Radwański et al., 2006; Studencka & Jasionowski, 2011; Górka et al., 2012). It embraces an area of several square kilometers over a distance of about one kilometer (Radwański et al., 2006: fig. 3). The reef exposed in this quarry is a member of the unique reef structure (almost 300 km long) formed within the Paratethyan realm, and distributed widely in the north-eastern and eastern borders of the Carpathian Foredeep Basin in Western Ukraine, Moldova and north-east Romania (Górka et al., 2012: fig. 1). The coralgal facies at Maksymivka is characterized by a complex structure: particular coralgal buildups of variable size (from centimetres of rodolith forms, to several metres thick), composed of red-algal (lithothamnian) colonies associated locally with sparse hermatypic corals. A survey of all these peculiar features/components is well reported by Radwański et al., 2006.

Other organisms associated with reefs are represented by mollusks (bivalves and gastropods), crabs, foraminifera, annelids, bryozoans and echinoderms. Almost all of the organisms of originally aragonitic shells were dissolved as a result of post sedimentary diagenesis and are now preserved in the form of moulds and/or imprints (see Górka et al., 2012: fig. 7A for a massive coralline-algae boundstone with embedded *Haliotis* shells).

The shells were collected manually inside the reef structure, paying particular attention to prevent breakage, and after were cleaned and measured (Table 1). The measurements are in millimeters (mm) and in degrees for the angle. About the references we considered only those works where species have been not only recorded, but also figured.

ABBREVIATIONS AND ACRONYMS. AS: Alexander Stalennuy collection, Ternopil, Ukraine; BD: Bruno Dell'Angelo collection, Genoa, Italy; BS: Bellardi and Sacco collection, Museo di Geologia e Paleontologia, University of Turin (now stored at the Museo Regionale di Scienze Naturali

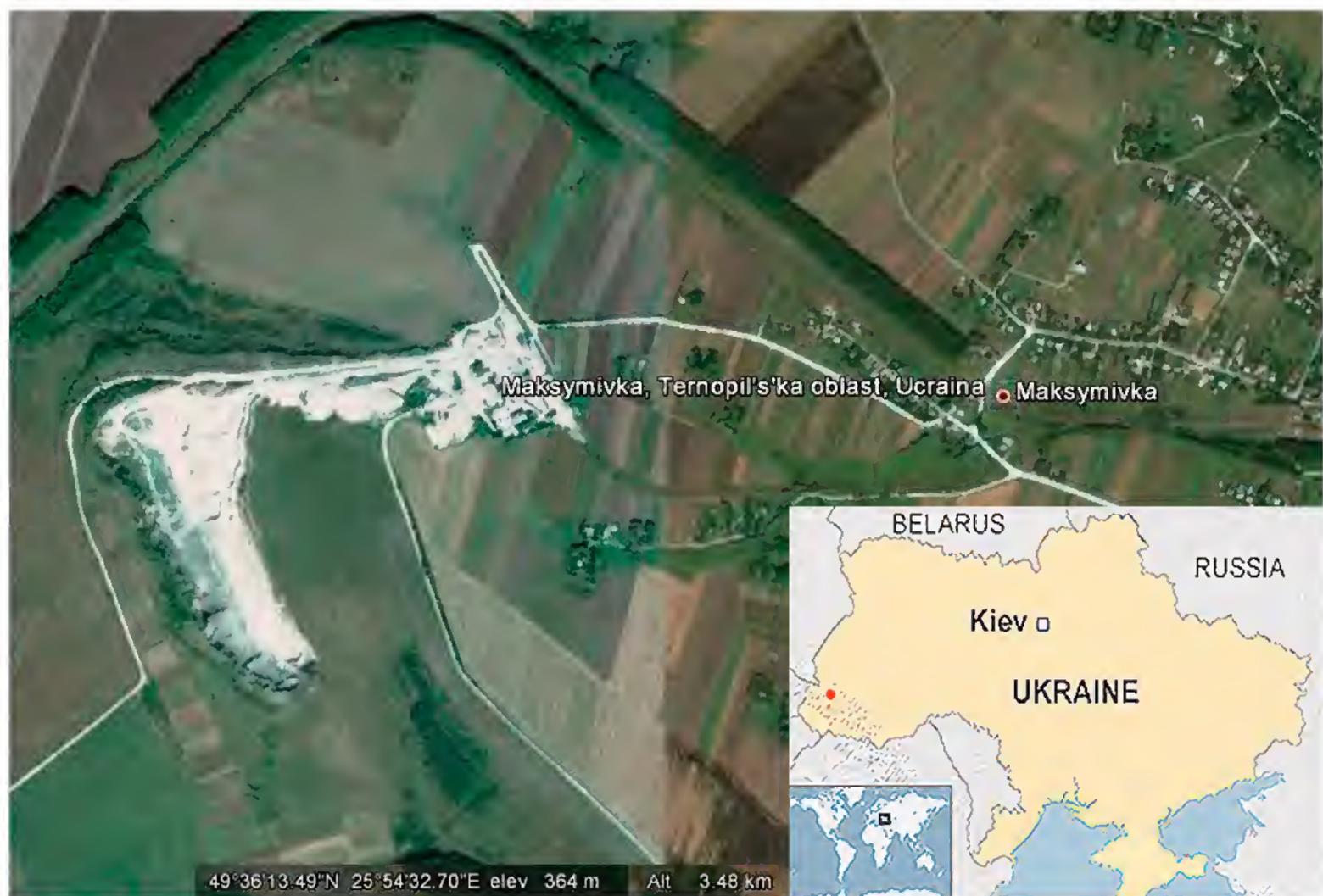


Figure 1. Maksymivka quarry near Ternopil (Ukraine), from Google earth.

of Turin), Italy; MF: Maurizio Forli collection, Prato, Italy; MZB: Museo di Zoologia, University of Bologna, Italy; L: length; W: width; H: maximum height of the shell, measured from the base to the top of the spire;  $\alpha$ : angle of inclination of the initial part of the spire; L/W: ratio between L and W.

**SYSTEMATICS**

Classis GASTROPODA Cuvier, 1795  
 Ordo VETIGASTROPODA Salvini-Plawen et Haszprunar, 1987  
 Familia HALIOTIDAE Rafinesque, 1815  
 Genus *Haliotis* Linnaeus, 1758  
 Type species: *Haliotis asinina* Linnaeus, 1758

*Haliotis volhynica* Eichwald, 1829  
 Figs. 2–14

1829. *Haliotis volhynica* Eichwald: 294, pl. 5, fig. 18.  
 1856. *Haliotis volhynica* Eichw. - Hörnes: 510, pl. 46, fig. 26

1928. *Haliotis volhynica* Eichw. - Friedberg: 530, pl. 34, figs. 8, 9  
 1937. *Haliotis volhynica* Eichwald - Davidaschvili: 540, pl. 1, fig. 5  
 1954. *Haliotis tuberculata lamellosoides* Sacco - Csepregy-Meznerics: 10, pl. 1, fig. 24  
 1955. *Haliotis (Haliotis) volhynica* Eichw. - Korobkov: pl. 2, fig. 3  
 1960. *Haliotis (Haliotis) tuberculata* var. *lamellosoides* Sacco - Kojumdgieva & Strachimirov: 84, pl. 28, fig. 9  
 1966. *Haliotis tuberculata volhynica* Eichwald-Strausz: 26, fig. 16c  
 1967. *Haliotis volhynica* Eichw. - Bielecka: 132, pl. 8, figs. 3, 4 (fide Bałuk, 1975).  
 1968. *Haliotis volhynica* Eichwald - Zelinskaya et al.: 95, pl. 27, fig. 1  
 1979. *Haliotis (Sulculus) volhynica* Eichwald - Jakubowski & Musiał: 61, pl. 5, fig. 5  
 1981. *Haliotis tuberculata* Eichwald - Krach: 39, pl. 11, figs. 1–3  
 2012. *Haliotis tuberculata* Linnaeus - Górká et al.: 163, figs. 7a, 15a, b

<i>Haliotis volhynica</i>	L	W	H	$\alpha$	L/W	Repository
1	57.4	38.1	14.9	28	1.51	MF
2	56.8	36.2	14.7		1.57	MF
3	53.2	35.3	14.8		1.44	MF
4	52.1	35.7	17	26	1.46	MF
5	50	32	16		1.57	MF
6	47.8	34.6	11.7	31	1.39	MF
7	42.5	29.8			1.43	MF
8	38.7	28.7	11.5		1.35	MF
9	34.8	25.1			1.34	MF
10	26.9	19.8	7.6		1.36	MF
11	26.3	18.7	6.3		1.41	MF
12		13	4.5			MF
13		12.8	3.5			MF
14	60.5	39.4			1.54	MZB 32038
15	70.4	44.8			1.58	BD
<i>Haliotis</i> sp.	L	W	H	$\alpha$	L/W	
1	60	34			1.77	AS
2	46.5	26	10	45	1.79	MF
<i>Haliotis tuberculata tauroplanata</i>	L	W	H	$\alpha$	L/W	
1	41	24	7.5	32	1.71	BS.082.01.004

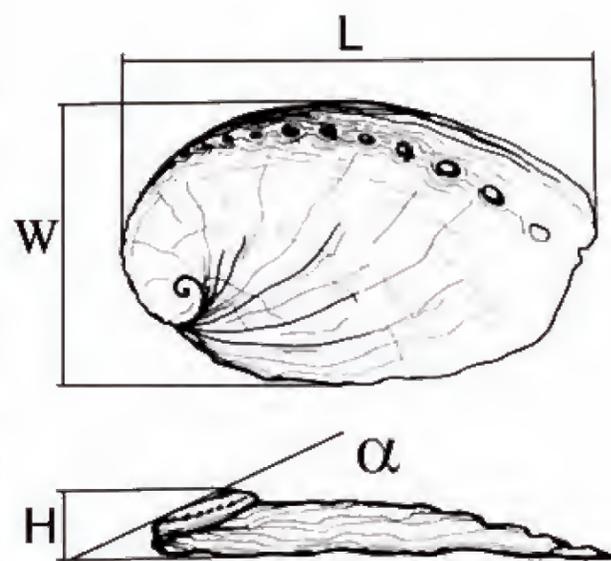
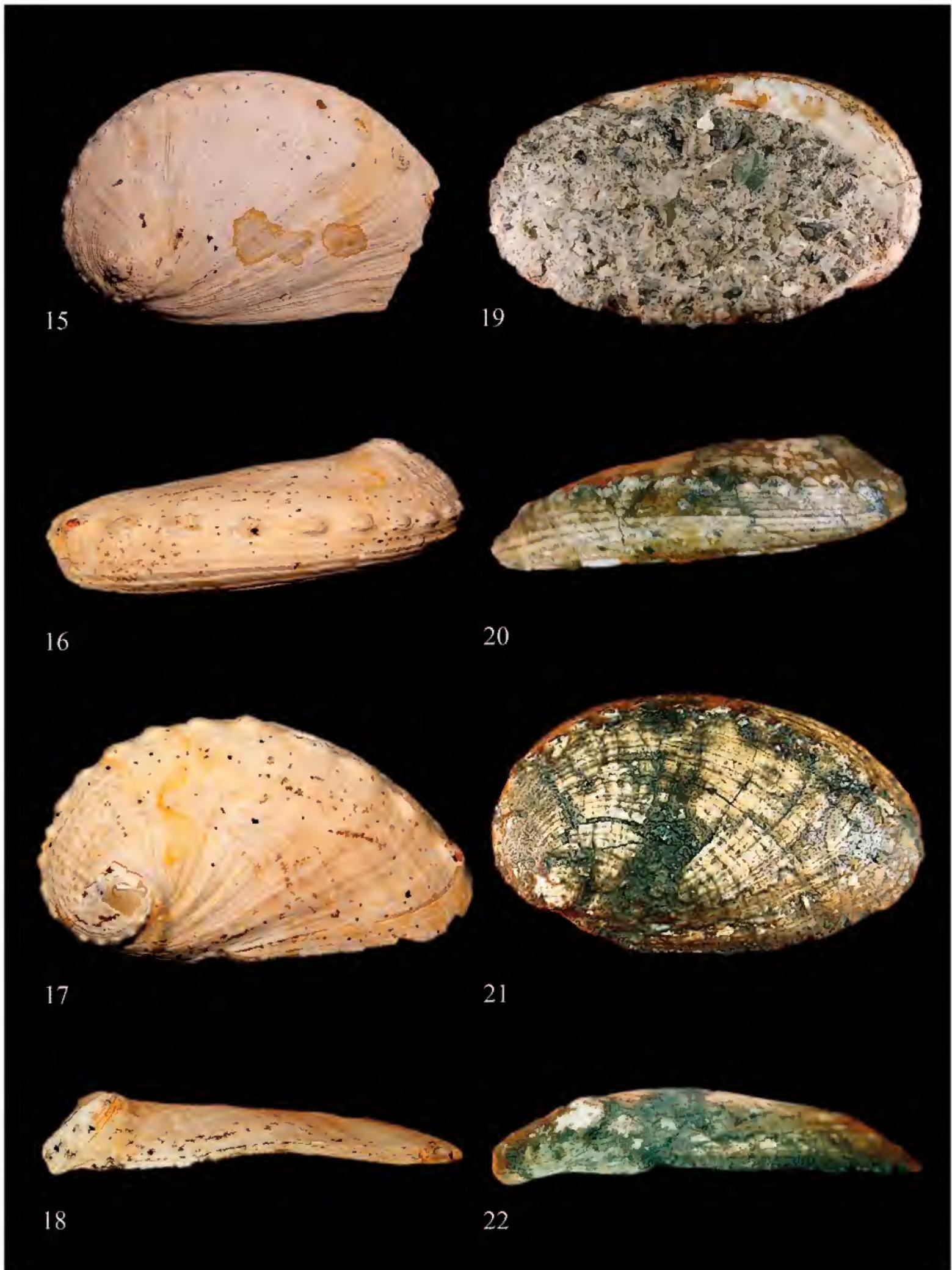


Table 1. Measurements of the examined specimens and their repository. See in Abbreviations and Acronyms.



Figures 2–14. *Haliotis volhynica* Eichwald, 1829 from the Middle Miocene (Badenian) of Maksymivka quarry (Ukraine). Figures 2–4: specimen 4 from Table 1. Figure 5: specimen 10 from Table 1. Figures 6, 7: specimen 11 from Table 1. Figures 8–10: specimen 6 from Table 1. Figures 11–14: specimen 1 from Table 1.



Figures 15–18. *Haliotis* sp. from the Middle Miocene (Badenian) of Maksymivka quarry (Ukraine). Fig. 15: specimen 1 from Table 1. Figures 16–18: specimen 2 from Table 1. Figures 19–22. *Haliotis tuberculata tauroplanata* Sacco, 1897, Early Miocene (Burdigalian) of Torino hills (Piedmont, Italy), BS. 082.01.004.

EXAMINED MATERIAL. Maksymivka: 15 specimens (MF, BD, MZB) (Table 1).

DESCRIPTION. Shell of medium size (L max about 70 mm), widened-oval, spire slightly raised, tilted about thirty degrees relative to the plane formed by the edge of the shell ( $\alpha$ ). Apex positioned on the left, moved to the center, about a third of the spiral width corresponding to that point. Regularly convex outer surface, with ornamentation spiral constituted by main cords detected, which develop at the beginning almost intermittently and then, becoming evident and irregularly wavy both in the sense of the spire and in height, form knobs scattered or aligned in radial folds more or less signed. The spiral cords are separated by evident furrows, sometimes side by side, giving rise to spiral cords of smaller width of the main, intersecting with growth striae more or less marked, form small imbricated lamellae, arranged irregularly. Openings with marginal conical-tubular protrusions pronounced, regularly spaced from each other by spaces almost equal to that of the size of the base of the next opening, which maintain the proportions, as the size of the shell, of which the last four open. Outer lip, from the edge of the keel formed by the openings up to the basal cords more pronounced, tilted and slightly concave. Columellar callus flattened with weak concavity.

DISTRIBUTION. *Haliotis volhynica* Eichwald, 1829 is a species with a wide geographical distribution that extends from the Paratethys of Central Europe (Austria, Romania, Bulgaria, Poland) to the Ukraine, with chronostratigraphic distribution limited to the Middle Miocene. It is particularly abundant in organogenic limestones of Ukraine related to sediments deposited at depths corresponding to the infralitoral.

REMARKS. The morphological characteristics of *H. volhynica*, at least of the specimens we examined and compared to those from the literature, are fairly constant, in particular the position of the apex and the spiral evolution, which is more rounded and closed with respect to that of *Haliotis* sp., as well as the ornamentation consisting of marked and tuberculate spiral cords (Csepregy-Meznerics, 1954; Zelinskaya et al., 1968; Krach, 1981; Górká et al., 2012). Even by the drawings can be found the same morphological characters that seem peculiar to *H. volhynica*, such as in Strausz (1966)

or in Friedberg (1928) by the shape of the internal moulds of the shell.

Specimens found at Maksymivka are well characterized and show a small degree of variability, and are different from the Recent species *H. tuberculata tuberculata* L., 1758 with its Atlantic and Mediterranean populations, contrary to what previously expressed by many authors about *H. volhynica*, considered as a subspecies *H. tuberculata volhynica* (Strausz, 1966; Geiger & Groves, 1999) or directly as *H. tuberculata* (Górká et al., 2012). Agreeing to Landau et al. (2003) we consider *H. volhynica* a separable species from the Recent *H. tuberculata*.

### *Haliotis* sp.

Figs. 15–18

1981. *Haliotis tuberculata tauroplanata* [non Sacco, 1897] - Krach: 40, pl. 11, figs. 4–7.

EXAMINED MATERIAL. Maksymivka: 2 specimens (AS, MF) (Table 1).

DESCRIPTION. Shell of small size, elongate-oval, with width about half the length. Spire little high with apex positioned a little more to the left than *H. volhynica*, about a quarter of the spiral width corresponding to that point. Regularly convex surface of the shell, with spiral ornamentation of the first two whorls consisting of 4–5 slender main cords spaced between them, which then become about ten or so, just signed, sometimes forming very small knobs, which disappear as increasing the spiral size, leaving the remaining surface of the shell, smooth or with sparse spiral cords just signed. Openings, of which the last four open, with marginal conical-tubular protrusions less raised. Outer lip, from under the keel of the openings to the edge columellar, with slightly convex profile. It was not possible to examine the internal part because it is filled with cemented limestone.

DISTRIBUTION. Paratethys, Middle Miocene (Badenian): Poland, Weglinek (Krach, 1981); Ukraine, Maksymivka (this work).

REMARKS. Only two specimens of a second species of *Haliotis* were recently found at Maksymivka, and this despite the numerous samples taken in recent years by one of the authors (AS). This second

species may therefore be considered quite rare, unlike *H. volhynica* which instead is found quite commonly, although it is hard to find complete and in fair condition specimens.

*Haliotis* sp. from Maksymivka differs from *H. volhynica* mainly by a different ratio L/W (1.34–1.58 for *H. volhynica* vs. 1.79 for *Haliotis* sp.) that gives rise to a more open spire and by the different ornamentation, without radial folds and evident spirals cords, if not in the early part of the spire. The similarity with *H. tuberculata tauroplanata* Sacco, 1897 from the Early Miocene (Burdigalian) of Turin hills (Piedmont, Italy) (Figs. 19–22) is evident when considering the general shape of the shell, but it is a bit less when comparing the two different spiral ornamentations. In *Haliotis* sp. the first part of the spire shows some slender spiral cords and small tubercles which disappear as increasing the spiral size, while there are not present in *H. tuberculata tauroplanata* which has also a spiral ornamentation made up of flattened cords which extend over the entire surface of the shell. Moreover *Haliotis* sp. has the anterior margin almost straight, while that of *H. tuberculata tauroplanata* is more convex and gives a more ellipsoid profile to the shell.

We consider the specimen reported by Krach from Weglinek (Poland) as *H. tuberculata tauroplanata* conspecific to the present species.

## CONCLUSIONS

The findings of *H. volhynica* from Maksymivka confirm that abalone species, as taxa typical for high-energy, rocky environments, are one of the most characteristic and abundant group of gastropods among Late Badenian free-living reef-dwellers. Particularly important is to be considered the recent discovery of a second species of *Haliotis* from the same site, only two specimens in several years of research that led to the discovery of many specimens of *H. volhynica*. This latter seems the more frequent species of gastropods found at Maksymivka, though most of the specimens are not complete or are so matted in the rock that they can not be extracted.

This second species, already reported in the past by Krach (1981) from Poland as *H. tuberculata tauroplanata*, show differences with the species of

Sacco from the Burdigalian of Piedmont, and must be considered as a different species. We leave it indeterminate at specific level because of the scarcity of material known to date, waiting for more material to give a specific determination and to confirm or not the differences with the species from the Miocene of Italy.

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## Planktonic and Fisheries biodiversity of Alkaline Saline crater lakes of Western Uganda

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### ABSTRACT

Eight (8) selected saline crater lakes in Western Uganda were sampled for fish biodiversity. Water samples collected from each of these lakes were analysed for zoo- and phytoplanktonic composition and abundance. In situ, physico-chemical parameters including average depth, salinity, temperature, conductivity, Dissolved Oxygen and pH were taken at each sample collection point. The Mean  $\pm$  SD of the different parameters ranged between 0.2 $\pm$ 0.0 m and 2.3 $\pm$ 0.3 m for average depth, 0.0 $\pm$ 0.0 mg l<sup>-1</sup> and 205.0 $\pm$ 15.3 mg l<sup>-1</sup> for salinity, 27.9 $\pm$ 0.3°C and 34.4 $\pm$ 2.4°C for temperature, 18.6 $\pm$ 0.1 mscm<sup>-1</sup> and 106.3 $\pm$ 3.5 mscm<sup>-1</sup> for conductivity, 1.7 $\pm$ 0.4 mg l<sup>-1</sup> and 6.0 $\pm$ 1.0 mg l<sup>-1</sup> for Dissolved Oxygen and 9.6 $\pm$ 0.1 and 11.5 $\pm$ 1.0 for pH. With the exception of the Lakes Bagusa, where *Anabaena circinalis* Rabenhorst ex Bornet et Flahaul was found to dominate the algal biomass, and Bunyampaka and Nyamunuka where no *Spirulina platensis* (Nordstedt) Gomont was found, the rest of the studied lakes had *S. platensis* dominating their algal biomass. All lakes showed very low zooplankton abundances and biodiversity, with Lake Kikorongo (the one with the highest zooplankton biodiversity) having *Brachionus calyciflorus* Pallas, 1766 as the most abundant, only ranging between 50 to 100 individuals/litre. None of the lakes had fish at the time of sampling.

### KEY WORDS

Zooplankton; Phytoplankton; Fish; saline; alkaline; lakes.

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### INTRODUCTION

Minute free-floating organisms found in various water bodies can be referred to as planktons and have been reported to be the main food for fish (Lind, 1965). Planktons have been reported to play pivotal roles in the biosphere in terms of both primary and secondary production (Boero et al., 2008). Plant-like minute organisms continuously drifting in the water are referred to as phytoplankton while the minute animal-like organisms, unable to syn-

thesize food are referred to as zooplankton. Planktons are not only food organisms for fish fry, fingerlings and adult fish but also influence key abiotic features in aquatic systems (Joshi, 2009).

Saline systems have been reported to have a generally low biodiversity (Hammer, 1986), with diatoms being more dominant among algal biomass in alkaline saline systems (Stenger-Kovács et al., 2014). Rotifera, Cladocera, Copepoda and Anostraca species generally are the dominant zooplankton in saline systems with their biodiversity decreasing

with increasing salinity (Hammer, 1993). In particular, East African saline lakes have been reported to show more rotifers in their zooplankton assemblages than either Copepods or Cladocerans, with the dominant species of Rotifera, Copepoda and Cladocera reported to change with the salinity gradient (Green, 1993). Alkaline saline crater lakes are considered very productive environments (Harper et al., 2003; Grant, 2006), with prokaryotic photosynthetic primary production suggested to be the driving force behind nutrient recycling in these systems (Jones & Grant, 1999). Community evenness decreases with increasing nutrient concentration, with the few favored species being dominant (Harper et al., 2003). Abundance of certain species like *Dunaliella* sp. dominate the saline waters of Utah lake in the USA (Larson & Belovsky, 2013), while 'Spirulina' *Arthrospira fusiformis* (Voronikhin) Komárek et J.W.G.Lund has been reported to be dominant in lake Bogoria which is a hypersaline lake in Kenya, east Africa (Harper et al., 2003; Matagi, 2004) with no macro-zooplankton and lesser flamingo, *Phoeniconaias minor* (E. Geoffroy Saint-Hilaire, 1798), as the only grazers (Harper et al., 2003).

Several fish species more especially amphihaline species have been described to have physiological mechanisms which enable them to migrate between freshwater and sea water, with many other species with ability to tolerate, adapt or even acclimate to salinity, alkalinity and ionic compositions levels outside the conventional freshwater and seawater conditions (Brauner et al., 2013). Whereas both native and exotic species were found in waters with salinities less than 30 mg l<sup>-1</sup> in a study of fish distribution in inland saline waters in Victoria, Australia, no inland fish species were found at salinities above 30 mg l<sup>-1</sup> (Chessman & Williams, 1974). Flamingo lakes with salinity levels below 20 mg l<sup>-1</sup> are reported to have fish species of commercial value (Hadgembes, 2006). Several species were said to tolerate salinities as high as 15,000 mg l<sup>-1</sup> with only the nine-spined stickle back resisting at salinities of 20,000 mg l<sup>-1</sup> (Rawson & Moore, 1944). *Oreochromis alcalicus alcalicus* (Hilgendorf, 1905), *O. alcalicus grahami* (Trewavas, 1983), and *O. amphimelas* (Hilgendorf, 1905), have been reported to be endemic in lakes Magadi and Natron which are among the East African saline lakes (Matagi, 2004).

A number of environmental factors including salinity and nutrients in hypersaline systems may be potential factors which do affect biodiversity in saline environments (Larson & Belovsky, 2013). Saline lakes show limited species complement in micro-organisms contrary to the considerable biodiversity in micro-organisms (Harper et al., 2003). Larson & Belovsky (2013) reported salinity and nutrient concentration in hypersaline lakes as among the strong determinants of phytoplankton diversity, with species richness decreasing with increasing salinity and increasing with increasing nutrient concentration. Despite the inverse proportionality between saline and aquatic biodiversity, the relationship between salts is still not well understood (Derry et al., 2003; Ríos-Escalante, 2013). Contrary to the numerous fish and planktonic biodiversity studies in fresh water systems, very little of such studies has been conducted in these unique saline systems (Jones & Grant, 1999; Larson & Belovsky, 2013). The aim of this study is, therefore, to investigate fish and planktonic biodiversity in selected saline crater lakes of western Uganda as a way of providing more information on fish and planktonic biodiversity in saline systems.

## MATERIAL AND METHODS

### *Study area*

Lakes considered in this study are small unique water bodies found in Katwe–Kikorongo volcanic field in western Uganda. Lake Katwe (029.87033°E, 00.13217°S), is the largest among these lakes with an average area of 2.5 km<sup>2</sup> (Nixon et al., 1971). Other lakes considered in this study were Katwe Munyanyange (029.88591°E, 00.13513°S), Nyamunuka (029.98743°E, 00.09344°S), Bagusa (030.17958°E, 00.09793°S), Murumuri (029.99186°E, 00.07323°S), Maseche (030.19019°E, 00.09355°S), Bunyampaka (030.12819°E, 00.03765°S) and Kikorongo (030.01228°E, 00.01190°S). Among the studied lakes, Bagusa and Kikorongo were at the lowest and highest altitude, 884 m and 939 m, respectively, above sea level (a. s. l). The majority of these lakes are alkaline and saline in nature with dominant anions being carbonates and sulphates (Nkambo et al., 2015). These lakes exhibit consid-

erable temporal variations in volume and surface area, with their total depth ranging between <1–6 m (Kirabira et al., 2013).

### ***Zooplankton and phytoplankton diversity***

Data collection in this study was done between the 26th of February and 3rd of March, 2014, a period towards the end of the dry season in this region. A Global Positioning System (GPS) unit (GARMIN 12XL) was used to take GPS coordinates and the Altitude / elevation above sea level of the different sampling points.

Zooplankton samples were obtained by filtering four liters of water collected from every set geo-referenced sampling point through a 50  $\mu\text{m}$  mesh zooplankton net. The samples obtained after filtration were preserved in 95% ethanol and carried to the National Fisheries Resources Research Institute (NaFIRRI) laboratory, Jinja, for identification to the lowest possible taxonomic level and counted under an inverted microscope. Using a Van Dorn water sampler, water samples for phytoplankton analysis were collected at a depth of 0.5 m in lakes whose average depth was more than 1 m. For the very shallow lakes (depth < 0.5 m), surface water samples were collected for zoo and phytoplankton analysis. 500 ml of the collected water samples were preserved using Lugol's solution in pre-rinsed Nalgene bottles which were kept in a cooler box containing dry ice and later transferred to the National Fisheries Resource Research Institute (NaFIRRI) laboratory in Jinja. In the laboratory, phytoplanktons in the collected water samples were identified to the lowest possible taxonomic level and the wet biomass of each of the identified group determined.

Selected physical and chemical parameters (depth, temperature ( $T^{\circ}\text{C}$ ), dissolved oxygen concentration (DO), pH, Conductivity (Cond) and salinity) were also measured in-situ at the lake surface and bottom. Where lakes were too shallow, physico-chemical measurements were taken at the lakes surface. Water temperature, dissolved oxygen concentration and conductivity were measured using a YSI oxygen/temperature/conductivity meter (Model YSI 550A), pH was determined using an OAKTON pH Tester 30, while salinity was measured with a refractometer. The depth was determined using a portable depth finder (Hondex PS-7).

### ***Fish diversity***

All the study lakes, deeper than 0.5 m were sampled for fish by setting gill nets and seine nets in the evening at 5 pm and removing them in the following morning at 7 am. In addition we also asked to the people belonging to the communities around each of the studied lakes whether they have ever seen or got any fish from these lakes.

## **RESULTS**

### ***Physico-chemical parameters***

Lakes Munyanyange, Nyamunuka, Murumuri, and Bunyampaka were found to be very shallow (depth < 0.5 m) at the time of sampling, whereas, lake Kikorongo was the deepest. The highest measured dissolved oxygen (DO) was  $6.0 \pm 1.0 \text{ mg l}^{-1}$  in Lake Kikorongo while Munyanyange and Murumuri had the lowest and second lowest DO ( $1.7 \pm 0.4$  and  $1.7 \pm 0.5 \text{ mg l}^{-1}$ , respectively). All the sampled lakes were found to be alkaline with pH ranging between  $9.58 \pm 0.1$  (lake Bunyampaka) and  $11.5 \pm 1.0$  (Nyamunuka). The highest temperatures ranged between  $28.9 \pm 0.4^{\circ}\text{C}$  and  $34.4 \pm 2.4^{\circ}\text{C}$ . Salinity was between  $0 \text{ mg l}^{-1}$  (lake Kikorongo) and  $205.0 \pm 15.3 \text{ mg l}^{-1}$  (Nyamunuka) Conductivity ranged between  $10.5 \pm 0.6 \text{ mscm}^{-1}$  (Nyamunuka) and  $106.3 \pm 3.5 \text{ mscm}^{-1}$  (Murumuri) (Table 1).

### ***Phytoplankton diversity***

A total of twenty nine (29) phytoplankton species were found in the eight study lakes. Out of them, nineteen (19) belonged to Cyanophyceae, commonly known as Cynobacteria (blue-green algae (BG)) which are predominantly photosynthetic prokaryotes containing a blue pigment in addition to the chlorophyll (WHO, 1999). Six (6) belonged to Chlorophyceae commonly referred to as Chlorophyta (green algae (G)). Four (4) belonged to Bacillariophyceae, commonly referred to as diatoms (D). Lakes Maseche ( $912,347 \mu\text{g L}^{-1}$ ) and Bagusa ( $210,290 \mu\text{g L}^{-1}$ ) were found to have the highest and second highest algal biomass. These were followed by lakes Katwe and Murumuri which had algal biomass of  $90,653 \mu\text{g L}^{-1}$  and  $86,240 \mu\text{g L}^{-1}$ , respectively. Lakes Katwe and

Lake	Depth (m)	D.O (mg l <sup>-1</sup> )	pH	Temp. (°C)	Salinity (mg l <sup>-1</sup> )	Cond (mScm <sup>-1</sup> )
Katwe	2.1±0.7	2.6±0.2	9.9±0.1	27.9±0.3	180±67.8	104.5±6.4
Munyanyange	0.2±0.1	1.7±0.4	10.8±0.4	34.4±2.4	101.0±7.1	59.7±8.2
Nyamunuka	0.2±0.2	2.6±0.3	11.5±1.0	30.5±3.1	205.0±15.3	10.5±0.6
Murumuri	0.2±0.0	1.7±0.5	11.1±1.3	32.0±0.8	162.8±34.2	106.3±3.5
Bunyampaka	0.2±0.1	2.20±0.6	9.6±0.1	30.33±1.5	199.50±16.4	103.90±4.3
Bagusa	1.9±0.5	3.2±0.8	10.5±0.4	32.1±2.0	199.5±16.4	103.9±4.3
Maseche	1.3±0.2	2.9±0.4	10.9±0.4	30.0±0.7	92.3±7.6	71.2±1.3
Kikorongo	2.3±0.3	6.0±1.0	10.4±0.0	28.9±0.4	0.0±0.0	18.6±0.1

Table 1. Mean±SD of the selected measured physico-chemical parameters in the selected studied saline crater lakes.

Bunyampaka showed the highest algal biodiversity while lakes Maseche and Nyamunuka had the lowest biodiversity. Cyanophyceae (BG) dominated the algal composition of all the studied lakes. With the exception of Lake Munyanyange, were no Chlorophyceae species (G) were found, the other lakes showed Chlorophyceae and Bacillariophyceae (D) species in relatively small abundances in comparison to Cyanophyceae. With the exception of Lake Bagusa where *Anabaena circinalis* was found to be dominant, and Bunyampaka and Nyamunuka where no *Spirulina platensis* was found, in the rest of the lakes *S. platensis* was dominant (Table 2).

#### Zooplankton diversity

Lakes Kikorongo, Maseche, and Katwe were found to have zooplanktons belonging to Rotifera. Lakes Maseche and Kikorongo showed also zooplanktons belonging to Copepoda and none of the studied lakes was found to have cladocerans at the time of sampling. Lakes Munyanyange, Maseche, Murumuli, Katwe and Nyamunukahad small cysts which could not be identified. Water samples from lakes Bunyampaka and Bagusa had neither zooplankton nor un-identified cysts (Table 3).

#### Fish diversity

None of the selected saline crater lakes considered in this study had fish at the time of sampling.

With the exception of Lake Kikorongo, in which the African catfish, *Clarias gariepinus* (Burchell, 1822), was observed (sometimes) during the rainy season, none of the other studied lakes was reported to have fish, ever.

## DISCUSSION

#### Phytoplankton diversity

In the present study, blue-green (Cyanobacteria) algae are dominant in all the lakes, with *Spirulina* P.J.F. Turpin ex M. Gomont being the most dominant phytoplankton in the majority of them (Table 2). This is in agreement with earlier studies done in alkaline, saline crater lakes which reported *Spirulina platensis* to be the most dominant (Hecky & Kilham, 1973) in contrast with the reported dominance of algal biomass by diatoms in anthroposaline lakes in Romania and Bolivia (Stenger-Kovács et al., 2014). The dominance of Cyanobacteria in these harsh environments can be attributed to their ability to withstand extreme water conditions like very high temperatures, pH and salinity. Some Cyanobacteria species have got special adaptations like ultraviolet absorbing sheath pigments which increase their fitness in relatively exposed environments; indeed they have been reported to occur in waters that are salty, brackish or fresh, in cold or hot springs and in environments where no other

Taxa Group	Taxa	Bagusa	Buny-ampaka	Munya-nyange	Maseche	Katwe	Kiko-rongo	Nyamu-nuka	Muru-muri
BG	<i>Planktolyngbya limnetica</i> (Lemmermann) Komárková-Legnerová et Cronberg	15845	2,773	-	8,216	7,343	-	-	7,805
BG	<i>Aphanocapsa</i> sp.	522	274	548	-	342	-	365	730
BG	<i>Spirulina platensis</i> (Nordstedt) Gomont	12,324	-	25,880	879,909	66,856	43,133	-	69,012
BG	<i>Anabaena</i> sp.	15,649	219	-	-	3,286	-	-	-
G	<i>Stichococcus</i> sp.	3,912	96	-	-	787	-	-	-
D	Centric diatoms	104	292	37	146	730	-	292	37
BG	<i>Planktolyngbya circumcreta</i> (G.S. West) Anagnostidis et Komárek	440	411	1,438	-	-	-	205	411
BG	<i>Chroococcus</i> sp.	391	137	-	365	-	23	-	-
BG	<i>Anabaena circinalis</i> Rabenhorst ex Bornet et Flahault	157,273	11,867	9,859	5,112	6,207	548	38,085	913
G	<i>Stichococcus</i> sp.	3,668	342	274	479	2,465	-	1,575	1,404
G	<i>Nephrochlamys rostrata</i> Nygaard, Komárek, J.Kristiansen et O.M. Skulberg	162	-	-	-	-	1,506	-	-
BG	Tiny blue green	-	101	151	-	-	228	-	-
BG	<i>Anabaenopsis tanganyikae</i> (G.S. West) Woloszyńska et V.V.Miller	-	55	-	-	-	-	-	-
BG	<i>Pseudoanabaena</i> sp.	-	411	411	-	103	-	308	-
BG	<i>Anacystis limnetica</i> (Lemmermann) Drouet et Daily	-	183	365	-	274	137	342	297
BG	<i>Romeria</i> sp.	-	55	-	-	-	-	-	-
D	<i>Nitzschia acicularis</i> (Kützing) W. Smith	-	274	-	-	23	-	137	23
G	<i>Closterium acerosum</i> Ehrenberg ex Ralfs	-	-	411	411	205	205	411	-
BG	<i>Oscillatoria tenuis</i> C. Agardh ex Gomont	-	-	-	17,253	-	-	-	-
BG	<i>Aphanocapsa nubila</i> Komárek et H.J. Kling	-	-	-	456	-	91	-	183
BG	<i>Coelosphaerium kuetzingianum</i> Nägeli	-	-	-	-	1,826	-	-	4,747
BG	<i>Planktolyngbya undulata</i> Komárek et H. Kling	-	-	-	-	103	-	-	-
G	<i>Ankistrodesmus falcatus</i> (Corda) Ralfs	-	-	-	-	103	-	-	-
BG	<i>Chroococcus dispersus</i> (Keissler) Lemmermann	-	-	-	-	-	68	-	-
D	<i>Cyclostephanodiscus</i> sp.	-	-	-	-	-	37	-	-
D	<i>Navicula gastrum</i> (Ehrenberg) Kützing	-	-	-	-	-	856	-	-
BG	<i>Merismopedia tenuissima</i> Lemmermann	-	-	-	-	-	-	-	292
G	<i>Monoraphidium contortum</i> (Thuret) Komárková-Legnerová	-	-	-	-	-	-	-	22
BG	<i>Aphanizomenon flosaquae</i> Ralfs ex Bornet et Flahault	-	-	-	-	-	-	-	365
	<b>Total</b>	<b>210,290</b>	<b>17,488</b>	<b>39,372</b>	<b>912,347</b>	<b>90,653</b>	<b>48,065</b>	<b>44,698</b>	<b>86,240</b>

Table 2. Mean Wet biomass ( $\mu\text{g/l}$ ) concentrations of the different phytoplanktons in the selected Alkaline, saline lakes considered in this study. BG = Blue green algae, G = green algae, D = Diatoms.

microalgae occur (WHO, 1999). Allelopathy can be another factor to explain the dominance of *Cyanobacteria* in these lakes. Freshwater *Cyanobacteria* like *Oscillatoria* sp. have been reported to have exudates which can inhibit green alga *Chlorella vulgaris* Beyerinck [Beijerinck] (Leão et al., 2010). In the same way *Cyanobacteria* in these saline crater lakes might be influencing the algal biodiversity through allelopathy. Matagi (2004) reported *Spirulina* (*Arthrospira fusiformis*) to be the most successful algae in colonizing alkaline, saline lakes found in the Eastern Rift valley. Lake Lonar, an inland alkaline saline crater lake in India was reported to have its phytoplankton biomass dominated by *Spirulina platensis* (Satyanarayan et al., 2007; Siddiqi, 2007; Yannawar & Bhosle, 2013). Lakes Nakuru, Bogoria and Elmenteita, which are alkaline-saline lakes in Kenya, were characterized by mass growth of *Cyanobacteria* including *Arthrospira fusiformis* (Harper et al., 2003; Ballot et al., 2004). The Presence of *Cyanobacteria* in these

alkaline-saline lakes is in conformity with the findings of the present study where *Spirulina* dominates the phytoplankton biomass. Jones & Grant (1999) reported *Spirulina* spp. to be among the main contributors to primary production in moderately saline lakes while studies by Hadgembes (2006) documented *Spirulina* to be one of the unique *Cyanobacteria* occurring in East African saline lakes.

The extreme inhospitable conditions in alkaline, saline crater lakes mean that the biodiversity in these systems is limited to organisms with special adaptations to survive such extreme conditions (Matagi, 2004). Primary production in Flamingo lakes of East Africa was reported to be dominated by *A. fusiformis* with *Ectothiorhodospira* sp. sometimes playing a key role (Jones & Grant, 1999; Matagi, 2004). *Nitzschia* sp. and *Navicula* sp. are some of the other algal species found in these lakes (present study) or in other highly alkaline and saline environments (Matagi, 2004). *Chroococcus* sp. is another species of *Cyanobacteria* recorded in this

	Munya-yange	Kiko-rongo	Maseche	Murumuli	Bunyampaka	Katwe	Bagusa	Nyamunuka
ROTIFERA								
<i>Brachionus calyciflorus</i> Pallas, 1766	-	+++	-	-	-	+	-	-
<i>Brachionus angularis</i> Gosse, 1851	-	-	+	-	-	-	-	-
<i>Lecane luna</i> (Müller, 1776)	-	+	-	-	-	-	-	-
<i>Trichocerca cylindrica</i> (Imhof, 1891)	-	-	-	-	-	-	-	-
<i>Syncheata</i> sp.	-	+	-	+	-	-	-	-
COPEPODA								
nauplii	-	+	-	-	-	-	-	-
cyclopoid copepodite	-	-	+	-	-	-	-	-
CLADOCERA								
<i>Moina micrura</i> Kurz, 1874	-	-	-	-	-	-	-	-
unidentified cysts	+	-	+	+	-	+	-	+

Table 3. Mean zooplankton abundance (Individuals per litre) in the different studied saline crater lakes. + = 1 to 10 individuals /l, ++ = 10 to 50 individuals/l, +++ = 50 to 100 individuals/l, - = 0 individuals/l.

study which was reported by Jones & Grant (1999) to play a key role in primary production in soda lakes of East Africa. In studies aimed at reconstructing relationships between diatoms assemblages with salinity, it was observed that salinity might not be the primary cause of the shift in the diatom assemblage but a factor highly related to drivers of species shift (Saros & Fritz, 2000).

In the same way salinity might be playing a key role in determining the Cyanobacteria species occurring in the alkaline saline environments, but other possible drivers should not be overlooked. In a study to determine the extent to which salinity influences community structures in saline systems, salinity was reported to play a less significant role in the determination of composition, species richness and biodiversity (William, 1998). For example, the highest algal biodiversity observed in lakes Katwe and Bunyampaka and the least algal biodiversity (in lakes Maseche and Nyamunuka) might be attributed to the daily anthropogenic disturbances experienced by the first two lakes during the process of salt extraction, while the other two are lakes with no daily anthropogenic disturbance. It should be noted that communities around lakes Katwe and Bunyampaka continuously extract salt from these lakes on a daily basis and such disturbances might be impacting various algal species differently.

### **Zooplankton diversity**

All the studied lakes showed a very low zooplankton biodiversity, with only *Brachionus calyciflorus* in lakes Kikorongo and Katwe; *Brachionus angularis* in Lake Maseche, and *Syncheata* sp. in lakes Kikorongo and Murumuli (the only species of the phylum Rotifera present, see Table 3). *Brachionus plicatilis* (Müller, 1786) and *Paradiaptomas africanus* (Daday, 1910) (= *Lovenula africana*) have already been reported to be characteristic zooplankton in alkaline saline crater lakes (Hecky & Kilham, 1973). Matagi (2004) listed *Lovenula africana* (Daday, 1910), *Brachionus dimidiatus* (Bryce, 1931), *B. plicatilis* (Müller, 1786) and chironomids as the dominant macro-invertebrates in the highly alkaline, hypersaline flamingo lakes of east Africa. All of these were absent in our study. Nauplii in Lake Kikorongo and cyclopoid copepodites in Lake Maseche were the only Copepoda members observed.

Other macro-zooplanktons like cladocerans, nekton fauna, and crustacean decapods were conspicuously absent, probably due to the highly alkaline pH. Lake Bogoria in Kenya which is an alkaline, saline lake was reported to have no macro-zooplankton with lesser Flamingo, *Phoeniconaias minor* as the only grazer occasionally visiting these lakes in high numbers (Harper et al., 2003). The absence of crustacean decapods in a limnological study of lake Lonar an alkaline, saline crater lakes in India was attributed to a pH shock (pH > 10–11, alkaline death point) (Siddiqi, 2007). An inverse proportionality between biodiversity and salinity was reported by Derry et al., (2003); Larson & Belovsky (2013), and Ríos-Escalante (2013); this might be the explanation for the slightly high zooplankton biodiversity in Lake Kikorongo since its salinity was found to be very low at the time of sampling (Table 1). In field and laboratory experiments designed to examine the consequences of climate-induced salinity increases on zooplankton abundance and diversity in coastal lakes, severe disturbances in zooplankton community structure and abundance were caused by even very small salinity changes, with even very small increments in salinity capable of leading to biodiversity depletion (Schallenberg et al., 2003). Similarly, the low zooplankton biodiversity in these lakes might be attributed to the high salinity levels (see Table 1).

The unidentified cysts found in some of the lakes might be dormant stages of zooplanktons released as a mean of surviving extreme environmental conditions. These dormant stages return to life on the set of suitable conditions within the lakes. Some zooplanktons, particularly members of the order Anostroca like *Artemia* Leach, 1819, have been reported to release dormant embryos in form of cysts. Indeed, all *Artemia* species and strains reproduce ovoviviparously (by generating live nauplii) under favorable conditions, and oviparously when dormant embryos are released in form of cysts to withstand the harsh unfavorable environmental conditions (Ghomari et al., 2011; Ben Naceur et al., 2012).

### **Fish diversity**

Although some fish species like *Oreochromis alcalicus alcalicus*, *O. alcalicus grahami*, and *O. amphimelas* were reported to inhabit lakes Magadi

and Natron which are both alkaline and saline in nature (Matagi, 2004), no fish were found in these lakes during the study. Hecky & Kilham (1973) also reported cichlid fish like *Alcolapia grahami* (Boulenger, 1912) to occur in some of the alkaline, saline lakes. The absence of fish in the different studied lakes at the time of sampling can be attributed to the extreme environmental conditions like the very high temperatures, salinity and alkalinity. Previously, the complete absence of fish in Lake Lonar was reported to be correlated with extreme environmental physico-chemical parameters (Siddiqi, 2007). Many lakes, being shallow, experience very high variations in volume and surface area with some of these lakes reported to evaporate to dryness during the extreme dry seasons (Nkambo et al., 2015). This makes difficult, if not impossible, for fish to survive during the dry seasons. Moreover, the absence of appropriate food organisms in form of zooplankton (i.e. *Brachionus plicatilis*) could be another probable reason for the absence of fish (see Table 3).

Some of the Cyanobacteria found in these lakes like *Anabaena* sp, *Anabaenopsis* V.V. Miller, 1923 and *Oscillataria* Vaucher ex Gomont, 1892, have been reported to release cyanotoxins with lethal effects on mammals (WHO, 1999; Lyra et al., 2001). Although several research works on cyanotoxins have focused on humans and other livestock (Leão et al., 2010), it is possible that these cyanotoxins have similar toxic effects on aquatic organisms including fish. *Anabaena* sp. have been reported to release anatoxin-a which is a neurotoxin reported to have lethal effects when tested on *Cyprinus carpio* Linnaeus, 1758 larvae (Oswawald et al., 2007). The presences of toxic Cyanobacteria might be hindering fish occurrence in these lakes considered under this study. With the exception of Lake Kikorongo, which sometimes receives flood waters from the neighboring lake Gorge (Hecky & Kilham, 1973; Mungoma, 1990; Nkambo et al., 2015), the rest of the lakes considered under this study are located in closed basins with no connections to other lakes or rivers. This implies that these lakes have no possibilities of being seeded with fish by inflowing waters from other natural systems. The reported occurrence of the African Catfish, *Clarias gariepinus*, in Lake Kikorongo in the rainy season might be due to flood waters from Lake Gorge. In fact, Nkambo et al., (2015) reported incoming flood waters from Lake Gorge to cause a

reduction in the salinity of Lake Kikorongo. A reduction in salinity might make this lake conducive for fish survival during the wet season. It is possible that catfish brought along with floods remain in this lake during the rainy season and die off in the dry season as the water conditions become extremely unbearable.

## CONCLUSIONS

Our findings are in agreement with earlier studies by Hecky & Kilham (1973), Matagi (2004), Satyanarayan et al., (2007), Siddiqi (2007) and Yanawar & Bhosle (2013) which reported Cyanobacteria to dominate algal biomass in saline systems, in contrast with earlier studies by Stenger-Kovács et al., (2014), which reported diatoms to dominate the algal biomass in saline lakes in Romania and Bolivia. Lakes considered under this study had very low zooplankton abundance and diversity with Lake Kikorongo, which had the highest zooplankton biodiversity, showing the rotifer *Brachionus calyciflorus*, the most abundant, ranging only between 50 to 100 individuals /litre. None of the study lakes had fish at the time of sampling.

In our opinion, this information on fish and planktonic biodiversity in these alkaline, saline systems is very useful in providing the ecological basis for the management of the lakes. Data on dominant zoo and phytoplanktons in the lakes can be used as bio-indicators in assessing the ecological status, as well as the impact of climate change on these unique systems.

## Recommendations

Further comprehensive studies are needed to assess the effect of season variability on fish and planktonic biodiversity. Detailed studies of the daily anthropogenic disturbances on the algal and zooplankton biodiversity in these lakes during the salt extraction process are required to give a better understanding of the changes in planktonic composition, species abundance and biodiversity due to anthropogenic disturbances.

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## New species of the genus *Cyclostremiscus* Pilsbry et Olsson, 1945 from Central Philippines (Gastropoda Tornidae)

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### ABSTRACT

*Cyclostremiscus* Pilsbry et Olsson, 1945 is a genus of the family Tornidae (Gastropoda Rissooidea) established for very small shells of prosobranch molluscs generally living in tropical seas. The new species here described was found in Cebu, Philippine, locality Tongo Point near Moalboal, in a modest quantity of seagrass beached after a windy day.

### KEY WORDS

Gastropoda; Tornidae; *Cyclostremiscus*; Moalboal; Philippines.

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### INTRODUCTION

*Cyclostremiscus* Pilsbry et Olsson, 1945 is a genus of the family Tornidae established for very small shells of prosobranch molluscs generally living in tropical seas. The family Tornidae from Caribbean area has been extensively studied and illustrated by Rubio et al. (2011).

A new species of this genus from Philippine is described in the present paper.

ACRONYMS. MHNUK: Natural History Museum of London, United Kingdom. MNHN: Muséum National d'Histoire Naturelle Paris, France. PC: I. Perugia collection, Ravenna, Italy.

### SISTEMATICS

Superfamily TRUNCATELLOIDEA Gray, 1840

Family TORNIDAE Sacco, 1896

Subfamily VITRINELLINAE Bush, 1897

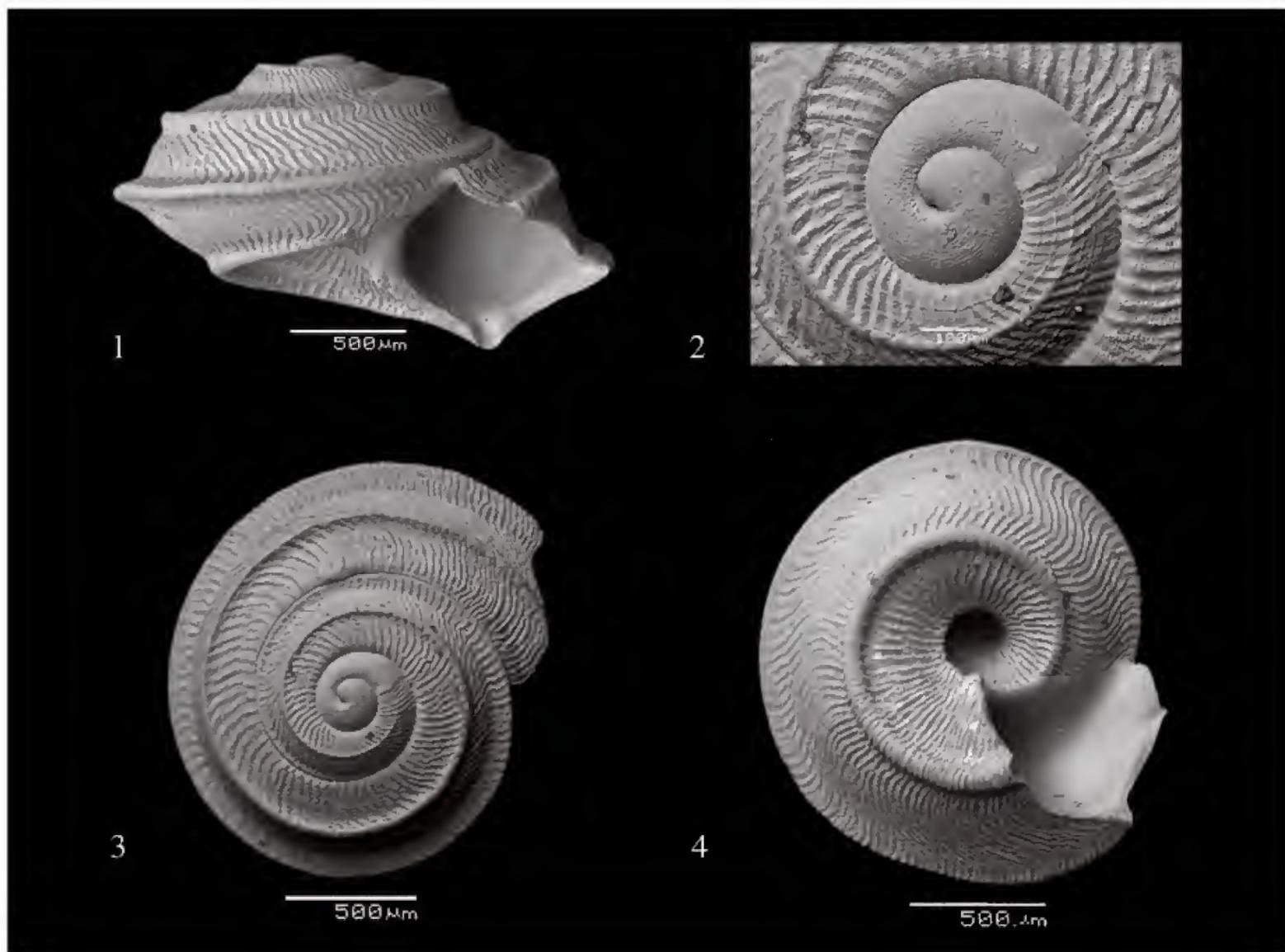
Genus *Cyclostremiscus* Pilsbry et Olsson, 1945

Type species: *Vitrinella panamensis* C.B. Adams, 1852

### *Cyclostremiscus albachiarae* n. sp.

EXAMINED MATERIAL. Holotype, Cebu (Philippine), locality Tongo Point near Moalboal, 29.XI.2007, I. Perugia legit, in a modest quantity of seagrass beached after a windy day, MNHN-IM-30079. Paratypes 1-5, same data of holotype, MNHN-IM-30080. Paratypes 6-26, same data of holotype (PC).

DESCRIPTION OF HOLOTYPE. Shell of small size (Figs. 1–4), diameter 1.5 mm, height 1.0 mm, much wider than high, discoid, rounded, relatively strong, vitreous, colourless. Protoconch of 1.5 whorls, rough, not elevated, max about 350 microns in diameter. Teleoconch: spire with 2 whorls, umbilicus open and deep, spiral and axial sculpture present on the entire surface. Spiral sculpture formed by strong prominence keels placed one on dorsum, one on periphery, one on base and another delimiting the umbilicus. Axial sculpture of numerous thin thick arcuate riblets, surmounting the keels, itself intersected by almost obsolete spiral lines. Aperture rounded, outer lip with 3 prominences caused by the end of spiral keels; anal sulcus well defined.



Figures 1–4. *Cyclostremiscus albachiarae* n. sp., holotype from Moalboal, Cebu, Philippines.

**VARIABILITY.** The paratypes do not show substantial morphological differences compared to the holotype. 36 specimens found have all the same size, diameter 1.5 mm, height 1.0 mm.

**ETYMOLOGY.** Dedicated to my granddaughter Albachiarra Perugia (Ravenna, Italy).

**REMARKS.** For *Cyclostremiscus albachiarae* n. sp. was possible a single comparison with *Cyclostrema gyalum* Melvill, 1904 (MHMUK 1904.7.29.13) which presents three similar keels on body-whorl but is larger (about 5 mm in diameter), has a fine spiral sculpture, not axial and the peripheral keel is slightly waved at the margin (giving a slightly stellate outline when viewed from above).

Besides the work of Rubio et al. (2011), other contributions to the knowledge of the family Tornidae were made by Melvill (1904), Adam & Knudsen (1969), Bosch et al. (1995), and Bouchet & Rocroi (2005).

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## New taxonomic data on some populations of *Carabus (Macrothorax) morbillosus* Fabricius, 1792 (Coleoptera Carabidae)

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### ABSTRACT

In this work we give new taxonomic data on some, little known, populations of *Carabus (Macrothorax) morbillosus* Fabricius, 1792 (Coleoptera Carabidae). In particular, *C. morbillosus lampedusae* Born, 1925 described from Lampedusa Island (Sicilian Channel, Italy) is reconsidered a valid subspecies and are designated the lectotype and paralectotypes. Similarly, *Carabus morbillosus bruttianus* Born, 1906 described from Southern Calabria is considered a distinct subspecies, including the populations of *C. morbillosus* from North-Eastern Sicily.

### KEY WORDS

Coleoptera; *Carabus*; taxonomy; W-Mediterranean.

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### INTRODUCTION

*Carabus (Macrothorax) morbillosus* Fabricius, 1792 (Coleoptera Carabidae) locus typicus "Mauretania" is a widely W-Mediterranean distributed species (La Greca, 1964; 1984; Vigna Taglianti et al., 1993; Parenzan, 1994) including several populations, even insular, more or less fragmented and differentiated, widespread in Southern France, southern Spain, Morocco, Algeria, Tunisia, Corse, Sardinia, Tyrrhenian central Italy, Southern Calabria, Sicily, Sicilian islands, and Malta.

From the biogeographic point of view, as the whole subgenus *Macrothorax* Desmarest, 1850, *C. morbillosus* is considered a "Tyrrhenian" element (Jannel, 1941 Antoine, 1955; La Greca, 1964; 1984; Casale et al., 1982) with all connected hypotheses and opinions on the origin and spread of the group. Some populations also seem to be originated from passive transport and, later, acclimatized (see Casale et al., 1989).

Currently, in Italy, are reported: *C. morbillosus morbillosus* in Sardinia, Lampedusa and some stations in Central Italy; *C. morbillosus alternans* Palliardi, 1825 (locus typicus: Sicily) in Sicily, Sicilian islands, and Calabria (Casale et al., 1982; Vigna Taglianti, 1995; Vigna Taglianti et al., 2002). In the "European Fauna" (Vigna Taglianti, 2015) the populations of North Africa, Sardinia and Lampedusa are attributed to *C. morbillosus constantinus* Kraatz, 1899 (locus typicus: Constantine, Algeria).

*Carabus morbillosus* is an eurieciuous species living in open areas or with sparse vegetation, often in ruderal areas, urban gardens and crops, under stones and debris, from the sea level up to about 1000 m a.s.l. *Carabus morbillosus alternans* is found in forests and wooded fields, as oak and eucalyptus groves (Bosco Ficuzza, Piazza Armerina, Bosco di Santo Pietro, etc.). It is present almost all year long, mainly active from September to April-May.

In this work we provide new taxonomic data on some little known populations of *C. morbillosus*.

In particular, *C. morbillosus lampedusae* Born, 1925 described from Lampedusa Island, is reconsidered as "bona subspecies" and its Lectotype and Paralectotypes are designated; the same is also for *C. morbillosus bruttianus* Born, 1906, described from Southern Calabria to which we attribute also the populations of *C. morbillosus alternans* from North-Eastern Sicily.

ABBREVIATIONS AND ACRONYMS. ETZH: Entomological Collection of ETH, Zurich, Switzerland; ex/s: exemplair/s; RC: Ivan Rapuzzi collection, Prepotto, Italy; SC: Ignazio Sparacio collection, Palermo, Italy.

## SYSTEMATICS

### *Carabus (Macrothorax) morbillosus lampedusae* Born, 1925

EXAMINED MATERIAL. *Carabus morbillosus lampedusae*. ETZH: male (Fig. 1). Length: 30.10 mm; width elytra: 10.85 mm; length elytra: 18.80 mm; width pronotum: 7.80 mm; length pronotum: 6.20 mm. Three labels: "Insel Lampedusa" (handwritten by Born on circular label); "53.565" (print label), "Carabus morbillosus lampedusae?" (handwritten in blu color, more recent and different calligraphy than original labels from Born); red label with present designation of the "Lectotype". Paralectotypes, 2 males (ETZH), two labels each specimens: "53.566" (print label); length: 30.50 mm; width elytra: 11.70 mm; length elytra: 19.00 mm; width pronotum: 7.60 mm; length pronotum: 6.20 mm. "Carabus morbillosus lampedusae?" (handwritten in blu color, more recent and different calligraphy than original labels from Born). "53.567" (print label); length: 30.30 mm; width elytra: 11.35 mm; length elytra: 18.80 mm; width pronotum: 7.95 mm; length pronotum: 6.00 mm. "Carabus morbillosus lampedusae?" (hand-written in blu color, more recent and different calligraphy than original labels from Born); red label with present designation of the "Paralectotype".

Other examined material. *Carabus morbillosus lampedusae*. ITALY, SICILY. Lampedusa Island (Agrigento), 15.V.1983, I. Sparacio legit, 3 males and 2 females (CS); idem, 10.II.2013, G. Maraventano legit, 2 males and 2 females (CS); idem, III.2014, T. La Mantia legit, 2 males and 4 females

(CS); Lampedusa (RC), 1 female; Lampedusa Island, 4.II.1994, M. Romano legit, 2 males and 1 female (RC); Lampedusa Island, XI.2012, A. Corso legit, 3 males and 1 female (RC).

*Carabus morbillosus constantinus*. TUNISIA. Saouaf-El Fahs, 10.V.1992, 1 female (CS); Hammamet, 25.IV.1998, 2 males (CS); El Fahs-Zaghouan, 28.IV.1998, 2 females (CS); Tabarka, 3/9.VI.1996, 10.V.1992, 5 males and 6 females (CS); Tunisi, Cap Gammarth, 4.IV.2014, 5 males and 4 females (CS), Tunisia, Bezeste, III.1982, 1 male (RC); Tunisia, Ain Draham, 11/20.VI.2008, G. Sama & P. Rapuzzi legit, 1 female (RC).

REMARKS. *Carabus lampedusae* was originally described by Born (1925) as a subspecies of *C. morbillosus* from Lampedusa Island (Sicilian Channel, Italy) without designation of the holotype. We had the opportunity to examine three male specimens preserved in the Entomological Collection of ETH Zurich, ex Born collection from Lampedusa Island, and we have designated the lectotype and paralectotypes. All the three specimens are well preserved.

From the systematic point of view, *C. morbillosus lampedusae* was considered mostly a variety or a synonym of the nominate subspecies of North Africa (Luigioni, 1929 sub *morbillosus* v. *lampedusae*; Breuning, 1932-36: sub natio *constantinus*; Porta, 1949 sub var. *constantinus*; Magistretti, 1965 sub *C. morbillosus morbillosus* natio *constantinus*; Casale et al., 1982 sub *C. morbillosus morbillosus*; Deuve, 2004 sub *constantinus*).

Based on the examined material, we believe "*lampedusae*" a valid subspecies of *C. morbillosus*, separate either from North African populations, which is related to, or from the Sicilian ones, that are more differentiated in morphology. In particular, *C. morbillosus lampedusae* differs from the populations of North Africa by its squat and convex body-shape, a darker and less bright color, with a dominant chromatic variety characterized by dark pronotum and dark green elytra in the middle, and red on the sides; pronotum has wider and deeper basal dimples with hind angles more sinuate on the sides; the 1st elytral interstria shows shallow points, well distinct and little confluent.

Hence, *C. morbillosus lampedusae* would be comprised within the group of autochthonous species of Lampedusa, of apparent North African origin, morphologically differentiated in insularity

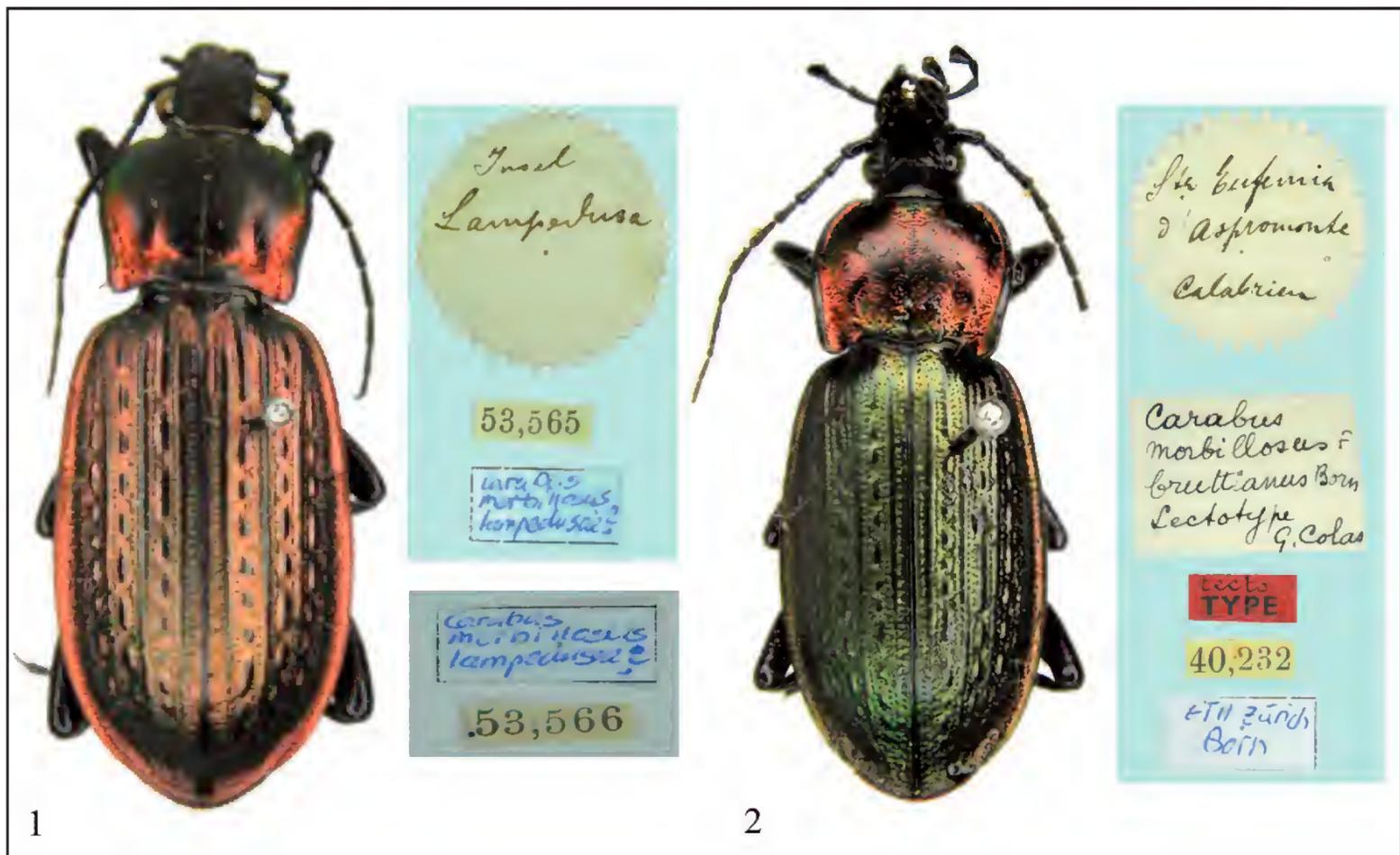


Figure 1. *Carabus (Macrothorax) morbillosus lampedusae* Born, 1925, lectotype with original labels.  
 Figure 2. *Carabus (M.) morbillosus bruttianus* Born, 1906 lectotype with original labels.

conditions. In the Conclusion section (see below), we report morphological characters that distinguish these populations to each other and those characterizing the populations under study in this work.

***Carabus (Macrothorax) morbillosus bruttianus***  
 Born, 1906

EXAMINED MATERIAL. ITALY, CALABRIA. *Carabus morbillosus bruttianus*. Lectotype male, Sta Eufemia d'Aspromonte, Calabrien (ETHZ) (Fig. 2); idem, Paralectotype female (ETHZ).

Other examined material. Calabria. Reggio Calabria dintorni, I. Sparacio legit, 8.XI.1999, 5 males (RC); Reggio Calabria dintorni, 5.III.2004, I. Sparacio legit, 2 males and 1 female (RC); Reggio Calabria dintorni, 8.XI.1999, 6 males and 5 females (SC); Reggio Calabria: Campo Calabro, 8.XI.1999, 6 males and 2 females (SC); Torrente Zagarella, 8.XI.1999, 8 males (Fig. 5) and 11 females (SC); Gioia Tauro, 9.XI.1999, 13 males and 10 females (SC). ITALY, SICILY. Messina dintorni, 4.XI.2001, 13 males (Fig. 4) and 9 females (SC);

Messina, Monte Ciccia, 4.III.2004, 7 males and 7 females (SC); Messina: Colle San Rizzo, 4.XI.2001, 3 males and 1 female (SC); Messina: Faro, 4.III.2004, 2 males and 2 females (SC); 3 males (SC); Messina, Torrenova, VIII.2013, A. Tetamo legit, 1 male (SC); Messina dintorni, 4.XI.2001, I. Sparacio legit, 1 male and 1 female (RC); Messina, Monte Ciccia, 4.III.2004, I. Sparacio legit, 2 males (RC); Lipari, Isole Eolie, V.2014, P. Lo Cascio legit, 3 males and 1 female (SC).

*Carabus morbillosus alternans*. ITALY, SICILY. Palermo. Carini, 9.X.1978, 3 males and 4 females; idem, 1.V.1979, 1 male (SC); Palermo, 18.X.1978, 1 male and 1 female; idem, 7.II.1979, 1 male; idem, 30.III.1980, 1 female (SC); Palermo: Sferracavallo, Grotta Conza, 3.XI.1978, 2 females (SC); Godrano, 25.XI.1978, 1 male and 2 females (SC); Palermo: Sferracavallo, 14.I.1979, 2 males; idem, 13.V.1980, 1 female (SC); Piana degli Albanesi, 8.II.1979, 3 males and 3 females; idem, 6.II.1992, 1 male and 3 females; idem, 15.IV.1995, 1 female (SC); Palermo: Favorita, Vallone del Porco, 3.III.1979, 1 male and 2 females (SC); Bosco Ficuzza, 21.XI.1979, 1 male (Fig. 3) and 1 female; idem, 9.II.1987, 1 female;

idem, 28.I.1989, 1 female (SC); Altofonte, 1.III.1981, 1 male and 1 female (SC); Altofonte: Poggio San Francesco, 13.III.1981, 1 male (SC); Cefalù, 7.XI.1987, 1 female (SC); Palermo: Mondello, 18.IX.1988, 1 male (SC); Capaci, 25.II.1989, 1 female (SC); Monreale: Giacalone, 12.I.1992, 3 males and 1 female (SC); Ficuzza: Bivio Lupo, 25.II.1992, 1 male; idem, 13.XI.2001, 2 males (SC); Santuario di Gibilmanna, 23.X.1994, 1 male (SC); Lercara Friddi: S. Caterina A.D., 24.X.2004, 2 males (SC); Bagheria: Monte Catalano, 14.X.2006, 1 female (SC); Roccamena: Maranfusa, 25.IV.2008, 1 female (SC); Prizzi, 12.VI.2009, 1 male and 1 female (SC); Palermo: Micciulla, 4.IV.2010, T. La Mantia legit, 1 male (SC); Rocca Entella, 18.XI.2011, 3 males (SC); Ficuzza: Gorgo del Drago, 25.XI.2012, 2 females (SC); Diga Poma, 10.XI.2013, 1 male and 1 female (SC); Trabia: Pizzo Cane, XI.2014, 2 males and 1 female (SC); Cefalù, Settefrati, VI.1984, 1 male (RC); Ficuzza, Godrano, XI/XII.2010, I. Rapuzzi & L. Caldon legit, 70 exs males and females (RC); Palermo, 13.III.1992, 1 female (RC); Gibilmanna, 500 m, VII.1984, 1 exs

(resti) (RC); Piana d. Albanesi, 700/800 m, III.1988, 1 male and 1 female (RC); Isnello, 700 m, III.1988, 2 males (RC). Trapani. Erice, 12.XI.1972, M. Romano legit, 1 male and 1 female (RC); Campobello di Mazara, Cave di Cusa, 28.XI.2009, 3 males and 3 females (RC); Mazara costiera, 13.I.1985, 1 male and 2 females (RC); Capo Granitola, 30.I.1986, V. Castelli legit, 2 males and 3 females (RC); Mazara, 3.II.1985, V. Aliquo' legit, 1 male and 1 female (RC); Selinunte, 24.XI.2002, I. Rapuzzi & L. Caldon legit, 2 males and 6 females (RC); Segesta, 15.II.2011, I. Rapuzzi & L. Caldon legit, 4 males and 2 females (RC); Santa Ninfa, XI.2009, I. Rapuzzi & L. Caldon legit, 1 male and 1 female (RC); Mazara del Vallo, 28.XI.1979, 2 males and 3 females (SC); San Vito Lo Capo (Trapani), 14.X.1984, 3 males (SC); Monte Cofano, 14.X.1984, 1 female (SC); Castellammare del Golfo, 12.XII.1984, 2 males and 1 female (SC); Cave di Cusa, 14.XII.2003, 2 males; idem, 31.XII.1988, 3 females (SC); Foci Fiume Belice, 20.IV.1989, 1 female (SC); Foci Fiume Birgi, 6.XI.1993, 1 female (SC); Selinunte, 3.XII.1995, 1 male and 1 female (SC); Valderice, I.2014, 4 males



Figure 3. *Carabus (Macrothorax) morbillosus alternans* male, Bosco Ficuzza, Palermo, Sicily. Figure 4. *Carabus morbillosus bruttianus* male, Messina surroundings, Sicily. Figure 5. *Carabus morbillosus bruttianus* male, Torrente Zagarella, Reggio Calabria, Calabria (Photos by M. Romano).

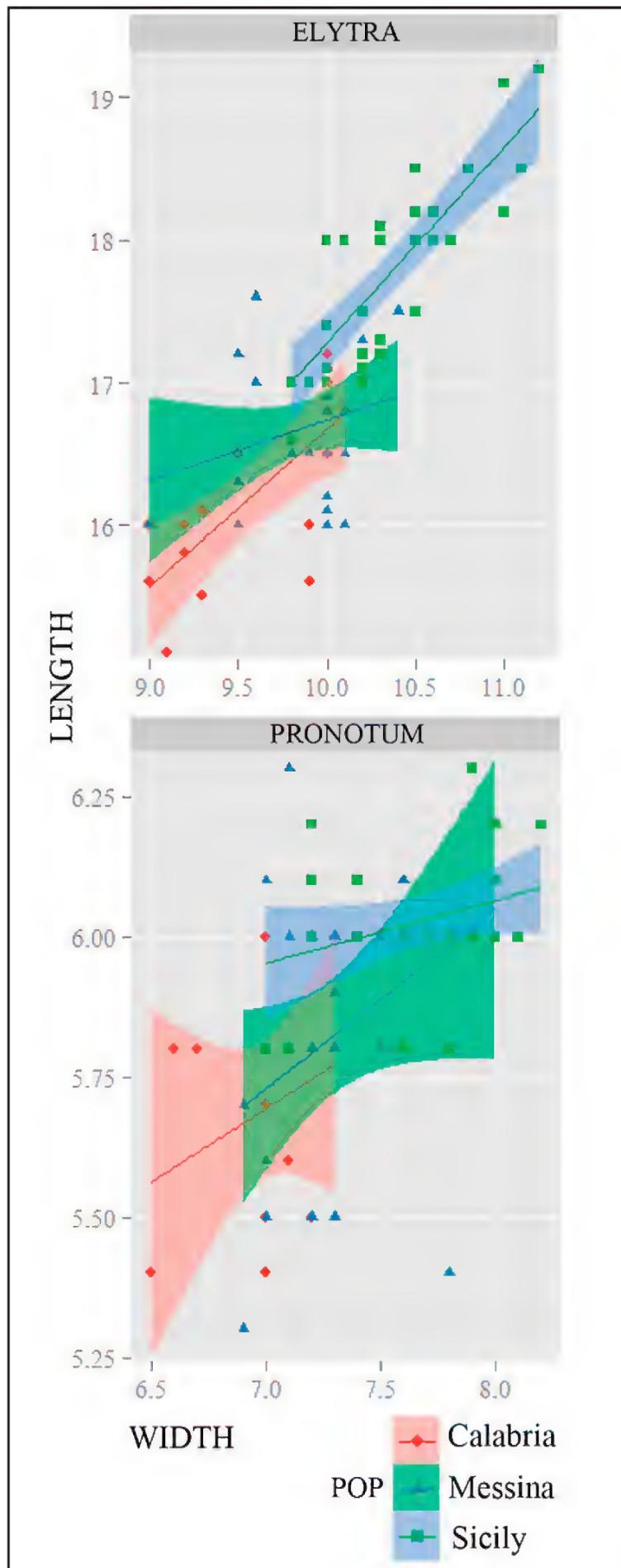


Figure 6. Scatterplot of the relationship between length and width of elytra (upper) and pronotum (bottom) for three populations examined. Are shown the regression lines with the associated confidence intervals (95%). Values of Correlation coefficients for width/length of elytra in the three populations are: Calabria 0.68\*, Messina 0.25, Sicilia 0.78\*. Those for width/length of pronotum are: Calabria 0.15, Messina 0.42\*, Sicilia 0.46\*. (\*  $P \leq 0.05$ ).

	Standardized coefficients		Pooled- within-groups correlations	
	Root 1	Root 2	Root 1	Root 2
Elytra Length	-0.782	1.007	-0.971	0.239
PronotumWidth	-0.305	-1.238	-0.790	-0.613
Eigenval	1.346	0.038		
Cum.Prop	0.973	1		

Table 1. Standardized coefficients (left) e Pooled-within-groups correlations (right) for the two variables selected by correspondence analysis.

Pop.	Means of Canonical Variables	
	Root 1	Root 2
Calabria	1.480	0.256
Messina	0.570	-0.235
Sicily	-1.283	0.067

Table 2. Means of Canonical Variables for the three examined populations.

	Percent correct	Cases		
		Calabria	Messina	Sicily
Calabria	56.3	9	7	0
Messina	73.1	4	19	3
Sicily	76.7	0	7	23
Total	70.8	13	33	26

Table 3. Classification Matrix. The first column shows the percentages of observations properly attributed to each population using discriminant analysis. The remaining columns show the number of cases falling into each population (diagonally, cases correctly classified).

and 3 females (SC). Agrigento. Agrigento, 21.I.1973, 1 male (RC); Agrigento: Valle dei Templi, I.1972, 1 male and 1 female (RC); Agrigento: Valle dei Templi, 9.II.1987, 1 female; idem, 2.I.1989, 1 male and 1 female (SC). Caltanissetta. Monte Capodarso: F. Imera meridionale, 5.VI.2006, 1 male (SC); Ponte Cinque Archi, 14.II.2015, 2 males (SC). Enna. Valguarnera (Enna), 25.IX.1979, 1 male (SC); Piazza Armerina: Monte Rossomanno, 10.III.2008, 1 female (SC); Piazza Armerina, XI.2009, I. Rapuzzi & L. Caldon legit, 1 female (RC). Syracuse. Vendicari, 18.VIII.1993, 2 males and 1 female (SC); Priolo, 28.XI.2010, 3 males; idem, 5.III.2011, 1 fe-

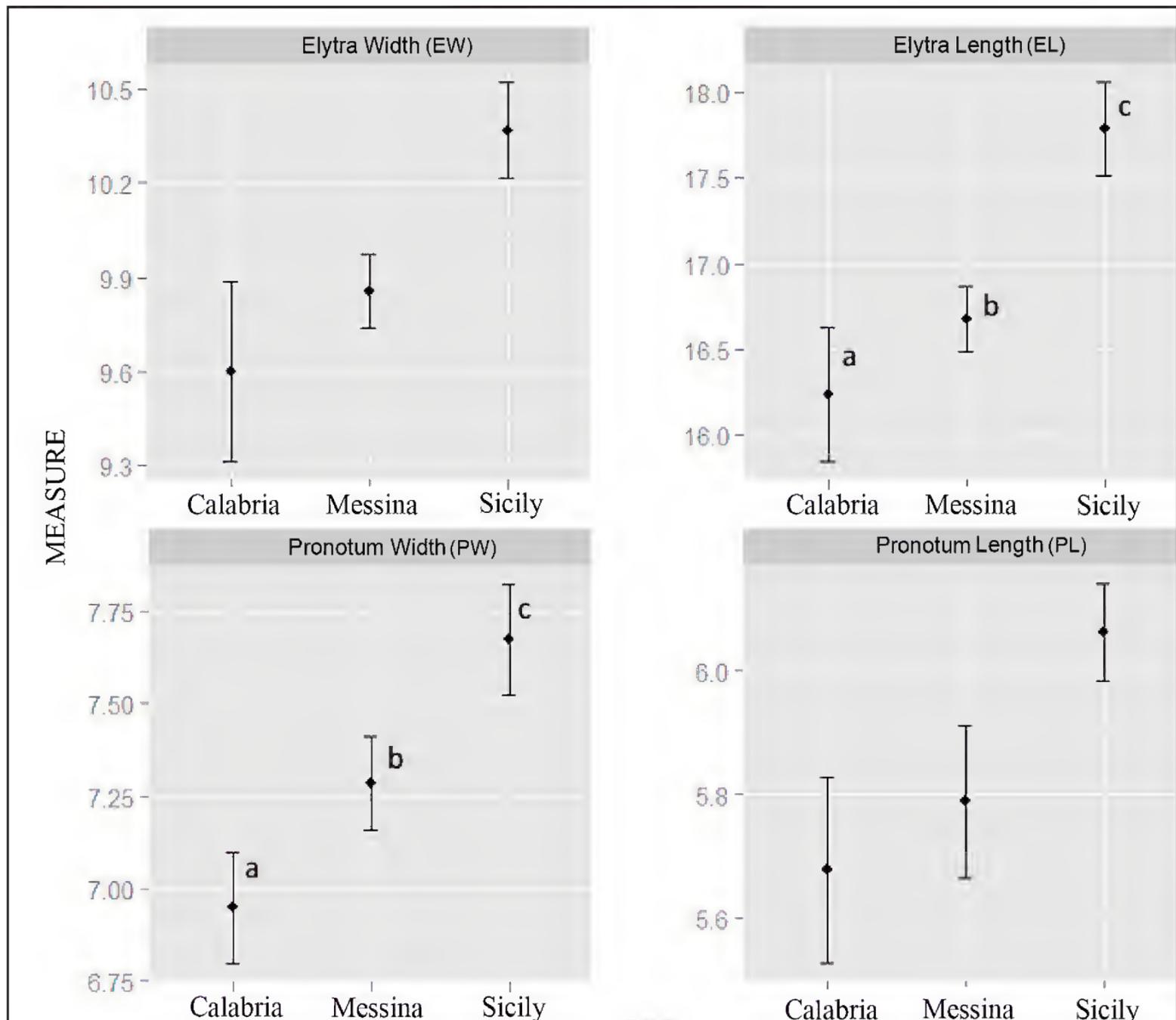


Figure 7. Comparison of means, and confidence intervals (95%) among the three populations for the four variables examined. For the variables selected by discriminant analysis (PW and EL) are shown the values of significance in multiple comparisons. PW: Messina/Calabria  $t = 3.211^{**}$ ; Sicilia/Calabria  $t = 7.426^{***}$ ; Sicilia/Messina  $t = 4.772^{***}$ . EL: Messina/Calabria  $t = 2.412^{*}$ ; Sicilia/Calabria  $t = 8.520^{***}$ ; Sicilia/Messina  $t = 6.983^{***}$ .

male (SC); Magnisi, 28.XI.2010, 2 males and 1 female (SC); Palazzolo Acreide, 5.III.2011 (SC); Vizzini, 14.II.2015, 1 male (SC). Messina. Nebrodi Mts., North from Capizzi, 1250 m, 23.VII.1991, 1 male (RC).

**DISCRIMINANT ANALYSIS.** We also made a biometric study on 30 male specimens of *C. morbillosus alternans* from Sicily, with the exception of the north-easternmost regions, 16 male specimens of *C. morbillosus bruttianus* from Southern Calabria and 26 males attributed to *C. morbillosus bruttianus* from Messina surroundings. The following measures were examined: pronotum width (PW), pronotum

length (PL), elytra width (EW), and elytra length (EL). In figure 6 are shown the graphs of the relationships between length and width of elytra and pronotum for the three populations. Our findings showed significant results when comparing *C. morbillosus alternans* and *C. morbillosus bruttianus* (Calabria and Messina); whereas slight differences were observed between the two populations of *C. morbillosus bruttianus* from Calabria and Messina.

In order to identify which one of the four morphometric characters used allows to distinguish the three populations of *C. morbillosus* it was used the discriminant functions analysis. Variable selection was done by the "Forward stepwise". The res-

ulting model shows a discriminating value not high but still significant (Wilks' Lambda: 0.4107060 approx.  $F(4.136) = 19.05342$ ;  $p < .0000$ ). Variables selected from the analysis are: EL and PW. Partial lambda values (0.761599 and 0.932681, respectively) indicate that EL followed by PW have the most discriminating power among the three populations examined. The analysis produced two linear functions, Root1 and Root2, the first appears negatively correlated mainly with "elytra length" and, to a lesser extent, with "pronotum width" (Table 1) and discriminates the population of Calabria from that of Sicily (Table 2). The second is negatively correlated with pronotum width (Table 1) and, although possess a low discriminatory power, partially contributes to distinguish the population of Calabria from that of Messina (Table 2).

In addition, the Mahalanobis distance between the centromeres of the three populations, although it is significant for all comparisons, shows high values only between Calabria and Sicily (Messina/Calabria 1,116 \*; Sicily/Calabria 8,004 \*\*\*; Sicily/Messina 3,673 \*\*\*. (P: \*\*\*  $\leq 0.001$ ; \*\*  $\leq 0.01$ ; \*  $\leq 0.05$ ). The classification matrix (Table 3) shows that more than 70% of the specimens from Messina and the rest of Sicily are properly classified, while this percentage drops to around 56% for specimens from Calabria.

To assess whether the averages of each of the two variables identified with the discriminant analysis significantly differ among the three populations, it has been carried out the analysis of variance (Fig. 7). Multiple comparisons were performed with the correction of Turkey. For both characters ANOVA was significant (pronotum width:  $Df = 2/62$ ,  $F = 23.61$ ,  $P < 1e-04$  \*\*\*. Elytra Length  $Df = 2/62$ ,  $F = 37.14$ ,  $P < 1e-04$  \* \*\*). Multiple comparisons between populations are highly significant except for the comparison Messina/Calabria for EL that is barely significant ( $p = 0.0477$ ).

REMARKS. Born (1906) describes *Carabus morbillosus bruttianus* from Calabria, locus typicus St. Eufemia d'Aspromonte, distinguishing it from the Sicilian populations of Palermo known as *C. morbillosus servillei* (= *C. morbillosus alternans*). Subsequently both Porta (1923) and Luigioni (1929) report it as a distinct "variety" of *C. morbillosus* from Calabria. In particular, Porta (1923) reiterates the morphological differences already reported by Born (1906) in its original description. However,

latest Authors consider *C. morbillosus bruttianus* as a synonym of *C. morbillosus alternans* of Sicily (Magistretti, 1965; Casale et al., 1982; Vigna Taglianti, 1995; Vigna Taglianti, et al., 2002).

The examination of numerous specimens from different places near Reggio Calabria (Southern Calabria), allowed us to confirm the morphological characteristics of this taxon, which results morphologically distinct from the neighboring populations of *C. morbillosus alternans* of Sicily. Populations attributable to *C. morbillosus bruttianus* are also present near Messina (north-eastern Sicily), described as *C. borni* Krausse, 1908 (= *sicanus* Csiki, 1927; nom. pro *borni* Krausse). Porta (1923) reports this taxon as a distinct "variety" of North-Eastern Sicily, thus distinguishing it, geographically, from the remaining populations of South-Western Sicily.

The populations of Messina are, in fact, morphologically distinct from the remaining Sicilian ones attributed to *C. morbillosus alternans* and, rather, similar to the Calabrian populations of *C. morbillosus bruttianus* from which differ only in a few minor characters, especially by color and shape of pronotum.

## CONCLUSIONS

Actually, the *C. morbillosus* population of Sicily, Sicilian islands, and the nearby Southern Calabria, turns out to be more diversified than considered up to now. In most of the islands, is confirmed the presence of *C. morbillosus alternans* which is very well-differentiated and distinct from all the other races of the species; *C. morbillosus bruttianus* is present in Southern Calabria, in the territories of North-Eastern Sicily (Messina and surrounding area) and, as to our knowledge, even in Lipari in the Aeolian Islands. In Lampedusa Island there is an island subspecies, *C. morbillosus lampedusae*, similar to North African populations of *C. morbillosus*.

At the moment, the populations covered by this work can be distinguished as outlined below:

1. Pronotum wider and arched forward with maximum width in the fore third. Primary intervals salient and very short, secondary ribs raised and wide, tertiary intervals broken down into lines of evident granules, 1st elytral interstria with small tubercles

and confluent points in the form of irregular furrow. Aedeagus apex distinctly more elongated, narrow and slightly curved.....*morbillosus constantinus*

- Squat and convex body-shape, less bright in color and dark. Pronotum with basal dimples large and deep, sinuate at sides before hind angles. Primary intervals wider, 1st elytral interstria with points on the surface, well separate from each other.....*morbillosus lampedusae*

2. Pronotum distinctly narrower forward with maximum width at the center. Primary intervals elongated and slightly salient, secondary ribs depressed, tertiary intervals less raised than secondary ones; 1st elytral interstria with wide points, deep, very distinct, sometimes juxtaposed with each other. Apex of aedeagus shorter, wider and curved. Shape great and flattened on the back, brilliant; elytra elongate, rounded and dilated in the rear third; elytra apex short and slightly sinuate at sides...  
.....*morbillosus alternans*

- Smaller and convex on the back of the elytra, less shine; pronotum narrower and slightly rounded forward with maximum width in the fore half; disc with evident points and transverse wrinkles thin and sparse; elytra short and ovalish, primary intervals in granules shorter and less raised; elytral apex stretched and clearly sinuate at sides.....  
.....*morbillosus bruttianus*

## ACKNOWLEDGEMENTS

We thank Dr. Andreas Müller (ETHZ) and Dr. Franziska Schmid (ETHZ) for the loan of the type specimens from Born Collection of *Carabus (Macrothorax) morbillosus lampedusae* and *C. (M.) morbillosus bruttianus*; Dr. Antonio Adorno (University of Catania, Italy), Dr. Andrea Corso (Syracuse, Italy), and Dr. Marcello Romano (Capaci, Italy).

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# About the presence of the Haifa Grouper *Hyporthodus haifensis* (Ben-Tuvia, 1953) (Perciformes Serranidae) in the Strait of Messina, Italy, Mediterranean Sea

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## ABSTRACT

In this paper is reported for the first time the presence of the Haifa Grouper, *Hyporthodus haifensis* (Ben-Tuvia, 1953) (Perciformes Serranidae) in the waters of the Strait of Messina, Italy which confirms the expansion process of the species toward the northern part of the Mediterranean Sea.

## KEY WORDS

Epinephelinae; *Hyporthodus haifensis*; Lampedusa; Pellarò; Serranidae.

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## INTRODUCTION

The subfamily Epinephelinae belonging to the family of marine bony fish Serranidae includes many genera, among which *Hyporthodus* Gill, 1861. The species belonging to this genus are commonly called "groupers" as some of their close relatives of the genus *Epinephelus* Bloch, 1793.

Haifa Grouper, *Hyporthodus haifensis* (Ben-Tuvia, 1953) is a marine fish, demersal and generally present in water depths between 90 and 220 meters (Froese & Pauly, 2014; Heemstra & Randall, 1993). The body has large pelvic and pectoral fins, often bordered with white, tail shape rather rounded, body color dark brown. Its distribution area appears to be the Eastern Atlantic from the coast of Angola in the south, to those in the southern part of Portugal.

*Hyporthodus haifensis* is also present in the southern part of the Mediterranean Sea (where the species arrived entering through Gibraltar) from the coast to the south of Spain, along almost all the

Mediterranean coast of North Africa to Lebanon, Israel, Turkey and southern Greece (Heemstra & Randall, 1993). The only indication of its presence in Italian waters was published in 2000 for the Lampedusa Island, Pelagie Archipelago, Sicily Channel (Azzurro et al., 2000). Considering the characteristics of Lampedusa and its geographical location, we can say that the island represents a bridge between the Italian and North African territory. This led to assume, even at the time of the report of *H. haifensis* in Lampedusa, a future movement of the species in the direction of the waters of Sicily and the Italian mainland (Heemstra & Randall, 1993).

## MATERIAL AND METHODS

The sighting occurred during a dives with scuba equipment. The camera equipment consisted of Canon G-15, Fantasea housing and Sea & Sea flashes.



Figures 1–3. Young specimen of *Epinephelus haifensis* (Pellaro, Reggio Calabria, Italy), 35 m deep, XI.2014, photographed by day (Figs. 1, 2) and during the night (Fig. 3).

## RESULTS AND CONCLUSIONS

The discovery of this species has occurred in Pellaro (Reggio Calabria, Italy) in the month of November 2014 on a backdrop of mixed sand and mud, 35 meters deep and with a water temperature of about 23 °C. The animal was a young specimen (Fig. 1) of about 25 cm in overall length, stationing around a small wreck of about 3 meters in length.

The identification was made possible by counting the number of soft rays in the anal fin, which is not less than nine; another distinctive character of

the species (but only valid for young specimens) is that the pelvic fins are not long enough to reach the anus. No wonder for the low depth at which the specimen was found intact, despite belonging to a species which prefers stationing at depths beyond 90 meters, it is well known the habit of young groupers to colonize shallow waters, within 30 meters. Also in the Strait of Messina, thanks to its weather and sea conditions or currents, peculiar at all, many species, such as the Longspine snipefish *Macroramphosus scolopax* (Linnaeus, 1758) (Syngnathiformes Centrisidae), generally station at depths

much lower than those where they are usually found in other areas of the Mediterranean Sea.

The specimen was found in the same spot in three separate dives performed during the same month of November and then photographed by day (Fig. 2) and during the night (Fig. 3). The latter photo was taken in a subsequent night dive, during which it was found the same specimen in the same place. The image depicts the specimen during sleep and is interesting because, as is well known, fish change their colors at night using special cells called chromatophores. This picture shows exactly the colors taken at night by Haifa's grouper, which is rarely documented.

This new record of *H. haifensis* is in continuity with the previous one recorded in Lampedusa, confirming the expansion process of the species toward the northern part of the Mediterranean Sea. This expansion was predicted by some authors (Heemstra & Randall, 1993) and will therefore be interesting to continue to monitor future developments.

It is also very likely that often the presence of specimens of this species may not be noticed, as they may be easily confused with specimens of other Mediterranean species.

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## Preface

# Speciation and Taxonomy: Neotropical Primate diversity

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During the last three decades Dr. Van Roosmalen has surveyed by boat, canoe, and on foot entire basins of some major tributaries of the mighty Amazon River in order to study primate diversity and distributions across the entire Amazon Basin (including large parts of the Precambrian Guiana and Brazilian Shields).

This way he tested and empirically came to fully validate Alfred Russel Wallace's river-barrier hypothesis first laid down in his 1852 account *On the Monkeys of the Amazon*. Wallace points at the larger rivers he sailed as the principal evolutionary cause of the Amazon's uniquely rich extant primate diversity and complex biogeography, for many rivers together with their floodplains effectively block off gene flow between populations along opposite riverbanks.

As the Amazon represents a largely pristine and vast natural realm not (yet) modified by human interference, no better place to retrace evolutionary processes that may have acted upon primates (including our own ancestors) and other mammals since the Pliocene. Moreover, Van Roosmalen's biodiversity surveys revealed a number of new monkeys from all over the Amazon (described elsewhere) and other megafauna (some from the Rio Aripuanã Basin described here), among which

even a new genus - the dwarf marmoset *Callibella humilis* M. van Roosmalen, T. van Roosmalen, Mittermeier et de Fonseca, 1998.

This peaceable, non-territorial, enigmatic, second smallest monkey in the world (here depicted in the upper left corner) occupying the smallest distribution of any monkey on the planet stands at the base of the phylogenetic tree of all extant marmosets. Interestingly, the whole family of advanced Callitrichidae (i.e., the genera *Cebuella* Gray, 1866 *Callithrix* Erxleben, 1758, *Mico* Thomas, 1920, *Saguinus* Hoffmannsegg, 1807, *Leontopithecus* Lesson, 1840) exhibits social groupings that fiercely defend a common living space or territory (Fig. 1).

Speciation, radiation and rate of metachromic bleaching among primates seem to be related to territoriality and social rather than sexual selection (as is the case in other mammals and birds). Consequently, the strictly territorial Amazonian marmosets (*Mico*), tamarins (*Saguinus*), lion tamarins (*Leontopithecus*), oquistitis (*Callithrix*), titis (*Callicebus* Thomas, 1903) and howling monkeys (*Alouatta* Lacépède, 1799) are the most diversified, species-rich and colorful genera among a total of 19 New-World monkeys, in striking contrast to Goeldi's Monkey *Callimico* and dwarf marmoset

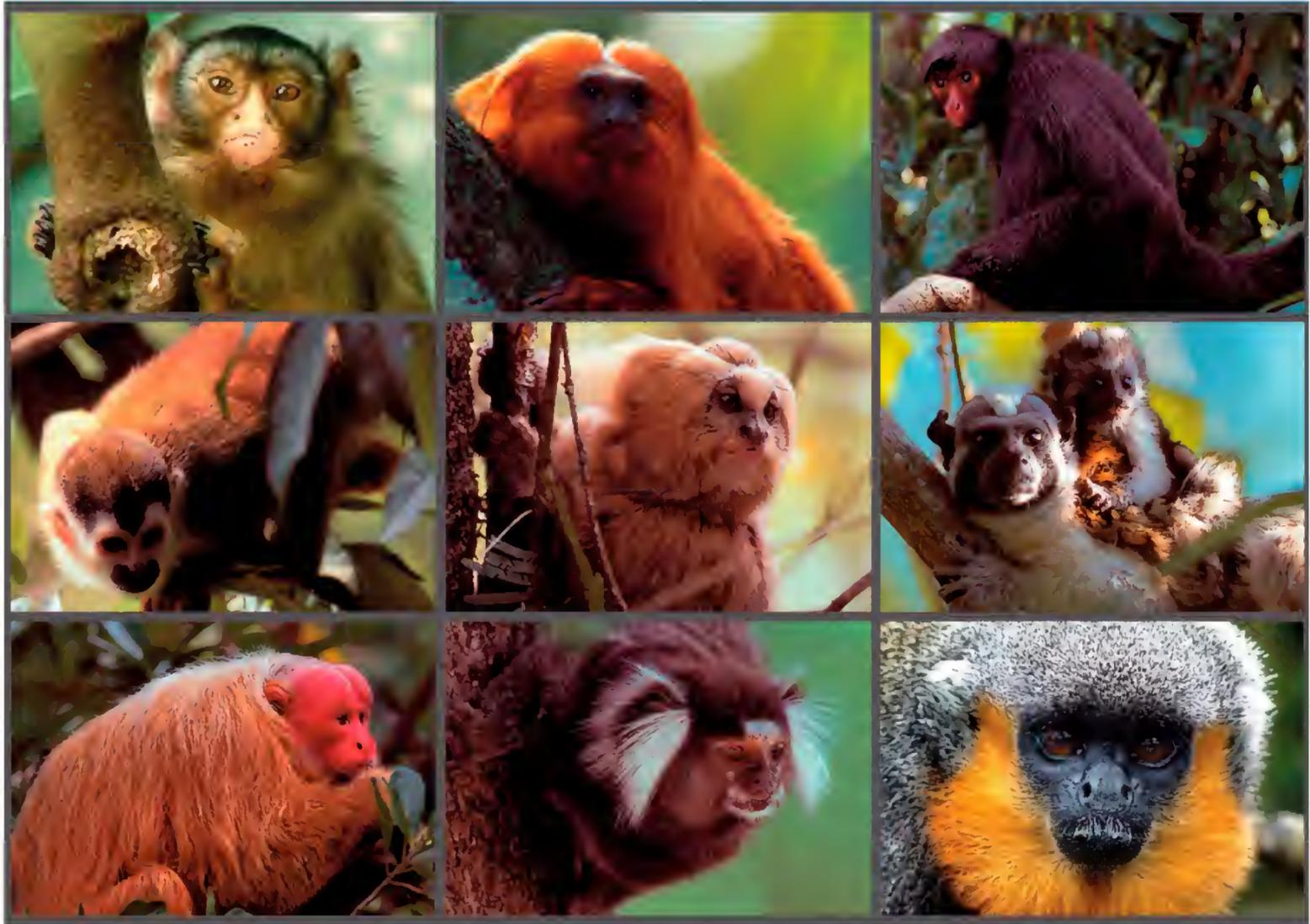


Figure 1. Neotropical Primate diversity - Amazon Basin, Brazil.

*Callibella* - the only two Neotropical primate genera being monotypic and archetypic in skin and

coat coloration (eumelanin black, brown and/or agouti).

## Introduction

# Speciation and Taxonomy: digressions at the edge of a meeting

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The title of the meeting organized by the *Biodiversity Journal* leads itself to reflections upon the cognitive relation between man and nature. Two different ways of looking at biodiversity are approached: explanation of its origin and classification of its diversity. The first looks into the processes that have led to the formation of that extraordinary, wonderful, tragic and cruel world that we call life. The result has been the impressive system of knowledge of the biological evolution. We are confident, on the other hand, that the processes of life are independent of any our interpretation. The second meets our need to name and describe the living beings appearing as separate discrete entities. The outcome of this activity is taxonomy, an object of our mind, whose first systematic form dates back to the *Systema Naturae*, elaborated by Linnaeus far before the emergence of the evolutionary theory, nearly actualizing the first job of Adam (Genesis 2, 19).

Speciation is a crucial event of evolution: genetic variations and adaptations to different environmental contexts have produced a multiplicity of species and a great diversity of living organisms. Taxonomy is able to represent only a time confined image of the result of this process; however its system becomes a new subject of our knowledge with implications on our perception of the diversity of life. May rules and methods of taxonomy affect the

comprehension of the life evolution? Indeed, we can suppose that, in the interaction between the static description of biodiversity and the analysis of its development, the mechanism of our mind plays a relevant role in guiding the thoughts towards the established knowledge.

Phylogenetic analysis is try to connect taxonomy to speciation and contributes to its redefinition. However both phylogeny and taxonomy respect a tacit postulate whose rational foundation is not considered problematic: similarity among beings indicates a common origin and the chain of reproductive events brings us to the common life origin. And, if life, in the famous primordial soup, had originated uncountable times, as an unavoidable consequence of the properties of inorganic matter, as the inorganic molecules arise from chemical reactions rigorously determined by their context? Should we hypothesize that at least a part of biodiversity was determined by distinct origins in the primordial soup?

Removing this heretic thought, arisen from the hesitations of my mind, let us consider a less worrying problem of our taxonomic system: the indefiniteness of taxonomic categories, detectable from a comparison between different phyla, classes or orders. Are taxonomic categories pure classification tools or they attempt to measure some aspect of diversity? Molecular analysis has allowed the

measurement of the genetic distances among taxa and to calculate the time of their separation, even in absence of paleontological data. But, the results, despite the sophisticated mathematical methods utilized, are grossly inadequate: solution of problems at the species or subspecies level is possible, but the phylogenetic trees remain highly hypothetical.

Current taxonomy tries to represent the surprising phenotypic diversity of beings that has a magnitude many times larger than the diversity of genetic material. It would be most likely possible to redefine the taxonomic categories according to the level of phenotypic diversity. This would require a free access to an exhaustive species' documentation (description, figures, ecological notes, and so on). Some farseeing scientists are pursuing this aim for a few taxa.

However there are good reasons to preserve the stability of taxonomy. For example, the great role of taxonomy in nature conservation strategies: one

cannot preserve any living organism that does not have a name. The prerequisite for the creation of the IUCN Red List of Threatened Species is precise taxonomic knowledge and changes in taxonomy (for example variation in synonymy) can determine changes in the status of a species. Also the level of nature protection in a territory may be increased by a new taxonomic evaluation of a biological species. Of course there is a great need for taxonomy experts to monitor the populations of protected species and to evaluate the status of habitats relevant for nature conservation. But, may these considerations of mine reveal a conflict of interest?

At the end, we will have a good solution if, while many mathematical minds endeavor to elaborate models to resolve evolutionary puzzles, traditional taxonomy continues to fulfil the biblical job of giving a name to animals and plants, whose shapes, colours and adaptations always attract the interest of numerous enthusiastic scientists, as proven by the success of this journal and of the meeting.

## Taxonomy faces speciation: the origin of species or the fading out of the species?

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### ABSTRACT

Efficient field sampling and new investigation tools, including barcoding and other molecular techniques, are bringing to light an unexpected wealth of new species, including sets of morphologically quite uniform, but genetically distinct cryptic species. On the other hand, increasing appreciation of the dynamic nature of the species and a better knowledge of speciation processes and introgression phenomena challenges the taxonomists' efforts to shoehorn all diversity of life into a formal classification of which the species would be the basic unit. Unfortunately, there is probably not a single best notion of species, either in theory or in practice.

### KEY WORDS

barcoding; cryptic species; hybridization; speciation; species concepts.

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### THE SPECIES - A SOLID PILLAR OF OUR REPRESENTATION OF LIVING NATURE?

A substantial percentage of recent books and articles in zoology, botany, palaeontology, biogeography and ecology may suggest that the species has passed undamaged through the Darwinian revolution. Although everybody, or so, in these disciplines is likely ready to accept that species are products of evolution, in practice a great many professionals describe and analyze the living world of the past and present time in terms not that different from those of Linnaeus and the other pre-Darwinian authors.

In the title-page of his magnum opus, Linnaeus (1758) announced an arrangement of his *Systema naturae per regna tria naturæ, secundum classes, ordines, genera, species*. Firmly placed at the bottom of the hierarchy, the species category was thus proposed as the fundamental unit of classification. In the author's creationist and largely fixist

views, species have been created at the beginnings of time and the naturalist's job is to piously explore Nature with the aim of completing their inventory.

What does survive to our time, of this reassuring pre-Darwinian conception of biological diversity? Little, if anything, in theory, but quite a lot in practice. This is true both of the approach with which taxonomists continue Linnaeus' project for a global inventory of biodiversity and of the perspective from which most of their colleagues in biology, ecology, biogeography and stratigraphy look at the extant or extinct forms of life that are the object of their studies.

To be sure, there are also the 'professionals of the species problem,' that is, biologists - but also philosophers of biology - who take very seriously the Darwinian challenge and specifically focus on all those contexts where the boundaries between species are less precise or less complete, and often largely arbitrary.

The species problem has, in fact, two main aspects. One is conceptual, the other is practical. The

conceptual aspect of the species problem is how the species can, or should be defined, provided that this question can be eventually answered to the general satisfaction of biologists and philosophers alike. The practical aspect is, how species are recognized by taxonomists working on the different groups of organisms and, most important, whether taxonomists can all agree on a single species concept, to be adopted as the universal currency in describing the diversity of life. A comparison of taxonomic practice as performed by leading specialists in a diversity of taxa, from mammals to fungi, from bacteria to flowering plants, has abundantly demonstrated that the entities called species in a group have little in common with the entities called species in another group (Claridge et al., 1997). Unfortunately, this heterogeneity is concealed under the (nearly) universal use of Linnaean binomials. It is thus all too easy to take taxonomic species as a set of broadly comparable units, of which we can make statistics for the most different purposes, e.g. biodiversity assessments and comparisons of extant or extinct faunas and floras. This practice should be best avoided (Minelli, 2000) but we do not have a real substitute for it; the global biodiversity estimates offered below are not exempt from this ‘original sin.’

In this article I will focus on this practical aspect to the species problem, mostly taking examples from papers published in 2014: with this temporal restriction I only wish to stress the lively interest surrounding these questions. The relevant literature is enormous, and rapidly increasing with the increasing availability of morphological and especially molecular methods, and their massive application to the most diverse kinds of organisms. Enormous is also the literature about the conceptual aspects of the species problem, but I will only mention here two articles (Bernardi & Minelli, 2011; Mallett, 2013) to which I refer the interested reader and summarize in Table 1 the most important among the more than 20 different species concepts proposed to date.

## HOW MANY SPECIES?

Even if we temporarily ignore the problems caused by the lack of a satisfactory species concept applicable to every kind of living things and thus simply frame the question in terms of taxonomic (named) species, it is difficult to say how many

species we know at present and, still worse, how many species still await description. Estimates of ‘valid’ described species range between 1.5 million and 2 millions; a document issued in 2011 by the International Institute for Species Exploration gave a figure of 1,922,710 species as described throughout 2009.

Something, however, must be wrong with many of these estimates. In the last few decades, the number of new species described each year has been in the order of 17500 (International Institute for Species Exploration, 2012). This means that since 1985 about half a million new entries have been added to the list of described species. The net increase has been sensibly smaller, because of the number of nominal species that in the same time interval have been recognized to be just synonyms of other species. However, the net increase has been probably in the order of 350 000–400 000, whereas the most recent estimates of the number of described species are not correspondingly larger than the estimates produced 30 years ago.

In the last two decades of the XX century a number of papers offered estimates of the number of living species that still await description, one of the first and most often cited being May (1988). Some estimates were based on the percentage of undescribed species in small but dense samplings in areas and habitats with high diversity, e.g. Hodgkinson & Casson (1991) for tropical insects and Grassle & Maciolek (1992) for deep-sea animals. Other estimates included ecological considerations, such as the degree of hostplant specialization of phytophagous insects, as in Erwin’s (1982) pioneering paper or Stork’s (1988) revisitation of the same. One of the most recent papers on the subject adjusts the estimates to ~8.7 million ( $\pm 1.3$  million SE) eukaryotic species globally, of which ~2.2 million ( $\pm 0.18$  million SE) are marine (Mora et al., 2011); another, more sensible one (Scheffers et al., 2012) acknowledges the plurality of unknown or poorly known factors, as a consequence of which uncertainty remains between a global total as low as 2 million species, microbes excluded, and estimates as high as 50 millions and over.

## PROLIFERATION OF NEW SPECIES

Strong catalysts favouring the description of new species are the new megajournals specifically

devoted to taxonomy. In zoology, the leading role of Zootaxa and ZooKeys is by now unrivalled and undisputed. According to the journal's editor-in-chief, in 2010 Zootaxa contributed about 20% of all animal taxa described that year as new, that is, a number in the order of 4000 (Zhang, 2011).

Launched a few years after their zoological equivalents, Phytotaxa and PhytoKeys have been also rapidly growing and by now outcompete the biggest journals long established in the field. According to Zhang et al. (2014), the total number of new plant taxa described in 2011 was 6024 (of which 575 in Taxon, 473 in Phytotaxa, 183 in Novon, 169 in the Botanical Journal of the Linnean Society); in 2012, the total was 6647 (of which 632 in Phytotaxa, 465 in Systematic Botany, 340 in Phytoneuron, 301 in the Kew Bulletin, 267 in Taxon); in 2013 the number decreased to 5116 (of which 501 in Phytotaxa, 248 in PhytoKeys, 199 in Biodiversity Research and Conservation, 196 in the Botanical Journal of the Linnean Society). In discussing these numbers, it is necessary to consider that these include taxa proposed at any taxonomic rank.

Despite the large and largely unknown degree of uncertainty surrounding the estimates mentioned above, these are nevertheless important. Besides the fact that these figures help bringing the urgency of biodiversity conservation to the public attention, estimates of gaps of knowledge to be filled can stimulate targeted efforts aiming at filling them.

Some research groups are currently addressing this specific problem through well-planned field work in lesser investigated and species-rich areas, with special regard to hyperdiverse taxa such as weevils. For example, a German team, supported by local investigators in tropical areas, has recently produced a couple of excellent papers on the wingless weevils of the genus *Trigonopterus*.

Previous to the most recent researches, this genus included 91 described species ranging from Sumatra to Samoa and from the Philippines to New Caledonia. Of these, 50 species of *Trigonopterus* had been described from New Guinea, the center of the genus' diversity. But new targeted samplings in seven localities across New Guinea have resulted in the recognition of 279 *Trigonopterus* species, most of which new to science; of these, a first set of 101 species have been

described by Riedel et al. (2013). Another 98 new species of *Trigonopterus* have been described in a paper (Riedel et al., 2014) devoted to materials recently collected in Indonesia (Sumatra, Java, Bali, Palawan, Lombok, Sumbawa, Flores), a large area from where only one species of *Trigonopterus* was previously known.

Perhaps less expected, there are also large numbers of undescribed species in the Lepidoptera, especially among the so-called micros. A recent study of the gelechioid genus *Ethmia* in Costa Rica revealed the presence of 22 undescribed species in addition to 23 described in the past (Phillips-Rodríguez et al., 2014).

Virtually unfathomed is, in some specialists' view, the world of Fungi, of which the number of existing species is estimated between 1.5 and 5 million, i.e. 15 to 50 times the number of currently described species. The wealth of undescribed fungal diversity is not limited to the microscopic forms: a recent study reported the identification of at least 126 species (and potentially up to 400) within a taxon of macrobasidiolichens currently regarded as one species (*Dictyonema glabratum* (Sprengel) D. Hawksw. also known as *Cora pavonia* E. Fries) (Lücking et al., 2014).

The use of new investigation tools such as barcoding (discussed below) is precious, indeed, in revealing the existence of a multiplicity of cryptic species hitherto shoehorned under one species name. I give here four examples, three of which from papers published last year.

In polychaetes, for examples, cryptic species crop up with virtually every accurate study. The detailed review published by Nygren (2014) includes several dozen examples, of which only the most conspicuous ones (those with  $\geq 5$  cryptic species inferred to be present within a taxon currently treated as a single species) are listed in Table 2. The taxonomic complexity revealed by this study is probably nothing more than the tip of a huge iceberg of species diversity in the annelids. Most of the cryptic diversity discovered to date in polychaetes is still formally undescribed, one of the few exceptions being the five species of *Archinome* listed in the Table.

Impressive are the results of some studies focusing on individual genera, where a systematic use of barcoding procedures has revealed an astonishing diversity of species, morphologically very uniform,

as in some amphipods living in desert spring of the southern Great Basin of California and Nevada, USA, where 33 ‘provisional species’ have been recognized within a clade hitherto referred to the one species, *Hyalella azteca* Saussure, 1858 (Witt et al., 2006).

A cornucopia of cryptic species, to use the words of the authors (Winterbottom et al., 2014) has been discovered in a DNA barcode analysis of the gobiid fish genus *Trimma*. Here, 473 specimens initially assigned to 52 morphological species revealed the presence of 94 genetic lineages separated by a sequence divergence usually typical of inter- rather than intraspecies differences.

To a quite smaller extent, but still worth mentioning here, new species are still being described at a sensible rate even in groups such as mammals, where a long tradition in taxonomy could be expected to have adequately accounted for extant species diversity. Taxonomic unrest is obviously larger in species-rich clades such as rodents or bats. For example, several new species of the bat genus *Miniopterus* have been recently described from Madagascar and the neighbouring Comoros archipelago, and at least seven out of the 18 species-level taxa recognized in the most recent study still require formal taxonomic treatment (Christidis et al., 2014).

## TESTING THE BARCODE

“In 2003, Paul Hebert, researcher at the University of Guelph in Ontario, Canada, proposed “DNA barcoding” as a way to identify species. Barcoding uses a very short genetic sequence from a standard part of the genome the way a supermarket scanner distinguishes products using the black stripes of the Universal Product Code (UPC). Two items may look very similar to the untrained eye, but in both cases the barcodes are distinct. [...] The gene region that is being used as the standard barcode for almost all animal groups is a 648 base-pair region in the mitochondrial cytochrome *c* oxidase 1 gene (“CO1”). COI is proving highly effective in identifying birds, butterflies, fish, flies and many other animal groups. COI is not an effective barcode region in plants because it evolves too slowly, but two gene regions in the chloroplast, *matK* and *rbcL*, have been approved as the barcode regions for plants.”

This is the way this technique is described, in very simple terms, in the official Barcode of Life website <http://www.barcodeoflife.org/>.

During the last few years, DNA barcoding has become a popular method for the identification of species. How efficient and reliable is it? The question can be reasonably asked in respect to groups and areas for which an exhaustive taxonomic treatment was already available, based on morphology, and the recent barcoding effort has covered a large percentage of the species recognized thus far.

In the case of insects, most published DNA barcoding studies focus on species of the Ephemeroptera (Ball et al., 2005; Ståhls & Savolainen, 2008), Trichoptera (Zhou et al., 2011), Lepidoptera (deWaard et al., 2009; Hausmann et al., 2011a, 2011b; Strutzenberger et al., 2011), Hymenoptera (Smith & Fisher, 2009; Zaldívar-Riverón et al., 2010) and Coleoptera (Raupach et al., 2010, 2011; Greenstone et al., 2011; Astrin et al., 2012; Woodcock et al., 2013).

Raupach et al. (2014) have recently tested the efficiency of DNA barcoding for the Heteroptera of Central Europe. Based on a conventional quantitative threshold currently accepted as a minimum molecular difference between two species, they found that species identification based on barcoding sequences is correct in a 91.5% of cases. In 21 cases, the molecular distance between two traditionally accepted species is lower (in ten cases, actually zero). To the contrary, intraspecific differences larger than the conventional species-level threshold have been found for 16 species traditionally regarded as valid. These results suggest that the barcode cannot be blindly accepted as a tool that allows quasi-automatic identification of all species, but at the same it turns to be a useful tool to discover taxa, or groups of closely related taxa, that are in need of in-depth revision. In particular, Raupach et al.’s study has provided evidence for ongoing hybridization events within various genera (e.g. *Nabis*, *Lygus*, *Phytocoris*) as well as the putative existence of cryptic species, e.g. within the aradid *Aneurus avenius* (Dufour, 1833) and the anthocorid *Orius niger* (Wolff, 1811).

Much larger success was obtained by Huemer et al. (2014) in the identification via barcode of 1004 species of Lepidoptera shared by two European countries, Austria and Finland, ca. 1600 km apart. Correct identification was possible for

98.8% of the taxa. However, deep intraspecific divergence, larger than the conventional threshold accepted as separating intra- from interspecific difference, was detected in as many as 124 taxonomic species hitherto recognized based on morphology. Authors concluded that despite the intensity of past taxonomic work on European Lepidoptera, nearly 20% of the species shared by Austria and Finland require further work to clarify their status.

The information obtained by systematically applying the barcoding method to groups for which traditional taxonomy is inadequate has different consequences. For example, this technique has been applied to the biting midges (Ceratopogonidae) of the county of Finnmark in northern Norway. Results indicated the presence of 54 species, of which 14 likely new to science, 16 new to Norway, and one new to Europe (Stur & Borkent, 2014). Another study involved a New World genus of Curculionidae (*Conotrachelus*). Two sets of specimens were compared, those emerged from some 17 500 seeds collected in six Central American rain forests and those collected in the same forests using interception traps that capture flying insects. Barcoding data suggested the presence of 17 species in the trapped samples, and 48 species among the specimens obtained from the attacked seeds. Little hope to use previous knowledge to identify them, however, as the barcoding of representatives of 24 species from museum collections provided matches for only three of the 17 species from the traps and no match at all for the putative 48 reared species (Pinzón-Navarro et al., 2010).

Overall, barcoding methods have proven much less informative for plants than the results obtained from animals would have allowed to hope. A near complete failure has been a study on willows (*Salix*) species, using two to seven plastid genome regions. Of the 71 Holarctic species in that study, only one has a unique barcode (Percy et al., 2014)!

## THEORY-DRIVEN SPECIES INFLATION

This legitimate, welcome progress in the appreciation of species diversity in lesser investigated groups contrasts, to some extent, with a recent proliferation of ‘new species’ proposed by some authors in a revisitation of the taxonomy of popular

mammal clades such as carnivores and ungulates. The theoretical background advocated by the zoologists responsible for this ‘taxonomic inflation’ is the phylogenetic species concept, according to which any arguably monophyletic and practically diagnosable lineage deserves to be considered (and eventually named) as a distinct species. With the increasing use in taxonomy of molecular techniques (e.g. barcoding), finding a differential trait between two populations, e.g. a single nucleotide difference, has become all too easy.

A first application to mammals of the phylogenetic species concept led Cracraft et al. (1998) to raise the Sumatran tigers to species status (*Panthera sumatrae* Pocock, 1929) based on three diagnostic sites in the mitochondrial cytochrome b gene. Shortly thereafter, Mazak & Groves (2006) added a third tiger species, the Javan tiger *P. sondaica* (Temminck, 1844), to the previously established *P. tigris* (Linnaeus, 1758) and *P. sumatrae*. Similarly, based on mtDNA and their analysis of morphological diagnosability, Groves & Grubb (2011) distinguished three species of European red deer: *Cervus elaphus* Linnaeus, 1758 (West European red deer), *C. pannoniensis* Banwell, 1997 (East European red deer) and *Cervus corsicanus* Erxleben, 1777 (Corsico-Sardinian and North-African red deer). Moreover, these are only a fraction of the total of 12 species recognized by these authors for the entire red deer/wapiti complex. Further examples of oversplitting caused by the application of the phylogenetic species concept include the 11 species of klipspringer recognized within one traditional species, *Oreotragus oreotragus* (Zimmermann, 1783), based on size differences and different sexual dimorphism, and the splitting of the mainland serow *Capricornis sumatraensis* (Bechstein, 1799) into six species (Groves & Grubb, 2011). Zachos et al. (2013), who are very critical of this trend in mammal taxonomy, acknowledge however that in other groups more than one species must be in fact recognized, as in the case of the African elephants (the forest elephant *Loxodonta cyclotis* Matschie, 1900 and the savanna elephant *Loxodonta africana* (Blumenbach, 1797); cf. Rohland et al., 2010), and the giraffe, within which six or more distinct species should be probably recognized (Groves & Grubb, 2011).

<i>Agamospecies Concept</i>	an operational, morphologically defined unit in organisms that reproduce asexually or by uniparental reproduction (without fertilization)	Cain (1954)
<i>Biological Species Concept</i>	a group of interbreeding natural populations, reproductively isolated from other similar groups	Dobzhansky (1935, 1937, 1970), Mayr (1940, 1942, 1963, 1970), Mayr & Ashlock, 1991)
<i>Cladistic Species Concept</i>	a group of organisms bounded by two events of speciation or by a speciation and an extinction event	Ridley (1989)
<i>Cohesion Species Concept</i>	the most inclusive group of organisms within which genetic and/or demographic exchange can occur	Templeton (1989)
<i>Ecological Species Concept</i>	a set of populations isolated through occupation of a specific ecological niche	Van Valen (1976).
<i>Evolutionary Species Concept</i>	an evolutionary lineage of populations in ancestor-descendant relationship, that maintains its identity vs. other lineages so defined, and with its own specific evolutionary trends and historical destiny	Simpson (1951, 1961)
<i>Genetic Species Concept</i>	the largest reproductive community of sexual interfertile individuals that share a common gene pool; or a field for gene recombination	Dobzhansky (1950), Carson (1957)
<i>Hennigian Species Concept</i>	a reproductively isolated natural population, or group of natural populations, issued from the dissolution of a stem species in a speciation event, that ceases to exist for extinction or speciation	Meier & Willmann (2000)
<i>Least Inclusive Taxonomic Unit</i>	a taxonomic group defined on the basis of apomorphies	Pleijel & Rouse (1999), Pleijel (2000).
<i>Morphological Species Concept</i>	a community or a number of related communities, whose distinctive morphological characters are, in the opinion of a competent systematist, sufficiently defined to qualify it or them with a specific name	Regan (1926)
<i>Phylogenetic Species Concept - diagnosable version</i>	the smallest diagnosable grouping of organisms, within which there is a pattern of ancestor-descendant relationship	Cracraft(1983)

<b><i>Phylogenetic Species Concept - monophyly version</i></b>	a monophyletic group of individuals characterized by one or more autapomorphies	Rosen (1978), De Queiroz & Donoghue (1988)
<b><i>Phenetic Species Concept</i></b>	a set of organisms that are phenotypically similar and that look different from other sets of organisms	Sneath (1976)
<b><i>Recognition Species Concept</i></b>	a group of organisms that share a common fertilization system, or better, a Specific Mate Recognition System	Paterson (1979, 1985)

Table 1. A selection of species concepts, with short definitions, mainly in accordance with Bernardi & Minelli (2011) and Mallett (2013), and some key references. Concepts that specifically apply to extinct organisms (the Successional Species Concept in the two versions: George's (1956) Chronospecies Concept, and Simpson's (1961) Paleospecies Concept) are not included.

Current taxon name(s)	Inferred number of species
<i>Archinome jasoni</i> Borda et al., 2013, <i>A. tethyana</i> Borda et al., 2013, <i>A. levinae</i> Borda et al., 2013, <i>A. rosacea</i> (Blake, 1985), <i>A. storchi</i> Fiege et Bock, 2009	5
<i>Branchiomma</i> spp.	11
<i>Capitella capitata</i> (Fabricius, 1780)	12+
<i>Eumida sanguinea</i> (Örsted, 1843)	11
<i>Harmothoe imbricata</i> (Linnaeus, 1767)	6
<i>Leitoscoloplos pugettensis</i> (Pettibone, 1957)	5
<i>Marenzelleria viridis</i> (Verrill, 1873), <i>M. bastropi</i> Bick, 2005, <i>M. neglecta</i> Sikorski et Bick, 2004, <i>M. wireni</i> Augener, 1913, <i>M. arctia</i> (Chamberlin, 1920)	5
<i>Marphysa sanguinea</i> (Montagu, 1815)	5
<i>Ophryotrocha labronica</i> Bacci et La Greca, 1961	14
<i>Owenia fusiformis</i> Delle Chiaje, 1844	5
<i>Palola</i> spp.	16
<i>Sabellastarte</i> spp.	7
<i>Scoloplos armiger</i> (Müller, 1776)	5–6
<i>Syllis alternata</i> Moore, 1908	5

Table 2. Cryptic diversity revealed in some polychaete 'species' taxa by recent molecular investigations (data compiled from Nygren, 2014, Table S1).

## TRICKY SPECIES COMPLEXES

Better investigated groups reveal a complexity of interrelationship within which any formal taxonomic arrangement is likely to remain provisional, or at least arbitrary. Species complexes are particularly intractable when the reproductive behavior of some of the forms involved deviates from the typical biparental scheme. Exemplary in this respect is the complex of the European green frogs, which includes a number of hybridogenetic entities whose survival strictly depends on an uninterrupted availability of sperm from a closely related biparental species, as in the case of the Edible Frog, i.e. the hybridogenetic *Pelophylax klepton esculentus* (Linnaeus, 1758). This hybrid between the Pool Frog *Pelophylax lessonae* (Camerano, 1882) and the Marsh Frog *Pelophylax ridibundus* (Pallas, 1771) is fertile, but usually unable to produce balanced gametes of the two sorts, whereas it usually survives by female hybrids mating with males of one of the parental species, usually *P. lessonae* (e.g., Spolsky & Uzzell, 1986; Christiansen, 2009). Local conditions are indeed extremely diverse and are hardly amenable at a conventional taxonomic treatment. In Central and Western Europe the hybrid *P. esculentus* lives in sympatry with the parental species *P. lessonae* (LE-system), but there are also gamete-exchanging systems of *P. ridibundus*/*P. esculentus* (RE) and *P. ridibundus*/*P. lessonae*/*P. esculentus* mixed populations (RLE) (reviewed by Günther, 1991; Plötner, 2005), and also rare all-hybrid populations (EE-system) reproductively independent of the parental forms (Graf & Polls Pelaz, 1989) but dependent for sperm on the presence of triploid individuals; the latter are obtained when diploid eggs produced by diploid hybrid females (LR) are fertilized by haploid sperm of diploid or triploid males (LR, LLR, LRR) (Arioli et al., 2010).

The taxonomic treatment of uniparental organisms is generally difficult and controversial. Linnaean species are quite pacifically recognized in some groups, e.g. in bdelloid rotifers, but in this group thelytokous parthenogenesis is a very old phenomenon and a number of largely fixed differences among strains have been fixed, that allow recognizing species- and genus-level taxa around which there is not much dispute. Things are different in groups where parthenogenesis, or apomyxis,

is a recent phenomenon and phenotypic differences between clonal strains are much more subtle and their taxonomic evaluation much more subjective. In the case of brambles (*Rubus* spp.) and dandelions (*Taraxacum* spp.) thousands of names have been introduced to accommodate slightly divergent phenotypes at what some specialists consider the taxonomic rank of species. In many instances, however, uniparental reproduction is accompanied by variation in ploidy level and/or by morphological and molecular distances comparable to those ordinarily existing between related bisexual species, or even larger. An interesting example has been recently illustrated by Marotta et al. (2014) in the freshwater oligochaetes of the genus *Tubifex*. Despite the occurrence of different reproductive mechanisms (biparental reproduction vs. thelytoky), many populations referable to this genus have been traditionally classified as a single species *Tubifex tubifex* (Müller, 1774). Under this name, however, is concealed an unexpected diversity, as suggested by a careful karyological and molecular analysis of samples collected in just one limited area, the Lambro River near Milano. Alongside a diploid form, for which a distinct name (*T. blanchardi* Vejdovský, 1891) is available in the literature, the authors found several polyploid lines (3n, 4n, 6n), with karyological differences matching with large molecular divergence in the 16S rRNA and COI sequences. It will be no surprise if this diversity will eventually emerge as just the tip of a still unfathomed iceberg.

The identification of gene flow between related species is very important when taxa of economic and especially medical or veterinary importance are involved. Fontaine et al. (2015; see also Clark & Messer, 2015) have recently demonstrated introgression in a medically important group of sibling species of Afrotropical mosquitos (*Anopheles gambiae* Giles, 1902, *A. coluzzii* Coetzee et al., 2013 and *A. arabiensis* Patton, 1905) that differ in behaviour and thus in medical importance. Allele exchanges between these malaria vectors have been found to involve most of their autosomal genes, it is therefore possible that traits enhancing vectorial capacity may be gained through interspecific gene flow.

## SPECIATION

Sooner or later, the taxonomist must confront the issue of speciation, traditionally a focal issue

in evolutionary biology, thus basically approached through the tools of population genetics. Eventually, even the good practicing taxonomist who is happy applying Regan's (1926) morphological species concept (cf. Table 1) is brought by the intricacies of his/her study material to admit how right was Darwin when he acknowledged that "*No line of demarcation can be drawn between species ... and varieties*" (Darwin, 1859, p. 469). It is beyond the scope of this article to present here even a short summary of current awareness, and current debates, on the issue of speciation. The interested reader is referred to Coyne & Orr's (2004) monograph, which is both a synthesis of modern understanding of speciation problems, a guide to older literature and a solid background against which to read the literature of the last decade. I will thus skip the traditional main issues, beginning with the geographic scenarios of speciation (allopatric, parapatric, sympatric). I will only glean from the very recent literature some exemplary cases that show how cautious should be the taxonomist in front of the temporal and spatial change to which natural populations are subjected. The more we know about these aspects, the more critical should be our attitude towards a taxonomic delimitation of species.

A first warning concerns the tempo of evolution. An unwarranted generalization of Darwin's depiction of evolution as proceeding through the gradual accumulation of changes happening at a very slow and essentially uniform pace led in the past to assume that a speciation event should take on the average some hundred thousand years or more. There is no reason, however, for us to expect that living nature adopts an essentially uniform pace of change. Indeed, we have now well-documented proofs of very rapid speciation events, and also of extremely conservative species pairs whose remote splitting is concealed under an amazing degree of morphological stasis. As a consequence, the taxonomist must be cautious in inferring relatedness from morphological, ecological or biogeographic evidence without the further support of molecular estimates of divergence times.

Consider, for example, that the divergence between two species of amphioxus, both currently classified in the same genus, *Branchiostoma floridae* Hubbs, 1922 and *B. lanceolatum* (Pallas, 1774), has been estimated at 186–189 million

years (Cañestro et al., 2002), whereas the origin of the whole radiation of extant Brassicaceae (3709 species; Warwick et al., 2006) is probably not older than 40 million years (Couvreur et al., 2010; Franzke et al., 2011), and perhaps even younger, around 16 million years (Franzke et al., 2009). This can be compared to the 22.4 million years through which the hummingbirds (338 living species) have been apparently radiating from their last common ancestor (McGuire et al., 2014). Still very long times, indeed, if compared to the 100 000 years, or so, within which the cichlids of Lake Victoria have radiated into a species flocks of five hundred species at least (Verheyen et al., 2003; Genner et al., 2007).

## GENES INVOLVED IN SPECIATION

Research on the genes more directly involved in speciation is attracting increasing interest, but convincing generalizations are still difficult to obtain.

Problems in fixing the boundary between two closely related taxa that broadly, but not completely exhibit the character of distinct species are often due to the fact that some parts of their genome are more readily and extensively affected by introgression, whereas other parts are much more resilient. A classic case – Carrion Crow (*Corvus corone* Linnaeus, 1758) vs. Hooded Crow (*Corvus cornix* Linnaeus, 1758) – has been carefully investigated by Poelstra et al. (2014). These authors have found that only a small number of narrow genomic islands are not affected by gene flow. As mirrored by these birds' livery, gene expression divergence between them is concentrated in pigmentation genes expressed in gray versus black feather follicles. Despite its limited genetic basis, this trait is critically important, however, as it affects mate choice and thus color-mediated prezygotic isolation.

In pairs of stick insect populations adapted to different host plants and undergoing parallel speciation, Soria-Carrasco et al. (2014) found thousands of small genomic regions, most of which unique to individual population pairs, to be significantly diverging between populations. These authors have also detected parallel genomic divergence across population pairs involving an excess of coding genes with specific molecular functions.

## STABILITY OF SPECIES IN THE FACE OF INTROGRESSION

While the existence of introgression between locally sympatric related species is well documented in a large number of animals and plant species pairs, very little is known about the long-term effects of a gene flow continuing over centuries. A recent study of two widely hybridizing tree species, the white spruce (*Picea glauca* (Moench) Voss) and Engelmann spruce (*P. engelmannii* Parry ex Engelm.) in western North America, suggests that these two species have a long history of hybridization and introgression, dating to at least 21 000 years ago, nevertheless they still maintain their distinct species identity (De La Torre et al., 2014).

The boundaries between closely related species are sometimes permeable in one direction only. For example, brown bear (*Ursus arctos* Linnaeus, 1758) and polar bear (*Ursus maritimus* Phipps, 1774) are genetically distinct, but evidence of polar bear genes has been found in the brown bear population of the Admiralty, Baranof and Chicagof Islands off Alaska, whereas no evidence of brown bear genes has been found in the local polar bear population (Cahill et al., 2015). Another example of asymmetric introgression has been recently described between a pair of freshwater fish, the North American darters *Etheostoma caeruleum* Storer, 1845 and *Etheostoma spectabile* (Agassiz, 1854) (Zhou & Fuller, 2014).

## HYBRIDIZATION

Opportunities for hybridization between closely related biological species are not restricted to species pairs that have been diverging only in recent time, witness a fern from the French Pyrenees (*Cystocarpium x roskamianum* Fraser-Jenk), a recently formed hybrid whose parental lineages diverged from each other ca. 60 million years ago, and are currently classified in different genera (*Cystopteris* and *Gymnocarpium*) (Rothfels et al., 2015).

Due to both climatic and biological reasons, hybrid zones are not fixed in space. Detailed evidence of moving hybrid zones has been summarized by Buggs (2007) for the following pairs of taxa (nomenclature updated where necessary):

## MAMMALIA

*Cervus nippon nippon* Temminck, 1838 - *Cervus elaphus* Linnaeus, 1758

## AVES

*Poecile carolinensis* (Audubon, 1834) - *Poecile atricapillus* (Linnaeus, 1766)

*Hippolais polyglotta* (Vieillot, 1817) - *Hippolais icterina* (Vieillot, 1817)

*Vermivora pinus* (Linnaeus, 1766) - *Vermivora chrysoptera* (Linnaeus, 1766)

*Corvus corone corone* Linnaeus, 1758 - *Corvus corone cornix* Linnaeus, 1758

*Quiscalus quiscula quiscula* (Linnaeus, 1758) - *Quiscalus quiscula versicolor* Vieillot, 1819

## SQUAMATA

*Pholidobolus montium* (Peters, 1863) - *Pholidobolus affinis* (Peters, 1863)

*Sceloporus tristichus* (Cope, 1875) - *Sceloporus cowlesi* Lowe et Norris, 1956

## AMPHIBIA

*Pseudophryne bibroni* Günther, 1859 - *Pseudophryne semimarmorata* Lucas, 1892

*Triturus cristatus* Laurenti, 1768 - *Triturus marmoratus* (Latreille, 1800)

*Plethodon glutinosus* (Green, 1818) - *Plethodon jordani* Blatchley, 1901

## OSTEICHTHYES

*Pseudorasbora parva* (Temminck et Schlegel, 1846) - *Pseudorasbora pumila* Miyadi, 1930

## INSECTA

*Heliconius hydara* Hewitson, 1867 - *Heliconius erato petiverana* (E. Doubleday, 1847)

*Anartia fatima* (Fabricius, 1793) - *Anartia amathea* (Linnaeus, 1758)

*Solenopsis invicta* Buren, 1972 - *Solenopsis richteri* Forel, 1909

*Orchelimum nigripes* Scudder, 1875 - *Orchelimum pulchellum* Davis, 1909

*Allonemobius socius* (Scudder, 1877) - *Allonemobius fasciatus* (De Geer, 1773)

*Limnaporus dissortis* (Drake et Harris, 1930) - *Limnaporus notabilis* (Drake et Hottes, 1925)

*Geomydoecus aurei* Price et Hellenthal, 1981 - *Geomydoecus centralis* Price et Hellenthal, 1981

## CRUSTACEA

*Orconectes rusticus* (Girard, 1852) - *Orconectes propinquus* (Girard, 1852)

## ANGIOSPERMAE

*Helianthus annuus* L. - *Helianthus bolanderi* A. Gray

*Mercurialis annua* L. diploid - *Mercurialis annua* L. hexaploid

Occasionally, the peculiar geographical distribution of a set of populations offers the opportunity to investigate different stages of an ongoing speciation process. This happens with the so-called ring species, where the two extremes, say A and E, of a series of progressively differentiated populations have recently come in contact but fail to interbreed. This happens generally when the whole complex is distributed, ring-like, around an inhospitable area, such as very high mountains, or an exceedingly arid area. Ring species are extremely rare in plants: recently, Cacho & Baum (2012) have presented the Caribbean slipper spurge (*Euphorbia tithymaloides*) as the first example among the flowering plants. More numerous are the zoological examples, as summarized by Irwin et al. (2001). These authors listed seventeen examples where the populations at the opposite ends of the chain overlap without any sign of hybridization, or nearly so. In many cases the two extreme forms have been given distinct specific names, whereas in other cases taxonomists still treat all the populations involved in the ring as belonging to the same Linnaean species: one example, among a number of possible ones, of the danger of inferring evolutionary status from simply considering the current taxonomic status (i.e., the nomenclature) of a set of populations.

Irwin et al.'s (2001) list includes a number of birds: Crested Honey-buzzard *Pernis ptilorhynchus* (Temminck, 1821) and Barred Honey-buzzard *P. celebensis* Wallace, 1868; Herring Gull *Larus argentatus* Pontoppidan, 1763 and Lesser Black-backed Gull *L. fuscus* Linnaeus, 1758 (with some hybridization); Ringed Plover *Charadrius hiaticula* Linnaeus, 1758 and Semipalmated Plover *C. semipalmatus* Bonaparte, 1825; Collared Kingfisher *Todiramphus chloris* (Boddaert, 1783) and Micronesian Kingfisher *T. cinnamominus* (Swainson, 1821); Eurasian Skylark *Alauda arvensis* Linnaeus, 1758, Japanese Skylark *A. japonica* Temminck et Schlegel,

1848 and Oriental Skylark (*A. gulgula* Franklin, 1831); Greenish Warbler *Phylloscopus trochiloides* (Sundevall, 1837); Chiffchaff *Phylloscopus collybita* (Vieillot, 1817) and Mountain Chiffchaff (*P. sindianus* W. E. Brooks, 1880); Sulawesi Triller *Lalage leucopygialis* Walden, 1872, Pied Triller *L. nigra* (J. R. Forster, 1781), and White-shouldered Triller *L. sueurii* (Vieillot, 1818); Brown Thornbill *Acanthiza pusilla* (Shaw, 1790) and Tasmanian Thornbill *A. ewingii* Gould, 1844; Large Tree-finch *Camarhynchus psittacula* Gould, 1837 and Medium Tree-finch *C. pauper* Ridgway, 1890.

The other taxa in the list are rodents (Deer Mouse *Peromyscus maniculatus* (Wagner, 1845); Pocket Mice *Perognathus amplus* Osgood, 1900 and *P. longimembris* (Coues, 1875), a bee *Hoplitis producta* (Cresson, 1864), a group of butterflies *Junonia coenia* Hübner, [1822] and *J. genoveva* (Cramer, 1780)/*J. evarete* (Cramer, 1782)) and a fruit fly (*Drosophila paulistorum* Dobzhansky et Pavan, 1949).

In the case of the salamander *Ensatina eschscholtzii* Gray, 1850, some hybridization between the end forms of the ring has been reported, and past but still recognizable hybridization has been found in the ring of the Japanese pond frogs *Rana nigromaculata* Hallowell, 1861 and *R. brevipoda* Ito, 1941.

In still other cases, there is no reproductive isolation between the two, now overlapping, terminal forms of the ring; as a consequence, a hybrid zone is formed. The cases listed by Irwin et al. (2001) include birds Crimson Rosella *Platycercus elegans* (Gmelin, 1788), Adelaide Rosella *P. adalaidae* Gould, 1841, Yellow Rosella *P. flaveolus* Gould, 1837, Great Tit *Parus major* Linnaeus, 1758, a mammal House Mouse *Mus musculus* Linnaeus, 1758 and two millipedes *Rhymogona silvatica* (Verhoeff, 1894) and *R. cervina* (Verhoeff, 1910).

Several ring species (putative ones as well as confirmed ones) have been extensively studied over the last few years. No wonder, the actual interrelationships among the involved populations are often more complex than in the simple model outlined above. For example, in the case of the Greenish Warbler *Phylloscopus trochiloides* (Sundevall, 1837) species complex Alcaide et al. (2014) have recently revisited the status, and the history, of the ring of populations distributed around Tibet. The two extreme, reproductively isolated forms co-existing in central Siberia are connected through a

southern chain of populations showing a gradient of genetic and phenotypic traits. The authors demonstrate that the gene flow has been interrupted in the past at more than one location around the ring, whereas the two Siberian forms have occasionally interbred. Eventually, this little bird displays a continuum from slightly divergent contiguous populations to almost fully reproductively isolated species.

## RETICULATION

Patterns of hybridization and introgression among closely related taxa take sometimes a reticulated structure. A recently investigated example involving the biogeographical history of the Eurasian species of *Fraxinus* has revealed the occurrence of an ancient reticulation between European and Asian species as well as other ancient reticulation events between *F. angustifolia* Vahl and *F. excelsior* L. and the other species of the section *Fraxinus*. Some of these events would have occurred during the Miocene, following climatic variations that may have led these species to expand their distribution range, eventually coming into contact (Hinsinger et al., 2014).

## SPECIATION REVERSED

Incomplete speciation and ongoing gene flux between partially isolated populations may cause divergence to be stopped and even reversed. Well-documented cases of reversed speciation are, however, very limited. An example has been described by Bhat et al. (2014) for the European whitefish *Coregonus lavaretus* (Linnaeus, 1758), of Lake Skrukkebukta in Northern Norway. This freshwater fish is highly polymorphic and in several lakes it has independently differentiated into sympatric morphs that specialize on different food (plankton vs. benthos) and are to some extent reproductively isolated and genetically differentiated. In 1993, Lake Skrukkebukta was invaded by another *Coregonus* species, the vendace *Coregonus albula* (Linnaeus, 1758). A zooplanktivorous specialist, this fish displaced the planktivorous whitefish from the pelagic niche pushing it into the benthic habitat already inhabited by the benthivorous whitefish morphs. As a consequence, within three generations

(15 years) the genetic differentiation between the two whitefish morphs has dramatically dropped: the invasion of a superior trophic competitor has thus caused incipient speciation to reverse. An overview of cases of speciation reversal was provided a few years ago by Seehausen et al. (2008).

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# The town as a concentrated source of reclaimable water and materials. Opportunities for an engineered conservation strategy

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## ABSTRACT

A fierce theoretical debate is ongoing about the human species' existence itself being sustainable for Earth and for living world. In the meanwhile cities, which are considered to concentrate the mankind's ecological footprints, are steadily growing and gathering huge populations worldwide. This paper assumes that margins do exist to relieve man's burden on Nature to some extent, and that, regardless of our general concept of the matter, these margins should be exploited. The focus of this note is on beneficial use of waste water and waste to spare new resources and to create filter areas close to towns or belts around them. A brief reference is made to some official declarations and indices published on biodiversity in anthropic environments, such as the one from UNEP.

## KEY WORDS

Anthropic environments; Biodiversity; City planning; Resources; Urban Ecology.

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## INTRODUCTION

Exactly forty years have elapsed since the issue of the ever most popular synthesis of criticism to unrestrained use of resources (Meadows et al., 1974). Pressure and unbalancing actions on natural cycles have not relented yet; and much of them are debited to cities, the exemplar man-made environment. It is documented that actually cities are steadily growing worldwide (WHO, 2014). The urban population in 2014 accounted for 54% of the total global population, up from 34% in 1960; with all the related needs for areas, for every kind of supplies and for waste management.

At least relieving measures are due and urgent, and some of them were envisaged as early as 1971 by Odum E.P. (1969) and by Odum H.T. (1983). It is still a matter of debate whether a urban ecology

can exist, and, if it can, whether it obeys to the general laws of ecology or to its own special rules. Anyway, in a pragmatic approach at least some indicators and indices ought to be agreed, in order to give a transparent measure of the environmental benefits achieved through certain actions.

## CITIES, MANKIND AND RESOURCES

Historically, villages, towns and cities have been made by men for themselves

- to develop broader and more free exchanges of goods, manpower and skills
- to find customers for technological artefacts
- to benefit of more qualified services; of medical care; of higher education
- to build up wealth
- to feel safer, etc.

Cities obviously use land that often formerly belonged to some other species. The ratio (covered area/people living in) can actually be lower in towns made of tall buildings than in sprawled ones; indeed, this was the concept of Le Corbusier and other architecture Masters. Denser towns, however, have less possibilities of growing orchards, vegetable gardens, firewood lands, fisheries, etc.; so they need to fetch resources from far, unless flat roofs are used to this purpose. The two arrangements can obviously coexist in different quarters of the same town (Fig. 1).

Cities necessarily draw most of the resources they need from far; freshwater first. Figure 2 shows the orders of magnitude of the materials and energy exchanges of a middle capital town peopled by about 600 000, *per annum*.

Is hardly possible that the used resources can be given back to their sources or original places or states. Restitution is usually not feasible because, for instance: water is drawn from higher elevation sources and discharged into lower water bodies; foodstuffs are partly simply eaten, partly discarded; energy is downgraded in its use.

### DOES URBAN CIVILIZATION NECESSARILY THREATEN BIO-DIVERSITY? COULD IT BE HELPFUL IN SOMEWAY?

It is likely that diversity decreases where and when

- a portion of a vital primary resource, e.g., high quality water, is diverted;

- great amounts of secondary resources such as wastewater and organic matter, although treated, are discharged into limited seawater volumes;
- nuisances like warming; lighting; noise; men's stamping on, or walking through; traffic; navigation etc. advantage opportunistic species like rats, wasps, seagulls, ravens, magpies and drive away the most sensitive ones.

Some blames to towns, however, appear still ill-founded. As for now it looks more an article of faith than a demonstrated and explained fact, that at sea the outfall of a constant - discharge sewer after treatment; or a storm sewer; would generate more harmful gradients of salinity and turbidity, than a river with its natural alternation of dry-weather flows and flood flows.

Some positive effects that a well intentioned town can develop towards wildlife are:

- Storing fresh water and, possibly, treated wastewater, smoothening floods/droughts
- Mitigating climate through managed green areas, leading to less ecological stress
- Providing shelter to timid species
- Pouring organic matter in oligo-trophic biotopes, resulting in an enhanced food pyramid.

The debate on urban civilization against biodiversity urges us to define - in a really scientific and consistent way - what the civilization could be like; how much of resources it strictly ought to require/use; and how bio-diversity is to be quantified (@suitable Indicators and Indices).

The concept of integrating town and nature through filter ecosystems was enunciated and gradually better defined in the Seventies by Odum



Figure 1. A historical walled town (left) with its circular gradient of buildings, green belt and surrounding countryside; a modern town (right) with regulated quarters planned for different functions.

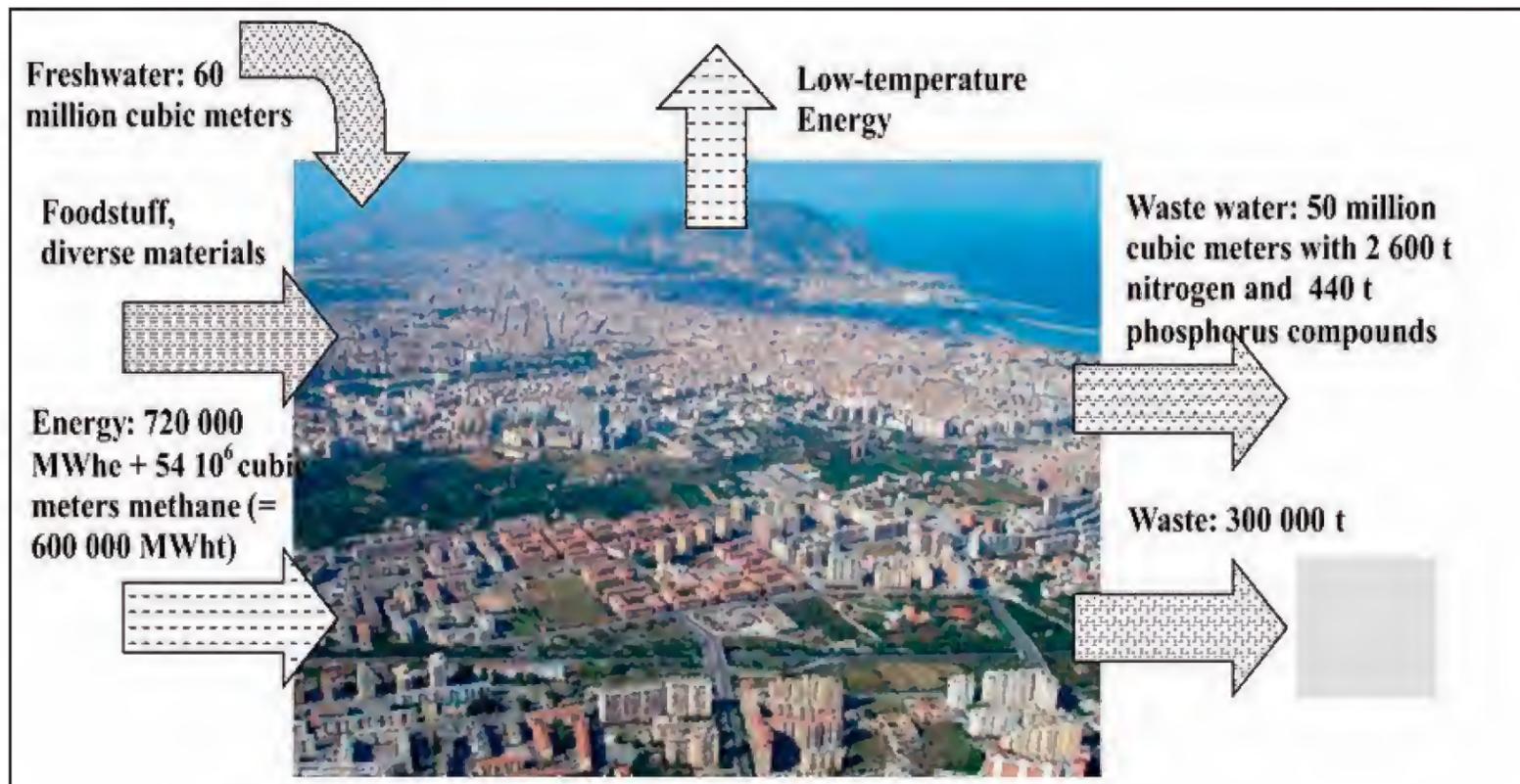


Figure 2. The city of Palermo as a case-study: some major flows of materials and energy (civil uses only).



Figure 3. Left: The reservoir Piana degli Albanesi (610 m above sea level) is a multi-purpose water source for uses in the plain of Palermo. Right: Example of heat losses in old-fashioned, low-tech town heating systems.

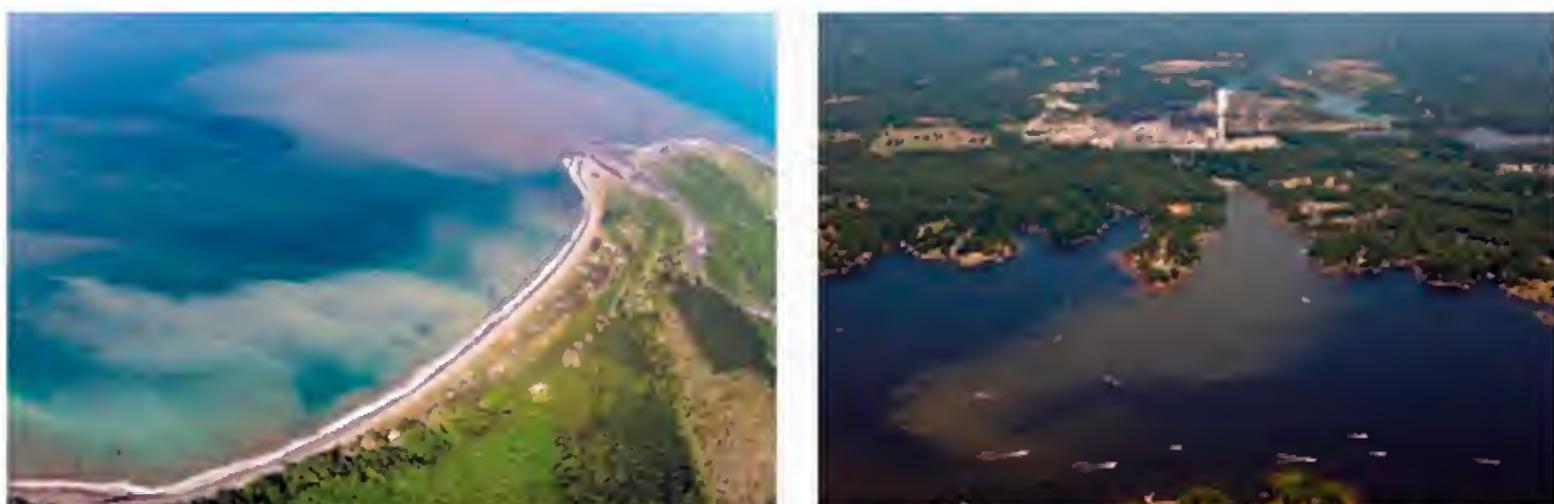


Figure 4. Plume of suspended solids at the mouth of a river (left) and flowing out from an on-shore outfall (right).

E.P. (1969) and by Odum H.T. (1983). Naveh (1982) used the term techno-ecosystem to represent systems where technology and ecology are associated. These are the realm of ecological engineering. Figure 5 suggests a possible application of these concepts.

### THE ACTUAL ORDERS OF MAGNITUDE

A medium-large town can provide, to itself and to its surroundings, treated wastewater enough to turn a squalid channel into a 2 m<sup>3</sup>/s steady flow watercourse; or 100 hectares brownfield into a wetland. This benefit is not entirely free, since 1 m<sup>3</sup> treated wastewater contains the embedded energy of about 0.4 kWh; but most of this amount should have been expended anyway, just to meet the quality requirements at the discharge point.

The same town can also provide to itself and to its surroundings 40 000 t compost: enough for 2 ÷ 4 000 hectares soil being annually amended. What to do with such engineered ecosystems is to the environmental biologists' expertise.

Two vast chapters apart are those of green roofs and of underwater barriers laid for aquatic fauna breeding and growing.

Green roofs can control urban climate; reduce and smoothen water runoff; give shelter and ecological corridors to animals and spontaneous plants, and more; provided that mechanical energy (usually drawn as electrical, actually) is supplied to lift stored rainwater from the underground reservoirs. Underwater barriers have been experienced, investigated and discussed too much for requiring treatment here.

### RESHAPING TOWNS AND SETTING THEM TO WORK FOR NATURE. INDICATORS AND INDICES OF ACHIEVEMENTS

Since urbanization is fundamentally changing the nature of our planet, preserving biodiversity on this new urban world requires going well beyond the traditional conservation approaches of protecting and restoring what we think of as "natural ecosystems," and trying to infuse or mimic such elements in the design of urban spaces.

After two official sources: CBD - the UN's Convention on Biological Diversity; and the Working Group CBO - Cities and Biodiversity Outlook; "... *unprecedented opportunities lie ahead in making urban expansion greener. Cities have a large*

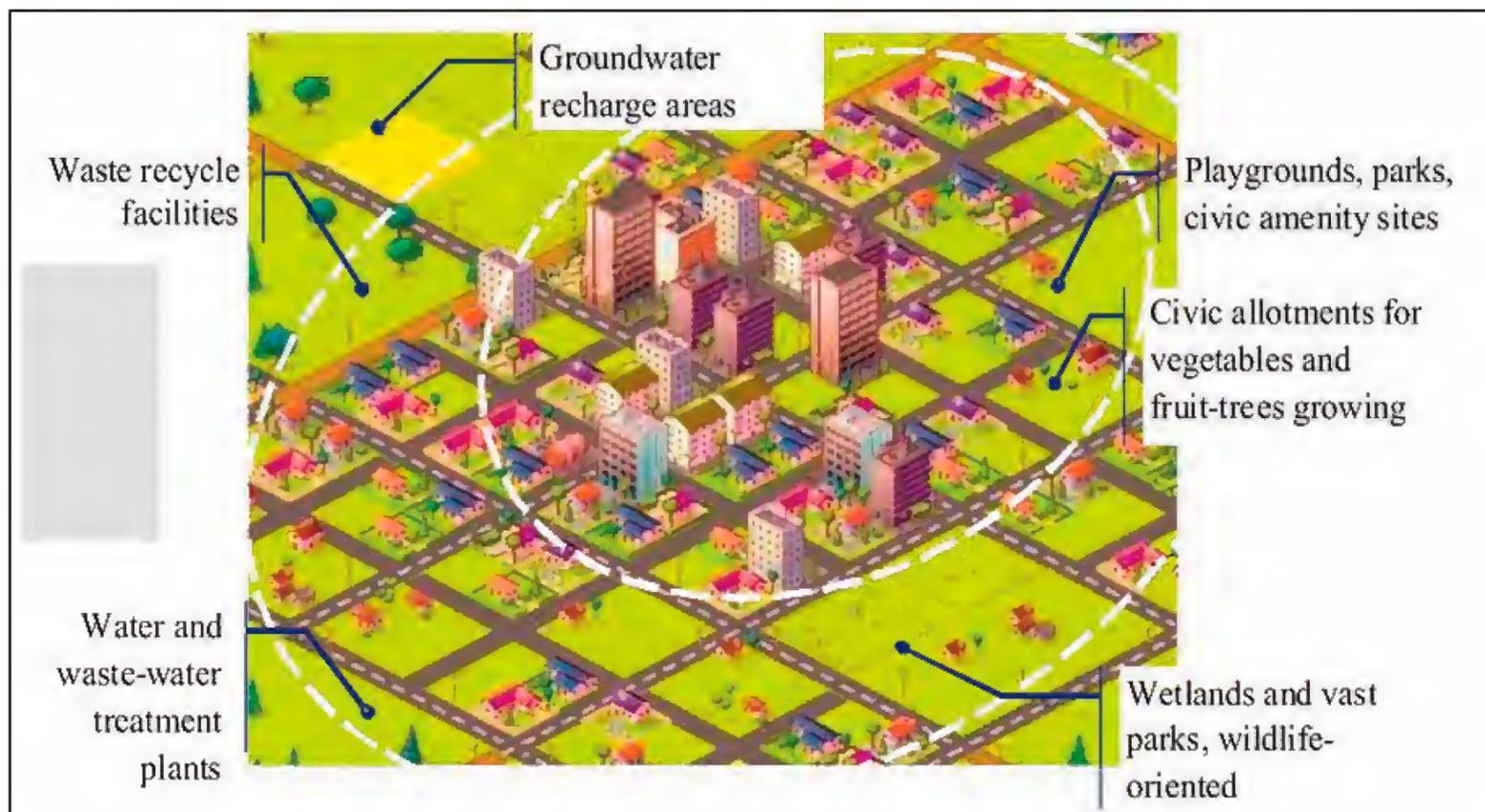


Figure 5. A urban area featuring an inner and an outer ecological filter areas, plus one filter belt in between.

*potential to generate innovations and governance tools and therefore can, and must, take the lead in sustainable development. Many of the opportunities can be found in nature based solutions, using ecosystems in novel ways to address some of the most pressing challenges, such as climate change, water and food security, and poverty relieving. The way forward involves reimagining cities as places of biodiversity, and as sources for unique valuable services, rather than only sinks that mark large ecological footprints.”*

After CBO (based at Stockholm University, SE), rich biodiversity can exist in cities; but it cannot be taken for granted that it will be the same as before urbanization. Habitat conversion often leads to the loss of “sensitive” species dependent on larger, more natural clusters of habitat for survival.

Cities already represent in themselves a new class of ecosystems shaped by the dynamic interactions between ecological and social systems. There is a suite of “cosmopolitan” species, skilled generalists that are present in most cities around the world. The net result is sometimes termed “biotic homogenization.”

It is still a matter of debate whether a urban ecology can exist, and, if it can, whether it obeys to the general laws of ecology or to its own special

rules. Anyway, in a pragmatic approach at least some indicators and indices ought to be agreed, in order to give a transparent measure of the environmental benefits achieved through certain actions.

Among the indicators of diversity we will cite here the Singapore Index (SI), 2008.

This is a self-assessment tool for cities to benchmark and monitor the progress of their biodiversity conservation efforts against their own individual baselines.

It comprises:

- a) the “Profile of the City”, which provides comprehensive background information on the city;
- b) 23 indicators based on the guidelines and methodology provided.

The scoring of the Index is quantitative in nature; a maximum score of 4 has been allocated to each indicator, and with the current count of 23 indicators, the total possible score of the Index is 92 points.

The year in which a city first undertakes this scoring program will be taken as the baseline year. The future applications of the index will be measured against the baseline to chart its progress in conserving biodiversity.

For 7 of the indicators, a statistical treatment will be applied to sample data sets coming from



Figure 6. A possible ecological succession for derelict land turned into wetland.



Figure 7. Left to right, clockwise: windrow composting; compost handling; plant germination.

several cities, to ensure the scoring ranges established are unbiased and fair to a broad spectrum of cities of different characteristics, over a wide geographical range.

### URBAN ECOLOGY; GOVERNING BIODIVERSITY IN CITIES: A NOBLE COMMITMENT OR A PURE DREAM?

We have now to look at the frame within which the actions for a sustainable town are developed, in order to judge about the theoretical substantiation of them and to forecast how far the pragmatic approach outlined above can arrive.

Among the optimistic sources we are quoting here a statement from CBO: “*There is a need for redefining the role of cities so that they increasingly provide stewardship of marine, terrestrial and freshwater ecosystems elsewhere. Developing the concept of nature based - solutions entails exploring a deeper dimension of how attributes of ecosystems, such as diversity, modularity and redundancy may be interpreted, applied and used*”.

Another affirmative statement comes from Jari Niemelä (1999): “*The question arises whether a distinct theory of urban ecology is needed for understanding ecological patterns and processes in*

*the urban setting. The answer is no; however, due to the intense human presence approaches that include the human aspect are useful in studying urban systems*”.

Collins et al. (2000) raise serious doubts and develop a strong criticism of these perspectives. For these Authors, in studying urban systems the intense human presence certainly obliges to approaches that include the human aspect; still, even such tentative integrated approaches could reveal themselves a dead way. Quoting the Collins’ words: “*From the perspective of a field ecologist examining a natural ecosystem, people are an exogenous, perturbing force. Human beings - and especially their cities, seemingly so "artificial"- fail to fit neatly into ecological theory. People mobilize some nutrients and deplete others, produce pollutants, drive species extinct, promote the survival of others, change the composition of the atmosphere and alter landscapes. In cities people create habitats that never before existed, divert water, increase temperatures and, by intent or by accident, manipulate the communities of other species found within city boundaries and beyond (...)*”.

Still after Collins and coworkers, “*We lack a method of modelling ecosystems that effectively incorporates human activity and behaviour. And the processes and dynamics within cities largely elude*

CBI	COMPONENTS	INDICATORS	VARIABLES	SCORE	MAXIMUM
	1. Native Biodiversity in the City	<p><b>(IND.2) Diversity of ecosystems</b></p> <p><u>RATIONALE FOR SELECTION OF INDICATOR</u></p> <p>The number of natural ecosystems found in a city gives an indication of the diverse range of niches for native flora and fauna. Since different ecosystems are found in different geographical regions, any scientifically acceptable terrestrial and marine ecosystems, including forests (tropical, subtropical, monsoon, temperate, lowland, montane, primary, secondary, etc.), mangroves, freshwater swamps, peat swamps, natural grasslands, rivers, streams, lakes, rocky shores, beach, mud-flats, sand dunes, sea grass beds, corals, etc., can be computed in the calculation of this index.</p>	<p><b>(IND.2) Diversity of ecosystems</b></p> <p><u>HOW TO CALCULATE INDICATOR</u></p> <p>Number of natural ecosystems found in the city</p> <p><u>WHERE TO GET DATA FOR CALCULATIONS</u></p> <p>Possible sources of data on natural areas include government agencies in charge of biodiversity, city municipalities, urban planning agencies, biodiversity centres, nature groups, universities, publications, etc.</p>	<p><b>(IND.2) Diversity of ecosystems</b></p> <p><u>BASIS OF SCORING</u></p> <p>A) Based on the estimation that realistically, any city can accommodate to about 10 natural ecosystems, within its boundaries, the scoring would be</p> <p>0 point - 0 natural ecosystem                      1 point - 1-3 ecosystems                      2 points - 4-6 ecosystems                      3 points - 7-9 ecosystems                      4 points - 10 and more ecosystems</p> <p>B) Baseline of 100</p> <p>C) Traffic line system of increase, neutral and decrease</p>	<p><b>(IND.2) Diversity of ecosystems</b></p> <p><u>MAXIMUM SCORE</u></p> <p>4</p> <p><b>(IND.2)</b></p>

Table 1. The Singapore Index (SI): example of the working tables: a local ecosystems inventory.

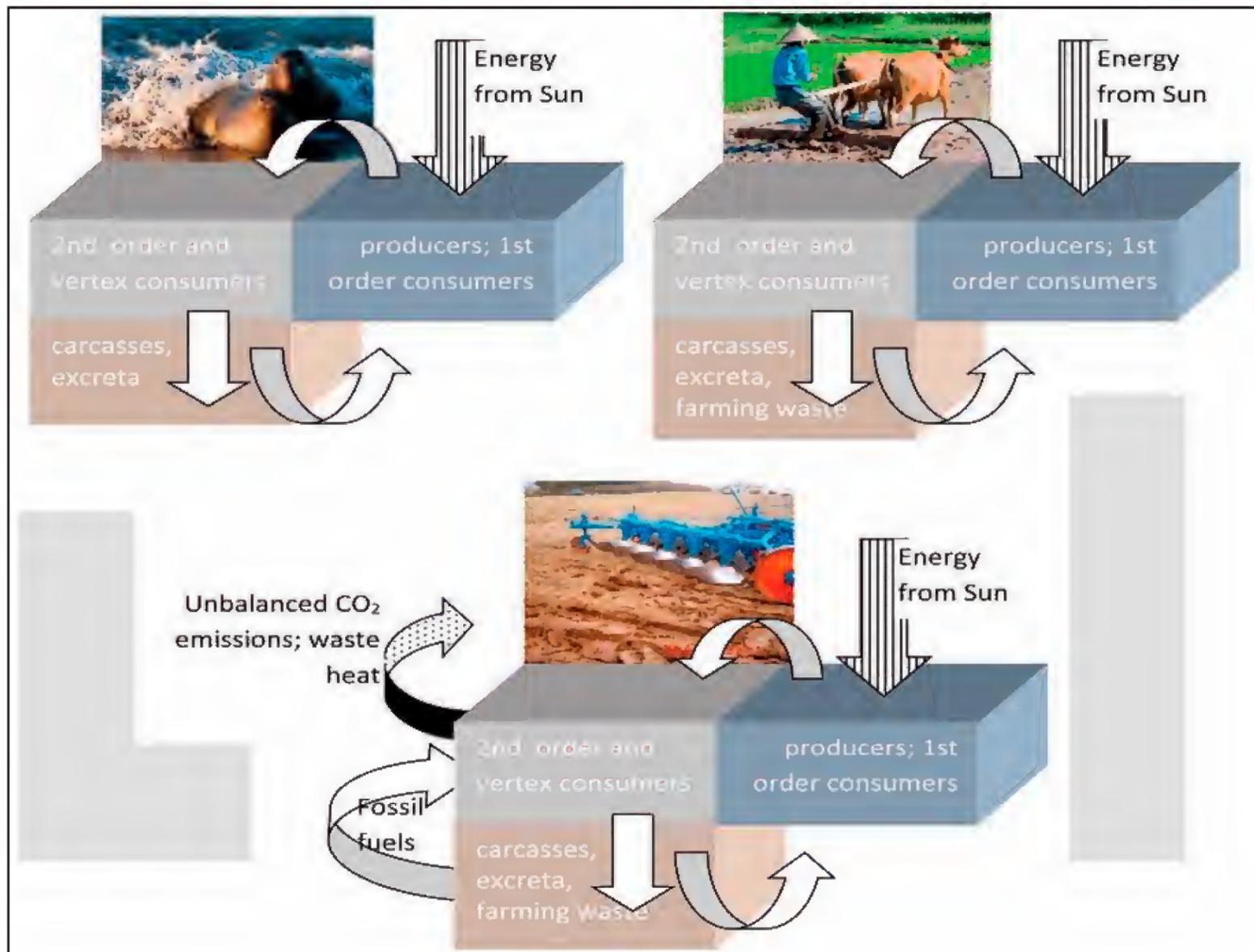


Figure 8. Three types of heterotrophic system (the one upper left in every picture) and their relationships with the surroundings. Tapping of fossil fuels to feed mechanical farming makes the main difference between the three.

*an understanding based on traditional ecological theories.*

*For most [natural] ecosystems the overall calculation is fairly well balanced between inputs and outputs. Urban energy budgets [instead], dominated as they are by deliberate human energy imports and by losses via fossil-fuel burning, do not resemble the energy budgets of any other ecosystem on earth".*

Figure 8 is an attempt to depict this concept.

## CONCLUSIONS

Much of the blame put on town ought actually to be put on the human way of life.

We believe that man, as a second-level or vertex consumer, is by no means the only species on Earth whose life is heterotrophic, or that lives in crowded communities.

It is true that his weaknesses (like the need for shelter and warmth and the inability to nourish himself of raw food) and his strengths (such as his unique ability to handle fire, and to make, build up and transfer knowledge, etc.) are peculiar. All this increases the singularities of mankind, but in our opinion does not entail any definition of supposed peculiar human ecological niches.

The only fundamental difference that we see stays in that, that men are not innocent in their behaviour, and ecological feedbacks to their actions are usually overbalanced by their obstinacy. Mankind usually neglects or denies the biosphere's response to its actions, and, if compelled, is more willing to force further than to ease. The renounce to such unjustified self-exemption from taking feedbacks into account; and a consistent commitment in respecting and saving the other species' lives and spaces, even in towns, at least as a mitigation measure, is the tribute that mankind still owes to Nature.

*The Author's speech was dedicated to the luminous memory of Giovanni Falcone and Francesca Morvillo Falcone, and of the men of their escort. Fallen at Capaci, Palermo, May the 23rd, 1992.*

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# **Pest management of citrus fruits in Sicily (Italy) through interventions of biological control. The example of the biofactory of Ramacca, Catania**

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## **ABSTRACT**

Since 2007, in Sicily, plant health protection against citrus mealybugs is taking place through the Biofactory of Ramacca, in the Plain of Catania, a property of the Institute for Agricultural Development of the Sicilian Region (i.e. Ente per lo Sviluppo Agricolo, E.S.A.). The Biofactory is unique being aimed to produce industrial quantities of auxiliary insects and is a center of European interest because it is fully organized to provide means of biological fight imposed by the Directive 128/2009/EC, which requires, from 1 January 2014, farms to comply with the application of general principles of integrated pest management. In this paper we examine structural features of the Biofactory, breeding techniques employed and results obtained in the period 2007–2013, which allowed many companies, from 200 to 360 (i.e. 20%–35% of the regional surface operating in organic citrus production) to be able to employ biological weapons against pest insects. We analyze dynamics and results of production deriving from the approval and adoption, by the owner (E.S.A.), of a new "discipline" that governs the assignment of insects to farmers at a very low price to balance E.S.A.'s purposes, which is both to ensure adequate performance in order to pursue institutional support to agriculture and, considering the Institute's economic nature, to partially cover the production costs incurred to ensure the service. The continuity of the project is assured by the ongoing program for the period 2013–2020 with an enlargement of the array of entomological production aimed at intercepting the needs of new productions (i.e. greenhouse horticulture, vines, ornamental and fruit trees).

## **KEY WORDS**

pest management; biological control; Biofactory; Ramacca; Sicily.

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## **INTRODUCTION**

A biofactory (or commercial insectary) is a structure in which takes place the breeding of arthropods on an industrial scale, aimed at the production of living organisms to be released in large amounts into the environment in the context of techniques of biological control and integrated pest management. On the contrary, the insectary is

a breeding realized for scientific purposes.

The multinationals of chemistry have never seen welcome the birth of biofactories, because the organic product stands as alternative to the use of pesticides (Tremblay, 1988; Pollini et al., 1988; Goidànich et al., 1990; Flint, 1991; Grafton-Cardwell & Reagan, 1995; Pollini, 1998; Ferrari et al., 2000, 2006; Masutti & Zangheri, 2001; Muccinelli, 2006; Penny & Cranston, 2006).

There are reports of a first biofactory already in 1916 in Santa Paula, California, the "Limoneira Company". In 1931, there were 16 and produced especially insects antagonist to citrus mealybugs like the coccinellid *Cryptolaemus montrouzieri* that is bred and successfully launched today.

In Northern Europe biofactories are used for biological control in greenhouses: here the chemical control had shown its serious limitations in the effectiveness of and compatibility with healthy products. In fact, the glass or plastic covers are an insurmountable physical barrier for antagonists of harmful species, warming accelerates the development of both plants and pests, the collection of the products can not be reconciled with respect to the "waiting period" fixed by law between chemical treatment and collection and, not least, greenhouses turn out to be "gas chambers" for the farmers who work therein.

A careless use of chemical products in agriculture with the aim to maximize the production has led over the years to a number of disorders that have resulted in considerable damage to the environment and to humans. Many chemicals have been banned and the defense of the plants has been oriented to the use of alternative methods equally effective and safeguarding the ecosystems (De Bach et al., 1969; Viggiani, 1977; Chiri, 1987; Walde et al., 1989; Celli et al., 1991; Hoffmann & Frodshan, 1993; Luck et al., 1996; Murdoch et al., 1996; Ferrari, et al., 2000; Vacante & Benuzzi, 2004; Sorribas et al., 2008, 2010; Tena & Garcia-Mari, 2011).

The first biofactories in Europe born in England and Holland around 1960 and, since then, have always grown both in number and in quantity of species bred and used. Today in Europe there are 26 biofactories with more than 30 species raised and excellent qualitative-quantitative standards.

In Italy there are only two biofactories: the first (in order of construction) is in Cesena (1987/90) while the second is in Sicily, in the Plain of Catania (Figs. 1, 2) in the territory of Ramacca (2001/03) (Greco 2014a, b). The latter is mainly distinguished by the quality and quantity of its products supplied aiming more at the diffusion of breeding techniques rather than for commercial purposes. Both biofactories serve an agricultural area which is considerably increasing in size, and achieve agricultural productions with the least possible impact on the territory, sustainable for the planet, whereas in other parts of the world, biological control has totally replaced chemical poisons.

Yet here, in the Mediterranean, people are not deeply aware of the benefits of this resource and the many solutions it offers, but the products of a biofactory are going to become even more relevant in the light of Directive 128/2009 / EC establishing a framework for Community action to achieve a sustainable use of pesticides.

This Directive was transposed into Italian law by Legislative Decree 150 of 14 August 2012. Since 1 January 2014, professional users of phytosanitary products (art. 19) should apply the general principles of integrated pest management required



Figure 1. Biofactory of Ramacca, Catania, Italy, Institute for Agricultural Development of the Sicilian Region (E.S.A.).



Figure 2. Biofactory of Ramacca, Catania, Italy: biofactory corridor.

among which is reported, as technical and fundamental element, the use of biological means of struggle.

## EXPERIENCE IN SICILY, AT THE CENTER OF THE MEDITERRANEAN: THE BIOFACTORY OF RAMACCA

In 1996 the Sicilian Region has commissioned the Institute for Agricultural Development (i.e., Ente per lo Sviluppo Agricolo, E.S.A.) to study the possibility of implementing active interventions of biological control. From that date until today E.S.A. carried out:

1) a preliminary plan for measures of biological control of *Ceratitis capitata* (Mediterranean fruit fly) at regional scale, prepared in collaboration with the FAO / IAEA Agriculture and Biotechnology Laboratory.

2) the planning of a biofactory alternative to the first one, to be built in Ramacca (Catania), aimed at the production of 3 species of insects beneficial to citrus cultivation (*Aphytis melinus*, *Cryptolaemus montrouzerii*, *Leptomastix dactylopii*) and 1 insect to be employed in horticulture. *Diglyphus isaea* Walker, 1838 (Hymenoptera: Eulophidae).

Actually, it was funded and implemented only the second project in which the biofactory of Ramacca is designed to be a flexible pole of production of material (insects) to be used in agriculture for most programs of biological or integrated control. For its start-up phase of production, have been considered, as reference, those crops that, more than others, are susceptible to these kinds of initiatives for their technical and economic characteristics: citrus and protected horticulturals. Therefore the biofarm has been designed and equipped for the production of:

a) 3 insect species beneficial to biological control programs for citrus cultivation (*Aphytis melinus*, *Cryptolaemus montrouzerii*, *Leptomastix dactylopii*);

b) 1 insect used for integrated pest management of vegetables and flowers grown under cover (*Diglyphus isaea*).

The factory is located in the territory of Ramacca (Catania), Margherito district, on a total

area of approximately 3.5 hectares that can be potentially increased and improved in case of changed conditions of the market.

The biofactory is composed of:

a) 1 shed of 2,500 sqm (72 m l, 10.00 m l x 34,30) which houses cells in a controlled and conditioned environment;

b) 6 greenhouses, each of 100 sqm ca. (10.00 m l x 10.00 m l), five of which are used for the production of *Diglyphus isaea* and one for *Lyriomiza* (guest of *Diglyphus*), this latter room is placed at a safe distance to avoid contamination between competitors since both species are raised in purity.

The 6 greenhouses are heated, to prolong the production season even in the coldest months (January and February), and equipped with an adequate irrigation system to allow the cultivation of bean plants in pots placed on anti-algae cloths;

c) 1 office building of 350 sqm (m l 34.30 m l x 10.00 m l).

The shed is composed of 36 rooms including cells, work rooms, service corridors, warehouse, workshop, toilets and transformer room, central cooling and boiler. Cold storage and processing rooms are 28, divided as follows:

9 for *Aphytis melinus*;

6 for *Cryptolaemus montrouzerii*

4 for *Leptomastix dactylopii*

9 in common for *Cryptolaemus montrouzerii* and *Leptomastix dactylopii*.

## BREEDING TECHNIQUES OF INSECT PRODUCTS IN BIOFACTORY

*Aphytis melinus* De Bach, 1959

Hymenoptera Aphelinidae

*Aphytis melinus* (Figs. 3, 4) is a parasitoid of *Aonidiella aurantii* Maskell, 1879 (Rhynchota Homoptera Diaspididae), or California red scale, a major pest of citrus, but it can also parasitize other species such Diaspididae *Aonidiella citrina* (Coquillett, 1891) and *Aspidiotus nerii* Bouché, 1833 (Flanders, 1953; De Bach & Argyriou, 1967; Abdelrahman, 1974; Rosen & Eliraz, 1978; Rosen et al., 1979; Luck et al., 1982; Orphanides, 1984; Yu et al., 1986; Opp & Luck, 1986; Reeve, 1987; Yu & Luck, 1988; Rodrigo & García-Marí, 1990,



Figure 3. *Aphytis melinus*  
(Photo by "Centrale Ortofrutticola of Cesena, Italy).

1992; Hare & Luck, 1994; Heimpel & Rosenheim, 1995; Tumminelli et al., 1996; Gottlieb et al., 1998; Pekas et al., 2003; Pasotti et al., 2004; Rodrigo et al., 2004; Pina, 2007; Pina T. & Verdú M.J., 2007; Vacas et al., 2009; Vanaclocha et al., 2009).

Agricultural use of the insect: *A. melinus* is launched at the adult stage and disperses easily in all the citrus grove, possessing excellent research skills. In citrus infected is good practice to make a winter treatment with white oil at 2-2.5%; this allows to reduce, albeit only partially, the wintering population of the cochineal. The parasitoid is launched following a pattern that includes a series of consecutive launches after the flight detection of cochineal males in late April-early May. When the plan of biological control is set up, in the first year are expected about 10-12 launches, 2/3 of which to be carried out in April-May-June until mid-July, while the remaining 3 or 4 launches take place from mid-September to throughout October. In the months of April, May and June, launches can be made every two weeks, moving on to a weekly frequency when temperatures increase. 8,000 to 12,000 parasitoids per hectare, for a total of 100 to 150,000 / ha for production season are launched. In 2-3 years the intensity of the pest is reduced so that is possible to reduce proportionally the number of launches, limiting them exclusively to the spring-summer period. It is very important to pay attention to chemical treatments performed before and to those that will take place.

Breeding techniques and production cycle in biofactory: breeding of *Aphytis melinus* is made in



Figure 4. Climate cabinets with *Aspidiotus nerii* bred on pumpkins for developing of *Aphytis melinus*.

climate cabinets, using the parthenogenetic strain of *Aspidiotus nerii* bred on pumpkins.

Pumpkins are kept in cells furnished with metal shelves; the environment of the cells is adjusted so as to have  $13 \pm 1$  °C and  $50 \pm 5$  % RH; pumpkins are previously washed and disinfected.

The production process has a duration of about 60 days, breeding is carried out in two areas: one for the multiplication of the host and one for the production of the parasitoid. Even the *Aspidiotus nerii* (host) is reared in cells whose furniture is made of metal shelving with lozenges. The nymphs of *Aspidiotus* are then collected and placed in a jar before inoculating other pumpkins. The environmental conditions for the breeding of *Aspidiotus* are the following: temperature  $26 \pm 1$  °C, RH  $50\% \pm 5$ .

At the 45th day, before the spill of nymphs, 10% of pumpkins are brought in the cells for development of *Aspidiotus* for harvesting nymphs to be used for the inoculation of pumpkins, whereas the remaining 90% is placed in plastic bins for the production of *A. melinus*. Pumpkins are put in contact with *A. melinus* for 24 h.

The adults are taken after 24 h, blowing carbon dioxide to saturation. After inoculation, pumpkins can be placed in the two cells intended for the production of *A. melinus*, air-conditioned to  $26 \pm 1$  °C and  $50 \pm 5$  % RH. After 10-15 days, *A. melinus* newborn are collected after release of carbon dioxide. Insects fall to the bottom of the cabinets and are put within cylinders where are measured volumetrically. Adults collected are packaged in trays of 10,000 or 25,000 insects containing honey as



Figure 5. *Leptomastix dactylopii*  
(Photo by "Centrale Ortofrutticola of Cesena, Italy).



Figure 6. *Planococcus citri*  
(Photo by "Centrale Ortofrutticola of Cesena, Italy).

feed. Packages can be stored for a few days in the refrigerator ventilated at 15 °C. The production ratio is 1: 3.

### ***Leptomastix dactylopii*** Howard, 1885

Hymenoptera Encyrtidae

Parasitoid (Fig. 5). Endophagous of *Planococcus citri* Risso, 1813 (Rhynchota Homoptera Pseudococcidae) (Fig. 6) (Chandler et al., 1980; Tingle & Copland, 1988, 1989). The United States are its country of origin and its cycle in nature takes place on mealybugs, *P. ficus* Signoret, 1875, *P. vitis* Ezzat et McConnell, 1963 and, in laboratory conditions, spread also over other hosts.

Natural cycle and agricultural use of the insect: at 25 °C, and 75% humidity, the cycle of *L. dactylopii* takes about 21 days. Adults, 12 hours after the flicker, begin to mate. Females move on the pseudococcid colony seeking - measuring them by antennae - for the nymphs with appropriate shape and age where to inject the eggs (one for each victim). From each egg comes out a larva that, in 13 days, making three mutes and through four larval stages, becomes pupa, at first light in colour, then darker. After a week from 'pupation, the adult flickers. Particularly remarkable it is that the larva produces chitin and hardens the outer wall by an aeroscopic plate from which it breathes atmospheric oxygen. At the end of metamorphosis, by the chewing apparatus severs an operculum placed in anal position of the host and flickers. *L. dactylopii*

is an insect yellow honey with three simple eyes. Its sizes range from 0.5 to 6 mm (11 antennomeres). Males have longer and silky antennae with 10 antennomeres, females shorter and hairless (11 antennomeres). *L. dactylopii* is marketed at the adult stage and can be used on citrus fruits in combination with *Criptolaemus montrouzieri* and on ornamental plants infested by *Planococcus citri*.

Breeding techniques and production cycle in biofactory: the production cycle of *L. dactylopii* takes place entirely in climate cabinets. The host is *P. citri* (mealybugs) which is bred on potato sprouts etiolated in areas separate from those of the parasitoid. For storage of potatoes are used cells conditioned to 5 °C and 50 +/- 5% relative humidity. The breeding cycle of the parasitoid lasts 9-10 weeks. In the first stage, are produced etiolated shoots of potato which, after 2-3 weeks, are infested with the citrus mealybug. When nymphs are ready, *L. dactylopii* is inoculated. After 20 days the adults are collected with aspirators and packed in jars of 100 individuals. Insects can be stored at 15 °C, if well fed with appropriate diets.

### ***Cryptolaemus montrouzieri*** Mulsant, 1850

Coleoptera Coccinellidae

Polyphagous predator (Hodek & Honek, 1996. Milán Vargas, 1999) that can live at the expense of several Pseudococcids or even other insects (Figs. 7, 8). The adult measures about 5-6 mm has black elytra, while the head, chest, abdomen and



Figure 7. *Cryptolaemus montrouzieri*  
(Photo by "Centrale Ortofrutticola of Cesena, Italy)



Figure 8. Larvae of *Cryptolaemus montrouzieri* on  
potato sprouts infested by *Planococcus citri*.

extremities of the elytra are orange. At a constant temperature of 25 °C females live about 60 days and, during this time, lay 60 to 120 eggs.

Eggs are located close to the cottony ovisacs of the prey so that and the young larva, just shelled, can easily reach its preferred food: eggs and young nymphs of the pest.

The Coccinellidae larva goes through four stages before pupating (by attaching to a support) after which it becomes an adult. It has a waxy coating to camouflage itself onto the colonies of *P. citri*, but cannot be mistaken for its larger size and its mobility. The cycle from egg to adult lasts, at 25 °C, 35 days. It is an insect native to Australia and therefore sensible to harsh winters; it has already acclimatized in many areas of southern Italy and, in the islands, winters as an adult.

Agricultural use of the insect: *Cryptolaemus* is sold at the adult stage. On citrus fruit it is used in association with *Leptomastix dactylopii* especially in the hotbeds of infestation, which are out of control of the parasitoid. In the field, it is employed from June up to August (3 months). *Cryptolaemus* could be used also on ornamental crops in greenhouses or in potted plants; on this item, it is developing an interesting market in northern Europe.

The production cycle of *Cryptolaemus* takes place entirely in climate cabinets. The host is *P. citri* (mealybugs) which is bred in purity on etiolated shoots of potato in a separate room. As *P. citri* is used as host also by *Leptomastix*, rooms designated for *P. citri* production are used for both insects.

In particular, in a section of the biofactory, there are cells for the storage of potatoes (at 13 °C and 60% RH); and in another section, cells for the development of the tubers and, still, other cells for the development of *P. citri* (at 25 °C and RH of 60 ± 5%) that will serve to feed both the auxiliaries (*Leptomastix* and *Cryptolaemus*).

In another area of the building there are cells for development of *P. citri*, cells for collection of *Cryptolaemus* and processing rooms. The breeding cycle of predator lasts 10–13 weeks. In the first phase *P. citri* is bred in purity on etiolated sprouts of potato. In breeding cells, potatoes are made germinate in the dark for 2–3 weeks; the shoots are infested with *P. citri* and the infestation is let to develop for 3–4 weeks; finally there is the inoculum with *Cryptolaemus*. Adults, collected after 35 days with vacuum cleaners, are packaged in cans from 100 to 200 units. They are then counted volumetrically. Insects can be stored at 15 °C, even up to a month if well fed with an appropriate diet.

## MANAGEMENT BIOFACTORY

In 2006, the managing of the biofactory of Ramacca began with the finding of the head-breeding strains (*Aphytis melinus*, *Cryptolaemus montrouzieri*, *Leptomastix dactylopii* and *Diglyphus isaea*) and of intermediate entomological materials (*Aspidiotus*, *Planococcus*, *Liriomyza*, etc.) of which such insects are parasitoids or predators. As planned, entomological breeding aimed, from the

beginning, at the production of *Aphytis melinus*, *Leptomastix dactylopii* and *Cryptolaemus montrouzieri*. At first it was even started a production of *Diglyphus isaea* (greenhouse parasitoid on *Liriomyza trifolii*, *L. bryoniae* and *L. huidohernsis*) then abandoned because of the uneconomic production cycle.

Until 2011 the entomological material was distributed free to farmers through peripheral companies belonging to E.S.A. (i.e. SOPAT, Offices for the Antiparasitic Fight) and to the Department of Agriculture and Forestry (SOAT, OMP).

The criteria developed by the Administrative Department of biofactory included a distribution of the product to farmers cultivating citrus, to organic or converting to organic farms, and to farms that apply and implement criteria of integrated pest management, according to a programming technique

agreed with local Institutes that provide agricultural technical assistance (ESA, SOAT and the Office of Agriculture and Forestry).

The reaching of full production was expected by the third year (29 March 2009), during which it has been programmed the full activity of the building with the following annual production levels:

- Aphytis melinus* 67,200,000 individuals;
- Cryptolaemus montrouzieri* 350,000 individuals;
- Leptomastix dactylopii* 1,000,000 individuals;
- Diglyphus isaea* 1,900,000 individuals.

### Data management in the period 2006-2011

During the period 2006–2011 (Fig. 9), insects have been distributed free to regional farms and other applicants who had a purpose in the public interest, including regional and national Universities,

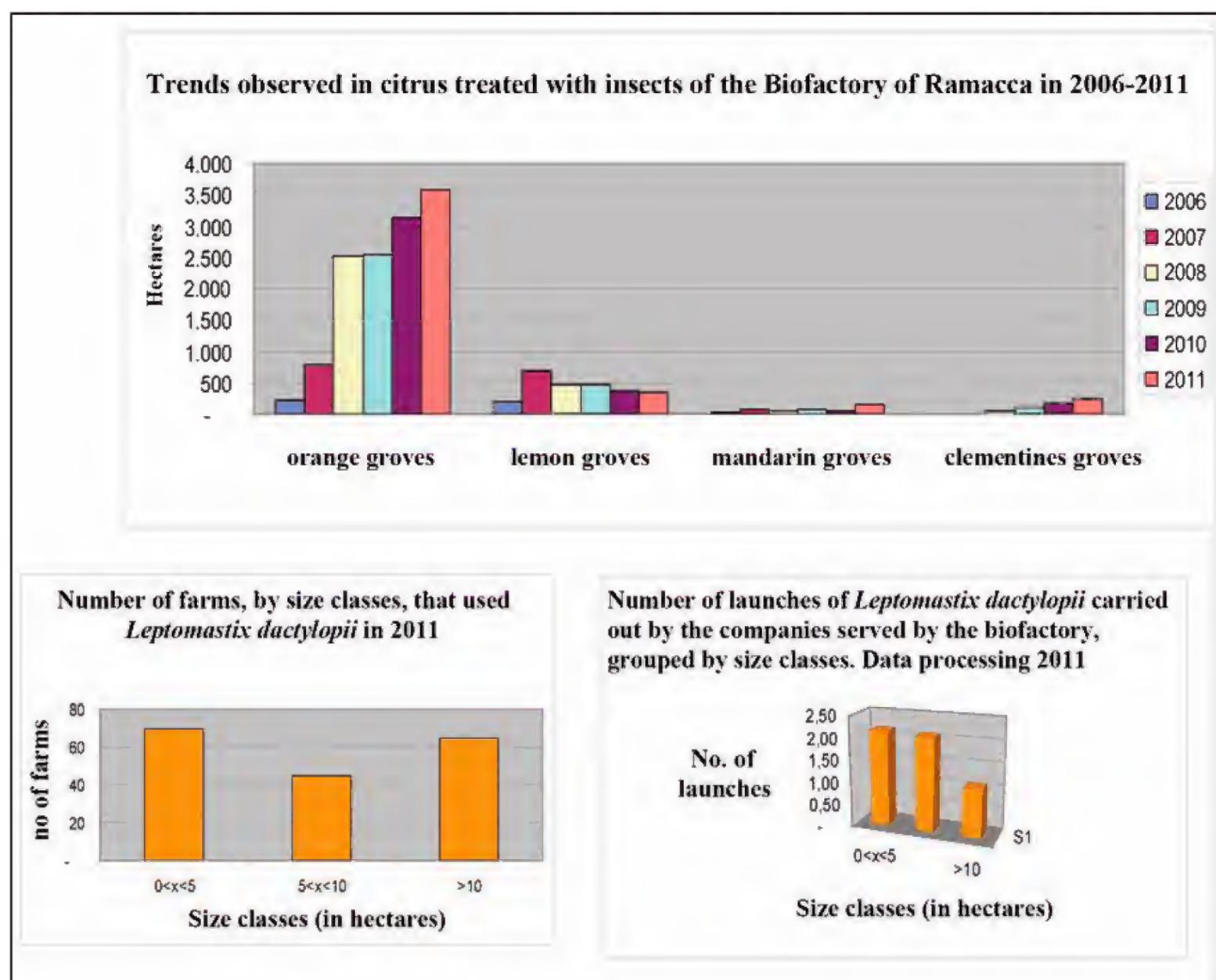


Figure 9. Data management in the period 2006-2011 (Source E.S.A.).

Regional Departments, Development Services, Institutes or Development Agencies of other Italian regions.

Maximum productions were distributed in 2010–2011, mostly to citrus farms, for a total of more than 4,300 hectares distributed in 325–355 entities. Noteworthy, as for the 2010–2011 data, there is a significant increase in production (+ 50% compared to 2010), correlated with a stabilization of the “protected” area, amounting to 4,361 hectares (-28 hectares compared to 2010); the maintenance of the substantial number of seasonal launches can be explained by a kind of loyalty of the users who, in manifesting an appreciable degree of satisfaction, show confidence in using alternative means of organic production.

### Data management in the period 2012-2013

In 2011, it was suggested to apply a reduced price to Sicilian farms. This is to contribute to the costs of production that, every year, E.S.A. supports to ensure its performance. So it was approved and put into effect a new “Discipline” which regulates the sale of insects to farmers at a “price of contribution”, in order to proceed, gradually, to compensate production costs. The “price of contribution”, which ranks, by definition, below the values of the free market, reconciles the needs of the Institute, which has to ensure adequate performance in providing institutional support to agriculture, with its financial nature aimed to partially cover the costs of production. This regulation does not exclude the transfer of beneficial insects also in favor of other subjects, in different places (extra-regional) and, possibly, for different purposes (agricultural as well as commercial or public). In this case, the above mentioned constraints do not apply, so that E.S.A. can set the products at different prices (to be considered net of shipping), commensurate with market values.

Application of new “Rules” recorded a drop in distribution in 2012–2013, and, during a period of 6 years of free distribution, it obviously resulted in a big change of the demand of the three species. A first effect of the new regime can be seen in the production levels of 2012–2013. In particular (Fig. 10), the amount of *Aphytis melinus*, *Leptomastix dactylopii* and *Cryptolaemus montrouzieri* - although often reached high profiles above those of

feasibility - stood at levels significantly lower than those of 2011, i.e. 139–149 million, 672–1766 thousand and 233–277 thousand individuals, respectively. In 2012, production reached 119% of what expected in steady-state conditions, (i.e. +19%). Briefly, these results can be explained with a production trend that had to take into account users’ requests, which resulted in a change of strategies and productive quality (when possible) that affected, for example, the extent and availability of traditional raw materials to be acquired (potatoes,

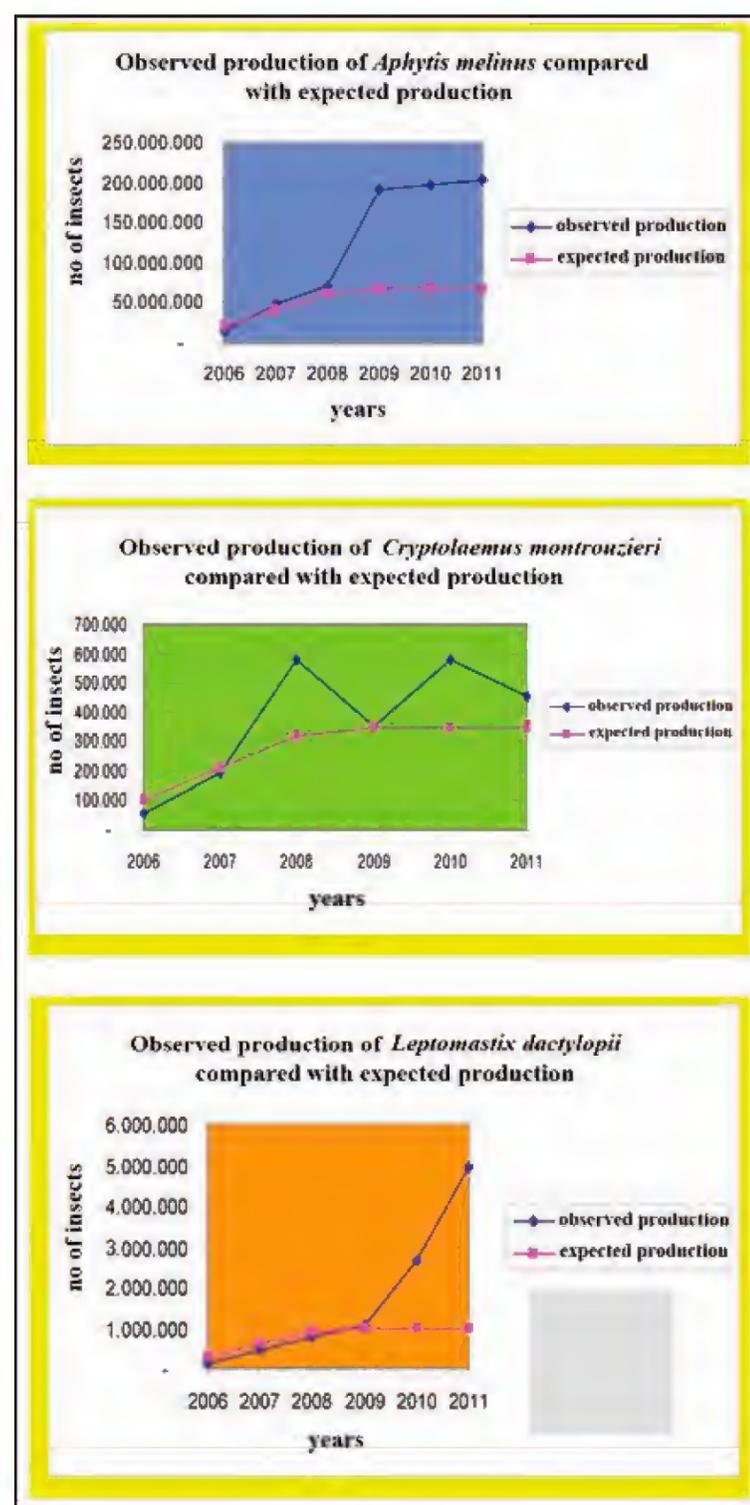


Figure 10. Development of production of *Aphytis melinus*, *Leptomastix dactylopii* and *Cryptolaemus montrouzieri* than expected feasibility (Source E.S.A.).

var. “Spunta” and “Desiree” and pumpkins var. “Butternut”). Another cause is to be found in distribution fees, which were fixed in the absence of solid experience of huge productions and, therefore, of necessary and useful market information. Finally, the price of each insect certainly influenced the users’ choice. For example the price / effectiveness or cost/utility ratio for *Aphytis melinus* was considered, by the regional users, more convenient than those fixed for *Cryptolaemus montrouzieri* and *Leptomastix dactylopii*.

### Profile of user companies in 2012-2013

Quantitative aspects of each entomological entity distributed to regional farms are of course also reflected on land statistics. In fact, Users (i.e. farms), primarily engaged in citrus cultivation, were more than 200 (213 to 298), for an area of at least 2,300 Ha. Just to quantify, 2,152 Ha of orange groves, 313 ha of lemon groves, 91 Ha of mandarin groves and 51 of clementine groves took advantage from the service provided by E.S.A.

The new payment system had a negative impact not only on the lemon groves of Syracuse: also other citrus groves suffered a regression of land extensions which reached its peak in the areas planted with orange trees. It also follows, that the biological defense against the citrus mealybug, (*P. citri*) and red scale (*A. aurantii*) by *Aphytis melinus*, *Cryptolaemus montrouzieri* and *Leptomastix dactylopii*, decreased to 2,441, 1,027 and 540 Has, respectively, Siracusa and Catania remain the provinces where biological fight is mainly performed, followed by an increasing number of farms in Agrigento province. Hence it is indirectly confirmed that the location of the Biofactory (Ramacca, Catania) is in line with the geographical distribution of its real users.

The profile of the more than 298 farms that, in 2012, took advantage of the service of the Biofactory of Ramacca is best represented in figure 11. Companies that follow programs of integrated biological defense or integrated fight in citrus and benefit of the insects provided by the biofactory have predominantly a size less than 5 hectares (161, 48 and 27 farms can be listed for *A. melinus*, *L. dactylopii* and *C. montrouzieri*, respectively). Medium-sized companies were those that, in 2012, performed more seasonal launches of *Aphytis*

*melinus* with an average of about 3.8; but also the other companies showed average values (3–4 seasonal launches).

For *C. montrouzieri* the number of launches is inversely proportional to the company size, ranging from about 1 for small farms to 0.6 for larger ones.

A similar pattern was confirmed for *Leptomastix dactylopii* with about 0.8 launches for companies under 5 Ha and 0.4 launches for larger ones. Average launches < 1 reveal a partial use of insects (for organic control) that, in these cases, are not employed on the entire surface of the citrus grove. The new payment system had an impact also on the number of launches that, with reference to 2006–2011 data, appear in decline. This could be due to a more parsimonious use of the “organic product” but also to a kind of “users’ loyalty” (i.e., farmers despite the new regulation, continue to show a certain degree of satisfaction).

### EVOLUTION OF SERVICE AND PROSPECTS FOR SEVEN YEARS FROM 2013 TO 2020.

The last items briefly discussed in the previous paragraph, led E.S.A. to review the current huge production and proceed, after an initial experimental phase, to the diversification of production, to improve the bouquet offered. In this context E.S.A. has already started a project that will be developed in the period 2013–2020. In particular, the service aimed at breeding and producing huge quantities of *Aphytis melinus*, *Cryptolaemus montrouzieri* and *Leptomastix dactylopii* is confirmed, re-thinking of new production levels, based on all the variables mentioned before. Moreover, seven additional experimental activities have also been designed one for each year, to be held simultaneously with the aforementioned base production, aimed at increasing the entomological list to be employed in other contexts, as viticultural, ornamental and floricultural. Each experiment involves the development of procedures for the breeding of the following auxiliaries (see below) to be performed, in proper conditions, for the production of huge quantities of insects.

1) *Cryptolaemus montrouzieri* larvae (predators of *P. citri*, citrus mealybug);

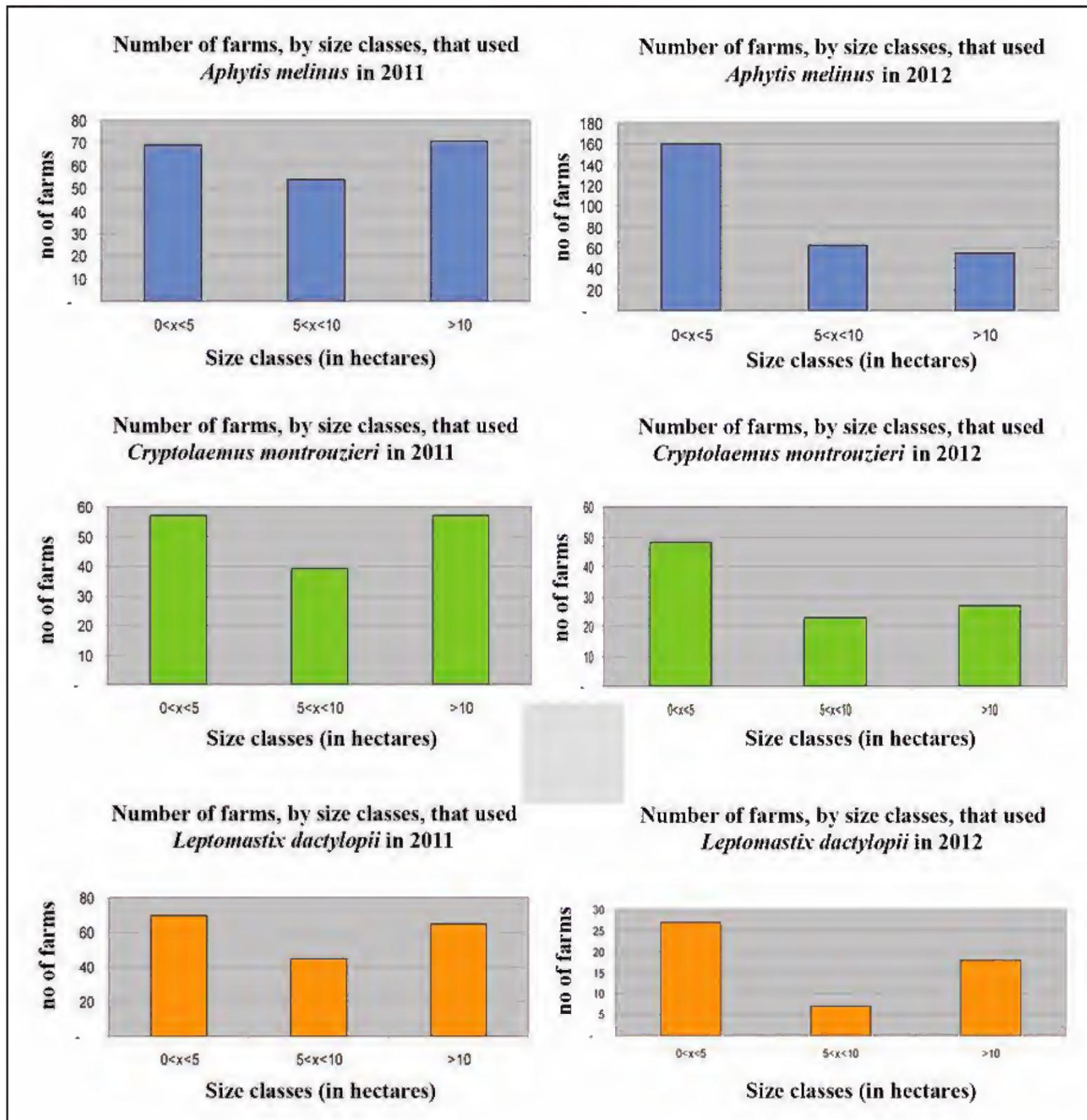


Figure 11. Number of companies, sorted by size classes, that used *Aphytis melinus*, *Cryptolaemus montrouzieri* and *Leptomastix dactylopii* in 2011 and 2012 (Source E.S.A.).

2) *Chrysoperla carnea* Stephens, 1836 (Neuroptera Chrysopidae) predator of aphids (Benuzzi & Nicoli, 1988; Osservatorio agroambientale di Cesena, 1991; Nicoli & Galazzi, 2000);

3) *Anagyrus pseudococci* (Girault 1915) (Hymenoptera Encyrtidae) parasitoid of *Planococcus vitis* and ornamental mealybugs, *P. ficus*, *Pseudococcus longispinus*, *Ps. affinis*, *Rhizoecus falcifer* (Avidov et al., 1967; Rosen & Rössler, 1966; Islam

& Jahan, 1993a, b; Blumberg et al., 1995; Islam & Copland, 1997, 2000).

4) *Encarsia formosa* Gahan, 1924 (Hymenoptera Aphelinidae), parasitoid of whiteflies as *Trialeurodes vaporariorum* (Westwood, 1856) (Hemiptera Aleyrodidae);

5) *Lindorus lophantae* (Blaisdell, 1892) (Coleoptera Coccinellidae) (generic predator of mealybugs, also active against *Aonidiella aurantii*);

6) *Orius laevigatus* (Fieber, 1860) (Hemiptera Anthocoridae) predator of thrips (Tawfik & Ata, 1973; Tavella et al., 1991; Villevieille & Millot, 1991; Chatnbers et al., 1993; Vacante & Tropea Garzia, 1993a-b; Meiracker van den, 1994; Alauzet et al., 1994; Tavella et al., 1994; Frescata & Mexia, 1995; Tommasini & Nicoli, 1995);

7) larvae of *Chilocorus bipustulatus* (Linnaeus, 1758) (Coleoptera Coccinellidae) (predators of *Coccus esperidum* (brown soft scale), *Ceroplastes sinensis* (Chinese wax scale), *Ceroplastes rusci* (fig wax scale), *Saissetia oleae* (Black scale), *Carnuaspis bekii* (Purple scale), *Aspidiotus blacks* (Oleander scale), *Chrisomphalus dictyospermi* (Morgan's scale), *Aonidiella aurantii* (California red scale).

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# Implantation of Stag beetle hostels in the city of Geneva (Switzerland)

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## ABSTRACT

Brief presentation of our ongoing project of implementation of a network of “Stag beetle hostels” in the city of Geneva (Switzerland) aiming at consolidating the last large populations of big woodboring beetles *Cerambyx cerdo* Linnaeus, 1758 (Coleoptera Cerambycidae) and *Lucanus cervus* Linnaeus, 1758 (Coleoptera Lucanidae) in Switzerland.

## KEY WORDS

Stag beetle hostels; Geneva; woodboring beetles; *Lucanus cervus*; *Cerambyx cerdo*.

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## INTRODUCTION

The large woodboring beetles *Cerambyx cerdo* Linnaeus, 1758 (Coleoptera Cerambycidae) and *Lucanus cervus* Linnaeus, 1758 (Coleoptera Lucanidae) are associated to oaks and beeches. Their larvae feeding on decaying wood take 3 to 5 years to develop into imagoes, which live only one summer and hardly disperse further than half kilometer from their native tree. In North and Central Europe, they can complete their life cycle only in trees big enough to protect larvae from the winter frosts. During the 20th century their distribution has however drastically regressed due to intensive exploitation of those trees for timber as well as changes in agriculture techniques.

Because of the large array of other useful and more elusive organisms benefiting of their favoured habitat (i.e. senescent oaks and beeches), they are considered umbrella species and received therefore protected status in Europe since 1992. In Switzerland, where they received federal protected status only in 2011 (OFEV, 2011), they can be found

today essentially in the southern part of the country, *Cerambyx cerdo* with only scarce populations in the cantons of Geneva, Valais and Tessin.

Despite a limited and rather urbanized territory, the canton of Geneva has the privilege to host the most abundant Swiss populations of both of these emblematic beetles. Amazingly, they are essentially found in the hearth of the city itself rather than in the surrounding countryside, where most old trees were cut in the early 20th century for timber and adaptation of the landscape to mechanized agriculture.

Renewal of suitable natural habitats better distributed in space and time in the countryside is a matter of several decades. Meanwhile, as falling branches put citizens and other park's users at risk, senescent oaks and beeches in town are gradually cut and removed. As a result, despite their apparent abundance in the city of Geneva, these urban populations of large wood-boring beetles are each day less abundant and more fragmented, in such a way that their disappearance seems programmed if nothing is attempted today.

## MATERIAL AND METHODS

We thus decided to try to consolidate the urban populations of these protected beetles by promoting in the city of Geneva the set up of a network of “stagg beetles hostels”. Already implemented successfully in several other places elsewhere in Switzerland and Europe, « woodboring beetles hostels» consist basically in 1 meter long logs half buried in the ground recreating artificially the appropriate conditions for female oviposition and subsequent developpement of the larvae.

However installation of such large and lasting structures in the heart of a densely urbanised city faces various technical and social problems. In first instance stagg beetles hostels are more cumbersome than birdhouse: they require several square meters of land, should remain over a decade to be really efficient, and as such must be installed only in close concertation with all relevant city services (urbanists, gardeners, maintenance, etc.). Therefore we dedicated a lot of time and energy explaining urbanists, gardeners and maintenance workers that stagg beetles hostels were as necessary as easy to build, but moreover that they consist indeed in an inevitable new element of the urban furniture of the Geneva of the 21th century.

Second and certainly most challenging problem is that most citizens perceive insects as a nuisance, a source of danger (punctures, vectors of diseases) or as revelators of defective sanitary conditions. *Lucanus* Scopoli, 1763 and *Cerambyx* Linnaeus, 1758 unfortunately don't escape this “rule”, which is even exacerbated by their quite impressive size in such a way that they are often mistaken as dreadful exotic beasts fallen off a plane from Africa or elsewhere.

Therefore we accompanied our project from the beginning with a real campaign for « social rehabilitation » of these large woodboring beetles. In first instance we made a call to the citizens for observations in the frame of a participatory inventory aiming at 1) bringing presence of these beetles to the knowledge of citizens, 2) teaching to recognize them, 3) explaining they role, 4) drawing attention to their patromonial status and the responsibility of Geneva citizens regarding their respect and protection, and 5) offering people the possibility to contribute directly to this issue by the transmitting their own observations.

Besides we took every opportunity to talk to school classes and publish in daily newspapers small articles declining these thema. A WEB page specially dedicated to that project and relaying permanently our call for observations was also created ([www.ville-ge.ch/mhng/coleopteres\\_bois\\_geneve.php](http://www.ville-ge.ch/mhng/coleopteres_bois_geneve.php)).

## RESULTS

It took some two years from the origin of our project in 2011 to the construction of the first stagg beetle hostel in Geneva, which was achieved on the 17th of April 2013 by gardeners of the city of Geneva assisted by childrens. Installed at the foot of three big senescent oaks colonized by both *Cerambyx* and *Lucanus* in the “Parc La Grange”, the most scenic and visited parc of the city of Geneva, this Stagg beetles hostel is agremented with a graphic pannel summarizing the biology, role and status of these beetles, with a flash code addressing smartphone users directly to our WEB page for further informations. The device was completed with an attractive giant oak *Lucanus* sculpted by a local artist aiming both at catching attention of the visitors and favouring perennality of the hostel, which symbolizes to us the participatory involvement of the Geneva citizens for a more rational management of their environment.

## CONCLUSIONS

This realisation will take all its meaning only if drawn in the future. In effect to modify the social perception of large woodboring beetles from the status of unwanted frightening pests to majestic useful animals being integral part of the environmental identity of the citizens will be certainly a long-term process. In this perspective participatory involvement of the public in a “continuous assesment” via regular calls for informations in the daily media seems very important to us. However it's obvious to our eyes that the best way to accelerate adhesion rate to the cause of large woodboring beetles will consist in penetrating public education programs, and that from the earliest school classes.

Nevertheless it appeared that once explained the environmental issues and technical feasibility



Figure 1. First Stagg beetles hostel of Geneva (Switzerland): construction with children.



Figure 2. First Stagg beetles hostel of Geneva (Switzerland): sculpture by Sylvio Asseo.



Figure 3. First Stag beetles hostel of Geneva (Switzerland) as completed (logs, sculpture, and didactic pannel).

of the project, most professional actors of the city services concerned were enthusiastic to contribute at their level to its realization. The best proof we can present is that additional 7 stag beetle hostels have been installed by the gardeners in other parks of the city in 2014, and more are planned for 2015. Next steps will be to increase the density the network of stag beetle hostels with a target of one each 300 m in order to enhance gene flows between each individual population, then to implement corridors of stag beetle hostels favoring natural dispersal of these beetles through the suburban crown toward the countryside they used to belong. Meanwhile we already work with forestal authorities in order to promote the plantation of oaks and beeches in the countryside with a better

scaling in space and time of suitable habitats for these magnificent insects.

The project received the “Geneva cantonal award for sustainable development edition 2014”.

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# Requalification of coastal plant landscape of South-Eastern Sicily, Italy: the case of Marina di Priolo

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## ABSTRACT

In this paper the Authors examine the psammophilous vegetation and the degrees of naturalness of the coastal plant landscape of a part of the South-Eastern littoral in Sicily. This area is characterized by considerable human pressure due to the presence of a large industrial center and beach tourism. The recent construction of the garden next to the beach, made mainly with ornamental plants has contributed to further amend the original physiognomy of the coastal landscape. Were analyzed, with phytosociological method, psammophilous plant communities and zonation of vegetation. The results of the analysis show a impoverishment of flora and a progressive decline in the psammophilous communities mainly due to the constant leveling the beach in summer. The authors propose a series of actions aimed at the requalification and conservation of coastal vegetation landscape of the investigated area.

## KEY WORDS

plant landscape; requalification; littoral; human pressure.

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## INTRODUCTION

In the present work we analyzed the plant landscape of Marina di Priolo, a stretch of sandy coast between Marina di Melilli and Magnisi peninsula, about 6 km north of Syracuse (Sicily, Italy) (Fig. 1). In a not too distant past the area was used for the production of salt in the saltmarshes of Magnisi, placed in a large basin behind the dunes adjacent to the study area. Although reduced from its original extent, this important humid environment is protected through the establishment of the R.N.O. "Saline di Priolo" managed by the L.I.P.U. (D.A. n. 807/44 of 12/28/2000). Since the 50s of last century, the area has undergone significant environmental change mainly due to the progressive establishment of one of the largest petrochemical industrial cen-

ters of Europe. The massive industrialization of the area has also led to the growth of urban centers and neighboring persistent anthropogenic coastal environment that, in recent years, was also affected by the profound transformations related to the increase in tourism.

The recent creation of a green area called "Garden of the Sea", adjacent to the beach, consists mainly of ornamental species, some exotic, helped to further modify the original structure of the coastal landscape. The purpose of this research is the cognitive analysis of the dune environment, spatial seriation of psammophilous plant communities and their state of preservation. Based on the results obtained, we propose actions for the rehabilitation and protection of plant landscape of the site investigated.

**The area of study.** From the perspective of geological-structural the area of Marina di Melilli, Syracuse (Sicily, Italy) is part of the Hyblean Plateau and the local stratigraphic succession is represented by ceno-neozoic carbonate rocks (Carbone et al., 1986). Examining the thermo-pluviometric data from the nearby station of Syracuse, the climate of the study area is Mediterranean, with mild, rainy winters and hot, dry summers (Zampino et al., 1997). While, as evidenced by Scelsi & Spampinato (1998) bioclimate is in the range inferior thermomediterranean dry type.

## MATERIAL AND METHODS

The methodological approach used for phytosociological study of the psammophilous vegetation is that of the Sigmatista School of Braun-Blanquet (Braun-Blanquet, 1964), while for syntaxonomical framing were followed proposals of Brullo et al. (2002).

The collected samples were determined according to the Flora of Italy (Pignatti, 1982), prepared and preserved in the herbarium of the Ecomuseo dei Monti Climiti Melilli (Laboratory of Nature and Environmental).

## RESULTS

Despite the heavy distortions of anthropogenic nature, the investigations carried out made it possible to identify, in the least disturbed stretches of coastline, different communities of psammophilous plants that, despite impoverished of many typical elements, hint at some aspects of the original plant landscape and suggest effective conservation measures for the protection and rehabilitation of ecosystems. Through the observations made could be detected, proceeding from the aphytoic zone inland, a first strip of terophytic halonitrophilous vegetation, parallel to the coast-line, which is closely pioneer, ascribable to the *Salsolo-Cakiletum maritimae*, characterized by the dominance of *Cakile maritima* Scop. associated with *Salsola kali* L. and *Polygonum maritimum* L.

The next strip, attributable to the *Cypero-Agrophyretum juncei*, is characterized by herbaceous perennial plants of low embryo dunes. The association physiognomically is characterized by the do-

minance of *Elytrigia juncea* (L.) Nevski which is associated with *Sporobolus virginicus* (L.) Kunth and *Achillea maritima* (L.) Ehrend. et Y.P. Guo. The vegetation parallel to the latter strip is dominated by *Centaurea sphaerocephala* L. and *Onosis natrix* subsp. *ramosissima* (Desf.) Batt.; are also present *Pancratium maritimum* L., *Euphorbia terracina* L. and *Lotus cytisoides*. It is a plant community ascribable to the *Centaureo-Ononidetum ramosissimae*, chamaephytic and hemipterophytic vegetation normally confined on the dunes further inland with little movement, the expansion of which is favored by human disturbance (Minissale & Sciandrello, 2010).

Proceeding inland, the psammophilous series is interrupted by a road parallel to the coastline. The analysis also revealed a degradation of the psammophilous vegetation due to the leveling and trampling of the dunes in the vicinity of the holiday season. The persistent action of scraping in sandy shore led to the demise of mobile dunes with typical vegetation with *Ammophila arenaria* (L.) Link, therefore, observing the current vegetation confirms the absence of the typical zonation of dune environments like those along the Ionian coast of south-eastern and far less degraded (see Brullo et al., 1988; Minissale & Sciandrello, 2010). The plant communities found are ranked according to the following syntaxonomical scheme:

- CAKILETEA MARITIMAE R.Tx & Preising in Br.-Bl. & R.Tx 1952  
 CAKILETALIA INTEGRIFOLIAE R.Tx ex Oberd. 1949 corr. Rivas-Martínez, Costa & Loidi 1992  
 CAKILION MARITIMAE Pignatti 1953  
*Salsolo-Cakiletum maritimae* Costa & Mansanet 1981 corr. Rivas-Martínez et al. 1992  
 AMMOPHILETEA Br.-Bl. & R.Tx ex Westhoff et al. 1946  
 AMMOPHILETALIA Br.-Bl. 1933  
 AMMOPHILION AUSTRALIS Br.-Bl. 1921 em. Gèhu, Rivas-Martínez & R.Tx in Rivas-Martínez et al. 1980  
*Cypero capitati-Agrophyretum juncei* Kühnholtz-Lordat (1923) Br.-Bl. 1933  
 CRUCIANELLETALIA MARITIMAE Sissing 1974  
 ONONIDION RAMOSISSIMAE Pignatti 1952  
*Centaureo-Ononidetum ramosissimae* Br.-Bl. & Frei in Frei 1937

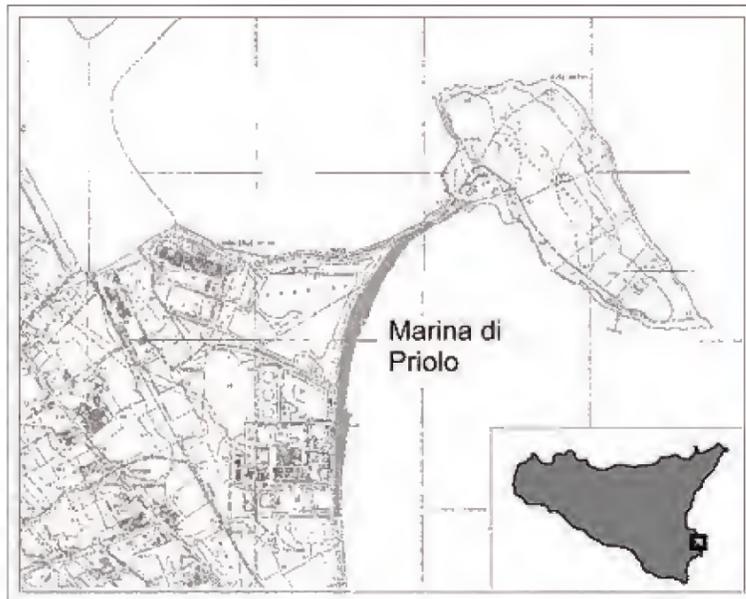


Figure 1. The area of study: Marina di Priolo, Syracuse (Sicily, Italy).



Figure 2. Marina di Priolo, Syracuse (Sicily, Italy): waste left along the beach.



Figure 3. Marina di Priolo, Syracuse (Sicily, Italy): psammophilous vegetation.



Figure 4. Marina di Priolo, Syracuse (Sicily, Italy): the green area called "Garden of the Sea".

## CONCLUSIONS

The research suggests a number of measures aimed at the improvement and protection of plant landscape of the study area:

- allocation of a minimum unit of surface protection to the progressive development of natural vegetation. The "minimum dynamic area" is defined as the balance between the effects of disturbance and the area required for the development of the psammophilous community. In our case, the situation found suggests to preserve space as widely as possible to enable us to reconstruct the seriation of vegetation and restore the dune system.

This could be achieved by:

- elimination of non-native flora, both spontaneous and ornamental, present in the area concerned with habitat restoration through the use of native species from propagation material (seed), local germplasm collected in a special center or in a neighboring area less anthropized and comparable with the examined site. It is therefore proposed a renaturalization especially in the "Garden of the Sea", by converting the area into a natural garden characterized by the recovery of plant communities typical of dune environments having a dual role: eco-functional and didactic educational.

- development of a seaside tourism compatible with the environmental restoration of the site.

<i>Salsolo-Cakiletum maritimae</i>				
Relevé Number	1	2	3	
Surface (mq)	50	50	20	
Slope (%)	50	40	40	
<b>Char. Ass.</b>				
<i>Salsola kali</i> L.	1	+	+	3
<b>Char. Euphorbion peplis &amp; Cakiletea maritimae</b>				
<i>Cakile maritima</i> Scop.	4	3	3	3
<i>Polygonum maritimum</i> L.	1	+	1	3
<i>Xanthium strumarium italicum</i> (Moretti) D. Löve	+	+	.	2
<i>Chamaesyce peplis</i> (L.) Prokh.	+	.	.	1
<b>Companions</b>				
<i>Sporobolus virginicus</i> (L.) Kunth	+	+	+	3
<i>Achillea maritima</i> (L.) Ehrend. & Y.-P. Guo	1	.	+	2

Table 1. The area of study, Marina di Priolo, Syracuse (Sicily, Italy):  
*Salsolo-Cakiletum maritimae* (Date 20.X.2012).

<i>Cypero capitati-Agropyretum juncei</i>				
Relevé Number	1	2	3	
Surface (mq)	30	30	30	
Slope (%)	70	60	60	
<b>Char. Ass.</b>				
<i>Elytrigia juncea</i> (L.) Nevski	4	3	3	3
<i>Sporobolus virginicus</i> (L.) Kunth	2	1	3	3
<i>Achillea maritima</i> (L.) Ehrend. & Y.-P. Guo	+	.	.	1
<b>Char. Ammophilion &amp; Ammophiletea</b>				
<i>Eryngium maritimum</i> L.	1	+	+	3
<i>Pancratium maritimum</i> L.	+	+	+	3
<i>Echinophora spinosa</i> L.	+	+	.	2
<i>Silene nicaeensis</i> All.	+	+	.	2
<b>Companions</b>				
<i>Cakile maritima</i> Scop.	+	+	+	3
<i>Polygonum maritimum</i> L.	+	+	.	2

Table 2. The area of study, Marina di Priolo, Syracuse (Sicily, Italy):  
*Cypero capitati-Agropyretum juncei* (Date 20.X.2012).

<i>Centaureo-Ononidetum ramosissimae</i>				
Relevé Number	1	2	3	
Surface (mq)	15	20	20	
Slope (%)	100	100	100	
<b>Char. Ass.</b>				
<i>Ononis hispanica ramosissima</i> (Desf.) Förther et Podlech	4	4	3	3
<i>Centaurea sphaerocephala</i> L.	2	1	2	3
<b>Char. Crucianelletalia &amp; Ammophiletea</b>				
<i>Euphorbia terracina</i> L.	2	2	1	3
<i>Pancreatium maritimum</i> L.	1	+	+	3
<i>Elytrigia juncea</i> (L.) Nevski	1	1	+	3
<i>Silene nicaeensis</i> All.	1	+	+	3
<i>Sporobolus virginicus</i> (L.) Kunth	1	+	.	2
<i>Ononis variegata</i> L.	+	+	.	2
<i>Cyperus capitatus</i> Vandel.	1	.	.	1
<b>Companions</b>				
<i>Anisantha rigida</i> (Roth) Hyl.	2	2	1	3
<i>Silene colorata</i> Poir.	2	1	1	3
<i>Lagurus ovatus</i> L.	1	1	+	3
<i>Vulpia fasciculata</i> (Forssk.) Fritsch	1	1	+	3
<i>Scolymus hispanicus</i> L.	1	+	1	3
<i>Glebionis coronaria</i> (L.) Spach	1	+	+	3
<i>Dittrichia viscosa</i> (L.) Greuter	1	.	+	2
<i>Cutandia maritima</i> (L.) Barbey	+	+	.	2

Table 3. The area of study, Marina di Priolo, Syracuse (Sicily, Italy):  
*Centaureo-Ononidetum ramosissimae* (Date 15.IV.2013).

The recommended actions will help restoring psammophilous communities also improving the ecological continuity between the dune environment and the wetland of RNO "Saline di Priolo" permitting, at the same time, visitors to perceive a higher degree of naturalness of the environment compared to the current situation of degradation. The proposed objectives are part of a broader scope of environmental restoration of the examined area, connecting with an ongoing project concerning the work of restoring of the former tenement ESPESI,

located on the peninsula Magnisi, to be allocated to the visitor center and guest house (PO FESR 2007-2013 axis 3 ob. specific 2.1; program agreement 31/08/2011 between Department of Environment and Regional Authorities of the "Enti gestori delle Riserve Siciliane").

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# The use of flora, vegetation and habitats in the studies of Environmental Impact Assessment

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## ABSTRACT

The paper examines local flora, vegetation and habitats in order to highlight the plant component's role as not only an indicator of the quality and state of the environment, but also as an extremely useful element in restoration activities required by environmental impact studies. Some methodological proposals have been done as objective criteria in the assessment procedures.

## KEY WORDS

local flora; biodiversity; indicators; restoration.

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## INTRODUCTION

In the studies of environmental impact, the biotic component as a whole (and which includes man) is normally the cornerstone on which the impact generated from plans and projects is assessed. This paper examines the plant component (limited to the vascular flora and plant communities) in order to highlight the way it plays a key role as indicator of the quality and state of the environment, as an accurate sensor of the impacts but also as an extremely useful element in restoration activities required or proposed by environmental impact studies. It also intends to make a few methodological proposals for the use of objective criteria in the assessment procedures.

## MATERIAL AND METHODS

The paper is a brief methodological review, resulting from experience gained on several impact assessments developed in recent years on the island

of Sicily, which is representative of the Mediterranean region. These assessments have allowed salient features of plant biodiversity to be recognized and taken into account in an impact assessment study in order to minimize the effects of exploitation of plant biodiversity in favour of conservation policies.

## INDICATORS OF THE QUALITY AND STATE OF THE ENVIRONMENT

The assessment of the quality or the degree of naturalness of a study area is crucial in making a considered judgment on the quality and intensity of the impact that the implementation of a plan or project leads to. Plants species and plant communities fully comply with these requirements.

Plant species are, in fact, indicators of the quality and state of the environment since each taxon of the flora of a study area is placed into specific habitats. The narrow endemic species, or otherwise rare or included in the national or regional red lists, are usually associated with the most natural and

sensitive habitats effected by human actions. In this way, they indicate the presence of important habitats to be protected. Furthermore, these plants are the preferred subjects for appropriate impact assessments (Rossi et al., 2014). In contrast, the most trivial synanthropic species are present in habitats with predominantly anthropogenic determinism such as farmland, edges of the road, landfills, etc. and therefore they are not very useful in the context of environmental assessments or, at the very least, they indicate the lack of floristic elements to be protected. In this case traditional agricultural landscape as a whole, rather than the natural one, will be focused on for the impact assessment (Barbera & Cullotta 2012).

Plant communities, better than single species, are very fine and accurate indicators of the type, quality and state of the environment since they are an expression of ecological factors such as climate, soil, and anthropogenic influence which allows them to exist within the framework of the vegetation series (1), where discrete units (with statistically uniform floristic composition) can usually be recognized (Pott, 2011). Plant communities are also the most characteristic and diagnostic element of habitat, which is considered as a uniform parts of the ecosystem and is almost always detectable in large to small scale on cartography.

In most cases, their identification is easier than a single species whose presence may be due to chance. For this reason, plant communities are the driving elements for impact assessments as they may have different value in the conservation policies and different sensitivity to human actions. The spatial mosaic of habitats is also useful in assessing the potential fauna of an area and therefore, it allows an opinion on the ecosystem as a whole to be expressed (Sabella, 2015).

A topic generally not highlighted for environmental impact studies is the great local diversity of the indicators mentioned above. In Italy, for example, it is possible to recognize at least three biomes,

Mediterranean, Alpine and Temperate. There are also significant differences in the flora and vegetation which exist in smaller territories as highlighted by several authors (Greuter, 2010; Blasi et al., 2010; Blasi & Frondoni, 2011). Due to this fact and although the method of investigation and assessment may be the same, the contribution of regional specialists who can better understand or highlight floristic and vegetational peculiarities is required. With regard to the assessment methodologies and to be able to converse with other specialists, it is necessary to use objective and quantifiable criteria as much as possible. One of these is the “floristic vegetational value” for plant species with endemism, rarity, and/or endangered taxa, while for plant communities and habitat the evaluation depends on vegetation series position and biogeographical significance. A proper scale of values, to be assigned to these biotic elements, must be compared with the induced changes by a plan or project, allowing more calibrated matrices to be created.

As explained regarding indicators, the botanist works on two main levels: plant species and plant communities, recognizable as habitats. A third level, the landscape, and in particular plant landscape, should be considered but this competence is to be shared with other specialists such as agronomists, geologists and architects. However, if we consider the natural plant landscape for which the recognition of vegetation series is key, the environmental analyst with a botanical background remains the only acceptable specialist.

The sources for plant species are the national and regional floras, the red lists, and the lists of protected species by laws and directives. However, these lists are often deficient because they ignore many important species. The most striking case is that of Annex 2 of the European Directive 92/43 in which many rare endemic species are not mentioned. A likely reason is that in the 1990s the specialists involved in making up this list did not fully understand its importance. At the level of plant communities, the list of habitats of Community interest is very useful (listed in Annex 1 of the above mentioned directive) where the deficiencies seem fairly small. As highlighted above, the need to know the vegetation series of each area is of great importance in order to safeguard and properly assess any mature stages if present. In Italy, a reference element is Blasi (2010a, 2010b) who indicates,

(1) A series of vegetation is made up of all the plant communities related by dynamic relationships that could occur in a ecologically homogeneous space with the same potential vegetation, having the same physical conditions (i.e. meso-climate, soil type, geomorphology). It is dependent on processes of vegetational succession, management and extreme events (e.g. fire, storm damage, volcanic eruption).

based on the collaboration of many regional specialists, all the vegetation series of the national territory. Also in this case, the general pattern must be checked and adjusted for each individual case study.

## ENVIRONMENTAL COMPENSATIONS

The main purpose of providing environmental compensation for the damage caused to nature through building and construction projects is to maintain the quality of the environment (Persson, 2013). This approach has been used to a large extent in Germany and the USA since the 1970s, and the EU has adopted several directives dealing with environmental compensation. Therefore, if environmental impact assessments show even a modest loss to the habitats or ecosystems, this gives the analyst the opportunity to propose compensatory actions that should result in the recovery of damaged habitats or improvement of neighbouring ones not directly affected by the plan or project. These compensatory activities, when related to environmental restoration, cannot be wasted or nullified by the planting of species that are not relevant to the site but they require a highly skilled design as will be explained in the following paragraph.

## RESTORATION ACTIVITIES

The use of plant species for environmental restoration is an opportunity, not only to mitigate or compensate the impact of construction or infrastructure work but also to trigger or facilitate the recovery of habitats often in decline. This assertion is valid only if the restoration activities are set in a rigorous way, i.e. taking into account the vegetation series and local potential vegetation. Once again, the local plant diversity is the driving element of the interventions. These assumptions are widely accepted in northern Europe and North America (Persson, 2013), but it is hard for them to be established in the Mediterranean region, and in Italy in particular.

At present, most of the infrastructure work (especially linear ones such as roads and railways) are marked by sometimes alien invasive plants. The presences of these alien plants are, in many cases, a legacy of the past (i.e. work created

decades ago) but in recent cases, such as the Catania-Siracusa highway completed in 2009, on the slopes, potentially invasive species such as *Cortaderia selloana* have been planted with some native plants (Basnou, 2009; Domènech et al., 2005).

Nevertheless, there are some pioneering activities developed in Sicily, which are following the new direction of environmental restoration (La Mantia et al., 2012; Barbera et al., 2013) and bodes well for the future.

## CONCLUSIONS

With the present paper, an attempt to highlight what the salient points in an environmental impact assessment regarding the flora and vegetation has been carried out. The outlined framework emphasizes the importance of taking into account the above-mentioned elements (species, communities, habitats) in all evaluations and proposal steps of a work as they are the perfect sensors of any positive/negative impact, the indicators of environmental quality, and the main protagonists in environmental restoration and mitigation activities.

On these basis, the environmental analyst must be able to better guide or mitigate the project's actions, considering that, in spite of any attempt to contain the rate of destruction or alteration of natural resources, the transforming activity of man and its resulting impacts on the biosphere, both large and small-scale, will never end.

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# The use of the entomofauna in the studies of the Environmental Impact Assessment (E.I.A.) and Assessment of Impact (A.I.)

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## ABSTRACT

The paper highlights the entomofauna's role as not only as an indicator of the environmental quality, but also as a useful component in the studies of the Environmental Impact Assessment (E.I.A.) and Assessment of Impact (A.I.). Some approaches and tools, with particular emphasis on Sicily, are proposed in regards to the use of the entomofauna in the assessment procedures.

## KEY WORDS

Environmental Impact Assessment; Impact Assessment; Entomofauna; tools; Sicily.

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## INTRODUCTION

This paper is a brief methodological review, resulting from the experience gained on several impact assessments elaborated in the recent years in Sicily.

In Europe there are three different types of environmental impact assessment: 1) S.E.A. (Strategic Environmental Assessment), based on the Directive 2001/42/EC on the assessment of the effects of certain plans and programs on the environment; 2) E.I.A. (Environmental Impact Assessment) based on the Directive 2004/35/EC, concerning the impacts assessment of public and private projects on the environment. The Directive determines the authorization of certain projects affecting the environment to an assessment by the competent national or regional authority. This assessment must identify the direct and indirect effects of these projects on the following: human, fauna, flora, soil, water, air, climate, landscape, material resources and cultural

heritage, and the interaction between these components; 3) A.I. (Assessment of Impact), regarding the assessment of plans and projects significantly affecting the sites of the Natura 2000 Network.

This evaluation is based on the Directive 92/43/EEC (Habitat Directive), on the conservation of natural habitats and of wild fauna and flora, and on the Directive 2009/147/EC on the conservation of wild birds (ex Directive 79/409 EEC). Particularly, the Assessment of Impact is defined and regulated by the article 6, of the Habitat Directive, that in the third paragraph reads: "*Any plan or project not directly connected with or necessary to manage the site but likely to have a significant effect, individually or in combination with other plans or projects, is subjected to impact assessment on the site respect to the conservation objectives of this site*". Through these guidelines the EU seeks to ensure biodiversity by conserving natural habitats, wild fauna, vegetation and flora in the territory of the Member States.

In the studies of evaluation of environmental impact, the analysis of the biotic component is fundamental to assess the impact generated from plans and projects; therefore it is obvious that the fauna is one of the minimum contents required for the preparation of environmental impact studies, together with vegetation, flora (see Minissale, 2015) and ecosystems.

### THE FAUNA IN THE ENVIRONMENTAL IMPACT STUDIES

Before delving into the issues related to the wildlife analysis in the environmental impact studies, the definition of the fauna's concept is necessary. According to La Greca (1995), the fauna is: "A set of species and subspecies of vertebrates and invertebrates, each divided into one or more populations, living in a certain territory not captive or farmed (indigenous species) and included in natural ecosystems, the presence of which in that area is due to historical events (paleogeographic and paleoclimatic), or to evolutionary processes in situ (autochthonous species or subspecies), or to indigenation of exotic species".

The study of wildlife shows numerous and complex problem: a) very large number of animals, especially invertebrates (over 80% of the animals belong to the phylum Arthropoda, inside of which more than 75% belong to the class Hexapod); b) basic knowledge in general unsatisfactory, even for protected areas; c) difficulty of making a quick faunistic list of a region, even with small extension; d) necessity to adopt different and very specialized sampling methods related to the animals mobility and the different habitats they occupy; e) difficulty in developing maps for wildlife.

In relation to these issues, two methodologies are used for the study of fauna in the environmental impact studies: 1) Ecosystem approach (review of certain natural habitats of particular interest in relation to the associated fauna component); 2) List of species (for a more detailed discussion of the topic see Sabella & Petralia, 2012). Really, the zoologists must interpret the territory as a mosaic of areas that provide real or potential opportunities (trophic, reproduction, shelter, etc.) for the various wildlife species.

The attention of the zoologists involved in the environmental impact studies, generally, focuses on the

terrestrial vertebrates (especially birds), because it is the best known component of the wildlife and responds to the needs to assess the environmental quality in relation to the targets of the impact studies.

### THE USE OF ENTOMOFAUNA: APPROACHES AND TOOLS

The insects are generally poorly used in the environmental impact studies. This component, instead, on account of its species richness (more than 1 million of taxa known heretofore), of its ubiquitous occurrence and very different diet (predators, phytophagous, saprophagous, parasites, pollinators, etc.) and of its diverse and articulated ecological requirements is suited for the environmental impact studies (Rosenberg et al., 1986). The study of entomofauna, in many cases, provides more detailed information on the fine structure and functioning of the ecosystems and/or allows to study in more detail the habitats or the microhabitats of particular naturalistic value (dunes and back-shore, springs, ripicolous environments, soil, caves, rotting stumps, hollow of old trees, etc.), which are sometimes very important in the environmental impact studies, and also in the territorial planning and in the nature conservation policy (Gobbi, 2000).

In relation to the high species number and to the great diversity of the environments in which they occur, the study of insects present all the problems outlined above in a more accentuated, so much so that, at first glance, it would seem almost impossible to use the insects in the assessment procedures. For this reasons guidelines for the use of insects in impact evaluation are, generally, lacking, with exception regarding the freshwater ecosystems (Adham et al., 2009; Walters, 2011; Barman, 2014) and the agro ecosystems (see for example Caoduro et al., 2014).

To do this you have, first, to give up the idea of establishing a more or less full list of insect species of a territory, even if small. In any case, this idea is unworkable for all faunistic studies. But ignoring entomofauna cannot solve this problem. In the last years, however, many tools have become available for use the insects in the environmental management and also in the impact assessment studies. For a review of the various sampling methodologies of entomofauna used in environmental monitoring and a case study see Burgio et al. (2013).

It is clear that for assessment studies can be used only a small fraction of all insect species that occur in the study area and should be considered those with conservation problems (IUCN status, inclusion in international conventions or European directive annexes) and/or scientific value (endemic, stenocious, at the areal limit, etc.).

Below are briefly treated the main tools usable for the evaluation of the environmental quality based on the presence of insects species.

They, substantially, consist of the European, national and regional red list drafted according to IUCN criteria, of the annexes of different international convention and European directive, of the checklists (sometimes georeferenced), and of the Standard Data Form and the Management Plan of the Natura 2000 site.

### SPECIES INCLUDED IN THE ANNEXES OF DIRECTIVE 43/92 EEC

#### *Insects species of Annex II to Directive 43/92 EEC present in Sicily*

The taxa listed in Annex II are named as “Community interest species whose conservation requires the designation of special areas of conser-

vation” (with an asterisk priority species are indicated). All these species are very important for Assessment of Impact because it is mandatory to take them into account and considering the possible negative effects induced by the territory's transformation linked to realize a project. Only if you can exclude negative effects on these species, or in the presence of negative impacts proposing effective mitigation measures, it is possible to give a positive evaluation of the environmental compatibility of the project.

The insect species included in the Annex II to Directive 43/92 EEC present in Sicily are show in Table 1, and briefly commentated on below, emphasizing the most important threat factors to consider for their conservation.

#### *Coenagrion mercuriale* (Charpentier, 1840)

The larvae live in streams, usually on limestone substrates. Sicilian populations (Fig. 1) are very localized. The species is rare in Italy and must be considered vulnerable. The major threats are: river straightening, water harnessing, swamps and soil drainage, water table lowering through irrigation, field destruction or conversion into other agricultural practices, water pollution (IUCN, 2014).

ODONATA	Coenagrionidae	<i>Coenagrion mercuriale</i> (o) - in Italy <i>C. mercuriale castellani</i> Roberts, 1948
	Cordulegastridae	<i>Cordulegaster trinacriae</i>
ORTHOPTERA	Gryllidae	<i>Brachytrupes megacephalus</i>
		<i>Myrmecophilus baronii</i> - only Pantelleria island
COLEOPTERA	Lucanidae	<i>Lucanus cervus</i> (?) (o)
	Geotrupidae	<i>Bolbelasmus unicornis</i> - in Sicily <i>B. romanorum</i>
	Cetoniidae	* <i>Osmoderma eremita</i> - in Sicily <i>O. cristinae</i>
	Cerambycidae	<i>Cerambyx cerdo</i>
		* <i>Rosalia alpina</i>
LEPIDOPTERA	Arctiidae	* <i>Callimorpha quadripunctaria</i> (now <i>Euplagia</i> ) (o)
	Satyridae	<i>Melanargia arge</i>

Table 1. Insects species of Annex II to Directive 43/92 EEC present in Sicily. All species listed in Annex II are present also in Annex IV excluding those followed by symbol (o). The symbol \* highlights the priorities species, while the symbol (?) indicates the uncertain presence of the species in Sicily.

***Cordulegaster trinacriae*** Waterston, 1976

The larvae live in clean streams with sandy bottom, shaded by tree vegetation. The species is threatened by chemical and physical water pollution, by water extraction for human use and by removal of riparian vegetation. Desiccation due to climate change is a further threat for this species (IUCN, 2014).

***Brachytrupes megacephalus*** (Lefevre, 1827)

Large cricket that lives in dune and back-dune environments, showing strong burrowing habits. It builds a long one-meter burrow using a spectacular technique of excavation. The species (Fig. 2) is threatened by habitat changes due to agricultural practices and touristic exploitation of beach (see Petralia et al., 2015).

***Myrmecophilus baronii*** Baccetti, 1966

Endemic species to Pantelleria Island. It is a mirmecophilous Grillidae generally enfeoffed with the ants of the genus *Lasius* Fabricius, 1804.

***Lucanus cervus cervus*** (Linnaeus, 1758)

The presence of this taxon in Sicily is to be confirmed. It lives in forests of oak and chestnut, sometimes, on the trunks and branches of willows and mulberries. The female lays the eggs at the foot of the trees; the larvae feed on humus and then penetrate into the trunk, but generally they dig their tunnels in the stumps remaining in ground and their development requires up to 5 years. The species is threatened by the coppicing of the forests and cleanliness of the undergrowth. The taxon not yet assessed for the IUCN Red List. In Sicily is certainly presents *L. tetraodon sicilianus* Planet, 1899, showing similar ecological requirements but is not listed in any Annex to the Habitats Directive.

***Bolbelasmus romanorum*** Arnone et Massa, 2010

*Bolbelasmus unicornis* (Schrank, 1789) is included in Annex II of the Habitats Directive and also *B. romanorum*, endemic to Sicily, should be inserted into Annex II. *B. romanorum* is relatively rare and localized species. Its biology is still poorly known. It can be occasionally observed wandering on the

ground or under stones and during crepuscular flight. The taxon not yet assessed for the IUCN Red List.

**\**Osmoderma cristinae*** Sparacio, 1994

The genus *Osmoderma* Le Peletier de Saint-Fargeau et Serville, 1828 includes species very sensitive to environmental changes and everywhere in rarefaction. *O. eremita* (Scopoli, 1763) is included in Annex II of the Habitats Directive as priority species. Even *O. cristinae* (Fig. 3), endemic to northwestern Sicily, and *O. italicum* Sparacio, 2000, endemic to Central and Southern Italy, with a biology entirely comparable with that of *O. eremita*, should be inserted into Annex II and regarded as priority species. *O. cristinae* is a silvicolous species. The larvae develop in old rotting trunks of oaks or maples. The main overall threat is likely to be degradation or loss of habitat quality, involving structural changes in the tree populations arising from changing land use - affecting age structures and trees density. Exploitation from forestry is often a key immediate issue, but equally damaging can be long-term changes towards canopy closure and loss of old trees as a result of non or minimum intervention management systems which all too often exclude grazing by large herbivores. Fragmentation and increasing isolation of beetle populations are also key factors. The restricted area of occupancy combines limited population size with reduced habitat availability, bird predation, fires, and frequently unsuitable local techniques of forest management (Audisio et al., 2007).

***Cerambyx cerdo cerdo*** (Linnaeus, 1758)

Silvicolous species. The adult feeds on leaves, fruit and lymph and actively flies in the twilight hours. After mating, which occurs between June and August, the female lays her eggs in the cracks of the bark of big oak trees. The saproxylic larva begins to dig tunnels in the cortical layers and then penetrates into the wood and its development requires 3-4 years. It is a species threatened by coppicing of oak trees and by the removal of old decaying plants.

**\**Rosalia alpina*** (Linnaeus, 1758)

The species (Fig. 4) lives preferentially in mature forests with a predominance of beech, especially

those characterized by very rainy or oceanic climate. Adults are active during the day on logs felled or inflorescences of Umbrelliferae. After mating, eggs are laid in the wood; the larval development takes 3 years, and it is preferably done in dead or decayed wood of beech exposed to the sun. The larva can develop also on alder, ash, hawthorn, linden and maple or conifers. The species is threatened by excessive cleaning the forest area; perhaps even by air pollution and by the general contraction of beech forests, especially mature ones.

**\**Euplagia quadripunctaria*** (Poda, 1761)

The only European species of this genus. It can be found in the cool forests and, in the Mediterranean region, most often in narrow valleys bounded by mountains with steep slopes with perennial streams and continuous woodlands, characterized by a microclimate cooler and wetter than the surround-

ing areas. Adults have primarily nocturnal habits and spending the day in the dense vegetation. The larvae emerge after 8-15 days after spawning and feed on various plants for a short time (like several Rosaceae, and other species such as black locust and eastern plane tree, vines and mulberry trees, honeysuckle) then they go into hibernation. After the 5th molt, the caterpillar spins a slight cocoon in the litter. The pupal stage lasts about 1 month; the imago emerges between June and August, most often in July, according to the altitude and the seasons.

***Melanargia arge*** (Sulzer, 1776)

The species is distributed in peninsular Italy and northern Sicily. Its habitat is represented by arid steppes with scattered bushes and isolated trees with outcropping rocks. Most of the sites are located in the valleys sheltered from the wind or in hilly areas inland. The fires favored by shepherds and the



Figure 1. *Coenagrion mercuriale castellani*, Sicily, Palermo, stazione Montemaggiore Belsito, 30.IV.2010. Figure 2. *Brachytrupes megacephalus*, Sicily, Trapani, Capo Feto, 1.V.2011. Figure 3. *Osmoderma cristinae*, Sicily, Madonie Mountains, Gibilmanna, 2.VII.2014. Figure 4. *Rosalia alpina*, Nebrodi Mountains, Biviere di Cesarò, 6.VII.2014 (Photos by C. Muscarella).

ORTHOPTERA	TETTIGONIIDAE	<i>Saga pedo</i>
LEPIDOPTERA	PAPILIONIDAE	<i>Papilio alexanor</i>
		<i>Parnassius apollo</i>
		<i>Parnassius mnemosyne</i>
		<i>Zerynthia polyxena</i>
	SPHINGIDAE	<i>Proserpinus proserpina</i>

Table 2. Insects species of Annex IV to Directive 43/92 EEC not listed in Annex II, present in Sicily.

overgrazing can have serious negative effects on this species along with other habitat alterations. This species is not believed to face major threats at the European level.

***Insects species of Annex IV to Directive 43/92 EEC not listed in Annex II, present in Sicily***

The taxa listed in Annex IV are named as “Community interest species in need of strict protection”.

Most of the species listed in Annex II are also mentioned in Annex IV, so in Table 2 are shown only the insects species present in Sicily and listed in Annex IV, but not in Annex II. They are briefly commented on below, emphasizing the most important threat factors to consider for their conservation.

***Saga pedo* (Pallas, 1771)**

Species distributed from central-southern and southeastern Europe to central Asia and north-western China. In Italy it is present in a few areas of the Alps and Apennines, Sardinia and Sicily. *Saga pedo* colonizes areas with more or less open herbaceous vegetation or shrubs. It can be observed on the ground or on bushes, where moves rather slowly. Predator species, feeding mainly on other Orthoptera (grasshoppers and locusts) that captures thanks to the long and strong forelegs armed with spines. Never common in areas where it is present, is threatened by habitat degradation.

***Papilio alexanor* Esper, 1800**

This butterfly is mostly found on warm and dry

calcareous slopes with flower-rich vegetation and low-growing bushes. It prefers slopes that are steep and rocky and it is especially active during the hottest hours of the day. Different foodplants are known, all of them umbellifers. Although this species shows a decline in a part of its European range, it is not believed to face major threats at the European scale.

***Parnassius apollo* (Linnaeus, 1758)**

Species widely distributed in the mountains of Western Europe and Southern and Fennoscandia, although it is extinct in some areas such as central Germany, Czechoslovakia and Denmark and it is absent in Britain. In Sicily, the species is at the southern limit of its distribution range and is extremely localized, it is in fact known only from a few stations on the Madonie Mountains and according to some authors belongs to a subspecies *P. apollo siciliae* Oberthür, 1899 (Fig. 5). *Parnassius apollo* is linked to stony and mountainous areas poor of vegetation. It shows a preference for calcareous soils and for some plants such as *Cardus* spp., *Cirsium* spp., *Origanum* spp., *Centaurea* spp., *Scabiosa* spp. and *Knauzia* spp.

***Parnassius mnemosyne* (Linnaeus, 1758)**

In Central Europe the species (Fig. 6) lives in hill and mountain areas up to 1,500 m of altitude, in Northern Europe in plain areas. In Italy he attends the clearings and the edges of deciduous forest (beech, turkey oak). Adults are attracted to many vegetal species, with a preference for red, purple and blue flowers as *Centaurea* spp., *Knauzia* spp., *Geranium* spp. and *Lychnis* spp. The two main

causes of its decline are the reforestation and the changes in traditional agricultural practices, which have caused the disappearance of many meadow areas.

***Zerynthia polyxena*** (Denis et Schiffermüller, 1775)

The only Italian species of this genus. It attends the plain near wetlands, the hilly and mountainous areas with arid terrain or rocky areas up to 900 m. It has a single annual generation, usually adults appear in April-May, but in Sicily may be active already at the end of February. The caterpillars feed on various species of *Aristolochia* L. The disappearance of this species, observed throughout Europe, is due to the reforestation and the habitat destruction. Locally may be threatened by excessive collection.

***Proserpinus proserpina*** (Pallas, 1772)

The only European species of the genus. It lives from the sea level up to 1,500 m in different biotopes such as valleys, forest edges, clearings and banks of the streams, in rich sites of *Epilobium angustifolium* L. Adults are primarily nocturnal and prefer nectar-rich flowers, such as the common oregano, several species of fireweed, wild pink and honeysuckle. The species has disappeared from many localities in recent times, but the causes are not known. Some populations seem to disappear for a few years and reappear suddenly, for no apparent reason.

**SPECIES INCLUDED IN THE RED LIST BASED ON IUCN CRITERIA**

One other very useful tool is represented of the Red Lists based on IUCN criteria (IUCN, 2012). On the site <http://www.iucnredlist.org/> can be check the Red List of Threatened Species, which are mentioned all insect species considered threatened at the global level. For each of them, informations on taxonomy, assessment, geographic range, population, habitat and ecology, and major threats are provided. However, there are European red lists among which are to mention those of saproxylic Coleoptera (Nieto & Alexander, 2010), of butterfly (Van Swaay et al., 2010), and of dragonflies (Kalkman et al., 2010). Also to be mentioned some national red lists such as those on Italian invertebrates (Cerfolli et al.,



Figure 5. *Parnassius apollo*, Sicily, Madonie Mountains, Pizzo Carbonara, 15.VII.2006. Figure 6. *Parnassius mnemosyne*, Sicily, Madonie Mountains, Piano Battaglietta, 12.VI.2012 (Photos by C. Muscarella).

2002), on butterflies (Prola & Prola, 1990) and the recent red lists of Italian saproxylic Coleoptera (Audisio et al., 2014) and Italian dragonflies (Riservato et al., 2014). For Sicily, currently, there are not regional red lists of insects, the only work, that concerns only Coleoptera and Lepidoptera, is a list of species present within the Regional Parks, in which, for each species, informations on assessment, geographic distribution, and habitat are provided (Sabella & Sparacio, 2004).

**SPECIES LISTED IN THE ENTOMOLEX**

A very useful tool, drawn up under the auspices of the Italian Entomological Society, is represented

by Entomolex (Ballerio, 2004). It is a review that aims to provide an overview of all the rules concerning the conservation of the Italian insects. For each mentioned species is considered its inclusion in the annexes of international conventions (Conventions of Washington and Bern), of EU legislation (Directive 43/92 EEC), and of national and regional (Regions Friuli Venezia-Giulia, Liguria, Lombardy, Piedmont, Tuscany, and Veneto and the autonomous provinces of Trento and Bolzano) laws.

### **CKMAP OF ITALIAN FAUNA, FAUNA D'ITALIA AND REGIONAL CATALOGUE**

The CKmap project (Ruffo & Stoch, 2005) and its database have made available information on the punctual distribution in Italy of approximately 10,000 terrestrial and freshwater species selected from the checklist because protected, threatened, with scientific or biogeographical interest, or bioindicators. The project represents an important tool for a correct and scientific management of the biodiversity and the natural habitats, as from Checklist of the Italian fauna (Minelli et al., 1993-1995), that comprises about 55,000 species. In the CKmap, for each species, geo-referenced data of the Italian localities, of the distribution, of the ecology, and its value as a bioindicator are provided. The analysis of so large sample of species has allowed to identify the most important areas in terms of the number of species, of the concentration of endemic species, of the species with restricted distribution and/or of particular biogeographical interest. All that permit to draw a picture of the overall distribution of animal biodiversity in Italy with a level of accuracy and detail unthinkable a few years ago.

The CKmap can provide, therefore, detailed information on many species of Sicilian entomofauna, and must be integrated with the many monographs of the series "Fauna d'Italia" dedicated to insects, some regional checklist (see for example Pilato et al., 2007 for Iblean region) and many regional faunistic catalogs concerning various taxonomic groups such as Ephemeroptera (Belfiore et al., 1991), Plecoptera (Fochetti & Nicolai, 1987; Ravizza & Gerecke, 1991), Neuroptera (Pantaleoni, 1986), Coleoptera Cerambycidae (Sama & Schurmann, 1980), Coleoptera Staphylinidae (Sabella & Zanetti, 1991), Coleoptera Pselaphidae

(Sabella, 1998), Coleoptera Tenebrionidae (Aliquò & Soldati, 2010; Aliquò & Soldati, 2014), etc. Of course many other citations of Sicilian insect species are dispersed in numerous scientific publications, it would be better to know, but the use of the tools suggested previously can be deemed sufficient to estimate the environmental quality of an area and assess the impact of the implementation of a project.

### **STANDARD DATA FORM AND MANAGEMENT PLAN OF NATURA 2000 SITES**

At each site Natura 2000 is associated a standard data form, available, for Italian sites, on the official website of the Ministry of Environment and Protection of Land and Sea (<http://www.minambiente.it/pagina/schede-e-cartografie>). The standard data form, which is still required in an Annex when processing a report of Impact Assessment, listing all habitats and species of Community interest whose conservation requires the designation of special areas of conservation (for the invertebrates see the section 3.2.f.) and also all other important species (see the section 3.3), because listed in the national red list (motivation A), endemics (motivation B); included in the international conventions (motivation C) or for other reasons (motivation D).

In regards to the sicilian Region, on the official website of the Regional Ministry of Land and Environment ([http://www.artasicilia.eu/old\\_site/web/natura2000/index.html](http://www.artasicilia.eu/old_site/web/natura2000/index.html)) most of the Management Plans of the sicilian Natura 2000 sites are available and downloadable in pdf format. In these plans can be find detailed information on the animal species including their distribution in the site habitats and their ecological requirements.

### **BRIEF CONCLUSIVE CONSIDERATIONS**

This paper attempts to emphasize the importance of the insect fauna study in environmental impact assessment and more generally in the territory planning and nature conservation.

The numerous problems related to the study of the entomofauna should not discourage, because by a reasonable approach, it can get to a list of species that, far from being exhaustive, may represent a

good basis for the assessment, in terms of fauna, of the environmental quality and thus to assess any impacts. In another article in this volume, a study case, in which were used the approach and tools previously treated, is proposed (Sabella et al., 2015).

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## A study case of Assessment of Impact using the invertebrates

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### ABSTRACT

A study case of Assessment of Impact (A.I.) in regards to the project of achieving diaphragm containment for homogeneous areas T and V of the Gela Refinery is explained. The invertebrates were used to evaluate the environmental quality and also to identify appropriate and effective mitigation measures and for preparing a post-operam monitoring. Some methodological proposals and an index of faunistic habitat value have been proposed.

### KEY WORDS

Assessment of Impact; Invertebrates; Sicily; Faunistic value index.

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### INTRODUCTION

The article 6 of the Directive 92/43 EEC establishes the rules, which govern and regulate the conservation and management of the Nature 2000 network sites, and determines the guidelines to be adopted by the member states for proper relationship between the protection of natural resources and the land use. In particular, the paragraphs 3 and 4 establish procedures governing the approval of plans or projects that insist on SCI or SPA, and not directly related to their management. Essentially, any transformation that interests a Natura 2000 site, as well as areas adjacent thereto must be subjected to a procedure for Assessment of Impact, which excludes negative effects on the site, or, if it recognizes them, proposes corrective measures (mitigation or compensation).

The realization of a diaphragm containment of some areas of the Gela Refinery (Sicily), fell back within the perimeter of the SCI and SPA ITA 050001 - Biviere and Macconi of Gela. Therefore, in compliance with the requirements of the aforementioned legislation, the project proposer has decided

to proceed to the elaboration of the Assessment of Impact to verify if the project could have the adverse effects on habitats and species in Annexes I and II Directive 92/43 EEC and species of Annex I to Directive 2009/147 EC of the Natura 2000 site.

The project involved the construction of a barrier to excavation with composite diaphragm (self-hardening mud and HDPE sheet) associated to a system of pumping wells of groundwater, already pre-existing for much, built upstream of the diaphragm. For its realization the excavation of a trench, about 1 meter wide, 25 meters on average deep, and about 2.5 kilometers long was foreseen, and so effects on soil fauna, which concerns substantially invertebrates, were expected.

Although invertebrates are little used in environmental impact assessments (Sabella et al., 2015), in this case, for project evaluation their study was necessary, given their importance in determining the composition and structure of the soil fauna. For this reason, at the study of terrestrial Vertebrates it is added that of the invertebrates, with particular attention to the Insects.

## MATERIAL AND METHODS

### *Study area*

The study area includes a territory in which it is believed, on the basis of the project data, are possible impacts on wildlife induced by its realization. The area is located in the district of "Piana del Signore", in the municipality of Gela, within the larger territory of "Piana di Gela". It is bordered to west by the Priolo Channel, to the east by the New Priolo Channel and is between the coast and the south side of the Gela Refinery (Fig. 1).

### *Sampling and analysis*

The species list refers to the study area identified in figure 1. The annotated catalogue of the terrestrial Vertebrates was based on the Nature 2000

site's Standard Data Form, and also on literature references believed to be accurate, on personal observations and/or on the presence of potentially suitable habitat for the species. The annotated catalogue of the Arthropods was based on the Natura 2000 site's Standard Data Form, on literature references believed to be accurate, on a faunistic sampling campaign, with a monthly intervals, from June to November, with various techniques (collection on view, mowing, and sifting). For the purposes of an biocoenotic investigation on soil fauna, was also used the method of pit-fall traps, which allowed to sample many species, not detected by other sampling methods.

For each species were reported data on: 1) scientific name, author and year, according to the nomenclature adopted by the check-list of Italian fauna (Minelli et al., 1993-1995) and Ckmap of Italian fauna (Ruffo & Stoch, 2005), considering

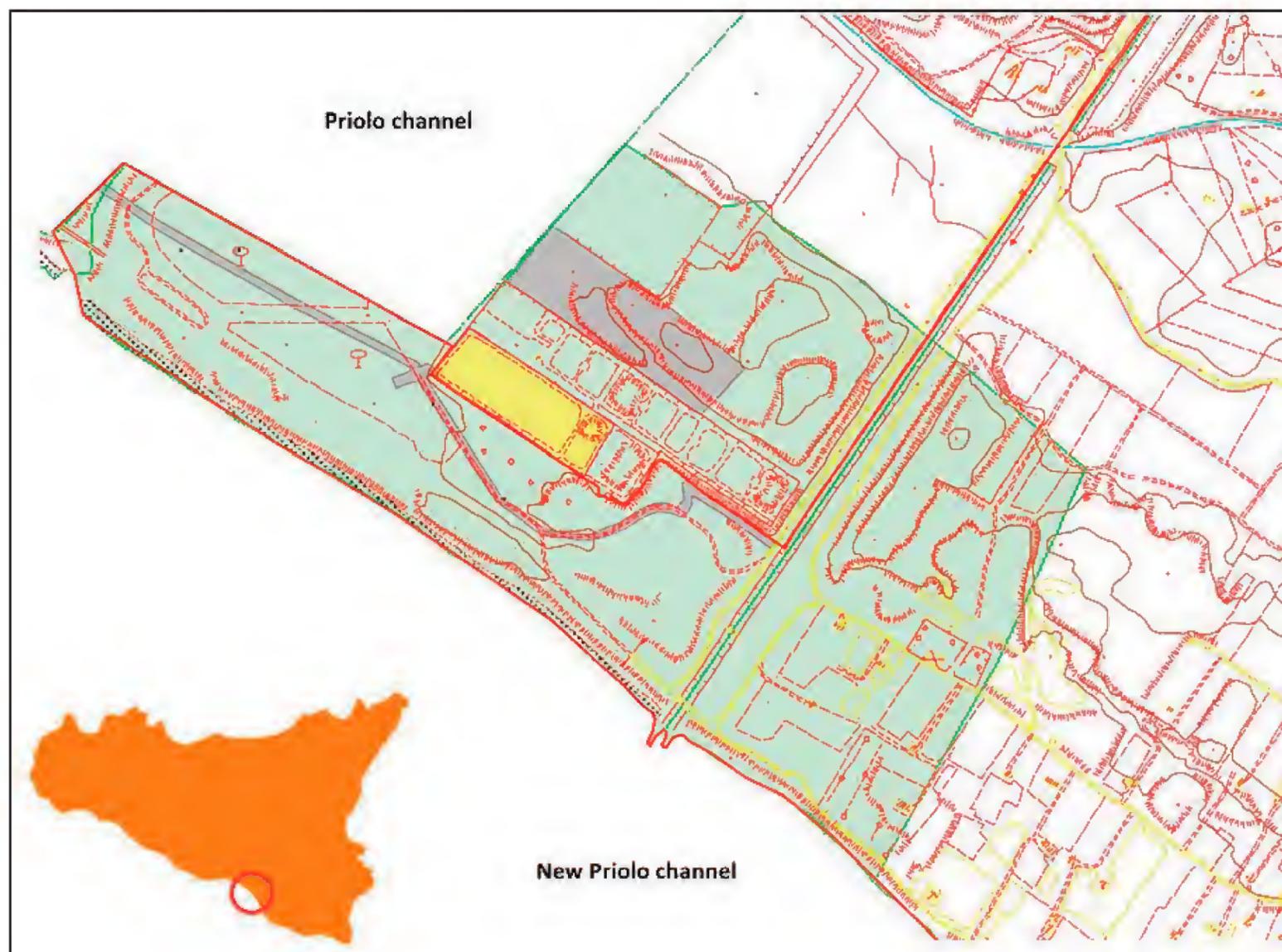


Figure 1. Study area. Red line: perimeter of the Natura 2000 site; in green: study area; in yellow: remediation area of basin A zone 2 of Gela Refinery, Sicily; in gray: affected area in the project of the diaphragm containment for homogeneous areas T and V of the Gela Refinery.

the subsequent changes in the nomenclature of the recent literature; 2) the chorologic category, according to Vigna Taglianti et al. (1992, 1999), while for birds according to Bricchetti (1997); 3) the habitats potentially utilized by the species in the area; 4) if known, the phenology of the species; 5) the trend of European and Italian populations.

Particular attention was given to measures of protection and conservation of which the species is the subject, indicating its presence in the following annexes:

- II (strictly protected species of fauna) and III (protected fauna species) of the Berne Convention, law 5 August 1981 n. 503, on the Conservation of European Wildlife and Natural Habitats in Europe;

- I (endangered migratory species) and II (migratory species to be the subject of agreements) of the Bonn Convention, law 25 January 1983 n. 42, on the Conservation of migratory species of wild animals;

- A (species threatened with extinction which are or may be an action of the trade) and B (species not necessarily threatened with extinction at the present time, but that may become so unless trade is not subject to regulation close) of the Washington Convention, law 19 December 1975 n. 874, on international trade in animal and plant species threatened with extinction (CITES) and subsequent amendments and additions;

- II (animal and plant species of Community interest whose conservation requires the designation of special areas of conservation), IV (animal and plant species of Community interest in need of strict protection) and V (animal and plant species of Community interest whose taking in the wild and exploitation may be subject to management measures) of EEC Directive 92/43, D.P.R. 8 September 1997 n. 357, on the conservation of natural habitats and of wild fauna and flora in Europe.

As for the birds, for each species was specified inclusion in the Annexes (I, II/A, II/B, III/A and III/C) of the Directive EC 2009/147 and the conservation status according the Species of European Conservation Concern of Birdlife International, 2004 (SPEC1, SPEC2, SPEC3, Non-SPEC<sup>B</sup> and Non-SPEC).

For Mammals and Birds species, their possible protection established by the law 11 February 1992, n. 157 (rules for the protection of homeotherme wildlife and for hunting) and their inclusion in article 2, which provides for such species specific protective measures, was also considered.

The species conservation status, inferred by the website IUCN 2014 and by the various national (Prola & Prola, 1990; Cerfolli et al., 2002; Rondinini et al., 2013; Audisio et al., 2014; Riservato et al., 2014) and regional (A.A.V.V., 2008) red lists, based on IUCN criteria (IUCN, 2012), was also indicated.

<p><b>Species of Annex II to Directive 43/92 EEC = 1.5 + 0.50 if priority</b></p> <p><b>Species of Annexes to international convention, or to national or regional laws = 1</b></p> <p><b>Species included in national red lists based on IUCN criteria</b></p> <ul style="list-style-type: none"> <li>■ CR = 1</li> <li>■ EN = 0.80</li> <li>■ VU = 0.60</li> <li>■ NT = 0.40</li> <li>■ LC = 0.20</li> </ul> <p><b>Species of biogeographical interest</b></p> <ul style="list-style-type: none"> <li>■ Sicilian endemic species = 1 + 0.20 if present only in southern Sicily</li> <li>■ Sicilian endemic subspecies = 0.50 + 0.20 if present only in southern Sicily</li> <li>■ Species with restricted distribution = 0.50</li> <li>■ Species at the northern end of their distribution = 0.70</li> <li>■ Species which in Italy are present only in Sicily = 0.50 (1.00 if in Europe are present only in Sicily)</li> <li>■ Species at the southern end of their distribution = 0.50</li> </ul> <p><b>Species relevant for ecological aspects</b></p> <ul style="list-style-type: none"> <li>■ Stenotops or stenoecious = 0.70</li> <li>■ Susceptible to human disturbance = 0.70</li> <li>■ Localized = 0.50</li> <li>■ Restricted populations = 0.50</li> </ul>
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Table 1. Criteria used for the faunistic value attribution to the invertebrates species.

A faunistic value (see for example Massa & Canale, 2008) to each species is assigned, for invertebrates it was based on the criteria showed in Table 1. If a species fell within in more than categories, the values were summed. Within the study area, based on the vegetation and the land use

Habitat	Acronym
Shoreline and sandy shore	BAR
Aquatic environment and riparian zone	ACQ
Sand dune	DUN
<i>Juniperus maritimus</i> scrub	MAG
<i>Retama raetam</i> scrub	MAR
<i>Tamarix</i> groupings	TAM
Back dune open environment	APR
<i>Saccarum monophytic</i> groupings	SAC
<i>Eucalyptus rostrata</i> reforestation	EUC
<i>Acacia saligna</i> reforestation	ACA
<i>Pinus pinea</i> reforestation	PIN

Table 2. Habitat types within the study area and used acronyms.

maps, the following 11 natural and seminatural habitat types have been identified (Table 2):

In order to compare the faunistic values of the habitats aforementioned, considering the specific biodiversity level in each habitat, and the faunistic value of each species, an index of the faunistic

$$I(h) = \frac{\sum_{j \in h} v'(j)}{\sum_{j \in S} v'(j)} \times 100 \quad \text{with} \quad v'(j) = \frac{v(j)}{nh(j)} + 0.01$$

$I(h)$  = Index of habitat faunistic value  
 $j$  = species  
 $h$  = habitat  
 $v(j)$  = faunistic value of species  
 $nh(j)$  = number of habitats in which the species is present  
 $S$  = species of all habitat

Figure 2. Formula used to calculate the faunistic value of the habitat.

value of the habitat,  $I(h)$ , calculated with the formula showed in Fig. 2.

Each species contributes to the ecosystems functioning, becoming part of the trophic networks, and using, at various levels, the habitat resources, so none of them can take a null faunistic value. Therefore, it was considered appropriate to assign a minimum value of 0.01 to each taxon. This value has been estimated as half of the minimum value of  $\frac{v(j)}{nh(j)}$  found.

## RESULTS

A total of 273 animal taxa were counted, of which 198 were Arthropods, and 186 Insects.

The study of the invertebrate fauna of a geographical area, although of limited size, requires very long times and the use of many specialists of different taxonomic groups, in consideration of its great richness and of its articulation, which allows it to occupy most part of habitats, and in any case, can not be exhaustive (Sabella et al., 2015). Just remember that the check-list of Italian fauna (Minelli et al., 1993-1995) cites for Sicily over 12,000 terrestrial taxa, with the Order of the Coleoptera which includes about 4,400 species and subspecies.

The study of the invertebrate fauna, therefore, was aimed to examine only some of the fauna components considered important to establish the environmental quality and to identify the potential impacts related to modifications of the environment. So, some groups were considered relevant to the study of the fauna of the soil, and of the sub-aerial environments. In particular, were considered, among the Chelicerata, Araneidae, and among the Mandibulata, Crustacea (terrestrials amphipods and isopods) and Insecta (Odonata, Orthoptera, Blattodea, Heteroptera, Coleoptera, Lepidoptera and Hymenoptera Formicidae). Among these 96 species were Coleoptera, 14 Lepidoptera, and 22 Hymenoptera Formicidae.

Among collected Insects taxa, three (*Orthetrum trinacria* (Selys, 1841), *Ochrilidia sicula* Salfi, 1931 and *Carabus faminii faminii* Dejean, 1826) have already been proposed for inclusion in Annex II to Directive 92/43 EEC, while two (*Calomera littoralis nemoralis* (Olivier, 1790), and *Eurynebria complanata* (Linnaeus, 1767) are included in annex A of regional law 6 April 2000 n. 56 of Tuscany

	Total	BAR	ACQ	DUN	MAG	MAR	TAM	APR	SAC	EUC	ACA	PIN
N of species	273	34	83	121	105	109	98	135	54	72	57	64
Faunistic value (VF)	89.75	9.017	13.623	14.510	7.540	10.115	7.682	12.959	2.811	4.723	3.281	3.490
N of species with VF = 0.001	169	17	45	75	62	64	57	88	29	40	33	38
N of species with VF > 0.001	104	17	38	46	43	45	41	47	25	32	24	26
N of species exclusives of habitat	39	5	16	1	0	2	4	11	0	0	0	1
$I(h)$		9.44	14.59	15.87	8.67	11.31	8.74	14.44	3.38	5.49	3.89	4.17

Table 3. Distribution per habitat of species number, faunistic value, and faunistic value index. BAR = Shoreline and sandy shore; ACQ = Aquatic environment and riparian zone; DUN = Sand dune; MAG = *Juniperus maritimus* scrub; MAR = *Retama raetam* scrub; TAM = *Tamarix* groupings; APR = Back dune open environment; SAC = *Saccarum monophytic* groupings; EUC = *Eucalyptus rostrata* reforestation; ACA = *Acacia saligna* reforestation; PIN = *Pinus pinea* reforestation. VF = Faunistic value.  $I(h)$  = Habitat faunistic value index.

Region (Ballerio, 2004). *Dociostraurus minutus* La Greca, 1962 is endemic to southern Sicily, while five species (*Ochridia sicula*, *Isomira paupercula* (Baudi, 1883), *Notoxus siculus* La Ferte-Senectere, 1849, *Temnothorax laestrygon* (Santschi, 1931), and *Temnothorax lagrecai* (Baroni Urbani, 1964), and six subspecies (*Euchorthippus albolineatus siculus* Ramme, 1927, *Erodius siculus siculus* Solier, 1834, *Tasgius falcifer aliquoi* (Bordoni, 1976), *Tasgius globulifer evitendus* (Tottenham, 1945), *Tasgius pедator siculus* (Aubé, 1842), and *Pimelia rugulosa sublaevigata* Solier, 1836) are endemic to Sicily.

Twelve taxa show a distribution restricted to the Mediterranean basin. Among these, one species, *Pimelia grossa* Fabricius, 1792, has a Sardinian-Sicilian-Maghrebian geonemy, four species, *Ocneridia nigropunctata* (Lucas, 1849), *Platycranus putoni* Reuter, 1879, *Broscus politus* (Dejean, 1828), and *Carabus faminii faminii*, show a Sicilian-Maghrebian geonemy, while *Cylindera trisignata siciliensis* (W. Horn, 1891) has a Sicilian-Tunisian distribution, and *Temnothorax krausseii* (Emery, 1916) shows a Sicilian-Sardinian-Corsican geonemy. Also, two taxa, *Brachygluta aubei* (Tournier, 1867) and *Plagiolepis schmitzi* Forel, 1895 in Italy are known only to Sicily, while two other, *Orthetrum trinacria* and *Hypocacculus elongatulus* (Rosenhauer, 1856) are known only to Sicily and Sardinia.

Twenty four species could be considered stenotopes and/or stenoecious, sometimes with a strict and exclusive binding to a particular type of habitat. They often show populations of a few specimens

and they are very localized and very sensitive to the antropic disturbance (e.g. *Orthetrum trinacria*, *Pterolepis annulata* (Fieber, 1853), *Ochridia sicula*, *Masoreus aegyptiacus* Dejean, 1828, and *Myrmica sabuleti* Meinert, 1861). Therefore, the insect fauna shows remarkable faunistic emergencies, which are related essentially to the dune and back-dunes ecosystems and to the open environments.

In Table 3 are shown, for each habitat, its species number, its faunistic value, and its faunistic value index, while figure 3 shows, in decreasing order, the  $I(h)$  values of each habitat.

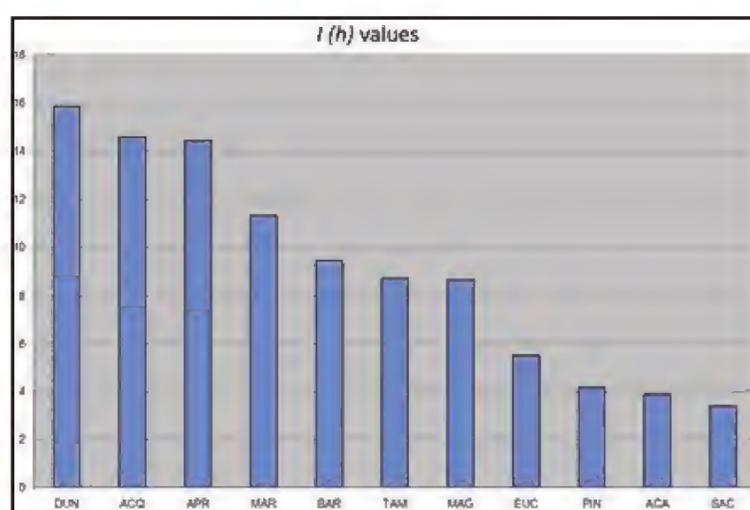


Figure 3. Histogram of  $I(h)$  values of the different habitats in the study area. DUN = Sand dune; ACQ = Aquatic environment and riparian zone; APR = Back dune open environment; MAR = *Retama raetam* scrub; BAR = Shoreline and sandy shore; TAM = *Tamarix* groupings; MAG = *Juniperus maritimus* scrub; EUC = *Eucalyptus rostrata* reforestation; PIN = *Pinus pinea* reforestation; ACA = *Acacia saligna* reforestation; SAC = *Saccarum monophytic* groupings.



The analysis of this map showed as the most part of the realization of the containment diaphragm concerned the areas of low or medium faunistic interest. On this base, the identification of the project potential impacts, and the propositions of an optimal allocation of building sites and of the safeguard of the neighboring habitats with high naturalistic value were also possible.

Were also proposed appropriate and effective mitigation measures, based on criteria, not aesthetic, but scientific and naturalistic. Specifically, renaturation actions with the restoration and the extension of the habitats of particular naturalistic interest, as back dune open environments and *Retama raetam* scrubs in place of reforestations, have been provided.

## CONCLUSIONS

The level of knowledge about the ecological responses of species and communities to environmental changes not still allows an accurate and precise quantification of their effects.

The study of the invertebrate fauna, in relation to its great species richness and the various and articulated ecological requirements of the latter, allows a more detailed assessment of the environmental quality and a more accurate prediction of the changes that may occur in the structure and in the dynamics of the zoocoenosis in response to perturbations induced by the realization of a project. So this study, together with that of the Vertebrates, enables better the identification of the areas of faunistic interest and the evaluation of their value. Then it is possible a more accurate assessment of potential impacts of the project on wildlife and the proposal for suitable and effective mitigation measures and the post-operam monitoring the actual effectiveness of these latter.

The study highlighted that, in unsuitable environmental conditions to the stay of the vertebrates community, in relation to their high levels of anthropic disturbance and/or to the limited extension of the territory, the study of invertebrates communities for the environmental quality assessment from the faunistic point of view can be very useful. In fact, confined habitats can retain good levels of animal biodiversity and represent a refuge for many rare species of invertebrates, and so they have a relevant importance for the wildlife conservation.

Unfortunately, in impact assessment studies, the invertebrates are often completely neglected and the evaluations are based solely on the vertebrate species. When "*umbrella species*" or habitats of community interest are lacking, the communities of invertebrates are, therefore, at risk.

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## Diversity in the population of *Brassica incana* Ten. (Cruciferae) in Sicily

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### ABSTRACT

Phenotypic diversity in Sicilian populations of *Brassica incana* Ten. (Cruciferae) is here analyzed in comparison with the only one known population of *B. raimondoi* Sciandrello et al., taxonomic close species recently described from the coastal relief of eastern Sicily. The analysis of diagnostic characters of these two taxa does not reveal significant differences that justify a treatment at species level of the population of *B. raimondoi*. On this base, the authors deemed to include this taxon in the infraspecific variability of *B. incana* and consider most appropriate the rank of subspecies. Therefore is here proposed the establishment of the trinomial combination *B. incana* subsp. *raimondoi*.

### KEY WORDS

Mediterranean flora; wild cabbage; Brassicaceae; taxonomy.

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### INTRODUCTION

The *Brassica* Sect. *Brassica* (Cruciferae), is a taxon represented by numerous forms described both at specific and infraspecific level. The Sicilian floristic district (sensu Fenaroli & Giacomini, 1968) is considered the diversity center of this group, because its geographical area, including Sicily, its archipelagos and the islands of Malta and Gozo, expresses the greatest biodiversity of this Section seen that 70% of species related to it, not counting the many infraspecific taxa, is concentrated in this district. (Raimondo, 1997; Raimondo 2001). The flora of Sicily includes in this section: *B. macrocarpa* Guss., *B. insularis* Moris, *B. rupestris* Raf., *B. villosa* Biv., *B. trichocarpa* Brullo C. et al. and *B. incana* Ten. To these, recently, has been added *B. raimondoi* Sciandrello et al. (Fig. 1) very close to *B. incana* and described from around Castelmola (Messina), restricted area above the village of

Taormina, *locus classicus* of the taxon (Sciandrello et al., 2013), next to one of the most classic coastal localities known of *B. incana* (Capo S. Alessio) (Fig. 2).

As part of the taxonomic review of the different Sicilian populations of Sect. *Brassica* (Mazzola & Raimondo, 1988; Raimondo et al. 1991; Raimondo & Mazzola, 1997), some taxa - previously considered at specific level as *B. tinei* Lojac., *B. drepanensis* (Caruel) Damanti and *B. bivonana* Mazzola et Raimondo were included in *B. villosa* at subspecific level. Similar treatment was given to some populations of *B. rupestris* differing from the type of the species by phenotypic, ecological and distributive characters; they were directly assigned the rank of subspecies (*B. rupestris* subsp. *hirsuta* Raimondo et Mazzola and *B. rupestris* subsp. *brevisiliqua* Raimondo et Mazzola) (Raimondo & Mazzola, 1997).

Based on these premises, and on the discovery of a new population of *B. incana* s.str. (Tenore,

1812) on the Madonie Mountains (Raimondo in PAL), we wanted to deepen the analysis of the variability of this taxon foreseeing to include in it *B. raimondoi*, taxon for which we propose the rank of subspecies within *B. incana*.

## MATERIAL AND METODHS

We studied the toptotypical population of *B. incana* Ten. and of *B. raimondoi* (Sciandrello et al., 2013). Diagnostic characters of the two taxa reported in Sciandrello et al. (2013) are analyzed and evaluated. In addition to morphological characters, the spatial distribution in comparison with the Sicilian populations of *B. incana*, in order to exclude possible genetic interferences between the populations, spatially but not orographic close, then, subjected to two different bioclimates.

## RESULTS AND DISCUSSION

Based on the analysis and evaluation of morphological characters and the criteria followed in the interpretation of the variability occurring in the other species of the same group previously treated, the distinctive characters of the taxon are not sufficiently discriminating to interspecific level. The color of the petals is not a character that is distributed continuously in *B. incana*. In Sicily, on the Tyrrhenian coast, between Capo d'Orlando and Gioiosa Marea (Messina), there are populations of this species with individuals with yellow or white flowers, respectively (Fig. 3), maintaining constant the other characters. In contrast, the same color of petals and length of siliques - given as discriminant of *B. raimondoi* by the authors - on the basis of the study of the toptotypical population are not constant. In fact, although the white flowered individuals are prevalent, yellow flowered individuals occur scattered (Figs. 5, 6). The indumentum of flowering pedicel and sepals (Fig. 4), of stem and adult leaf hairless or weakly pubescent, are variable characters in *B. incana* and therefore are not considered stable enough to be discriminating. Also in *Brassica*, the different characters of the silique, Mazzola & Raimondo (1988) distinguished *B. bionana* from *B. villosa*, then reduced to the rank of subspecies of *B. villosa* by the same authors (Rai-

mondo & Mazzola, 1997) [*B. villosa* subsp. *bionana* (Mazzola & Raimondo) Raimondo & Mazzola].

Similarly, on the same characters and their variability was based the distinction, within *B. rupestris*, of a new subspecies occurring in the western limit of the distribution end of this species including the Tyrrhenian coast between the promontory of Cefalù (Palermo) to the east, the promontory of Macari (Trapani) to the west and the inland of the Madonie and Palermo Mountains, including Rocca Busambra, to the south; it is the case of *B. rupestris* subsp. *brevisiliqua* Mazzola et Raimondo.

In light of the above considerations and of the knowledge of the group, the authors believe that *B. raimondoi* is not sufficiently distinct at specific level and consider the population of *Brassica* of the cliffs of Castelmola (Messina) as part of the variability of *B. incana*, close and spatially overlapping to this taxon, present in the underlying Ionian coast, near Cape S. Alessio. Therefore, we give to it the following arrangement:

*Brassica incana* Ten. subsp. *raimondoi* (Sciandr., C. Brullo, Brullo, Giusso, Miniss. et Salmeri) Raimondo & Spadaro **stat. & comb. nov.**

Bas. *Brassica raimondoi* Sciandrello, C. Brullo, Brullo, Giusso, Minissale & Salmeri in Pl. Biosyst. 147(3): 813 (2013).

## CHOROLOGICAL AND TAXONOMIC REMARKS

In the Mediterranean Region, among the species of *Brassica* sect. *Brassica*, there are many endemic taxa. Two in particular have a distribution almost specular from north to south. They are *B. insularis* Moris and *B. incana* Ten. The first, to the west, from the French coast, via Sardinia, goes south to Pantelleria and Tunisia; the second extends its distribution throughout the Tyrrhenian and Adriatic coasts to Sicily, including in this trajectory the eastern and western sides of the Italian peninsula to Sicily where *B. incana* occupies the eastern sector; the Madonie Mountains represent the southern-western limit.

In the south-eastern part of the distribution of this species, an isolated population of the Ionian coastal sector of the Island, described sub *B.*

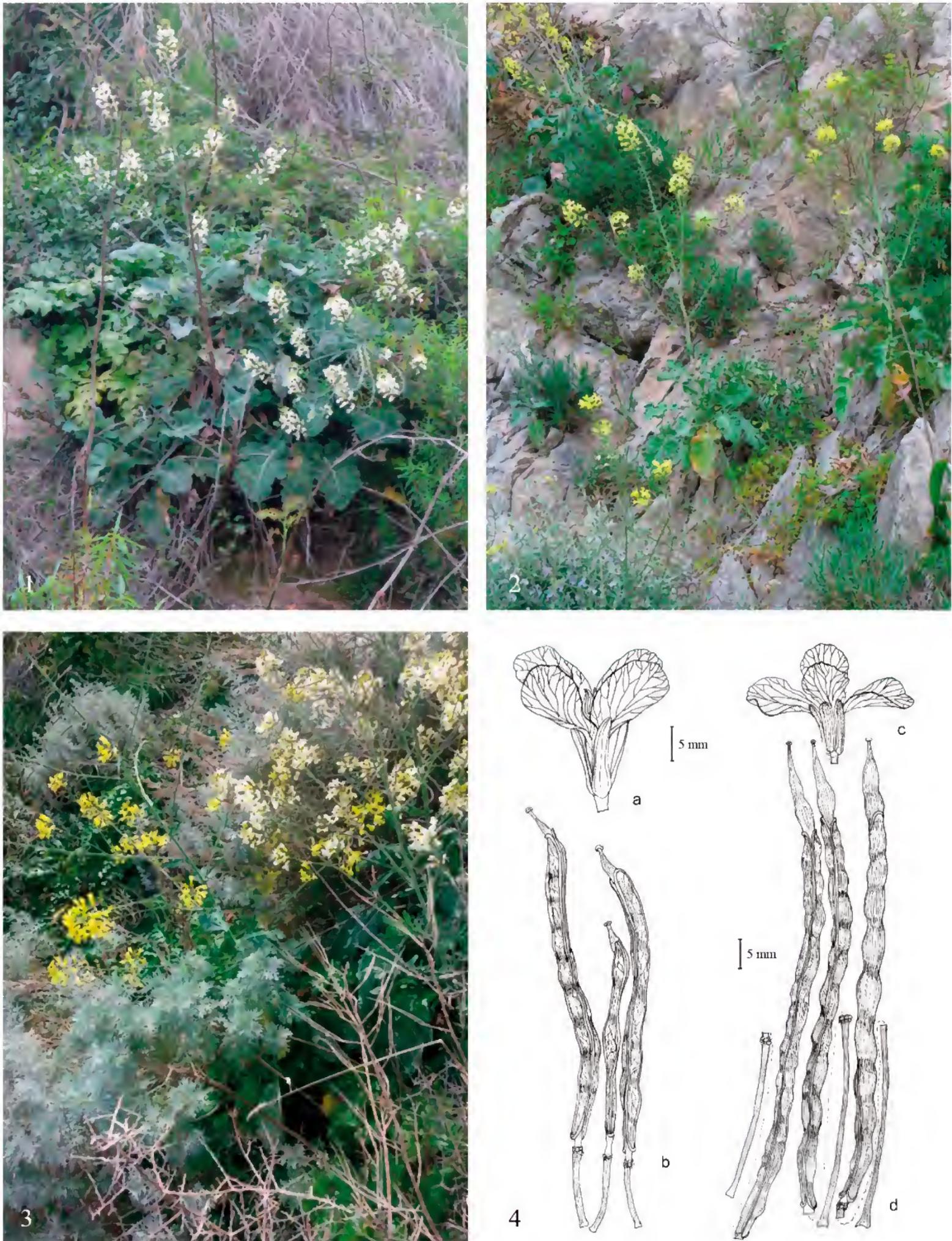


Figure 1. *Brassica raimondoi* in flower (white): *locus classicus*, Castelmola, Jonian coast of Sicily. Figure 2. *Brassica incana* in flower (yellow): Capo S. Alessio, Taormina, Jonian coast of Sicily. Figure 3. *Brassica incana* at S. Gregorio, Capo d'Orlando, Tyrrhenian coast of Sicily: plants with yellow and white flowers respectively. Figure 4. Comparison between *Brassica raimondoi* and *B. incana* s.str.: a (flower) and b (siliqueae) of *B. raimondoi*; c (flower) and d (siliqueae) of *B. incana* (recomposed from Sciandrello et al., 2013).



Figure 5. *Brassica raimondoi*, rarely with yellow flowers, in his locus classicus (Castelmola).

Figure 6. *Brassica raimondoi* in the locus classicus (Castelmola): plants with white and yellow flowers respectively.

*raimondoi*, has not significantly discriminant phenotypic characters which suggest to include the taxon within *B. incana*. For the small size of the population and the spatial isolation of the population of *B. raimondoi* remains taxonomically distinct and still subject to subspecific level.

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# Taxonomy and conservation in Higher Plants and Bryophytes in the Mediterranean Area

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## ABSTRACT

The Mediterranean Region is among the areas of the world richest in wild and cultivated taxa. Extinctions in the Mediterranean area are bound to have occurred in historical times but they are not documented. The probable and documented cases of plant extinction in specific areas within the Mediterranean are equivalent to 0.25% of total species-by-area records. Species with a large range are more prone to local population size fluctuations and eventual extinction than species with a reduced population. Small islands floras are more prone to extinction than those on large islands and on the mainland. Reliability of our data on Mediterranean plant extinctions is poor. New emphasis on floristic research is needed to boost our deficient knowledge of the Mediterranean flora. A closer collaboration between scholars and amateurs can increase floristic knowledge and also help unravel taxonomic problems.

## KEY WORDS

vascular plants; mosses; extinctions; nomenclature.

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## INTRODUCTION

The Mediterranean Region is among the areas of the world richest in wild and cultivated taxa. The vascular flora comprises about 25.000 species. 50% of the Flora (about 12.500 species) are endemic (Médail & Quézel, 1999). This richness is not due to high local species density but to small mean distributional areas reflected in a remarkable number of narrow endemics (Greuter, 1991; 2001). In spite of this high biodiversity, not all Mediterranean countries have their own Red List of endangered plants as yet; it is therefore quite difficult to make between-country comparisons. An overview was offered by Leon et al. (1985), who summarised the risk status of endemics in Mediterranean countries. More recently new lists were prepared for single countries. The red list of the flora of Greece (Phitos

et al., 2009) is an outstanding example. Global summaries for Europe have been presented by Sharrock & Jones (2009), Bilz et al. (2011), and Heywood (2012), but for the extra-European parts of the Mediterranean they are still wanting.

## MEDITERRANEAN VASCULAR PLANT EXTINCTIONS

Extinctions in the Mediterranean area are bound to have occurred in historical times, with the advent of agriculture and the profound transformation of the biota it entailed; but they are not documented. Even the alleged extinction of the famous “silphium” is not proven with certainty. The plant, probably a *Ferula* or other giant umbellifer, was used in classical antiquity in medicine and was also

fed to sheep and cattle. It was an essential item of trade with the ancient North African city of Cyrene (Fig. 1). By the first century A.C. the species, due to overgrazing and over-collection, was considered extinct in nature (Applebaum, 1979). However, from extant written documents and paintings it is not possible to name the plant with certainty. Its identity with several species has been suggested in lively and long-lasting debates, but it is still not possible to know for certain whether or not the plant is indeed extinct (Parejko, 2003).

The probable and documented cases of plant extinction in specific areas within the Mediterranean, as recorded in Med-Checklist volumes 1, 3, and 4 (Greuter et al., 1984-1989), are 116, equivalent to 0.25% of 47,298 total species-by-area records (Greuter, 1991). The reported cases of total extinctions of taxa are 22 (0.17 % of 12,886 taxa), of which: 7 are “mystery cases”, 5 are cases of possible or actual rescue, and 10 are genuine cases of (presumed) extinction (Greuter, 1991). Since 1991, continuing field research has resulted in even more reassuring figures: the 7 “mystery cases” remain the same, 4 cases of possible or actual rescue were added (*Coincya monensis* subsp. *puberula*, *Salvia peyronii*, *Silene rothmaleri*, *Silene tomentosa*), bringing the total to 9; and of the genuine cases of (presumed) extinction, only 6 remain.

The 7 “mystery cases” are: 1) *Alyssum paniculatum* Desf. (Cruciferae), based on a painting by Aubriet, allegedly representing a Cretan plant found by Tournefort in 1700 that matches no species known to grow in that area. 2) *Armeria arcuata* Boiss. et Reuter (Plumbaginaceae), once collected by Welwitsch in Portugal and never again found; according to Nieto Feliner (1987) it may well have been an occasional intersectional hybrid. 3) *Campanula pyrenaica* A. DC. (Campanulaceae), based on two specimens, one allegedly from the Balearic islands, the other from the Pyrenees. It has recently been considered a synonym of *Campanula schuchzeri* Vill. (Castroviejo et al., 2010). 4) *Genista melia* Boiss. (Leguminosae), described from Milos (Cyclades, Greece) and once doubtfully reported from the Troad (Anatolia). The origin of the type, which may well belong to the W Mediterranean *Genista scorpius* complex, is in doubt. 5) *Lathyrus allardii* Batt. (Leguminosae), described from near Alger (Algeria) in 1879 and never seen since then. Its native status has already been doubted by its

author. Perhaps it is only a form of *Lathyrus gorgoni* Parl., native further east and occasionally introduced. 6) *Quercus sicula* Lojac. (Fagaceae), described from a tree cultivated in the Botanical Garden of Palermo of unknown, probably not Sicilian origin. An altogether doubtful taxon, perhaps a mere variant of the *Quercus pubescens* complex. 7) *Silene vulgaris* subsp. *aetnensis* (Strobl) Pignatti (Caryophyllaceae), described in 1885, at varietal rank, from a single spot on Mt. Etna (Sicily). Considered an enigmatic plant not recently seen (Giardina et al., 2007).

The 9 cases of possible or actual rescue are: 1) *Coincya monensis* subsp. *puberula* (Pau) Leadlay (Brassicaceae), described in 1902 from Saniján in Galicia (Spain) but looked for unsuccessfully in its locus classicus by Castroviejo (1982), was reported from 4 localities in 1995 (Vioque & Pastor, 1995). 2) *Diplotaxis siettiana* Maire (Brassicaceae), an endemic of Alborán island (Spain) where its only population has recently been destroyed. It survives in cultivation and seed banks, and reintroduction into its native habitat looks promising (Pérez Latorre & al., 2013). 3) *Erodium astragaloides* Boiss. et Reuter (Geraniaceae), described from Sierra Nevada (Spain) where it has always been rare and was not again found in this century, was recently rediscovered in the Sierra de Cazorla (Gómez-Campo, 1987). 4) *Lysimachia minoricensis* Rodr. (Primulaceae), an endemic of Menorca (Balearic Islands, Spain) that has disappeared from its natural habitat but survives in cultivation. Reintroduction into its original habitat has been attempted (see Gómez-Campo, 1987) but so far has not been successful, although attempts continue (Galicia Herbada & Fraga Arquimbau, 2011). 5) *Onobrychis aliacmonia* Rech. f. (Leguminosae), described from Greek Macedonia, had its single locality, on the banks of Aliakmon River, flooded by an artificial lake in c. 1975. A very similar plant, discovered in Laconia (Peloponnesus), was first identified with it but later described as a distinct subspecies then species, *O. peloponnesiaca* (Iatroú et Kit Tan) Iatroú et Kit Tan. The genuine *O. aliacmonia* was rediscovered in 1985 close to its classical locality, where it managed to colonise new habitats (Greuter, 1987). 6) *Limonium dufourii* (Girard) Kuntze (Plumbaginaceae), an endemic of the Albufera de Valencia (Spain), first described in 1842, last seen in 1972, was considered a victim of



Fig. 1. Silver Coin of Cyrene dating back late 6th-early 5th centuries BC. depicting the silphium © Trustees of the British Museum (Reproduced by kind permission of the British Museum of London) on the left and *Ferula communis* on the right.

reclamation of its native wetland areas. At present, 6 small populations are known to have survived (Laguna et al., 1994). 7) *Salvia peyronii* Post (Lamiaceae), discovered in 1883 on cliffs near Feitroun (Lebanon) and never seen until recently, although it is showy and had been looked for repeatedly, was found again in the same area (Jabal Moussa) in 2011 (Tohmé & Tohmé, 2011). 8) *Silene rothmaleri* Pinto da Silva (Caryophyllaceae), described in 1945 from Cabo S. Vicente (Algarve, Portugal) and not seen since in spite of a thorough search by Jeanmonod (Greuter & Raus, 1984), was rediscovered in 2000 (Dinter & Greuter, 2004). 9) Of *Silene tomentosa* Otth (Caryophyllaceae) a few 19th-Century specimens were known, all from the E side of the Gibraltar rock (Spain), but until 1984 none had been collected in the 20th Century (Jeanmonod, 1984). In 1994 the species was rediscovered growing in the wild and is since cultivated in the Alameda Botanical Gardens (Linares, 1998).

The 6 remaining cases of (presumed) extinction are: 1) *Cephalaria kesruanica* Mouterde (Dipsacaceae), discovered in 1939 in Lebanon. Its type locality was probably destroyed; a record from a further locality requires confirmation (Mouterde, 1980). 2) *Trachelanthus foliosus* (Paine) Tristram (Boraginaceae), discovered in Jordan in 1973 and

found in a second locality in 1886. It has not been seen again (Feinbrun, 1978). 3) *Dianthus multinervis* Vis. (Caryophyllaceae) discovered by Botteri on the isolated islet of Jabuka (Pomo, Croatia) where it was not collected again and has probably disappeared (Greuter, 1995). 4) *Fibigia heterophylla* Rech. f. (Brassicaceae), discovered in 1911 between Homs and Palmyra in Syria and never again collected (Mouterde, 1970). 5) *Morina subinermis* Boiss. (Dipsacaceae), described from plants collected in Bithynia (Anatolia) without exact locality and never seen since, although it is a showy species. 6) *Trifolium acutiflorum* Murb. (Leguminosae). Described from Murbeck's own gathering made at Marrakesh (Morocco), but never collected again in spite of thorough searches (Fennane & Ibn Tattou, 1998).

The above figures do not refer to the entire Mediterranean vascular flora but only to that part (ca. 45 %) covered by the first three published volumes of Med-Checklist (Greuter et al., 1984-1989). An attempt has subsequently been made by Greuter (1994) to produce a similar list for the entire Mediterranean flora, using various other sources. The result was a table with 33 names, not taking into account the "mystery cases" and redeemed species. Of the taxa in this second list 21 are additional to the first, of which 12 were included but not

considered extinct in Med-Checklist and 9 have not yet been treated in that work. Focusing on the former, we find that not all are worthy additions to the extinct (Ex) category. One represents an interspecific hybrid (*Thalictrum simplex* subsp. *gallicum* (Rouy et Fouc.) Tutin = *T.* × *timeroyi* Jord., see Hand 2001). *Limonium dubyi* (Gren. et Godr.) Kuntze, described from France, is currently included in the synonymy of *L. bellidifolium* (Gouan) Dumort. *Tephrosia kassasii* Boulos, from the borders of the Nile in Egypt, is not considered as extinct in that country's recent floristic and conservational literature. *Thymus oehmianus* Ronniger et Soska obviously survives in its locus classicus in the Treska gorge, as its live portrait appears on a recent (2003) postage stamp of the FYR Makedonija. Of the 7 Turkish endemics listed on the faith of Ekim et al. (1989), 4 apparently survive according to recent assessments of that country's flora (Ekim et al., 2000, Eken et al., 2006): *Campanula oligosperma*

Damboldt, *Onosma affinis* Riedl, *Sedum polystriatum* R.T. Clausen, and *Silene oligotricha* Hub.-Mor. This leaves us with a reduced number of 4 genuine, additional presumed extinctions: Local and Global extinctions

Species with a large range are more prone to local population size fluctuations and eventual extinction than species with a reduced population. *Neslia paniculata* (L.) Desv. (Brassicaceae) is an example of a species with large distribution that registered important local extinctions at the borders of its range (Fig. 2). *Spirodela polyrrhiza* (L.) Schleid. (Lemnaceae), a species distributed almost world-wide, was considered extinct in Catalonia but has been found in the lower course of the Ebro River and in the Vallvidrera reservoir (Curto et al., 2013). *Rhamphidium purpuratum* Mitt. (Bryophyta, Ditrichaceae), known to be widely distributed in Macaronesia and Crete, had its only mainland site, known since 1940, in the north of Portugal. The

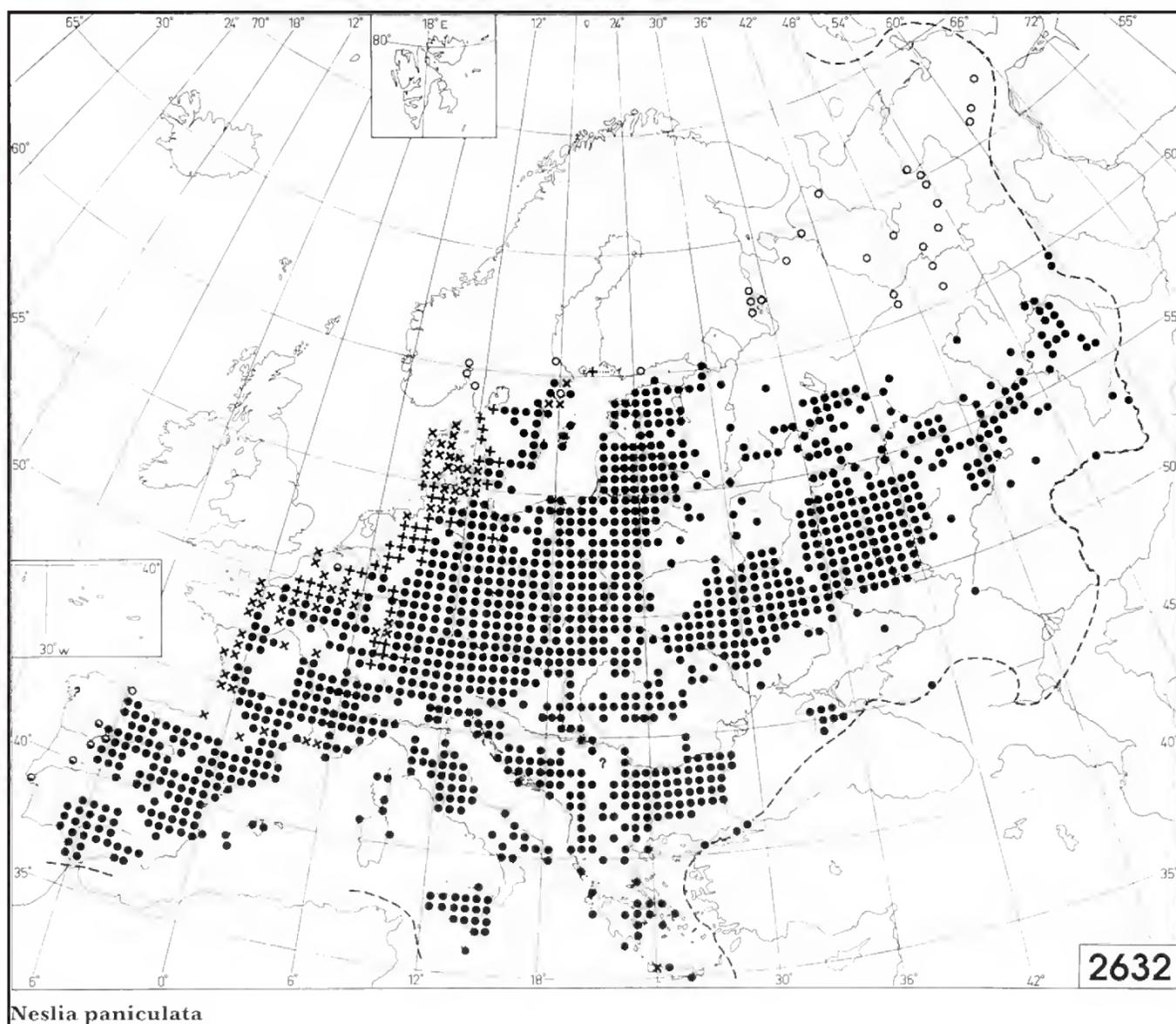


Fig. 2. Distribution of *Neslia paniculata* from Jalas et al. (1996). The crosses in the NW part of the distribution indicate the extinction of the plant in that area.

species was considered as vulnerable in the European Red List ([www.bio.ntnu.no/ECCB/RDB/Taxon.php](http://www.bio.ntnu.no/ECCB/RDB/Taxon.php)), and later considered extinct in Portugal by Sérgio et al. (1994, 2001). After more than 60 year it was found again in south-west Portugal near the Monchique mountains (Sérgio et al. 2011).

For taxa with a single locality destruction of the habitat implies its complete loss: *Adenostyles alpina* subsp. *nebrodensis* (Wagenitz et I. Müll.) Greuter (Asteraceae) is known from a single locality in a canyon of the Madonie Mountains (Sicily); the capture of a source, c. 50 years ago, has aridified the area and brought the taxon to the brink of extinction, with but a single individual still alive.

*Limonium catanense* (Lojac.) Brullo (Plumbaginaceae), at the beginning of the 20th century, was only known in an area that now belongs to the harbour of Catania.

Small islands floras are more prone to extinction than those on large islands and on the mainland (Greuter, 1995). This may be due to the greater fragility of island habitats due to their smaller surface and higher human pressure (Domina & Mazzola, 2011). The population of *Daucus rupestris* Guss. (Apiaceae) on Lampione is extremely depleted and faces imminent extinction due to high concentration of nitrogen from gull droppings, of which the plant is intolerant (Lo Cascio & Pasta, 2012). *Limonium intermedium* (Guss.) Brullo (Plumbaginaceae) was growing on Lampedusa in a salt marsh near the harbour, now converted to a soccer field (Fig. 3); at present only some individuals survive in the Botanical Garden of Catania, grown from seed sampled in the field about 40 years ago (Brullo, pers. comm.).

*Cistus ×skanbergii* Lojac. (Cistaceae) is the natural hybrid between *C. monspeliensis* and *C. parviflorum* and occurs in scattered localities in the Mediterranean, wherever the two parents meet. It was described from the island of Lampedusa (Italy), where today but a single individual is known and only one parent still occurs. Efforts to conserve that individual would be a futile exercise.

There are several cases of old, unconfirmed records, due perhaps to misidentification, and of taxa of uncertain taxonomic position, that must be taken into account in management and conservation plans for endangered species. *Orobanche aegyptiaca* Pers. (Orobanchaceae) was reported in error from Italy (Monte Gallo and Lampedusa). It was recorded in Scoppola & Spampinato (2005) as being



Fig. 3. The soccer field in Lampedusa on the place of the salt marsh near the harbour locus classicus et unicus of *Limonium intermedium*.

very rare and endangered. The study of specimens from both sites showed that they had been misidentified and belong to *O. mutelii* F.W. Schultz (Domina et al., 2011). *Euphrasia mendoncae* Samp. (Orobanchaceae) was described by Sampson in 1936 from specimens collected in 1932 by F. Mendonça and thought to be endemic to Bragança (Portugal). It was never found again despite extensive searches in 1990 and 1996. In Flora Iberica (Vitek, 2009) now it is treated as a synonym of *E. minima* Jacq. ex DC. The presence of such non-species in lists of plants requiring protection diverts attention from others that are really threatened.

Among the mosses there are also cases of taxa considered as extremely rare or extinct, only to be later included in other, widely distributed taxa. *Clasmatodon parvulus* (Hampe) Sull. (Brachytheciaceae) was believed to occur in North America and very rarely in Germany and Spain. Meinunger (1992) deemed it as extinct in Germany because it had not been found again since 1851, and it came to be known as one of the rarest mosses of the European continent (Frey et al., 1995; Düll, 1985), being so was included as endangered (EN) in the Red Data Book of European Bryophytes (Schumacker & Martiny, 1995). Heras et al. (2006) found that both the German and Spanish records were based on misidentified plants of *Pseudoleskeella tectorum* (Funck ex Brid.) Kindb. ex Broth. and must be excluded from the European and Mediterranean bryoflora. *Thamnum cossyrense* Bott. (Neckeraceae), described by Bottini (1907), was considered endemic to Pantelleria until 2001, when Mastracci

(2001) included it in *Scorpiurium sendtneri* (Schimp.) M. Fleisch., a species widely distributed in Mediterranean area. *Fissidens exiguus* Sull. (Fissidentaceae), considered rare in France and Greece (Schumacker & Martiny, 1995), is now synonymised with *F. bryoides* Hedw., a common taxon in Temperate areas (Pursell, 2007). Likewise, *Trichostomopsis aaronis* (Lorentz) S. Agnew & C. C. Towns (Pottiaceae), thought to be a rare taxon of Spain and Turkey (Schumacker & Martiny, 1995), has recently been synonymised with *Didymodon australasiae* (Hook. et Grev.) R. H. Zander, a common taxon throughout the Mediterranean area (Ros et al., 2013).

### DELIMITATION OF TAXA

Different delimitation bear on the range and the conservation status of taxa (Lastrucci et al., 2014). A glaring example is *Thymus herba-barona* Loisel. that can either be considered to comprise a single taxon, occurring in the Balearic islands, Corsica and Sardinia (Molins et al., 2011), or split into different taxa based on chromosome number: the diploid *Thymus herba-barona* subsp. *bivalens* Mayol et al. ( $2n = 28$ ), endemic to a single locality in Serra D'Aljabis (Mallorca) with only about 50 mature individuals; *Thymus herba-barona* subsp. *herba-barona*, tetraploid ( $2n = 56$ ) growing in Corsica, and *T. catharinae* Camarda, hexaploid ( $2n = 84$ ), restricted to Sardinia.

*Arenaria bolosii* (Cañig.) L. Sáez et Rosselló (Caryophyllaceae), a critically endangered taxon only known from a single site on the island of Mallorca (Bibiloni & Mus, 2006), was first described as a variety, *Arenaria grandiflora* var. *bolosii* Cañig., then considered a subspecies, *A. grandiflora* subsp. *bolosii* (Cañig.) Colom, eventually to be recognised as a separate species.

Some taxonomists, called lumpers, tend to favour a broad taxon concept, whereas others, known as splitters, emphasize minute differences. These preferences depend in part on the size of the area on which a researcher is working. Those who study plants of a restricted territory will likely search for differences whereas botanists with a broad geographical interest may favour a synthetic approach. Several taxa considered to be narrow endemics can just as well be interpreted as local expressions of wide-ranging taxa. However, as long as there can be

reasonable doubt it is better to maintain the local taxa rather than letting them disappear in synonymy. As an example, in *Pancremium maritimum* L., some populations may not deserve the status of separate species yet they possess a well-diversified genome that deserves being preserved (Giovino et al., 2015).

### CONSIDERATIONS

New emphasis on floristic research is needed to boost our deficient knowledge of the Mediterranean flora. Amateurs, if well directed, can play an important role in this endeavour. Many academic scholars spend much of their time and efforts in the laboratory, to the detriment of field research, yet they may dispose of funds for networking that allow combining the efforts of amateurs over a wider geographical area than they might cover individually. A closer collaboration between scholars and amateurs can, by promoting field research by the latter, not only increase floristic knowledge but also help unravel taxonomic problems.

Lists of taxa that are part of laws or regulations and their annexes should be updated at regular intervals. In order to apply to the originally intended taxa they must use their currently correct names; but they should also, in addition, include synonyms to reflect historical usage and accommodate alternative taxonomic views. For higher plants, synonymic checklists now exist that are widely accepted by the scientific community, notably Euro+Med Plantbase (<http://www.emplantbase.org/>), resulting from a project funded within the V and VII Framework Programme of the European Community. Likewise, the checklists published by Ros et al. (2007, 2013) provide a sound basis for channeling conservation measures of Mediterranean hepatics, anthocerotous and mosses.

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## Diversity in the genus *Hieracium* Linnaeus s. str. (Asteraceae) in Sicily

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### ABSTRACT

The present taxonomic and floristic knowledges on *Hieracium* L. s. str. in Sicily are commented. In total, 11 taxa occur in this island, 10 of which are endemic and 1 has a wider range. For each of these taxa, biological form, phenology, distribution, ecology, chromosome number, conservation, and taxonomy are taken in consideration. A key to the taxa is also provided.

### KEY WORDS

Apomixis; conservation; endemism; taxonomy; vascular plants.

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### INTRODUCTION

*Hieracium* Linnaeus (1753) s. str. (Asteraceae) is well known as one of the most species-rich plant group in the world. It includes perennial herbs distributed predominantly in temperate regions of Europe, Asia and North America (Chrtek et al., 2006). *Hieracium* belongs to a group of genera in which diplosporous agamospermy and polyploidy seem to prevail (Chrtek et al., 2006). The great majority of *Hieracium* taxa are triploid ( $2n=27$ ) or tetraploid ( $2n=36$ ) apomicts (Mraz et al., 2001). Sexuality is extremely rare and confined to a few diploid species, mostly distributed in South Europe (Merxmüller, 1975; Chrtek et al., 2004).

Hybridization also appears as a very rare phenomenon and is most likely confined to crosses between diploid sexual species (Chrtek et al., 2006). Agamospermy together with sexuality and hybridization in the past have given rise to a very large number of variants that have been described as sub-

species, as has traditionally been the case in Central Europe (Zahn, 1921-1923), or at rank of species (British Isles, Scandinavia, East Europe) (Mraz et al., 2001; Chrtek et al., 2006).

The Sicilian taxa (Fig. 1) have recently been revised as far as taxonomy and distribution are concerned (Raimondo & Di Gristina, 2004, 2007a, b; Di Gristina et al., 2005, 2006; Geraci et al., 2007; Di Gristina et al., 2012; Gottschlich et al., 2013; Di Gristina et al., 2013; Caldarella et al., 2014).

These studies have already resulted in the description of five new taxa: *Hieracium racemosum* subsp. *pignattianum* (Raimondo & Di Gristina, 2004) Greuter (2007), *H. schmidtii* subsp. *madonense* (Raimondo & Di Gristina, 2007b) Greuter (2007), *H. pallidum* subsp. *aetnense* Gottschlich, Raimondo & Di Gristina (2013), *H. hypochoeroides* subsp. *montis-scuderii* Di Gristina, Gottschlich, Galesi, Raimondo & Cristaudo (2013) and *H. busambarense* Caldarella, Gianguzzi & Gottschlich (2014).

Furthermore, the names of four taxa described by Michele Lojacono (1903), *H. cophanense*, *H. crinitum* var. *caulescens*, *H. crinitum* var. *eristachyum* and *H. nebrodense*, have been typified by Aghababayan et al. (2008). The remaining five accepted taxa described from Sicily, *H. crinitum* Smith (1813), *H. lucidum* Gussone (1825), *H. atrovirens* Froelich (1838), *H. pallidum* Bivona-Bernardi (1838), *H. symphytifolium* Froelich (1838), and three other names usually treated as synonyms, *H. racemosum* subsp. *todaroanum* Zahn (1922), *H. siculum* Gussone (1844) and *H. siculum* var. *minus* Gussone (1844), have been typified by Di Gristina et al. (2012).

On the whole, at present, several taxonomic and chorological questions still remain open. Among these, several issues of biodiversity conservation are important especially for some strictly local apomictic endemics, that are often considered of

secondary relevance respect to sexual species (Rich et al., 2008) and, then overridden as for as conservation is concerned.

Presently, an extensive field survey on the Sicilian territory is carried. The programme includes: (1) field surveys in order to verify the occurrence of the taxa known only from old reports or herbarium data but not recently observed, (2) the collection of data of biological, ecological or phytogeographical interest for in situ and ex situ conservation.

A molecular approach using “DNA barcoding”, in order to define the phylogenetic and systematic relationships among the Sicilian taxa, and a cytogeographical analyses at population level, are also in full progress. Waiting for a comprehensive update account of the genus, the framework of present knowledge is here summarized for each taxon.

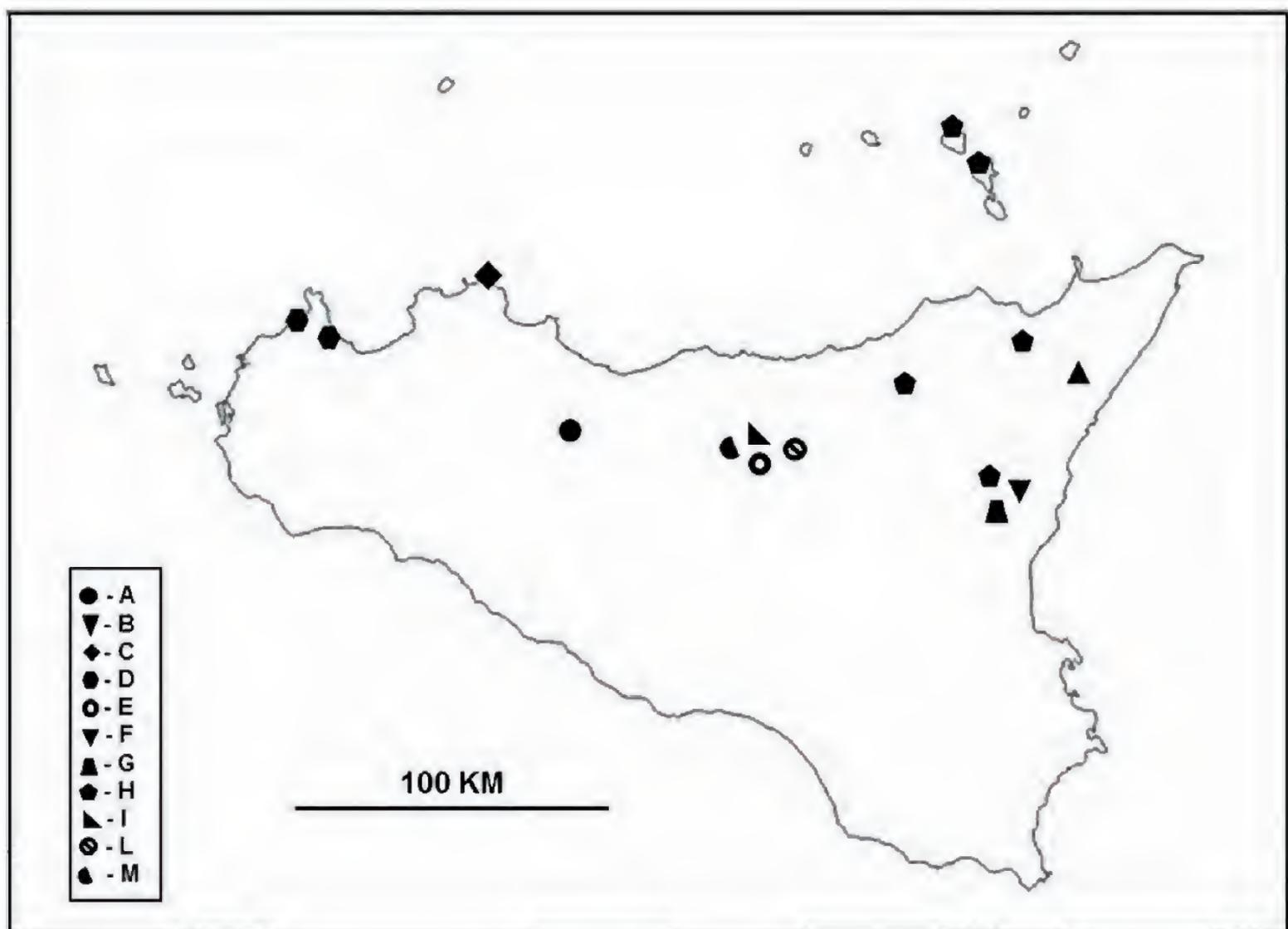


Figure 1. Distribution of the Sicilian *Hieracium* taxa. A) *Hieracium busambarense*; B) *H. hypochoeroides* subsp. *montiscuderii*; C) *H. lucidum*; D) *H. lucidum* subsp. *cophanense*; E) *H. murorum* subsp. *atrovirens*; F) *H. pallidum*; G) *H. pallidum* subsp. *aetnense*; H) *H. racemosum* subsp. *crinitum*; I) *H. racemosum* subsp. *pignattianum*; L) *H. schmidtii* subsp. *madoniense*; M) *H. symphytifolium*.

## MATERIAL AND METHODS

Floristic, herbarium, and literature research carried out between 1999 and 2014 are surveyed here. Specimens collected in the respective loci classici and some other Sicilian localities are stored in PAL. Zahn's species and subspecies concept (Zahn, 1921-1923) has been adopted for taxonomic nomenclature. Biological forms, following Raunkiaer's classification (1934), are abbreviated as proposed by Pignatti (1982). Chromosome numbers come from our karyological analyses and other literature data. Conservation status follows the IUCN (2010) criteria.

## RESULTS AND DISCUSSION

In Sicily *Hieracium* s. str. is so far represented by 11 taxa. 10 of them (*H. busambarense*, *H. hypochoeroides* subsp. *montis-scuderii*, *H. lucidum*, *H. lucidum* subsp. *cophanense*, *H. murorum* subsp. *atrovirens*, *H. pallidum*, *H. pallidum* subsp. *aetnense*, *H. racemosum* subsp. *pignattianum*, *H. schmidtii* subsp. *madoniense* and *H. symphytiformium*) are endemic to the island; the remaining (*H. racemosum* subsp. *crinitum*) has a wider range. These taxa are well differentiated from morphological point of view and belong to sections Bifida (Arv.-Touv.) Clapham, Grovesiana Gottschl., Italica (Fr.) Arv.-Touv., *Hieracium* (Pulmonaria Monnier), Oreadea (Fr.) Arv.-Touv. Most of them are chasmophytes confined to vertical cliffs or rocky slopes. Their chorology and ecology testify the relict state of the genus *Hieracium* in Sicily.

The island is indeed situated at the southern border distribution of the genus (see map in Bräutigam, 1992) and its climatic conditions are suitable for only a few taxa of *Hieracium* (Gottschlich et al., 2013). However, among them, the diploid *H. lucidum*, according to Pignatti (1979, 1982, 1994), ascribes the interesting role of likely differentiation centre of the genus to Sicily.

Most of the taxa are endemic to restricted areas (one population with an estimated area of occupancy less than 10 km<sup>2</sup>) in which periodical wild-fires occur. Therefore, according to the IUCN (2010) criteria for the conservation status assessment, they should be classified as "Critically Endangered" (CR). Their phytogeographical and

taxonomical relevance, together with the extreme conservation status require special protection measures. Unfortunately, the current status and priorities for conservation of the *Hieracium* taxa, as for many other Sicilian endemics, are poorly known, and consequently they are neglected by local administrations.

### Taxonomic list

***Hieracium busambarense*** Caldarella, Gianguzzi et Gottschl., Pl. Biosystems, 148: 439. 2014.

H. sect. Grovesiana Gottschl.

BIOLOGICAL FORM. H ros/ H scap.

PHENOLOGY. Flowering from second half of June to first decade of July; fruiting in July (Caldarella et al., 2014).

DISTRIBUTION AND ECOLOGY. Chasmophyte endemic to Rocca Busambra (PA) (CW-Sicily) (Fig. 2). Calcareous-dolomite vertical cliffs between 1500 and 1600 m a.s.l, in shaded localities (Caldarella et al., 2014).

CHROMOSOME NUMBER. Unknown.

CONSERVATION STATUS. "Critically Endangered" (CR): C2ab(i) (Caldarella et al., 2014).

TAXONOMICAL NOTES. *H. busambarense* belongs to the H. Sect. Grovesiana, recently described from Italy (Gottschlich, 2009). Its distribution area is located at the extreme southern limit of the Apennines range of that section, therefore it could be interpreted as an endemo-vicariant unit, probably originated after the long geographical isolation of the population on Rocca Busambra (Caldarella et al., 2014). Among the taxa of H. Sect. Grovesiana, *H. busambarense* appears very close to the Calabrian endemic *H. terraccianoii* Di Gristina, Gottschlich & Raimondo (2014), but it differs from this species in having no spotted leaves, more acute involucre bracts and in the bract indumentum (less stellate hairs and more glandular hairs) (Di Gristina et al., 2014).

***Hieracium hypochoeroides*** subsp. *montis-scuderii* Di Gristina, Gottschl., Galesi, Raimondo et Cristaudo, Fl. Mediterr., 23: 49. 2013.

*H. sect. Bifida* (Arv.-Touv.) Clapham

BIOLOGICAL FORM. H ros.

PHENOLOGY. Flowering June; fruiting from June to the first decade of July.

DISTRIBUTION AND ECOLOGY. Chasmophyte endemic to Mt Scuderi (ME) (NE-Sicily) (Fig. 3). NW-facing carbonate rocks and vertical cliffs between 1145 and 1180 m a.s.l.

CHROMOSOME NUMBER. Unknown.

CONSERVATION STATUS. "Critically Endangered" (CR): B1a+2a; C2a(ii).

TAXONOMICAL NOTES. *H. hypochoeroides* s.l. is a young aggregate of apomictic microtaxa with often local distribution, that have evolved during the post-glacial period. The map given by Bräutigam (1992, under the name *H. wiesbaurianum*) indicates a very disjunct area. Only in southern France an extensive closed area exists. In southern Europe one can only find local populations, most of them seem to be relict (Di Gristina et al., 2014). *H. hypochoeroides* subsp. *montiscuderii* is also such relict endemic taxon.

*Hieracium lucidum* Guss., Index Sem. Hort. Boccadifalco 1825: 6. 1825.

*H. sect. Italica* (Fr.) Arv.-Touv.

BIOLOGICAL FORM. Ch suffr.

PHENOLOGY. Flowering from October to November; fruiting in November.

DISTRIBUTION AND ECOLOGY. Chasmophyte endemic to Mt Gallo (PA) (NW-Sicily) (Fig. 4). NW-facing calcareous rocks and vertical cliffs between 220 and 310 m a.s.l.

CHROMOSOME NUMBER.  $2n = 18$  (Merxmüller, 1975; Brullo & Pavone, 1978; Brullo et al., 2004).

CONSERVATION STATUS. "Critically Endangered" (CR): B1a+2a; C2a(ii).

TAXONOMICAL NOTES. *H. lucidum* is one of the few diploid species in the whole genus. Therefore it could be considered as a probable ancestor for many European *Hieracium* taxa (Pignatti 1979, 1982, 1994).

*Hieracium lucidum* subsp. *cophanense* (Lojac.) Greuter, Willdenowia, 37: 164. 2007.

≡ *H. cophanense* Lojac., Fl. Sic. 2(1): 218. 1903.

*H. sect. Italica* (Fr.) Arv.-Touv.

BIOLOGICAL FORM. Ch suffr.

PHENOLOGY. Flowering from October to November; fruiting in November.

DISTRIBUTION AND ECOLOGY. Chasmophyte endemic to Mt Cofano and Mt Passo del Lupo (TP) (NW-Sicily) (Fig. 5). NW-facing calcareous rocks and vertical cliffs between 220-280 and 670-710 m a.s.l.

CHROMOSOME NUMBER.  $2n = 18$  (Brullo et al., 2004; Geraci et al., 2007).

CONSERVATION STATUS. "Critically Endangered" (CR): B1a+2a; C2a(ii).

TAXONOMICAL NOTES. It differs from *H. lucidum* in having few to moderately dense simple hairs on the stem and on the margin, along the midrib at the lower surface of the basal and cauline leaves.

*Hieracium murorum* subsp. *atrovirens* (Froel.) Raimondo et Di Grist., Willdenowia, 37: 165. 2007.

≡ *H. atrovirens* Froel., in Candolle, Prodr. 7: 231. 1838.

*H. sect. Hieracium* (Pulmonaria Monnier)

BIOLOGICAL FORM. H scap/ H ros.

PHENOLOGY. Flowering June; fruiting from June to first decade of July.

DISTRIBUTION AND ECOLOGY. Endemic to the Madonie Mountains (PA) (N-Sicily) (Fig. 6), along the NW-facing carbonate rocks and stony slopes of the Passo della Botte and Rocca di Mele (Petralia Sottana, PA), in clearings of the beech forest, between 1350 and 1580 m a.s.l.

CHROMOSOME NUMBER.  $2n = 3x = 27$  (Geraci et al., 2007).

CONSERVATION STATUS. "Critically Endangered" (CR): B1a+2a; C2a(ii).

TAXONOMICAL NOTES. In the past, the taxonomic rank has been rather controversial. It was described as a species (Froelich, 1838), but it was sub-



Figures 2–7. Blooming individuals in nature of: Fig. 2) *Hieracium busambarense* (from Caldarella et al., 2014); Fig. 3) *H. hypochoeroides* subsp. *montis-scuderii*; Fig. 4) *H. lucidum*; Fig. 5) *H. lucidum* subsp. *cophanense*; Fig. 6) *H. murorum* subsp. *atrovirens*; Fig. 7) *H. pallidum*.

sequently considered as synonym of *H. murorum* Linnaeus (1753) (Fries, 1862; Belli, 1904) or of *H. glaucinum* Jordan (1848) (Zahn, 1921; Fiori, 1928). Recently, the Sicilian population has been considered distinct and treated at subspecific rank of *H. murorum* (Raimondo & Di Gristina, 2007).

***Hieracium pallidum*** Biv., in Bivona-Bernardi, Nuove piante: 11. 1838.

H. sect. Grovesiana Gottschl.

BIOLOGICAL FORM. H ros/ H scap.

PHENOLOGY. Flowering from second half of June to first decade of July; fruiting in July.

DISTRIBUTION AND ECOLOGY. Chasmophyte endemic to Mt Etna (CT) (E-Sicily) (Fig. 7). Shaded volcanic rocks and stony slopes of Mt. Pomiciaro, Mt Zoccolaro and Serra del Salifizio facing the Valle del Bove (Zafferana Etnea, CT),

between 1550 and 1900 m a.s.l.

CHROMOSOME NUMBER.  $2n = 4x = 36$  (Brullo et al., 2004; Di Gristina et al., 2005).

CONSERVATION STATUS. “Critically Endangered” (CR): B1a+2a; C2a(ii).

TAXONOMICAL NOTES. According to Greuter (2008), it should be placed in the “collective species” (Zahn, 1921-1923) *H. schmidtii*. Nevertheless, the presence of 2 cauline leaves with winged petioles (in *H. schmidtii* s.l. 0-1 not winged leaf per stalk) allow to treat it as a local endemic species to Sicily belonging to H. sect. Grovesiana (Gottschlich et al., 2013).

***Hieracium pallidum*** subsp. *aetnense* Gottschl., Raimondo et Di Grist., Pl. Biosystems, 147: 826. 2013.

H. sect. Grovesiana Gottschl.

BIOLOGICAL FORM. H scap.

PHENOLOGY. Flowering from second half of June to first decade of July; fruiting in July.

DISTRIBUTION AND ECOLOGY. Endemic to Mt Etna (CT) (E-Sicily) (Fig. 8). Volcanic soil, on the border and in clearings of scrubland in a very restricted area on Mt Pomiciaro (Zafferana Etnea, CT), between 1580 and 1650 m a.s.l.

CHROMOSOME NUMBER.  $2n = 4x = 36$  (Di Gristina et al., 2014).

CONSERVATION STATUS. "Critically Endangered" (CR): B2ab(iii, v); C2a(ii), D.

TAXONOMICAL NOTES. Closely related to *H. pallidum*, but different by morphology of basal leaves (more lanceolate and dentate), number of cauline leaves (up to 3) and by peduncles and bracts indumentum (more simple hairs and stellate hairs only at the margin of the bracts).

*Hieracium racemosum* subsp. *crinitum* (Smith) Rouy, Fl. France, 9: 410. 1905.

≡ *H. crinitum* Sm., Fl. Graec. Prodr., 2: 134. 1813.

= *H. crinitum* var. *caulescens* Lojac., Fl. Sic., 2(1): 219. 1903; *H. crinitum* var. *eriostachyum* Lojac., Fl. Sic., 2(1): 219. 1903; *H. racemosum* subsp. *todaroanum* Zahn, in Engler, Pflanzenr., 79: 979. 1922.

H. sect. Italica (Fr.) Arv.-Touv.

BIOLOGICAL FORM. H scap/ H ros.

PHENOLOGY. Flowering from second half of August to first decade of November; fruiting from September to second decade of November.

DISTRIBUTION AND ECOLOGY. Corsica, Italy, Balkan Peninsula and Turkey (Fiori, 1928; Pignatti, 1982). In Sicily (Fig. 9), the taxon frequently occurs in shaded stony slopes and in clearings of woods on the main mountains of north-east (Nebrodi, Peloritani and Etna) and on the islands of Salina and Lipari (Lojacono, 1903), between 350 and 1750 m a.s.l.

CHROMOSOME NUMBER.  $2n = 3x = 27$  (Brullo et al., 1997, 2004; Geraci et al., 2007).

CONSERVATION STATUS. "Least Concern" (LC).

TAXONOMICAL NOTES. Taxon highly polymorphous. Sicilian and southern Italy populations appear very differentiated and need critical revision.

*Hieracium racemosum* subsp. *pignattianum* (Raimondo et Di Grist.) Greuter, Willdenowia, 37: 171. 2007.

≡ *H. pignattianum* Raimondo & Di Grist., Pl. Biosystems, 17: 314. 2004.

H. sect. Italica (Fr.) Arv.-Touv.

BIOLOGICAL FORM. H scap/ H ros.

PHENOLOGY. Flowering from second half of August to October; fruiting from September to first decade of November.

DISTRIBUTION AND ECOLOGY. Endemic to the Madonie Mountains (PA) (N-Sicily) (Fig. 10), along the NW-facing carbonate rocks and stony slopes of Mt Mufara (Isnello, Polizzi Generosa, Petralia Sottana, PA), Mt Quacella (Polizzi Generosa, PA), Mt Daino, Cozzo del Filatore, Pizzo dell'Inferno and Rocca di Mele (Petralia Sottana, PA), in clearings of the beech forest, between 1300 and 1700 m a.s.l.

CHROMOSOME NUMBER.  $2n = 3x = 27$  (Raimondo & Di Gristina, 2004).

CONSERVATION STATUS. "Vulnerable" (VU): B1a + 2a.

TAXONOMICAL NOTES. Similar to subsp. *crinitum* but the two subspecies show marked differences regarding indumentum, leaf morphology and size of the bracts (Raimondo & Di Gristina, 2004).

*Hieracium schmidtii* subsp. *madoniense* (Raimondo & Di Grist.) Greuter, Willdenowia, 37: 173. 2007.

≡ *H. madoniense* Raimondo & Di Grist., Boccionea, 141: 86. 2007.

H. sect. Oreadea (Fr.) Arv.-Touv.

BIOLOGICAL FORM. H ros.

PHENOLOGY. Flowering second half of June; fruiting from June to first decade of July.

DISTRIBUTION AND ECOLOGY. Chasmophyte endemic to the Madonie Mountains (PA) (N-Sicily) (Fig. 11). NW-facing carbonate rocks and stony

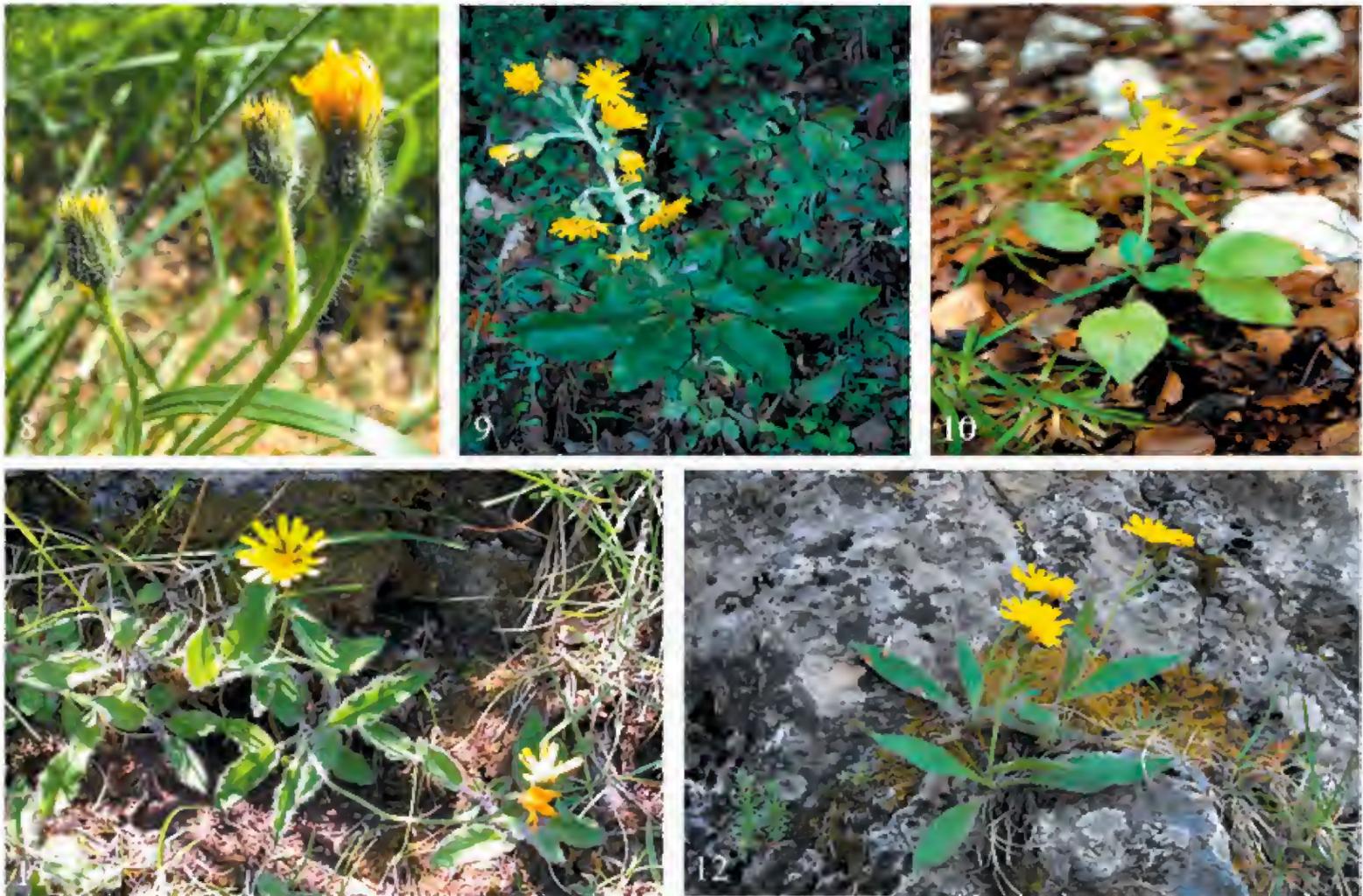


Figure 8–12. Blooming individuals in nature of: Fig. 8) *Hieracium pallidum* subsp. *aetnense*; Fig. 9) *H. racemosum* subsp. *crinitum*; Fig. 10) *H. racemosum* subsp. *pignattianum*; Fig. 11) *H. schmidtii* subsp. *madoniense*; Fig. 12) *H. symphytifolium*.

slopes of Rocca di Mele (Petralia Sottana, PA), in clearings of the beech forest, between 1520 and 1700 m a.s.l.

CHROMOSOME NUMBER.  $2n = 3x = 27$  (Di Gristina et al., 2005).

CONSERVATION STATUS. “Critically Endangered” (CR): B1a+2a; C2a(ii).

TAXONOMICAL NOTES. For a long time confused with *H. pallidum* but easily distinct by leaf, stem, bract indumentum (short simple crisp hairs) and more lanceolate and dentate leaves (Raimondo & Di Gristina, 2007).

*Hieracium symphytifolium* Froel., in Candolle, 7: 232. 1838.

= *H. siculum* Guss., Fl. Sicul. Syn., 2(1): 404. 1844; *H. siculum* var. *minus* Guss., Fl. Sicul. Syn., 2(1): 404. 1844.

H. sect. *Italica* (Fr.) Arv.-Touv.

BIOLOGICAL FORM. H ros/ H scap.

PHENOLOGY. Flowering from end of June to July; fruiting in July.

DISTRIBUTION AND ECOLOGY. Chasmophyte endemic to the Madonie Mountains (PA) (N-Sicily) (Fig. 12). NW-facing carbonate rocks and stony slopes of the highest reliefs, between 1250 and 1800 m a.s.l.

CHROMOSOME NUMBER.  $2n = 4x = 36$  (Brullo et al., 2004; Di Gristina et al., 2006).

CONSERVATION STATUS. “Critically Endangered” (CR): B1a+2a; C2a(ii).

TAXONOMICAL NOTES. The status of this plant has only recently been clarified. According to Zahn (1921-1923), the taxon represented an “intermediate species” between *H. lucidum* and *H. crinitum* (*Hieracium racemosum* subsp. *crinitum*). However, morphological and genetic studies showed that it is not a hybrid, but an independent species (Di Gristina et al., 2006).

*Key of the Sicilian taxa*

1. Achenes dark when mature. Flowering June-July.....2
  - Achenes pale when mature. Flowering end of August-November.....3
2. Bracts with rather dense glandular hairs and sparse or no simple hairs .....  
.....*H. murorum* subsp. *atrovirens*
  - Bracts with few to moderately dense glandular hairs and moderately dense to rather dense simple hairs.....4
4. Cauline leaves 3-6. Bracts 0.9-1.3 mm wide .....  
.....*H. symphytifolium*
  - Cauline leaves 0-3. Bracts 0.4-1 mm wide .....5
5. Plants with 1-4 mm long, denticulate soft or crisp simple hairs.....6
  - Plants with 4-10 mm long, denticulate rigid simple hairs.....7
6. Basal leaves unspotted; cauline leaves 1-2(3) .....  
.....*H. busambarensense*
  - Basal leaves few to intensely dark spotted; cauline leaves 0-1.....8
8. Leaves denticulate above, on the margin and along the midrib with crisp simple hairs.....  
.....*H. hypochoeroides* subsp. *montis-scuderii*
  - Leaves dentate to serrate-dentate only on the margin and along the midrib with crisp simple hairs.....*H. schmidtii* subsp. *madoniense*
7. Basal leaves ovate, denticulate, truncate or cuneate at base; cauline leaves 2.....*H. pallidum*
  - Basal leaves lanceolate, denticulate or serrate-dentate, long attenuate at base; cauline leaves up to 3.....*H. pallidum* subsp. *aetnense*
3. Leaves coriaceous, glabrous or with few to moderately dense simple hairs.....9
  - Leaves soft with moderately dense to rather dense simple hairs.....10
9. Leaves glabrous.....*H. lucidum*
  - Leaves with few to moderately dense simple hairs on the margin and along the midrib .....  
.....*H. lucidum* subsp. *cophanense*
10. Basal leaves with moderately dense stellate hairs on both surfaces. Bracts 0.7-1 mm wide .....  
.....*H. racemosum* subsp. *pignattianum*
11. Basal leaves without stellate hairs on both surfaces. Bracts 0.8-1.3 mm wide.....  
.....*H. racemosum* subsp. *crinitum*

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# Lycopodiidae for the “Flora Critica d’Italia”: material and methods

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## ABSTRACT

Procedures are presented that were followed during the preparation of the first pteridophyte family treatments for the “Flora Critica d’Italia”: Lycopodiaceae, Isoetaceae, Selaginellaceae. The work was mainly based on the study of literature and herbarium specimens. In some cases SEM observation of spores has proved useful. Data collected from herbarium specimens and other verified sources were loaded into a database, from which a distribution map was prepared for each taxon. Several preliminary papers have been published, and for each family a taxonomic conspectus, with type designations, maps and an identification key, has been prepared. The treatment of these three families for the “Flora Critica d’Italia” (in Italian) is about to be published or (Isoetaceae) has already been published.

## KEY WORDS

Italy; flora; vascular plants; pteridophytes; lycopodiophytes; herbarium; SEM; taxonomy.

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## INTRODUCTION

The need for an up-to-date “Flora Critica d’Italia” has long been recognized. About 10 years ago the Società Botanica Italiana (Italian Botanical Society) endorsed the project and prepared a model (Pignotti, 2006). The project, after the establishment of the Fondazione per la Flora Italiana (Foundation for the Italian Flora), has now entered its active phase of implementation: a few months ago the first preliminary results have been published (Cecchi & Selvi, 2014; Troia & Greuter, 2014). Procedures are presented that were followed during the preparation of the first pteridophyte family treatments for the “Flora Critica d’Italia”: Lycopodiaceae, Isoetaceae, Selaginellaceae.

According to recent literature, these three families (known as lycopodiophytes or “lycophytes”)

constitute the Lycopodiidae, the first of the five major subclasses of pteridophytes recognized by Christenhusz et al. (2011) and Christenhusz & Chase (2014) (Fig. 1).

## MATERIAL AND METHODS

The treatment is mainly based on the study of literature and herbarium specimens. It encompasses all Lycopodiidae taxa that grow spontaneously in the National territory, either native or naturalized.

We studied all Italian and selected foreign Lycopodiidae specimens kept in the Herbarium Centrale Italicum (FI) and Herbarium Mediterraneum Panormitanum (PAL, including PAL-Gr); several specimens, notably original material for

relevant names, were supplied by the Herbarium of the Botanischer Garten und Botanisches Museum Berlin-Dahlem (B). Each specimen has been documented photographically. In addition, we examined high-resolution digital images, available online or provided on request, from the following herbaria: APP, BOLO, CAT, GDOR, MFU, MRSN, MSNM, PAD, RO, ROV, SIENA, TO, TR, and K, LINN, P, PH, UPS (abbreviations according to Thiers, 2014), and had the presence of selected specimens verified by colleagues in others (e.g. MI). Specimens conserved in the private collections of Bonafede (Bologna, Italy), Selvi (Florence, Italy), Tondi (Rome, Italy) have also been studied.

For mapping the distribution, reports based on photographs have been considered only when

species identification was not in doubt; in particular, data from popular websites such as Acta Plantarum ([www.actaplantarum.org](http://www.actaplantarum.org)) have been taken into consideration. However, literature reports not supported by herbarium vouchers have been discarded for mapping purposes; comments have been added for those of special historical or phytogeographical interest.

Data (both original data and metadata) were loaded into a specific spreadsheet. Data fields included not only the scientific name and geographical parameters but also biological aspects, so as to enable future searches on, for example, phenology or altitudinal range. All specimens with sufficient locality data have been georeferenced and plotted on a base map of Italy (Cecchi & Selvi, 2014).

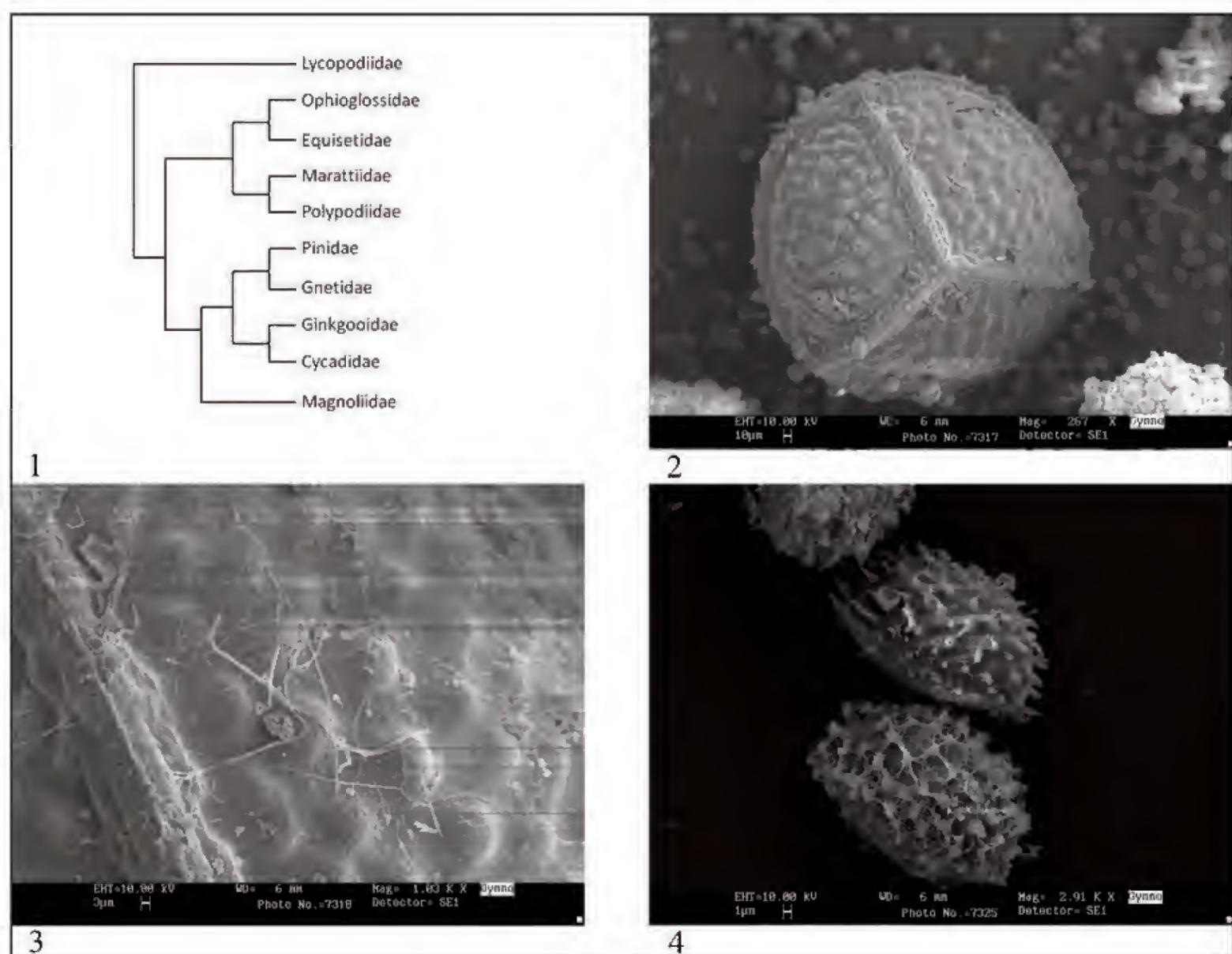


Figure 1. The main subclasses of living vascular plants, cladogram based on Schuettpelz & Pryer (2008), Pryer et al. (2009), and Grewe et al. (2013); clade names according to Christenhusz et al. (2011) and Christenhusz & Chase (2014) for pteridophytes, Chase & Reveal (2009) for spermatophytes. Figures 2–4. Example of SEM images prepared for the “Flora Critica d’Italia”: *Isoetes gymnocarpa* (Gennari) A. Braun, megaspores and microspores from the type specimen in TO (see Troia & Greuter, 2014). Figure 2: megaspore in proximal view. Figure 3: detail of Fig. 2. Figure 4: microspores.



Figure 5. Example of a distribution map prepared for the Flora Critica d’Italia: *Isoetes longissima* Bory.

Currently, a map is used that shows physiological rather than administrative territorial units, following the model proposed by Cecchi & Selvi (2014). In a first phase, only a selection of specimens have been mapped: 1 to 3 preferably recent specimens for each territorial units, so as to avoid excessive crowding of the dots; territorial units in which the species in question is present were shaded.

For some critical taxa, particularly in the genus *Isoetes*, scanning electron micrographs were produced to illustrate and document megaspore and microspore features (Figs. 2–4).

## RESULTS AND CONCLUSIONS

With regard to Isoetaceae, a synthetic paper with a taxonomic conspectus, type designations and an identification key has been published in the journal *Plant Biosystems* (Troia & Greuter, 2014), and similar papers for Lycopodiaceae and Selaginellaceae, including distribution maps (Fig. 5), are ready for publication. Preliminary results were

presented by Troia et al. (2012, 2014b) and Troia & Greuter (2013), as well as a paper with a SEM study of spores of the *Isoetes longissima* group (Troia et al. 2014a).

The treatment (in Italian) for the Flora Critica d’Italia of these three families, following guidelines prepared by the Editorial Committee, has just been published (Isoetaceae: Troia & Greuter, 2015) or is about to be published (Lycopodiaceae and Selaginellaceae: Troia & Greuter, in prep.).

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# Hotspot of new megafauna found in the Central Amazon (Brazil): the lower Rio Aripuanã Basin

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## ABSTRACT

Here I announce the discovery of a whole new ecosystem in the central-southern part of the Brazilian Amazon: the Rio Aripuanã Basin. Overall, it seems to have created more ecological niches than any other river basin in the Amazon, in particular so to aquatic and non-volant terrestrial mammals. This is plausibly explained for by the unique geo-morphological history of the region. During the Pliocene and Early Pleistocene the entire area to the southeast of the Rio Madeira contained one huge clear-water system that was drained toward the south into the Atlantic Ocean. In the course of several million years a biome quite different from the rest of Amazonia could evolve in this drainage system. Living relicts from ancient times that happened to survive in isolation here, are: a dwarf manatee here described as *Trichechus pygmaeus* n. sp., a dolphin locally called “boto roxo” that is suspected to be closer related to marine Rio Plata dolphins *Pontoporia blainvillei* (Gervais et d'Orbigny, 1844) than to Amazonian dolphins of the genus *Inia* (d'Orbigny, 1834), a black dwarf tapir (*Tapirus pygmaeus* Van Roosmalen, 2013, with *T. kabomani* Cozzuol et al., 2013 as junior name), a dwarf marmoset *Callibella humilis* Van Roosmalen et Van Roosmalen, 2003, a new monospecific genus of Callitrichidae that stands at the base of the phylogenetic tree of all extant marmosets (i.e., *Cebuella* Gray, 1866, *Mico* Lesson, 1840, and *Callithrix* Erxleben, 1777), a giant striped paca here described as *Agouti silvagarciae* n. sp., and an arboreal giant anteater spotted in the wild but remains to be collected and described (*Myrmecophaga* n. sp.). A number of other, more advanced mammalian species discovered in the Rio Aripuanã Basin, among which a third species of brocket here described as *Mazama tienhoveni* n. sp., evolved after a dramatic vicariance took place about 1-1.8 MYA (million years ago), the break-through of the continental watershed by the proto-Madeira River during one of the glacial epochs of the Middle Pleistocene. It marked the birth of the modern fast-flowing Rio Madeira, in terms of total discharge the biggest tributary of the Amazon proper and the second strongest river barrier in the entire Amazon Basin. Furthermore, current threats to the environment in this sparsely inhabited and poorly explored river basin will be addressed. We intend to have this ‘lost world’ preserved as a UNESCO Natural World Heritage Reserve through the divulgation of new, hitherto not yet identified mammals that it appears to harbor.

## KEY WORDS

Brazilian Amazon; nova species; Rio Aripuanã Basin.

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## INTRODUCTION

Overall, the Rio Aripuanã Basin (Fig. 1) seems to have created more ecological niches than

any other basin in the Amazon, in particular to aquatic and terrestrial mammals. In terms of species evolution and phylogeography the Rio Aripuanã Basin distinguishes itself from Amazo-

nia west of the Rio Madeira and north of the Rio Amazonas by harboring:

- Five sympatric species of peccaries (Tayassuidae: *Tayassu* G. Fisher, 1814; *Pecari* Linnaeus, 1758), instead of two species elsewhere in the Amazon;

- Three sympatric species of brocket deer (Cervidae: *Mazama* Rafinesque, 1817), including a new species we here describe as *M. tienhoveni* n. sp., instead of two species elsewhere in the Amazon;

- Two sympatric species of coati (Procyonidae: *Nasua* Storr, 1780), including a newly identified red-coated pair-living coati we here resurrect as *N. solitaria* Schinz (ex Wied, MS), 1821, as Spix & Martius (1823-1831) refer to it in their account "Reise in Brasilien in den Jahren 1817-1820", instead of only one gregarious species elsewhere in the Amazon;

- Two sympatric species of giant anteater (Edentata: *Myrmecophaga* Linnaeus, 1758), including a new species being tree-dwelling and climbing by its hind feet, instead of only one ground-dwelling species elsewhere in the Amazon;

- Two sympatric species of lowland tapir (Tapiridae: *Tapirus* Brännich, 1772), including a new species in 2013 described by me as *T. pygmaeus* (with *T. kabomani* Cozzuol et al., 2013 as a junior synonym), instead of only one species elsewhere in lowland Amazonia;

- Two sympatric species of jaguar (Felidae: *Panthera* Oken, 1816), including a new larger-sized species reported to hunt in pairs, its coat being all-black but a white throat, instead of only one species elsewhere in the Amazon;

- Two sympatric species of paca (Rodentia: *Agouti* Lacépède, 1799), including a new species here described as *A. silvagarciae* n. sp., being larger-sized, its coat orange-brown with white stripes instead of dots, instead of only one species elsewhere in the Amazon;

- Two sympatric species of porcupine (Rodentia-Erethizontidae: *Coendu* Lacépède, 1799), including a new species described as *C. (Sphiggurus) roosmalenorum* Voss et Da Silva, 2001 belonging to the *vestitus* group of small-bodied dwarf porcupines formerly known only from the Andean Mountains in Colombia, instead of only one species elsewhere in lowland Amazonia;

- Two sympatric species of woolly monkey (Primates: *Lagothrix* Humboldt, 1812), including

*L. nigra* n. sp. that is all-black, small, and ranging in atypical small social groups (Van Roosmalen, 2013a; 2014; 2015; Van Roosmalen & Van Roosmalen, 2014), instead of only one species elsewhere in lowland Amazonia;

- Two sympatric species of Amazonian marmoset (Primates, Callitrichidae), including a new species, first described as *Callithrix humilis* Van Roosmalen, Van Roosmalen, Mittermeier et De Fonseca, 1998, and later as a new genus, *Callibella* Van Roosmalen et Van Roosmalen, 2003, which is much smaller, does not show any territorial behavior, and occurs in sympatry with *Mico manicorensis* Van Roosmalen, Van Roosmalen, Mittermeier et Rylands, 2000, instead of only one species elsewhere in the Amazon east of the Rio Madeira;

- Two sympatric species of a large-bodied river dolphin (Delphinidae), including a new species locally called "boto roxo" that we suspect to belong to the marine genus *Pontoporia* Gray, 1870, it being smaller, having an overall bluish-grey colored skin, lacking a distinct melon (and therefore maybe foraging by eye-sight and not by echo location), living in pairs with a single offspring, and restricted to the clear-water habitat of the lower Rio Aripuanã, instead of only one species elsewhere in the Amazon Basin;

- Two sympatric species of freshwater manatee, including a new species described in this work as *Trichechus pygmaeus* n. sp., it being less than half the size and one-fifth of the body weight of common Amazonian manatees *T. inunguis* (Natterer, 1883), and its skin deep black instead of grey, instead of only one species elsewhere in lowland Amazonia downstream of rapids and waterfalls;

- A number of newly identified large-fruited, large-seeded, synzoochorically dispersed trees and lianas that are demographically confined to the terra firme forests east of the Rio Madeira (Van Roosmalen, 2013b). These woody plants seem to have co-evolved with scatter hoarding rodents belonging to the genera *Dasyprocta* Illiger, 1811 (agoutis) and *Myoprocta* Thomas, 1903 (acouchis), among which we identified some possibly new species;

- Primate diversity, here defined as the total number of taxa that occur in sympatry within a 10x10 km quadrant of land overlying both banks of a river at certain latitudes, is the highest for the Rio Madeira at the longitude of the mouth of the Rio Aripuanã, reaching at least 25 (!) valid species. That



Figure 1. Study area. Central Amazon (Brazil): the Rio Aripuanã Basin (shaded area).

exceeds with at least two species the hitherto highest primate diversity (in total 23 valid species) found west of the Madeira River, along the Rio Purús at its confluence with the Rio Tapauá (Van Roosmalen, 2013a; 2015; Van Roosmalen & Van Roosmalen, 2014).

- The Rio Aripuanã is a clear-water river draining the area north of the Chapada dos Parecís, a mountain range that is part of the crystalline Pre-Cambrian Brazilian Shield. Together with the clear-water Rios Tapajós-Juruena, Teles-Pires, and Xingú, the Rio Aripuanã seems to harbor relicts of a highly species-rich endemic Miocene freshwater mollusk (shellfish or bivalve) fauna with extant shells, oysters and mussels only to be found east of the Madeira River (Hoorn & Wesselingh, 2010).

## RESULTS

### New mammalian species descriptions from the Rio Aripuanã Basin, Brazilian Amazon

#### 1. New species of living brocket deer (*Mammalia Cervidae*) from the Rio Aripuanã Basin

Up to recently, only two members of the Neotropical *Odocoileinae* (brocket deer), a subfamily of the *Cervidae* (deer), from lowland Amazonia were known to science, belonging to the extant genus *Mazama* (Wilson & Reeder, 1993): the red brocket *M. americana* (Erxleben, 1777), and the

grey brocket *M. nemorivaga* (F. Cuvier, 1817). The latter has been recently (Rossi, 2000) distinguished from *M. gouazoupira* (G. Fischer, 1814), which species is said to range south of Amazonia on the open savannas and shrub savannas (cerrado) of Central Brazil, Bolivia, Paraguay, N Argentina and Uruguay. Although the evolutionary history of brocket deer dates back almost 20 million years ago (MYA), Duarte et al. (2008) suggest that in the Late Pliocene, approximately 2.5-3 MYA, the uplift of the Panamanian land bridge allowed deer to spread south, as participants in the “great American interchange” between North and South America. According to Duarte et al. (2008), these were the first deer to enter the South-American continent, and their surprising success in South America may be attributed to the absence of other ruminants (Webb, 2000).

Class Mammalia

Order Artiodactyla or Cetartiodactyla (if whales are to be included)

Family Cervidae Goldfuss, 1820

Subfamily Odocoileinae Pocock, 1923

Genus *Mazama* Rafinesque, 1817

#### *Mazama tienhoveni* Van Roosmalen et Van Hooft

EXAMINED MATERIAL. Two skins in possession of hunters from the village of Tucunaré along the lower Rio Aripuanã were examined. Moreover, a complete skull and mandible still in the flesh from an adult female specimen, and one spike from an adult male specimen were obtained from them in the course of the year 2006. The settlement of Tucunaré is situated along the Paran do Santa Maria, a shortcut from the community of Santa Maria to that of Tucunar, along the left bank of the middle Rio Aripuan, State of Amazonas, Brazil (0545’S, 6015’W). Holotypus: Specimen MR204, complete head with partly damaged mandible (Fig. 3), adult female, on May 12, 2006 killed for food by a local hunter along the left bank of the Rio Aripuan near the settlement of Tucunar, skull, spike (Fig. 4) and skin (Fig. 5). The type specimen MR204 is deposited as INPA4273, Mammal Collection of the National Institute for Amazon Research, Manaus, Amazonas, Brazil.



Figures 2–9. *Mazama tienhoveni* n. sp. Figure 2. *M. tienhoveni* n. sp. drawing reconstructed from plate depicting *M. nemorivaga* (Eisenberg, 1989). Fig. 3. Skinned head of a holotype female fair brocket deer *M. tienhoveni* n. sp. Fig. 4. Two spikes of *M. nemorivaga* and one (the smallest) of *M. tienhoveni* n. sp. Fig. 5. Skin of *M. tienhoveni* n. sp. from Tucunaré village, Rio Aripuanã. Figs. 6–8. skull and mandible of gray brocket deer *M. nemorivaga* (MPEG 1969). Fig. 9. Distribution map for *M. tienhoveni* n. sp.

**DESCRIPTION OF HOLOTYPE.** Measurements. Two skins obtained from hunters along the lower Rio Aripuanã were measured. Body weight not taken but according to local hunters ranges from 20–25 kg. Skull length 185 mm, mandible length 145 mm. Diastema length in skull 53 mm. Condylbasal length 167 mm. Palatal length 114 mm. Length of nasals 55 mm. Interorbital constriction 41 mm. Zygomatic breadth (= breadth across zygomatic arches) 80 mm. Breadth of braincase 55 mm. Length of upper tooth-row 53 mm. Length of lower tooth-row 58 mm. Breadth of M<sup>2</sup> 12 mm, breadth of M 2 8 mm. Dental formula: I 0/3, C (1)/1, P3/3, M 3/3.

Length of spikes (including the coronet) 55 mm.

**VARIABILITY.** No paratypes have been collected thus far.

**ETYMOLOGY.** We would like to name the species for Dutch lawyer and naturalist Pieter Gerbrand van Tienhoven (1875–1953), co-founder of a mainstream conservation organisation in the Netherlands (Natuurmonumenten) and one of the founding fathers of the International Union for the Conservation of Nature and Natural Resources (IUCN): Van Tienhoven's fair brocket deer, *M. tienhoveni* n. sp.

Van Tienhoven's fair brocket deer *M. tienhoveni* n. sp. is locally known as "veado branco", which means "white brocket deer". This way locals distinguish it from *M. americana* commonly known as "veado vermelho" or "veado capoeira", which means "red brocket" or "secondary-growth brocket", referring to its overall orange-red color and preference for edge habitats and forest clearings, and from *M. nemorivaga* locally known as "veado roxo", which means "purplish-grey brocket".

**DISTRIBUTION.** The geographical distribution of Van Tienhoven's fair brocket is thought to be restricted to the lower and middle part of the Rio Aripuanã Basin, but it might well be distributed across the entire interfluvium delineated by the Rio Madeira in the west, the Rio Tapajós-Juruena in the east, the Rio Amazonas in the north and the Rio Guaporé in the south. Since it seems to be confined to terra firme rainforest habitat, we assume that its real distribution is much smaller and does not extend into the northern part of the Rios Madeira/Tapajós interfluvium, where many open savannas and extensive floodplains are found. We have observed the species in the wild only along both banks of the Rio Aripuanã.

**ECOLOGY.** Van Tienhoven's fair brocket, *M. tienhoveni* n. sp., seems to be restricted to dense terra firme (upland) rain forest, where it lives solitary or in pairs. It occupies rather small territories and occurs in the Rio Aripuanã Basin in sympatry with the locally much rarer grey brocket *M. nemorivaga*, and the greater red brocket *M. americana*. The latter, however, occurs more frequently in disturbed areas with secondary growth and edge habitats, and in open areas such as white-sand savannas, which are common in the region. Nothing is known about Van Tienhoven's fair brocket, its ecology, and habits in the wild. The author has seen it only a few times in the wild during the dry season, while it was visiting the *Bactris maraja* (palm) dominated margins of muddy ponds, mud pools and saltlicks. These can be found locally in the middle of the rain forest at sometimes long distances from any substantial water supply, such as rivers, streams, lakes and ponds.

**PHYLOGENY.** DNA was extracted from a skin sample from each of the two brocket species, *M. tienhoveni* n. sp. and *M. nemorivaga*, both collected from the forests along the left bank of the Rio

Aripuanã. Partial mitochondrial cytochrome b DNA sequences of 233 bp (sites 133-365) and 295 bp (sites 108-402) in length were obtained for respectively *Mazama tienhoveni* n. sp. and *M. nemorivaga* with the conserved primers L14841 and H15149 (Kocher et al., 1989). DNA extractions, PCR reactions, and DNA sequencing were performed according to standard laboratory protocols. The sequences are deposited in Genbank under the accession numbers: GQ268320 (*M. tienhoveni* n. sp.) and GQ268321 (*M. nemorivaga*). Unfortunately, we did not have a skin sample from a specimen of the third sympatric brocket *M. americana*. However, different cytochrome b DNA sequences from this species and all other currently known Amazonian deer species could be obtained from Genbank (Genbank accession numbers given in Fig. 10). Most of these sequences have been used in a recent phylogenetic study on the South American deer (Duarte et al., 2008). We generated a minimum-evolution (ME) distance tree by adding our two sequences to those used in Duarte et al., 2008. Furthermore, we included Genbank sequences not used in that study, belonging to various South-American deer species, and excluded those with a large number of missing data in the 133-365 bp region of cytochrome b. The ME-tree was constructed with MEGA 4 (Tamura et al., 2007). We used the substitution model K2P (Kimura, 1980) with a constant rate applied and with *Rangifer tarandus* (Linnaeus, 1758) being outgroup, as has also been done in Duarte et al., 2008. The tree is based on the 133-365 bp region of cytochrome b with unresolved nucleotides deleted by pairwise deletion. Divergence times were estimated assuming separation between *Blastocerus/Pudu* and *Mazama/Odocoileus* 5 MYA (Duarte et al., 2008).

*Mazama tienhoveni* n. sp. and Genbank sequence AY886753, not being used in Duarte et al. (2008) although being from a brocket classified as *M. gouazoupira*, formed a distinct clade that diverged from the other South American deer species (average sequence divergence: 8.3%) 5 MYA (Fig. 10). This would imply that *M. tienhoveni* n. sp. diverged already before the uplift of the Panamanian land bridge and invaded South America during the "great American interchange" between both continents. A distinct clade not only supports the separate species status of *M. tienhoveni* n. sp., it also indicates that Genbank sequence AY886753 was wrongly identified as *M. gouazoupira*. The latter

observation is not unlikely, as low levels of morphological differentiation in the genus *Mazama* have caused numerous errors in species identification in the past (Duarte et al., 2008). Genbank sequence AY886753 should either be attributed to *M. tienhoveni* n. sp. or to a separate species in its own right, which is very well possible considering

the fact that it diverged 2-3 M YA from the *M. tienhoveni* n. sp. sequence. This divergence seems to have occurred, more or less coinciding with the uplift of the Panamanian land bridge.

REMARKS. *Mazama tienhoveni* n. sp. differs from the two other known Amazonian species, the

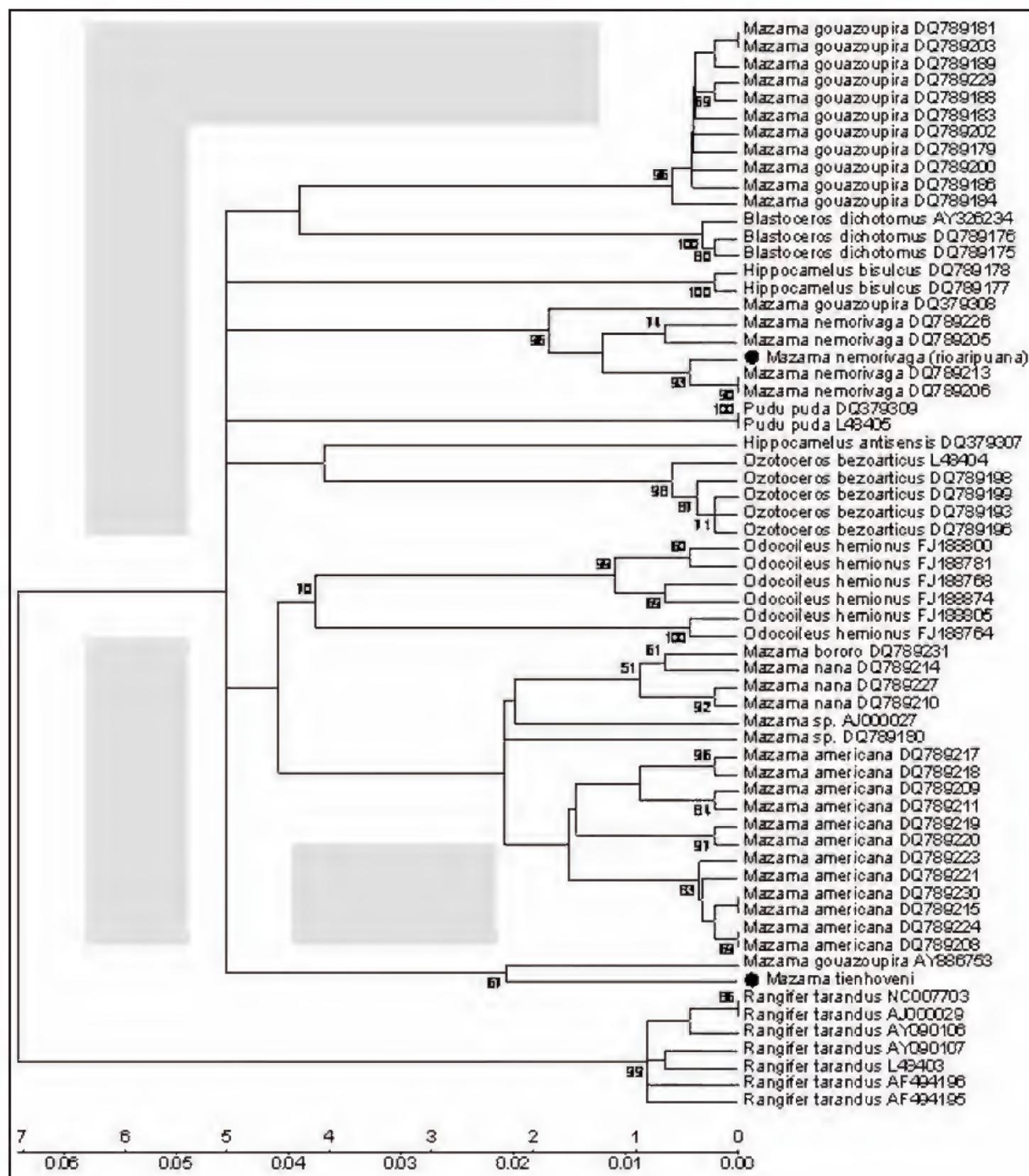


Figure 10. Linearized minimum-evolution tree showing phylogenetic relationships among South American deer derived from a 233 bp fragment of the mitochondrial cytochrome b. The scale on top corresponds to the time scale in millions of years while the scale below corresponds to the observed mean sequence divergence using the substitution model K2P. Bootstrap values (1000 replicates, > 50%) are denoted above nodes. Numbers behind taxon names correspond to Genbank accession numbers.

Greater Red Brocket *M. americana* and the Gray Brocket *M. nemorivaga*, in being intermediary in size, but with 55 mm total length and coronet diameter 24x30 mm having the shortest but most robust spikes (mean spike length 74 mm and coronet diameter 21x22 mm in *M. nemorivaga*). Most of the body is overall light brown colored, grading toward almost white on the sides and ventrally, whereas the dorsal parts of *M. americana* are of a (deep) reddish brown color, grading ventrally into a more rusty color, and those of *M. nemorivaga* are dull or pale yellowish or grayish brown to chestnut brown, grading ventrally into yellowish or whitish (Husson, 1978). The males of *M. tienhoveni* n. sp. do not have the distinct crest of hairs on the forehead as *M. nemorivaga* has, neither do the males of *Mazama americana*. Head-body length is not known yet, but *M. tienhoveni* n. sp. is said to be intermediary in size between *M. nemorivaga*, being 760-1015 mm (N=6) (Rossi, 2000), with shoulder height 480 mm (Duarte, 1996), and *M. americana* being 1120-1135 mm. The short tail is 75 mm long, dorsally has the same color of the back but shows a conspicuous white tuft at the end, being predominantly white below, whereas the tail in *M. americana* is 160-200 mm long, including the tuft, and 60-106 mm in *M. nemorivaga*. Furthermore, hind foot length (with hoof) in *M. americana* is 313-318 mm and ear length is 94-100 mm, and 82-93 mm in *M. nemorivaga* (Husson, 1978; Rossi, 2000). Weight of adult specimens is reported less than 15 kg in *M. nemorivaga*, 25-40 kg in *M. americana*, and about 20-25 kg in *M. tienhoveni* n. sp., according to local hunters. *M. tienhoveni* n. sp. can be distinguished from other brocket deer by its intermediary-sized head and various other intermediary skull characters (Table 1). Overall, the cranium of *M. tienhoveni* seems more related to that of *M. nemorivaga* than that of *M. americana*, but it differs clearly from *Mazama nemorivaga* in the following mean cranial measurements: greatest skull length 185 versus 174 mm; palatal length 114 vs. 105 mm; length of nasals 55 vs. 50 mm; interorbital constriction 41 vs. 39 mm; zygomatic breadth 80 vs. 73 mm; braincase breadth 55 vs. 53 mm; alveolar breadth of the upper second molar 12 vs. 11.3 mm; alveolar breadth of the lower second molar 8 vs. 7.4 mm; and length of mandible 145 vs. 134 mm.

The divergence time between *M. tienhoveni* n. sp. and the two other brocket deer, derived from partial cytochrome b DNA sequences, is estimated

Skull	<i>M. americana</i> (n=11)	<i>M. nemorivaga</i> (n=5)	<i>M. tienhoveni</i> (n=1)
Greatest or condylobasal length (=length anterior tip of I <sup>1</sup> to rear of condyles)	221	174	185
Basal length (= length anterior tip of I <sup>1</sup> to proximal end of condyles)	210	162	167
Palatal length	137	105	114
Length of nasals	65	50	55
Interorbital constriction	47	39	41
Zygomatic breadth (breadth across zygomatic arches)	97	73	80
Breadth of braincase	63	53	55
Length of diastema	70	52	53
Alveolar length of upper tooth-row	63	52	53
Alveolar breadth of M <sup>2</sup>	14.6	11.3	12
Length of mandible (=length from I <sup>1</sup> to rear of processus condylicus)	172	134	145
Alveolar length of lower tooth-row	72	59	58
Alveolar breadth of M <sup>2</sup>	9.7	7.4	8
Length of spikes	101 (n=5)	74 (n=2)	55
Distance between spikes	36 (n=5)	35 (n=2)	
Diameter of coronet	21-22 RA (n=2)		24-30 RA

Table 1. Skull measurements (in mm) of *Mazama americana* (N=11; NHML), *M. nemorivaga* (N=5; NHML), and *M. tienhoveni*; *M. tienhoveni* n. sp. is represented by the holotype - an adult female from Tucunaré, Rio Aripuanã, State of Amazonas.

at 5 million years before present, which is well before the uplift of the Panamanian land bridge. As in other brocket deer, Van Tienhoven's fair brocket seems to live solitary or in pairs. In view of recent developments in the Rio Aripuanã Basin where it lives and due to its limited distribution, we consider Van Tienhoven's fair brocket highly endangered.

**CONSERVATION STATUS.** All three brocket species, occurring in sympatry in the Rio Aripuanã Basin, are favorite game to the locals. Hunting the 'blond' or fair brocket *M. tienhoveni* n. sp. is said to be more successful. Along the lower Rio Aripuanã, it is said to be the most commonly encountered type of brocket, at least in terra firme (upland) rain forest, whereas greater red brocket are more often

found near forest edges and clearings, such as fields and plantations. Although human occupation in this part of the Amazon is very low nowadays, this situation might soon change. In the Rio Aripuanã region unprecedented illegal extraction of timber, gold and gravel is taking place, ironically after the whole lower Rio Aripuanã region was declared a State of Amazonas Sustainable Development Reserve (Reserva de Desenvolvimento Sustentável - RDS do Baixo Rio Aripuanã). Recent road building through the area has as objective to connect the town of Manicoré on the right bank of the Rio Madeira with the now booming town of Apuí at the border of the Tenharim Savanna and the State of Mato Grosso, areas of large-scale industrialized soybean agriculture. As recently as the year 2006, gold was found where the road from Novo Aripuanã crosses the Rio Juma, a clear-water tributary of the right-bank Rio Aripuanã. A crowd of over 10,000 gold diggers then settled in. Locals told us that ever since commercial hunters flocked into the area.

They use trained dogs for the hunt on game species as giant peccary *Pecari maximus* Van Roosmalen et al., 2007, Van Tienhoven's fair brocket *M. tienhoveni* n. sp., and both dwarf tapir *Tapirus pygmaeus* Van Roosmalen, 2013 (also known as *T. kabomani* Cozzuol et al., 2013 - a junior name) and lowland Brazilian tapir *Tapirus terrestris* (Linnaeus, 1758) to feed hungry settlers and gold-miners. Taking increasing hunting pressure and the species's limited distribution into account, *M. tienhoveni* n. sp. is considered highly endangered. It is recommended to include this new species in the IUCN Global Red List, based on criterion D (very small or restricted population). Besides Van Tienhoven's fair brocket, the Rio Aripuanã region seems to harbor a number of other faunal elements new, or possibly new, to science. Identified so far are a new species of peccary *Pecari maximus* (Van Roosmalen et al., 2007), a new species of dwarf porcupine *Coendu (Sphiggurus) roosmalenorum* (Voss & Da Silva, 2001), and at least four new primate species (Van Roosmalen et al., 1998; Van Roosmalen et al., 2000; Van Roosmalen et al., 2002; Van Roosmalen and Van Roosmalen, 2003). Among these primates, the black-crowned dwarf marmoset *Callibella humilis* Van Roosmalen et al., 1998 represents a complete new genus first seen and collected by me in 1996. Most surprisingly, up to

today not a single area exists in the region that is effectively protected by Brazilian environmental law. Given the uniqueness of the region in terms of biodiversity and its current status of biological terra incognita, we here suggest UNESCO to urge the Brazilian Government to declare the entire lower Aripuanã Basin a Natural World Heritage Reserve.

## 2. New species of living rodent from the Rio Aripuanã Basin: the giant striped paca (*Mammalia Agoutidae*)

Up to recently only two members of the Neotropical family Agoutidae (pacas), synonymous to Cuniculidae, were known to occur in the Americas belonging to the extant genus *Agouti* (Wilson & Reeder, 1993): the spotted common paca *Agouti paca* (Linnaeus, 1766), which species ranges in C+S America from San Luis Potosi, SE Mexico, to Paraguay, the Guianas, and S Brazil (the species was introduced into Cuba) and occupies suitable lowland habitats, and the mountain paca *A. taczanowskii* (Stolzmann, 1865), a species from the high cloud forest (altitudes between 2,000-3,000 m) of Andean regions of Peru, Ecuador, Colombia, and NW Venezuela (Eisenberg, 1989; Eisenberg & Redford, 1999).

Class Mammalia Order Rodentia

Family Agoutidae Gray, 1821

Subfamily Agoutinae or Cuniculinae

Genus *Agouti* Lacépède, 1799

### *Agouti silvagarciae* Van Roosmalen et Van Hooft

EXAMINED MATERIAL. Holotypus: adult female, complete head (Fig. 13), killed for food by a local hunter on May 28, 2006, along the left bank of the Rio Aripuanã near the settlement of Tucunaré. Paratypus: stuffed specimen found under number MPEG 22302 in the mammal collection of the Museu Paraense Emílio Goeldi, Belém, Pará, Brazil, its provenance not given (Fig. 14). Head-body length 750 mm. The heads were preserved on spirit (Fig. 13). Grain shot had severely damaged the skull of the giant paca specimen making it impossible to take cranial measurements.



Figures 11–16. Fig. 11. Plate from Eisenberg (1989) depicting the common spotted paca *Agouti paca*; Fig. 12. The common spotted paca *A. paca* as depicted in Emmons & Feer (1990). Fig. 13. Heads of freshly killed common spotted paca *A. paca* (at bottom) and Silva García's striped giant paca *A. silvagarciæ* n. sp. (at top). The skulls and mandibles of these specimens are stored at Tucunaré village, Rio Aripuanã, State of Amazonas, Brazilian Amazon. Figs. 14, 15. Stuffed specimen of striped giant paca *A. silvagarciæ* n. sp. found by the first author in the collection of Museu Paraense Emílio Goeldi under MPEG 22302 - without locality and misidentified as *A. paca*. Fig. 16. Skull of the common spotted paca *A. paca* found by the first author in the collection of Museu Goeldi under MPEG 5418, from the locality of Tapirinha. Skull length 147 mm, skull width 97 mm.

**DESCRIPTION OF HOLOTYPE.** The general dorsal pelage color of the common spotted paca *Agouti paca* is uniformly chestnut or mummy brown to almost black, usually with a striking pattern of four horizontal lines of white or light yellowish dots on each side of the body, the two middle ones at least extending all the way from the neck to the rump. In these two middle rows, the spots in the middle part may be fused to an uninterrupted stripe. The lower of the rows of spots is only visible in the extreme anterior and posterior parts, as the middle part is fused with the white ventral surface of the body. One or two of the upper rows of spots are shorter than the other rows; they are visible only in the posterior half of the body. The hairs are stiff and shiny. The dark brownish hairs show a lighter

median line. The dorsal surface of the head is of the same color as the back, but the hairs are shorter and less stiff. On the snout, there are long stiff whiskers. The upper whiskers are blackish and the lower are white, the color difference being quite striking. Similar stiff whisker-like hairs, though fewer, are implanted below and slightly in front of the ears; here too, upper hairs are blackish brown, lower ones white. The ears are relatively large; a tuft of blackish and yellowish longer hairs is implanted before the opening of the ear. The throat and the cheeks are uniformly cream-colored, as is the entire ventral surface of the body. The line of demarcation between the dark dorsal and the whitish ventral color is distinctly marked. The outside of the legs is of the same brown color as the dorsal surface of

the body; the inside of the legs is yellowish white basally, brown or brownish distally. The tail is vestigial, very short, and hardly noticeable. There are four toes with nails both on the fore- and hind-feet. In the forefeet, the nail of the thumb is very small, the others are well developed and of equal size. In the hind-feet, the three middle nails are large and of about the same size, while the nails of the inner and outer toes are markedly smaller and implanted higher, the inner nail being again somewhat smaller than the outer one. In the female there is on each side one pectoral mamma, at about the level of the bases of the front legs. Dental formula: I1/1, C0/1, P1/1, M3/3. The skull of an adult common paca is immediately characterized by the zygomatic arch that has grown out to an enormously swollen, distinctively sculpted bony plate, which is about two-third the length of the palate; this plate is strongly produced downward, in lateral view obscuring the teeth and the basal part of the mandible. Anteriorly, this plate encloses a deep and very large cavity at each side of the very narrow palate in front of the tooth-rows. In comparison to other rodents, the teeth are placed far backward. The palate ends at the line between the last and the penultimate molars. The infra-orbital opening has become a narrow canal almost entirely enclosed by bone. The outer surface of the zygomatic arch is covered with a honey-comb of irregular bony ridges, giving it a strongly rugose appearance. These rugosities extend also onto the larger parts of the nasals, frontals and parietals; in full-grown specimens the sutures between these bones are not or only partly visible. Even in newborn and juvenile specimens, the zygomatic arch is relatively high, but still smooth. The external measurements of three adult specimens of *Agouti paca* from Suriname on which the above mentioned description is based, are: head-body length 650; 676; 662 mm; tail length 18; 17; 19 mm; hind foot (including nail) 119; 117; 113 mm; ear length 46; 41; 48 mm; weight 9.2; 9.1; and 9.5 kg (Husson, 1978). Eisenberg (1989) gives head-body length averages 600-795 mm, vestigial tail length 19 mm, hind foot 188 mm, ear length 45 mm and weight 7.5 kg. He also states that the adult male is about 15% larger than the adult female. Silva Garcia's giant paca *A. silvagarciae* n. sp. from the Rio Aripuanã Basin has been reported by locals to weigh between 12-15 kg, its general color is bright orange brown. Average weight of the sympatric

common paca *A. paca* in the Rio Aripuanã Basin is reported to be 5-6 kg. The head of the giant paca shot near Tucunaré settlement measures 155 x 80 mm (compared to 115 x 80 mm in the common paca specimen shot the same night at the same locality of Tucunaré) (Fig. 13). The eight upper whiskers are black and about 110 mm long, the eight lower whiskers are white, stronger and stiffer than the upper ones and 105-110 mm in length (similar to those in the common paca). Three out of four lateral rows show the white spots (almost) completely fused (Figs. 14, 15).

Measurements. Body weight was not taken from the holotype specimen of *A. silvagarciae* n. sp., but according to local hunters body weight ranges from 12-15 kg. The head of the giant paca shot near Tucunaré settlement measured 155 x 80 mm, whereas that of the adult common paca shot at the same locality the same night measured only 115 x 80 mm (Fig. 13).

VARIABILITY. Paratype: stuffed specimen of striped giant paca *A. silvagarciae* n. sp. found under number MPEG 22302 in the mammal collection of the Museu Paraense Emílio Goeldi, Belém, Pará, Brazil, misidentified as *A. paca*, its provenance not given (Figs. 14, 15). Head-body length 750 mm.

ETYMOLOGY. This paca is named in honor of the author's spouse Antonia Vivian Silva Garcia. During our visit to the community of Tucunaré she heard the villagers talk about the two types of paca the locals there distinguish, one specimen of each a local hunter had shot for food that very night. Undoubtedly, the two species of paca must therefore be considered (micro)-sympatric.

Vernacular name: *A. silvagarciae* n. sp. is known locally as "paca concha", which means "shellfish paca". This way, locals distinguish it from the common paca *A. paca* that is known as "paca pintada" ("spotted paca").

DISTRIBUTION. Members of the genus *Agouti* are distributed from southern Mexico to northern Argentina in suitable lowland habitats. The geographical distribution of the giant paca is thought to be restricted to the interfluvium confined by the Rio Amazonas in the north, the Rio Madeira in the west, the Rio Ji-Paraná or Rio Guaporé in the south, and the Rio Tapajós-Juruena in the east (Fig. 1). We have observed the species in the wild only along both banks of the Rio Aripuanã. Type locality of

<i>Agouti paca</i> Rg n°	23902	18233	17756	21889	21891	21892	18013	18017	M
Sex	-	?	-	-	-	-	?	?	
Greatest length mm	139	143	143	142	148	148	136	141	143
Condylbasal length	129	138	144	136	145	139	128	137	137
Basal length	123	131	136	128	138	133	121	129	130
Palatal length	77	82	86	82	86	85	75	82	82
Length of nasals	45	fused	56	44	50	47	46	50	48
Zygomatic breadth	92	96	104	87	100	95	-	92	95
Hght zygomatic arch	46	50	60	39	56	47	37	47	48
Lgth zygomatic arch	80	87	102	80	98	86	72	82	86
Interorbital constr.	45	42	44	40	45	45	37	40	42
Braincase breadth	45	43	47	45	49	46	44	43	45
Mastoid breadth	61	57	65	60	65	62	59	55	61
Bullae lgth x bdth	20x15	18x14	18x17	21x17	17x14	20x18	20x14	19x17	19x16
Height of rostrum	39	40	42	39	41	42	37	40	40
Diastema	44	48	51	46	51	50	42	46	47
Alveolar length P-M <sup>3</sup>	28	30	29	28	32	28	29	30	29
Breadth of m <sup>2</sup>	7.1	7.2	7.9	8.0	7.4	7.3	7.0	7.6	7.4
Length of mandible	97	87	103	-	-	-	93	96	95
Alveolar length P-M3	30	31	32	-	-	-	31	33	31
Breadth of M3	7.5	6.8	8.5	-	-	-	7.2	8.0	7.6

Table 2. Cranial measurements (in mm) of eight specimens of the common spotted paca *Agouti paca* from Suriname (zoological collection of the NHML, Leiden, the Netherlands) on which our description is based. With "height of zygomatic arch" is meant the greatest height; with "breadth of the braincase" is meant the width of the skull at the level just above the external auditory meatus. Also, the total length of the zygomatic arch is noted being the distance between the extreme anterior and posterior borders. The length of the mandible was measured from the processus angularis. Mean skull length 143 mm, mean mandible length 95 mm. Diastema length in skull 47mm. Condylbasal length 137 mm. Palatal length 82 mm. Length of nasals 48 mm. Interorbital constriction 42 mm. Zygomatic breadth (= breadth across zygomatic arches) 95 mm. Breadth of braincase 45 mm. Breadth of M<sup>2</sup> 7.4 mm, breadth of M<sup>3</sup> 7.6 mm. Dental formula: I 1/1, C 0/0, P1/1, M 3/3.

*A. silvagaraciae* n. sp. is the Rio Aripuanã, close to the settlement of Tucunaré, situated along the Paranã do Santa Maria, a shortcut from the community of Santa Maria to that of Tucunaré, sitting on the left bank of the middle Rio Aripuanã, State of Amazonas, Brazil (05°45' S, 60°15' W).

**ECOLOGY.** Pacas of both species are nocturnal and have their hiding-places in hollow fallen tree trunks. They always carefully make two entrances to their burrows, so that they can escape when hunted down by dogs. Pacas usually live close to rivers and creeks. When pursued by dogs, they frequently take refuge in the water. Notwithstanding its fat body, it manages to walk on the bottom of any substantial water body. The formidable teeth and enormous masticatory muscles of pacas enable them to break open the hardest fruits and seed kernels. In contrast to the agouti, the paca digs

burrows that are sometimes interconnected with others.

The giant paca *A. silvagaraciae* n. sp. is assumed to be restricted to dense terra firme upland rain forest, where it lives solitary or in pairs. It occupies rather small territories and occurs in the Rio Aripuanã Basin in sympatry with the locally much more common spotted paca *A. paca*. The latter, however, is more frequently found along edges, such as roadsides, streams and creeks, in disturbed areas with secondary growth, and in open areas on white-sand savannas common in the region. Nothing is known about its ecology and habits in the wild. I myself have seen it in the wild only a few times during the dry season while visiting the *Bactris maraja* Mart (palm) dominated margins of muddy ponds, mud pools and saltlicks. These can be found locally in the middle of the rain forest,

often at long distances from any substantial water body, such as rivers, streams, lakes or ponds.

**PHYLOGENY.** One complete mitochondrial D-loop and two nuclear SINE PRE-1 DNA sequences of Silva Garcia's giant paca were carried out and compared with Genbank sequences of the sympatric common paca (*A. paca*). The results (15.5% difference between species) clearly support the distinction into valid species. As genetic distances based on partial mtDNA cytochrome b sequences (283 bp) in Bovidae are estimated 1.25% = 1 MYS, divergence time between *A. paca* and *A. silvagarciæ* n. sp. is estimated at about 10 million years. The giant paca therefore seems to have derived from ancestral pacas in the Late Miocene to Early Pliocene.

**Remarks.** This second species of paca from the Brazilian Amazon is distinctly bigger than the morphologically most related species that occurs in the Amazon, the common spotted paca *A. paca*. One complete mitochondrial D-loop and two nuclear SINE PRE-1 DNA sequences of the giant paca compared with that of the sympatric common paca (*A. paca*) supports the distinction. Divergence time is estimated at 10 million years. As in the common paca, giant pacas are nocturnal and reported to live solitary or in pairs. In view of recent developments in the interfluves where it lives, due to its limited distribution and for being a prime target to local hunters, we consider Silva Garcia's giant paca on the verge of extinction.

Several specimens of stuffed pacas in the zoological collection of Museu Paraense Emílio Goeldi, Belém, Pará, identified as common pacas, are suspected to represent giant pacas, hereafter named *A. silvagarciæ* n. sp. (Figs. 14, 15). This assumption is based on the orange-brown skin color, the pattern of horizontal white stripes instead of spots, total body length, weight, and cranial measurements. Unfortunately, none of them has been given a proper geographic locality.

**CONSERVATION STATUS.** The two paca species occurring sympatrically in the Rio Aripuanã Basin are favorite game to the locals. Although human occupation in this part of the Amazon is very low nowadays, this situation may change in the near future. In the Rio Aripuanã region unprecedented extraction of timber and gravel is taking place. Recent road building through the area is intended to connect the town of Manicoré on the right bank

of the Rio Madeira with the boomtown of Apuí located at the border of the Tenharim Savanna and the State of Mato Grosso, areas of large-scale industrialized soybean agriculture. In view of these developments, we fear that commercial hunters using trained dogs will focus first on large animals, such as the giant paca *Agouti silvagarciæ* n. sp., to feed hungry settlers and gold-diggers. Taking increasing hunting pressure and the species's limited distribution into account, I consider *A. silvagarciæ* n. sp. on the verge of extinction. It is recommended to include this new species in the IUCN Global Red List, based on criterion D (very small or restricted population). Besides the giant paca, the Rio Aripuanã region is thought to harbor a number of other mega-faunal elements new to science. I have identified so far a new species of peccary *Pecari maximus* (Van Roosmalen et al., 2007), a new species of dwarf porcupine *Coendu (Sphiggurus) roosmalenorum* (Voss & Da Silva, 2001) - and seven new primate species, four of which are already officially described [Van Roosmalen et al. (1998); Van Roosmalen et al. (2000); Van Roosmalen et al. (2002); Van Roosmalen & Van Roosmalen (2003)]. Among these primates, the dwarf marmoset *Callibella humilis* represents a new primate genus first seen and collected by me in 1996. Most surprisingly, not a single area protected by Brazilian environmental law exists in the region. Given the uniqueness of the region in terms of biodiversity and its current status of biological terra incognita, we here suggest UNESCO to urge the Brazilian Government to declare the entire region a Natural World Heritage Reserve.

### **3. New species of living manatee (Mammalia Trichechidae) from the Rio Aripuanã Basin - shallow clear-water adapted dwarf manatee is on the verge of extinction**

Manatees (Mammalia Trichechidae) are fully aquatic mammals of the ancient Order Sirenia. Worldwide there are two extant genera, *Trichechus* Linnaeus, 1758 and *Dugong* Lacépède, 1799. The Amazonian manatee *T. inunguis* (Natterer in Pelzeln, 1883) is the only species strictly adapted to fresh-water environments. However, here we announce the discovery of a second taxon from the Amazon that is also adapted to fresh-water habitat.

Class Mammalia  
 Order Sirenia  
 Family Trichechidae  
 Genus *Trichechus* Linnaeus, 1758

***Trichechus pygmaeus*** Van Roosmalen et Van der Vlist

**EXAMINED MATERIAL.** Holotype: skull with lower jaw of adult male is numbered CCM181, Zoological Collection of the Brazilian Institute for Amazon Research (INPA), Manaus-Amazonas, Brazil, collected eight km upstream from the mouth of the Rio Arauazinho (Fig. 17), a left bank tributary of the lower Rio Aripuanã, State of Amazonas, Brazil (06°16'94"S, 60°20'87"W), 25.IX.2002, M.G.M. van Roosmalen legit.

**DESCRIPTION OF HOLOTYPE.** Holotype skull length 24 cm, greatest width 15 cm. Mandible length 15.5 cm. Rostrum length 6.5 cm. Frontal bones convex, greatest width 5.1 cm. Cheek teeth (fully erupted molars) 4, maxillary molars 0.9 x 0.9 cm (Fig. 18), mandibular molars 0.8 x 0.6 cm. Skull roof 5 cm wide, lacking parasagittal crests. Braincase volume approximately 210 cc.

**VARIABILITY.** The species description is based on two adult males and generalized in accordance with reports from local hunters. Both adult male dwarf manatees have been examined, each measuring 130 cm in length, 90 cm in circumference, and weighing about 60 kg. The skin is overall pitch-black with a circular to tear-shaped white patch on the abdomen reported to be so in both the sexes, measuring in the captive male ca. 52 cm long and 26 cm in diameter. The flippers measured 32x11 cm and the paddle 36x40 cm. Snout comparatively short, circumference 46 cm, 19 cm in diameter, beset with long, stiff bristle hairs. Whole body is thinly beset with bristle-hairs (see also Fig. 19).

**ETYMOLOGY.** *Pygmaeus* in Latin means "short", "very small" or "dwarf", reflecting as such the fact that the new taxon of manatee is a dwarf compared with the common Amazonian manatee *T. inunguis*. Vernacular name: "Dwarf manatee", or "peixe-boi anão". It is locally known as "pretinho", which means "little black fellow". This way, the locals distinguish it from the common Amazonian freshwater manatee *T. inunguis* widely known as

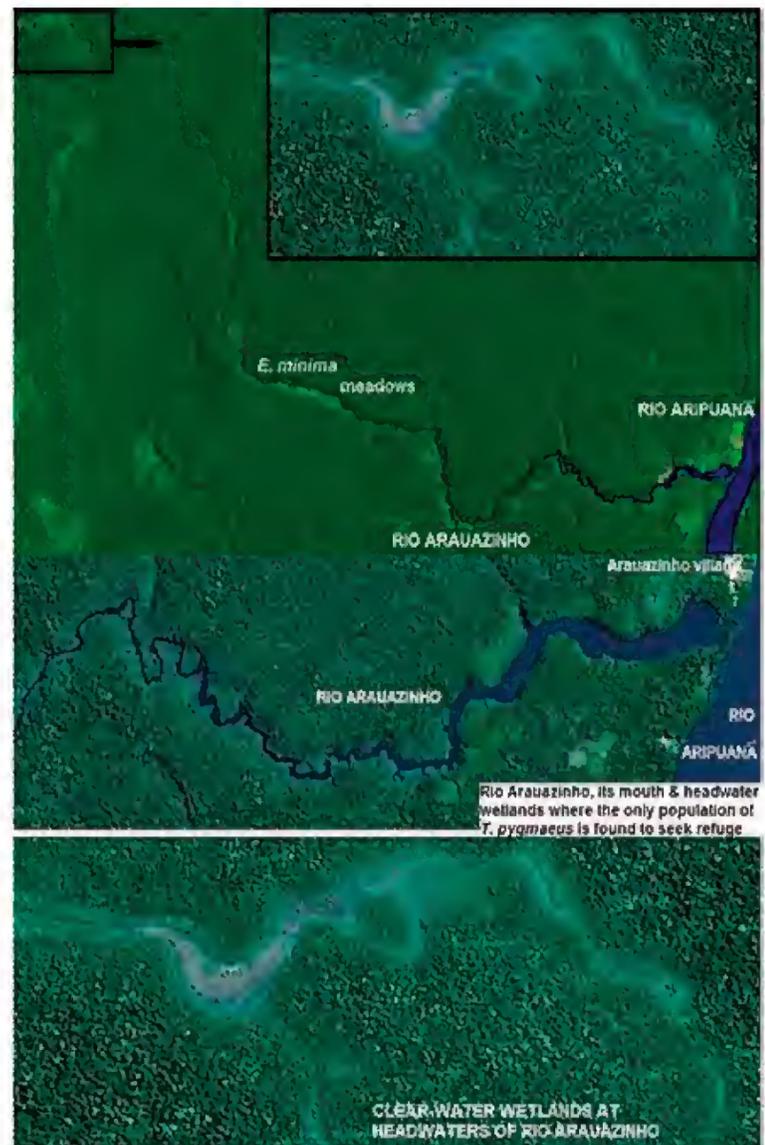


Figure 17. Landsat images of the Rio Arauazinho, branching off in three directions, one lengthy branch coming from the south running parallel with the Rio Aripuanã, one short branch coming straight from the north, and one main branch coming from the northwest. The latter drains the extensive wetlands along the watershed with the upper Rio Mariepaua, which harbor the last remaining population of *T. pygmaeus*.



Figure 18. (Above) Maxillary molars of a young juvenile male *T. inunguis* (Inpa Pb248) compared with those of the holotype adult male *T. pygmaeus* n. sp. (below).

“peixe-boi comum” (Portuguese for “common fish cow”).

**DISTRIBUTION.** Currently known distribution restricted to the Rio Arauazinho Basin, a clear-water tributary of the left-bank Rio Aripuanã, State of Amazonas, Brazil. Dwarf manatees may also occur in the headwater region of the Rio Mariepaua, the wetlands of which are interconnected with those of the northernmost branch of the Rio Arauazinho.

**COMPARISONS.** The new taxon is assigned to the genus *Trichechus*, because it possesses a number of traits in common with the parapatric, though in ecological respect allopatric Amazonian manatee, *T. inunguis*, from which it differs by its total adult body length 130 cm (280-320 cm in *T. inunguis*), and weight ca. 60 kg (350-500 kg in *T. inunguis*) (Domning & Hayek, 1986). Growth curves of free-ranging Amazonian manatees (*T. inunguis*) in Brazil

are described by Vergara-Parente et al., 2010. Age estimates and biometrics from 60 Amazonian manatees captured between 1993 and 2006 by local residents of the mid-Solimões and Pirativa Rivers in the Brazilian Amazon are given as follows: length at birth for *T. inunguis* is estimated at 133.2 cm (average = 113.0 cm; SD = 34.4 cm) for males, and 131.0 cm (average = 124.7 cm; SD = 22.0 cm) for females. A maximum length of 299.4 cm is given in males, and 256.1 cm in females. Therefore, both the adult male holotype *T. pygmaeus* n. sp. and the adult male dwarf manatee that we kept alive for over four months in an enclosure by fencing off a bend in the Rio Arauazinho, had the same total body length as just-born infants of the common manatee *T. inunguis*. Moreover, the skin in *T. inunguis* is evenly dark grey colored, with individually very variable irregular elongated white stripes on the abdomen in females and only a few small



Figure 19. Adult dwarf manatee male kept for over four months in a fenced-off river bend of the Rio Arauazinho where it was fed with its local natural food; note the saturated eumelanin black skin, relatively short head, short trunk and flippers, the bristle hairs on the snout, and the large, tear-shaped albinotic white patch on the abdomen.

irregular white blotches in males (Da Silva, pers. comm.). Dwarf manatees, in contrast, are saturated eumelanin coal black, the black pigmentation most likely being an adaptation to its preferred habitat, fast flowing shallow clear-water streams, protecting them from skin burn by UV radiation (Fig. 19). Common Amazonian manatees that are evolutionarily adapted to murky silt-laden white-water or low visibility dark-brown stained black-water, kept in clear-water tanks at INPA, Manaus, have to be protected from severe skin burn by blocking off any direct sunlight (Da Silva, pers. comm.). Male *T. pygmaeus* n. sp. have a white tear-shaped, ca. 52 cm long patch on the abdomen, greatest width 26 cm (Fig. 19). Flippers of the captive male measuring 32 x 11 cm were too short to reach the mouth. In contrast, the flippers of *T. inunguis* are proportionately longer in the animals kept at INPA. They are used to push floating stems and foliage toward the trunk and into the mouth. The snout of adult *T. pygmaeus* n. sp. is beset with long bristle hairs (Fig. 19), whereas that of infants *T. inunguis* kept at INPA is smooth lacking bristle hairs. The large white ventral patches reported in both sexes of *T. pygmaeus* n. sp. perhaps have been selectively evolved as protection against stingray attacks (an irregular black-and-white belly pattern may deceive its visual perception) during horizontal browsing of pastures of *Eleocharis minima* Kunth (Cyperaceae) and *Thurnia* spp. (Thurniaceae). These aquatic herbs grow on the sandy bottom of the mostly shallow clear-water Arauazinho River. Those pastures offer ideal hiding places for stingrays of all sizes (Fig. 22).

The holotype skull of *T. pygmaeus* n. sp. is 24 cm long and 15 cm wide, the rostrum is 6.5 cm in length and lacks the expanded nasal basin of adult *T. inunguis*. The skull of *T. inunguis* measures 34 x 19 cm and the rostrum 11.5 cm (Figs. 20, 21). Frontal bones in the holotype skull of an adult male *T. pygmaeus* n. sp. are convex and 5.1 cm wide, whereas in *T. inunguis* they are concave and only 4 cm wide (Fig. 21 - note that the skull of the juvenile male *T. inunguis*, INPA Pb248, is not damaged, but falls apart along the fissures). The skull roof lacks the parasagittal crests of *T. inunguis*, and the braincase volume in both taxa is about equal being ca. 210 cc. Therefore, it is much larger in *T. pygmaeus* relative to its total body size. The total number of cheek teeth (fully erupted molars) in each jaw

quadrant is 4 in the holotype *T. pygmaeus* n. sp. (indicating a trend to neotony), but 6(-8) in *T. inunguis* (Domning & Hayek, 1986). Furthermore, they are much smaller-maxillary molars are 0.9 cm in diameter in *T. pygmaeus*, and 1.3 cm in diameter in *T. inunguis* (Fig. 21). While the 3-4 anterior molars in juvenile *T. inunguis* are hardly worn in comparison to the just erupted posterior molar, this is strikingly different in the holotype *T. pygmaeus* with the 3 anterior molars strongly worn, thus showing indisputably its adult status (Fig. 18). The skull of the holotype male *T. pygmaeus* compared with a similar-sized skull (23 x 15 cm) of a young male *T. inunguis* (INPA Pb248) reveals the following major differences: 1/ the skull of *T. pygmaeus* n. sp. is thick, robust and solid (the cranial sutures, especially the basisphenoid-basioccipital one, are fully fused), whereas the skull bones of the young *T. inunguis* are thin and not fused yet, so that its skull falls apart along the fissures; 2/ the frontal bones in *T. pygmaeus* n. sp. are convex and 5.1 cm wide, whereas in *T. inunguis* they are concave and only 3.8 cm wide; and 3/ the 3-4 anterior molars in *T. pygmaeus* are fully worn, whereas in young *T. inunguis* only three cheek teeth are fully erupted.

The latter are sharply crested and do not show any rate of abrasion (Figs. 18, 21). We have sequenced a fragment of 410 bp of the left domain of the mitochondrial control region (D-loop), using DNA extracted from a skin sample of a living specimen. We used the same primers as were used for *T. manatus* and *T. inunguis* in Garcia-Rodriguez et al. (1998). The resulting sequence was identical to the most frequent *T. inunguis* haplotype-haplotype T, frequency 31% (Garcia-Rodriguez et al., 1998). At first sight, this result seems to be discrepant with the valid species status allocated by us to the dwarf manatee. We first thought this result could be explained by the relatively slow control region mutation rate in manatees, being only 1.5%/1 million years (equivalent to 1 point mutation/163,000 years) between lineages as compared to 8-15%/1million years in most terrestrial mammals (Garcia-Rodriguez et al., 1998). This would indicate a maximum divergence time of 485,000 years before present ( $p=0.05$ ). Within such a long space of time, sub-specific and even specific dwarfism is possible. For example, episodes of invasion and subsequent dwarfing affected many

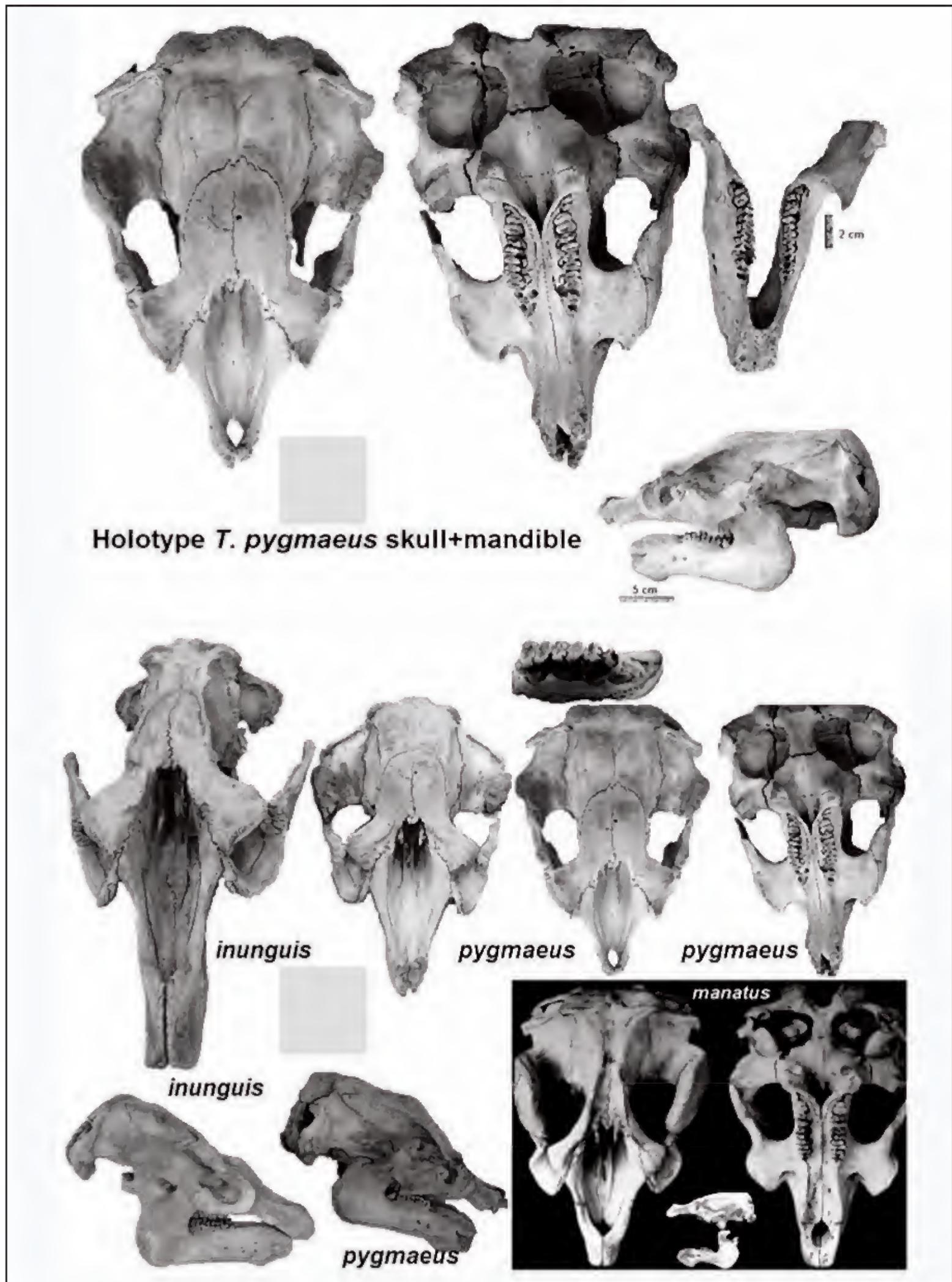


Figure 20. Comparing skull and mandible of *Trichechus inunguis* adult female Inpa Pb197; *T. pygmaeus* adult male holotype Inpa CCM181; and *T. manatus* (illustration taken from Husson, 1978). Note the convex and wider frontals in *T. pygmaeus*, and the comparatively greater resemblance of its skull to that of *T. manatus*.

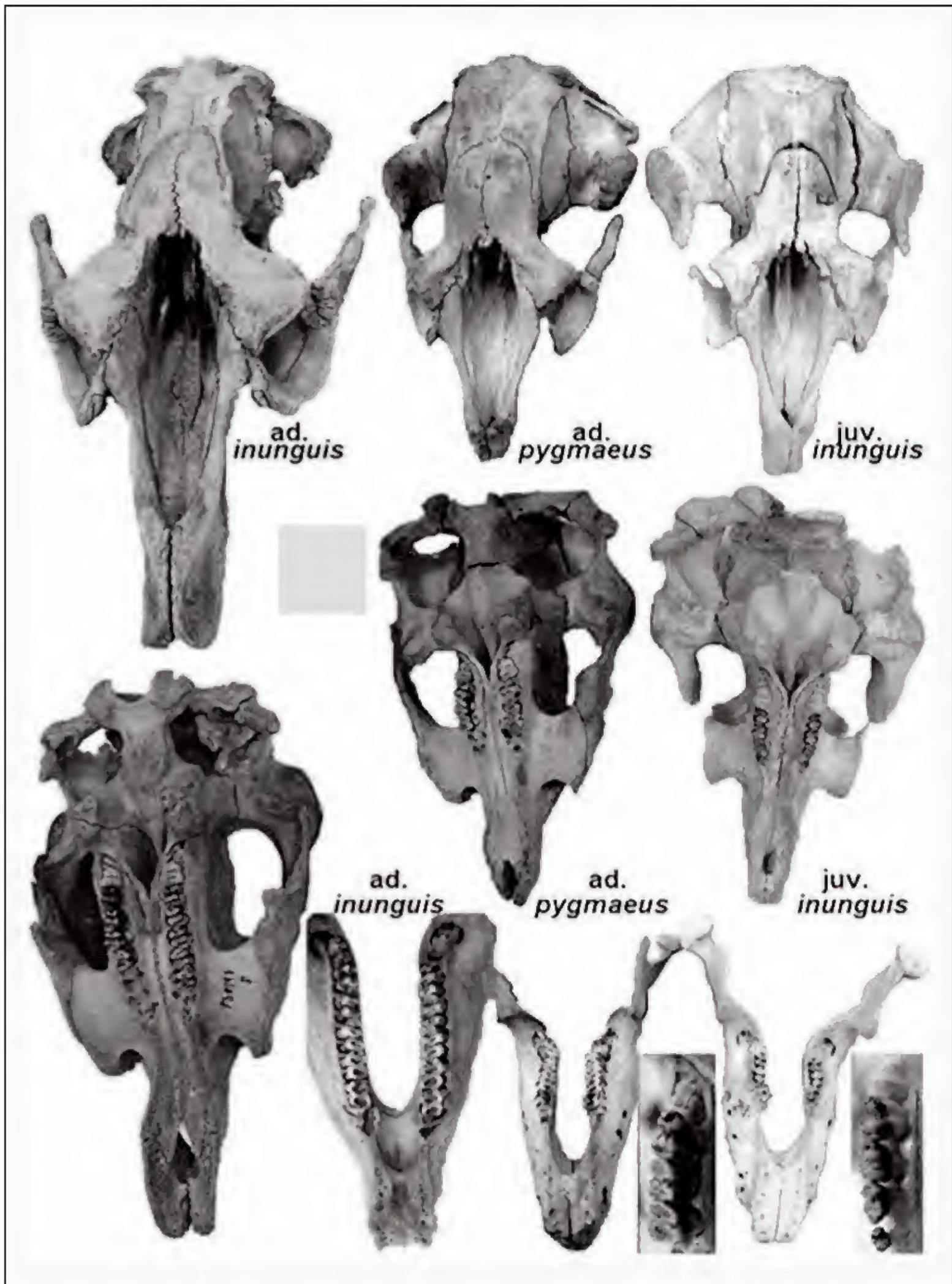


Figure 21. Comparing skull, mandible and cheek teeth (fully erupted molars) of *Trichechus inunguis* adult female Inpa Pb197; *T. pygmaeus* n. sp. adult male holotype Inpa CCM 181; and *T. inunguis* juvenile male Inpa Pb248. Note the strikingly different wearing pattern when comparing the cheek teeth of the adult male *T. pygmaeus* n. sp. and the juvenile *T. inunguis*.

insular fossil Elephantidae species from islands in the Mediterranean and Wallacea Seas. Some of these have become dwarfs in less than 5,000 years (Lister, 1993; Lahr & Foley, 2004). Also, Wrangel Island mammoths diminished by about 65% in body size within at most 5,000 years after the severing of the Late Pleistocene land bridge to Eurasia (Lister, 1993). Early Pleistocene large elephants, with which the Sirenians are closely related, swam and walked from the European mainland to the island of Crete. There, they evolved into a 90 kg weighing dwarf species *Elephas creticus* Bate, 1907 (Caloi et al., 1996). It could be hypothesized that common Amazonian manatees once accidentally got trapped in the Rio Arauazinho Basin isolated from the main population in the Rio Aripuanã Basin. Forced to survive in (to the species inappropriate) clear-water habitat, these colonizers may have drastically changed their diet and adopted a different foraging technique. In addition, they might have dwarfed under strong selective pressure of limited food resources. Nowadays, hybridization between the two extant taxa will not take place easily, for dwarf manatee's preferred habitat, diet and foraging strategy is completely different from that of the common Amazonian manatee. However, a local from San Antonio village once reported having seen twenty years ago a group of seven dwarf manatees ("Pretinhos") swimming along the fishing nets he had put up along a sandy beach at Prainha, right bank of Rio Aripuanã, during the peak of the dry season. If true, in theory female dwarf manatees that accidentally drift into the Aripuanã River during the flood season and are not able to return to the Rio Arauazinho (because its mouth has fallen dry earlier than expected), may be fertilized by male *T. inunguis*. The latter are said to hibernate during the dry season in deep pools in the main Aripuanã River. Even if hybridization would take place only once in the course of tens of thousands of years, some gene flow between populations of both taxa would significantly obscure their true divergence time. Accordingly, we believe that the dwarf manatee should be placed at the base of the phylogenetic tree of all freshwater-adapted manatees. In this quadrant of the Amazon Basin south of the Rio Amazonas and east of the Rio Madeira, it might have adapted to clear-water wetland habitat already in Late Miocene to Early Pliocene, times in which the landscape east of the

proto-Madeira was predominately drained by clear-water rivers and streams - until the Late Pleistocene vicariance that marked the birth of the modern fast-flowing Rio Madeira. According to this geophysical scenario, common Amazonian manatees may have derived from archetypical ancestral dwarf manatees during the Pliocene by adapting to black- and white-water floodplain systems. This could have happened after the Amazon reversed its course about 8 MYA and began to drain the East-Andean region into the Atlantic Ocean. At the same time, this evolutionary scenario would explain for the horizontal feeding posture of dwarf manatees in which they stand on their flippers while browsing on aquatic vegetation growing on the bottom of fast-flowing clear-water streams. The horizontal posture of dwarf manatees during feeding and foraging resembles that of marine manatees from which they could have derived during Late Miocene to Early Pliocene, when the Andean uplift was crucial for the evolution of Amazonian landscapes and ecosystems reconfiguring drainage patterns, creating a vast influx of sediments into the Amazon Basin, and boosting its biodiversity (Hoorn & Wesselingh, 2010).

**ECOLOGY AND CONSERVATION.** Along the lower and middle Rio Aripuanã *T. inunguis* is during the flood season commonly found in the deep, slow-moving, rather turbid dark waters of the Rio Aripuanã, its floodplain and deep back-water lakes. The latter are filled with black-water coming from local streams that drain nearby alluvial sand savannas. *T. pygmaeus* n. sp., on the contrary, occurs exclusively in the shallow, fast-flowing, clear waters of the Rio Arauazinho Basin. During the rainy season, the water level of the lower Arauazinho rises over 7 m annually, and the dark rather turbid waters from the Aripuanã River then inundate the riparian forest (igapó) fringing the lower Arauazinho. Dwarf manatee's preferred food, most importantly *Eleocharis minima* R. Br. grass (Cyperaceae), dies off for lack of sunlight. Its rhizomes survive and hibernate in the dark during the flood season. According to locals living in a small community at the mouth of the Arauazinho, and confirmed by us during surveys of the entire Rio Arauazinho Basin in 2006 (on foot) and 2011 (by dugout canoe), shortly before the Rio Aripuanã starts flooding the igapós, a number of dwarf manatees migrate back to the headwater wetlands,



Figure 22. The lower Rio Arauazinho showing the dwarf manatee's preferred habitat: shallow fast-flowing transparent waters with *Eleocharis minima* meadows growing on arenite white-sand substrate. At places shown above, where the river becomes shallow and flows faster, abundantly growing meadows of *E. minima* attract dwarf manatees from as far upriver as the head-water wetlands in the northwest (see Fig. 17). During the entire dry season (July to January), this amphibian herb belonging to the family of Cyperaceae provides the dwarf manatee with its preferred staple food. Then, the Rio Arauazinho is teeming with stingrays in all sizes representing a true danger, for dwarf manatees expose their bellies while standing on their flippers browsing pastures of *E. minima*. Dwarf manatees are reported to associate with “jaraquí” fish *Semaprochilodus insignis* (in a picture above seen swimming near a *Paleosuchus caiman*). The fish's sharp eye-sight together with the manatee's extraordinarily keen sense of hearing seem to provide both species with the perfect audio-visual protection against electric eel and potential predators, such as anaconda, jaguar and man fishing with bow and arrow or harpoon.

swamps and lakes located in the northwest (Fig. 17). From there, they had wandered down during the dry season while feeding upon *Eleocharis minima* meadows that grow locally on a thin layer of arenite sand overlying the pre-Cambrian sandstone bedrock (Fig. 22). During the wet season the entire population is believed to hibernate there while feeding upon *Eleocharis minima*, two aquatic coarse-leaved *Thurnia* Hook.f. species belonging to the aquatic plant family Thurniaceae, one *Cabomba* Aubl. (Cabombaceae) species locally called “camarão”, a wild variety of rice (*Oryza* sp.) and several algae (called “sulape”). All these aquatic

food plants grow abundantly in the narrow but locally deep river itself and in the wetlands it drains, that contain numerous clear-water lakes, ponds and swamps dominated by *Mauritia flexuosa* L.f. palms. During the dry season, some animals browsing *Eleocharis minima* meadows may descend as far as seven km from the mouth of the Rio Arauazinho. Before it flows into the Rio Aripuanã, the Arauazinho widens into a 0–30 cm deep lake. During the summer *T. inunguis* cannot enter and *T. pygmaeus* cannot leave the mouth and lower course of the Rio Arauazinho. Therefore, the two parapatric manatee taxa cannot hybridize.

Performing above-substrate browsing in a horizontal feeding posture, dwarf manatees appear to have adapted to feeding on (semi-)aquatic herbs that grow attached to the sandy bottom of shallow, fast-flowing clear-water streams. Its seasonally available preferred staple food is *Eleocharis minima*, a Cyperaceae grass that grows in submerged pastures up to 1 m below the surface on a shallow arenite-sandy substrate overlying the sandstone bedrock.

It has edible leaves and rhizomes that the dwarf manatee easily pulls whole from the sandy substrate with its trunk and lips. Chewing the entire plant including the sand-containing rhizomes seems to be responsible for the strong abrasion of the molars as seen in adult *T. pygmaeus* n. sp. (Figs. 20, 21). In contrast, *T. inunguis* feeds on floating and submerged plants in deeper waters (>2 m deep), being consumed in situ or, in the case of floating plants, taken below the surface and manipulated into the mouth by the flippers, preferentially if depth allows in a vertical position. While foraging in shallow waters, dwarf manatees when detecting people walking or canoeing along the riverbank immediately seek seclusion in the deep pools found in river bends. There, they stay underwater for three minutes at the most. When on ease, they slowly come to the surface and take a breath every 30–55 seconds.

*Trichechus inunguis*, when persecuted, can stay underwater up to 20 minutes without breathing. According to the locals and confirmed by our own observations, dwarf manatees tend to associate with schools of “jaraquí” fish (*Semaprochilodus insignis* - Prochilodontidae) while browsing on *Eleocharis minima*. This polyspecific association helps to protect them against defensive shocks from electric eels, and attacks of potential predators such as over 8 m long anacondas and spotted jaguars (Fig. 22). Dwarf manatees are considered critically endangered due to their most restricted geographical and ecological range, small population size (we estimate it to be less than 100 individuals), value as game, and their extremely vulnerable and delicate preferred habitat, clear-water streams and wetlands. The skull of the type specimen is recovered from game occasionally killed with bow and arrow and eaten by the locals. Habitat favorable to dwarf manatees occurs, aside of the Rio Arauazinho, only in the basins of two other clear-water tributaries of

the lower Rio Aripuanã - Rio Aracú and Rio Juma.

*Trichechus pygmaeus* n. sp., though, is not reported to exist there. The Rio Aracú Basin has been completely destroyed after a colonization scheme was implanted by the local government in the late 1970s. The Rio Juma Basin has been significantly affected after a goldmine was opened in 2006. Over 10,000 people flocked into the area polluting the Juma and Aripuanã Basins using high-pressure hose-pipes and large amounts of mercury. Illegal mining of gravel and gold, timber extraction, commercial hunting and fishing in the Rio Aripuanã Basin pose serious threats to the survival of both Amazonian manatee species. The discovery of *T. pygmaeus* adds to the uniqueness of the lower Aripuanã Basin and shows once more that it is a poorly explored hotspot of biodiversity and endemism. My biodiversity surveys conducted after the year 2000 indicate that the region harbors at least seven primates new to science, four of which being described, including the new genus *Callibella* never reported or collected before (Van Roosmalen et al., 1998; Van Roosmalen et al., 2000; Van Roosmalen et al., 2002; Van Roosmalen & Van Roosmalen, 2003; 2014; Van Roosmalen, 2013b; 2015). Disturbingly, there is not a single officially protected area in the entire basin.

CONCLUSION. *Trichechus pygmaeus* n. sp., the dwarf manatee, represents a second taxon of living fresh-water manatees and the smallest (130 cm in length) of all extant sirenians. The new species differs from the other known western Atlantic manatees, *T. inunguis* and *T. manatus*, in being two to three times smaller, with a more streamlined, less bloated appearance, a deep black instead of dark greyish skin, a large symmetrical, circular to tear-shaped white patch on the abdomen in at least the males (and reported equally in the females), a shorter head and shorter flippers, the tips of which do not reach the mouth (Fig. 19).

In September 2002, the author collected a complete skull of a recently killed adult male. Two years later, he could film, photograph, examine, and study for the first time an adult male dwarf manatee while keeping it alive for over four months in its natural habitat. It then escaped and returned to its natural environment. Figure 23 shows the fenced-off river bend along the lower course of the Rio Arauazinho in which we kept, fed and observed for

over four months a solitary adult male dwarf manatee that was captured by a local from Arauazinho while feeding on *Eleocharis minima* at about seven km from the confluence with the Aripuanã River. Floating vegetation was systematically refused. Food plants we brought in from the nearby river consequently had to be fixed onto the sandy bottom of his pan in order to be recognized as food, browsed and eaten in a horizontal feeding posture.

Nine years later, Van Roosmalen and Van der Vlist conducted an expedition by canoe and found

the last existing population of dwarf manatees in the wetlands situated along the northern branch of the upper Rio Arauazinho near the watershed with the Rios Uruá and Mariepaua (Figs. 17, 22). Dwarf manatees were found to be fully adapted to foraging in fast-flowing shallow clear-water streams. Standing on their flippers they browse in a horizontal position on aquatic grasses and other non-floating plants that grow on or near the bottom. In contrast, the three times bigger common freshwater manatee *T. inunguis* is restricted to calm



Figure 23. The fenced-off river bend along the lower course of the Rio Arauazinho. Here we kept, fed, filmed and observed for over four months a solitary adult male dwarf manatee that was captured at seven km from the mouth of the Rio Arauazinho by a local from Arauazinho village.

waters of rivers and lakes of the black- and white-water types offering limited visibility.

It feeds on floating aquatic plants and submerged foliage of floodplain (igapó and várzea) plant species. Mitochondrial control region DNA sequences revealed a haplotype identical to *T. inunguis*. We believe that this resulted from some gene flow that must have taken place in the past, as the two taxa are parapatric and only allopatric in ecological respect.

We consider the dwarf manatee at the verge of extinction, for only the headwaters of the northernmost branch of Rio Arauazinho, a 120 km long left-bank clear-water tributary of the Rio Aripuanã, are thought to harbor a viable relict population.

## DISCUSSION

In phyto-sociological respect, the many scrub and open savannas on white-sand alluvial soils in the entire Rio Aripuanã Basin are unique and found nowhere else in the Amazon. Together with the adjacent low savanna forests their branching pattern seen on satellite images does indicate that the entire basin preceding the Late Pleistocene was drained southward - instead of northward like the Rio Aripuanã and its tributaries nowadays drain the area into the Madeira River, and through the Rio Madeira into the Amazonas and eventually into the Atlantic Ocean. The alluvial sand deposits of former Pliocene and Early Pleistocene creeks and rivers show a branching pattern in their headwaters, meaning toward their northernmost end. Toward the southernmost end of the basin, where the Rio Aripuanã later in the Pleistocene originated, is situated nowadays the Tenharim Savanna, a large continuous savanna area. It is located east of the city of Porto Velho, close to the Rio Jí-Paraná, a river that together with the Rio Guaporé drains the western part of the Brazilian Shield into the Rio Madeira. The huge Tenharim Savanna has been interpreted by geo-morphologists as the result of sedimentation in a Quaternary long-lived clear-water inner lake. If we look at the geo-morphological history of the Rio Aripuanã Basin, it is assumed that during part of the Miocene a large freshwater inland lake existed, called the Beni Lake.

This lake stretched westward across the Bolivian Amazon. The brackish-water marine molasses-lakes from the Oligocene might have turned in the Miocene into the fresh-water molasses-lakes, and in the Pliocene into the sub-andine inner or inland lakes. During the Pliocene and Pleistocene these lakes filled with rainwater flowing down from the eastern foothills of the (by then) higher Andes Mountains (Hoorn & Wesselingh, 2010). In the Pleistocene era, three main drainage systems or basins were formed in former Amazonia: the white-water basin influenced by the eroding volcanic Andes in the western part of Amazonia, drained by the proto-Amazon River flowing toward the Atlantic Ocean; the clear-water basin draining the south-east Amazonian crystalline Brazilian Shield with the watershed running across the Chapada dos Parecís toward the south through the proto-Beni, proto-Mamoré, and proto-Guaporé Rivers; thirdly, the black-water basin draining the northern Amazonian alluvial white-sand area through the proto-Rio Negro. During the Late Pleistocene oceanic levels repeatedly have dropped on a global scale and the sub-andine inner lakes were quickly emptied by the much stronger eroding power of the proto-Amazon rushing toward the Atlantic Ocean - its surface lying 100-120 m lower during the subsequent ice ages of the Pleistocene.

During the glacial periods of the Late Pleistocene (1-2 MYA) the ancient continental watershed running across the Chapada dos Parecís has been broken through by the proto-Madeira River, which in turn was connected with the mighty Amazon River. The Madeira/Amazonas drainage system, as a way of speaking, then 'sucked' its way through the watershed powered by huge water volumes on their way to the up to 120 m lower lying water table of the Atlantic Ocean. The vortex holes in what a geologist would call an "unripe riverbed" - in the 400 km long stretch of the upper Madeira River and a shorter stretch in the middle Rio Aripuanã, as well as in the Rio Roosevelt - tell the tale about a former battle over one watershed between two drainage systems, each draining one side of it. The proto-Madeira and Amazonas Rivers thus conquered the clear-water catchment area of the Brazilian Shield. From then on, they made a connection with what was left of the former Pantanal/Chaco Lake through the Mamoré, Beni, and Abunã Rivers. Thereafter, these white-water rivers began to leak the sub-

andine Bolivian drainage system, this time to the north instead of to the east, connected as they now were with the Madeira and Amazon Rivers. The Pantanal/Chaco Lake was quickly emptied out to the east through the Madeira flowing into the Amazon and then into the Atlantic Ocean. In the northern part of the former Pantanal/Chaco Lake one or more clear-water lakes that had formed there since the Pliocene, were now also emptied out by the combined Rios Madeira/Amazonas drainage system.

One of these large clear-water lakes was situated exactly where nowadays the Tenharim Savanna is located, just north of the pre-andine watershed running across the Chapada dos Parecís. This Tenharim Lake was so far fed by rivers running in a north-south direction within what is nowadays the larger Rios Madeira/Amazonas/Tapajós-Juruena interfluvi-um (the Tenharim Lake was drained southward toward the Pantanal through the proto-Guaporé River). After the conquest of the watershed by the combined Madeira/Amazonas drainage system, rivers such as the Jí-Paraná, Roosevelt, Guariba, and Aripuanã began to flow north- and westward, this way draining the entire Aripuanã Basin directly into the Rio Madeira. Clear evidence that rivers like the Aripuanã and Roosevelt originated in a more recent geological era (the Late Pleistocene) is the occurrence of so-called "Strudellöchern" in the crystalline bedrock of the middle and upper courses of these rivers. In the Rio Aripuanã, south of Prainha, are nowadays found the unsurpassable Periquito Falls, among other extensive stretches of rapids and waterfalls. Moreover, the very deep deposits of gravel in the form of small brown rounded-off, polished pebbles that are laid down in calmer waters downstream of the rapids, assign to the afore-mentioned geological (vicariance) event of a Pleistocene watershed break-through.

Once the complex history of South-America's continental landscape and river systems, and, in particular, the relatively recent (Pliocene through Pleistocene) geo-morphological model of the Aripuanã River's drainage system is clearly understood, about all demographic and evolutionary odds of this river basin, that were hitherto considered 'hit and miss' distributions, may now be plausibly explained for. It seems that during a large part of

the Pliocene and Early Pleistocene eras the entire pre-Aripuanã river drainage system with its predominantly clear-water habitats was effectively blocked off from Amazonia west and north of the proto-Madeira River, for it was drained by rivers flowing southward toward the eastern part of the late-Miocene sub-andine Pantanal/Chaco Lake, and from there into the Atlantic Ocean. The continental watershed built from pre-Cambrian crystalline rock, together with the (those days) extensive lacustrine habitats, effectively isolated this peripheral drainage system from sub-andine white-water river systems, that were drained by the proto-Madeira and Amazon Rivers. Over millions of years opportunities for allopatric divergence were provided, for no gene flow could take place between non-volant terra firme and aquatic fauna of the clear-water drainage system and the rest of Amazonia, which was drained to the far northeast into the Atlantic Ocean. A number of ground- as well as tree-dwelling vertebrates, but also aquatic (mostly mammalian and mollusk) fauna, could therefore evolve in seclusion. The first vicariance must have taken place already in the Early-Pliocene, about 5 MYA, when ancestral proto/archetypical forms of all-Amazonian generic groups (i.e., the marmosets, spider-, woolly-, capuchin-, saki-, titi-, night- and howling monkeys, tapirs, anteaters, rodents like porcupines, pacas, agoutis, and acouchis, manatees, and 'botos') have diverged from closely related species found in the rest of the Amazon - to the west and north of the proto-Madeira and Amazon Rivers.

A second, more dramatic vicariance took place during one or more of the glacial epochs of the Middle Pleistocene, about 1-1.8 MYA, the breakthrough of the continental watershed by the proto-Madeira, being in turn powered by the modern Rio Amazonas drainage system in times that ocean levels had dropped over 120 m. So far, this watershed had run across the Serra dos Parecís in the Brazilian State of Rondônia. This way, the modern Madeira River originated and, at the same time, the Rios Aripuanã, Ji-Paraná, Tapajós-Juruena, and, perhaps, also the Rios Xingú and Araguaia, although the headwaters of the latter two rivers are found in the 'cerrado' (white-sand savannas) of Mato Grosso. These rivers also cleared themselves a way through the watershed of the former clear-water north-south directed drainage system and

began to empty their waters into the modern Madeira and Amazonas Rivers. From then on, the Rio Madeira became the rather straight and fast-flowing, second largest river barrier in the entire Amazon Basin, after the Amazon proper.

Ever since, no gene flow of terrestrial mega-fauna could take place to and from the western and northern Amazon. The Rios Aripuanã and Ji-Paraná first emptied out the former Tenharim Lake into the modern Madeira, there where for a long time lacustrine environments and wetlands had deposited white sand. The former clear-water drainage system left behind, aside of the Tenharim Savanna, many smaller patches of white-sand savanna and savanna forest on alluvial sandy soils deposited by former Pliocene and Early Pleistocene rivers and streams. Locally, new rivers arose and began to drain these areas dotted with white-sand savannas and stretches of savanna forest. That explains why they are of the black-water type. To name a few: the Rios Arauá, Mariepaua, Uruá, Manicoré, Atininga, Canumã, Sucundurí, Acarí. Some local rivers draining areas that do not contain alluvial white-sand deposits, but instead having heavily weathered pre-Cambrian arenite (sandstone) reaching the surface, remained of the clear-water type, such as the Rios Aracú, Arauazinho, and Juma. The entire former (Pliocene) clear-water drainage system, from then on, was intersected by new rivers draining the system in opposite (south-north) direction, most importantly the Rios Aripuanã, Tapajós- Juruena, Xingú, Teles-Pires, and Araguaia. In the course of several millions of years, a different biome could develop in this SE Amazon clear-water drainage system harboring a mixture of endemics and newcomers. The latter were ancestral forms of non-volant terrestrial mammals that, after crossing the Panamanian land bridge formed between 2.5-3 MYA, had migrated into the northern and western sub-andine regions of the Amazon. Subsequently, some managed to traverse the proto-Madeira River and established themselves in most of this ancient clear-water drainage system.

As such, newcomers such as ancestral collared and white-lipped peccaries, jaguars, pumas, small cats, canids, coatis and mustelids, lived side by side with endemics such as primates, rodents (squirrels, pacas, agoutis, acouchis, capybaras, spiny rats), marsupials (Didelphidae), edentates (anteaters,

armadillos, sloths), tapirs, and porcupines. Not before the last glacial period of the Holocene, about 10,000 YA, some modern mega-fauna elements, among which the common spotted paca *A. paca*, that had evolved west and north of the strong geographic barrier formed by the non-meandering Rio Madeira, managed to circumvent the headwaters of the Rio Madeira. Thereafter, they migrated into the Rios Madeira/Tapajós interfluvium. They took either the northwestern route following the western border of the Tenharim Savanna, or the southeastern route circumventing the Tenharim Savanna along the southern border, or they migrated into the Rios Madeira/Tapajós interfluvium along both paths. So, they entered a different ecosystem full of phylogenetically related but formerly allopatric species endemic to the region. Consequently, the new-comers may then have out-competed closely related species that occupied similar ecological niches, causing their extinction. Or, one species may have become genetically absorbed by the other through cross-breeding. Or, allopatric species may have diverged that much from one another in habitat and dietary preferences, foraging strategy and/or social and sexual behavior, that they were able to co-exist and live on in sympatry. The latter scenario may well explain, for instance, the sympatric occurrence in the Rio Aripuanã Basin of two different species of brocket deer (i.e., *Mazama nemorivaga* and *M. tienhoveni* n. sp.) and two different species of paca (i.e., the common spotted paca *A. paca* and Silva Garcia's striped giant paca *A. silvagaraciae* n. sp.).

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## The diversity of wild animals at Fezzan Province (Libya)

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### ABSTRACT

Fezzan province (Libya) is a segment of true Sahara, is characterized by diverse habitats that are utilized as shelters and feeding ground for many desert wildlife species. Oases with water table near the surface are the most prominent feature in the Libyan desert. The diversity in habitats resulted in diversity in wildlife, as well as the plant cover (trees and bushes) is the most effective factor for the existence and the abundance of wild animals, in particular bird species. This study observed many species of reptiles, birds and mammals. In the study is also reported the rock hyrax *Procavia capensis* Pallas, 1766 (Hyracoidea Procaviidae) a rare and endemic species at the area.

### KEY WORDS

Oases; diversity; endemic; wild animals.

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### INTRODUCTION

Libya is mostly characterized by arid climatic conditions, except the coastal strip and the northern hills toward the east and the west, while the rest of the country is located under the conditions of desert and semi-desert because of its geographical location in terms of latitude. This resulted in the presence of environments with distinct characteristics in terms of temperature, humidity and rainfall that reflected on the biological components of the plants and the animals that are able to co-exist in various ways with those difficult environmental conditions (Hufnagel, 1972).

In Libya there are a lot of ecosystems that range from the coastal environment with all its scattered salt marshes along the coastline, to green plains in the northeastern region and northwest highlands (which include Nafusa Mountains), to desert and semi-desert ecosystem showing its content of oases and valleys (Toschi, 1969). The desert is ecologic-

ally sensitive and very important in terms of wildlife (flora and fauna), which coexist in this habitat in spite of the harsh living conditions as much heat, especially during the summer months in addition to water scarcity and drought. However, these systems include a few diversity and abundance of species particularly those that have the capacity to live under these circumstances and some of them are endemic.

Fezzan province is a segment of true Sahara, is characterized by many habitats that are utilized as shelters and feeding ground for many desert wildlife species (Bundy, 1976). It is situated in the southwest of Libya within the desert ecosystem, which includes desert wadis, oases, palm plantations and irrigated cropland. Studies and reports, which are relatively scarce since the period of Italian occupation until the present, concluded that the wildlife in this region has declined in terms of number of species and individuals to alarming situation where some taxa are either subject to

extinction or already had disappeared from their previous range. The reason of it can be attributed to: (i) urbanization in some areas on the expense of natural resources and natural vegetation; (ii) construction of roads leading to the open areas where the shelters and habitats for wildlife are; (iii) modern vehicles which facilitated access to rugged areas; (iv) overhunting; (v) explorations and oil investments and activities associated with this industry; (vi) establishment of some sites for the purpose of various agricultural activities which led to the presence of human activity with a negative impact on wildlife communities and, (vii) desert tourism that led to the emergence of some negative effects (Sbeta et al., 2006).

In spite of all the mentioned circumstances met in this region, either due to Nature (high temperatures and scarcity of water surfaces and precipitation), or to different activities of humans that have negative effects on wildlife, especially those onset early in the sixties, there still are a number of species inhabiting the desert wadis and oases.

In this study we report some examples of animal species which were recorded in the region, and whose presence we hope to continue to record in some areas of the region, even if they are few in number. However, wildlife studies in the province of Fezzan need to focus on areas that may be susceptible of urbanization and Industrial sprawl, in order to save (for future generations) what can be saved of wildlife that still inhabit some of these sites. This study is based on a review of available publications and reports since the last decades until now, supported by field visits to the selected sites of the region to investigate the species of reptiles, birds and mammals.

### Study area

This study was focused on the diversity of animals in eight sites (Wadi Al-shati, Sebha, Traghan, Murzuq, Ubari, Al-awenat, Ghat and Akakus) at Fezzan region (Fig. 1).

The habitat type is mainly arid (72% of the total area of the region) with very harsh environmental conditions which are unsuitable for the growth of plants (Sbeta et al., 2006). The rest of the region can be classified into; irrigated crops area, plantations of palm trees, pastoral land and salt marshes (Table 1).

## MATERIAL AND METHODS

Field visits were conducted in summer 2006 by the authors of the present paper. Observations, collection of samples and bird watching started from dawn to dusk. Opticron binoculars (with magnification 10x50) and Optolyth spotting-scope were used for accounting of birds, as well as for some wild mammals. Field guides (Heinzel et al., 1998;



Figure 1. Map of Libya showing the study area.

Habitat type	Area in hectare	%
Irrigated agricultural land	137.500	0.25
Plantation of palm trees	39.675	0.07
Pastures and dry valleys	80.651	0.15
Arid land	40,137.185	72.25
Sands and sand dunes	15,109.334	27.20
Salt marshes (Sobkhas)	36.536	0.07
Urban areas	11.949	0.02
<b>Total</b>	<b>55,552.830</b>	<b>100.00</b>

Table 1. The percentage of each habitat type in Fezzan province. Source: Project of natural resources mapping for agricultural use and planning (Libya/04).

Mullarney et al., 2001) were used to identify birds. However, the status of bird species was assigned by their frequency of occurrence.

The following categories were adapted from Bundy (1976) and Toschi (1969): MB - Migrant breeder; PV - Passage visitor; RB - Resident breeder; WV - Winter visitor. Reptiles were collected by using rubber bands, while life traps were fitted for overnight to catch rodents species.

## RESULTS AND DISCUSSION

### Amphibians and Reptiles

Despite the harsh climatic conditions in the

whole province, which is inappropriate for the presence of life, the streams and cultivated areas, including some wetlands easily available, provided an opportunity for some amphibian species to inhabit the area. Amphibian diversity in the Mediterranean basin is much lower than reptile diversity. This being largely a reflection of the extent to which arid and semi-arid habitats predominate in large parts of the region (Cox et al., 2006). In this study two species of amphibians and fourteen species of reptiles were encountered (Table 2).

The sub desert Toad *Amietophrynus xeros*, previously known as *Bufo xeros*, was observed in pools and farms in Sebha and Ghat, this finding is in accordance with the results of Ibrahim (2008). We also observed Green Toad *Bufo viridis* in either

	COMMON NAME	SCIENTIFIC NAME	SITE OF OBSERVATION
1	Sub desert Toad	<i>Amietophrynus xeros</i> (Tandy, Tandy, Keith et Duff-MacKay, 1976)	Sebha, Ghat
2	Green Toad	<i>Bufo viridis</i> (Laurenti, 1768)	Sebha, Murzuq, Al-awenat and Ghat
3	Bibron's agama	<i>Agama impalearis</i> Boettger, 1874	Al-awenat, Akakus
4	Desert agama	<i>Trapelus mutabilis</i> (Merrem, 1820)	Ubari, Al-Awenat
5	Bell's dabb-lizard	<i>Uromastix acanthinura</i> Bell, 1825	Al-shati, Traghan, Al-awenat
6	Ragazzi's fan-footed gecko	<i>Ptyodactylus ragazzii</i> Anderson, 1898	Traghan
7	Elegant gecko	<i>Stenodactylus sthenodactylus</i> (Lichtenstein, 1823)	Traghan
8	Moorish gecko	<i>Tarentola mauritanica</i> Linnaeus, 1758	Al-shati, Sebha, Traghan, Murzuq
9	Tripoli dwarf gecko	<i>Tropicolotes tripolitanus</i> Peters, 1880	Al-Shati, Sebha, Traghan
10	Nidua lizard	<i>Acanthodactylus scutellatus</i> (Audouin, 1827)	Traghan, Murzuq, Ubari
11	Leopard Fringe-fingered Lizard	<i>Acanthodactylus pardalis</i> (Lichtenstein, 1823)	Murzuq
12	Red-Spotted Small Lizard/ Desert-Racer	<i>Mesalina rubropunctata</i> (Lichtenstein, 1823)	Traghan, Murzuq
13	Ocellated skink	<i>Chalcides ocellatus</i> Forsskål, 1775	Al-Shati, Sebha, Murzuq
14	Sand fish	<i>Scincus scincus</i> (Linnaeus, 1758)	Al-Shati, Traghan, Ubari
15	Schokari Sand Snake	<i>Psammophis schokari</i> (Forsskål, 1775)	Traghan, Ubari
16	Horned viper	<i>Cerastes cerastes</i> Linnaeus, 1758	Al-shati, Sebha, Traghan, Murzuq

Table 2. Species of amphibians and reptiles recorded in study area.

cultivated lands or wetlands in Sebha, Murzuq, Al-awenat and Ghat. Scortecchi (1935) mentioned the presence of this species in the province of Fezzan.

Studies on reptiles are very rare, but the desert valleys and some habitats in the region are the most important areas for some species of lizards, such as: Desert monitor *Varanus griseus* (Daudin, 1803), Chameleon *Chamaeleo chamaeleon* Linnaeus, 1758 and Spiny-tailed lizards *Uromastix acanthinura*. Furthermore, the most important species of snakes that live in this environment is the Horned desert viper *Cerastes cerastes* (Bennett, 1970; Awami, 1976; Ibrahim, 2008). A total of 14 species of reptiles were recorded in the present paper in the province (Table 2). However, the majority of them are mentioned in some previous studies (e.g. Kramer & Schnurrenberger, 1963; Schleich et al., 1996; Frynta et al., 2000; Ibrahim, 2008), except the Desert agama *Trapelus mutabilis* which was observed in Al-Awenat and Akakus and recorded for the first time in these sites (Fig. 2). Schleich et al. (1996) reported the presence of this species in Cyrenaica (east to Tubruk) and Wagner et al. (2011) mentioned another record of this species in Tripoli.

## Birds

The present study accounted a total of 2975 individuals belonging to 26 bird species; the majority of them were non-waterbirds species with a disparity in numbers of species and individuals between sites (Table 3). A total of 12 species were reported as resident breeders (Bundy, 1976). However, many previous studies during decades ago reported the presence of more than 100 species as winter visitors during their migration from Asia and Europe to Africa, where they stop for few days and then continue to the south. While around 20 species were recorded as residents along the year seasons such as; Sandgrouses *Pteracles orientalis*, *Pteracles senegalensis*, Owls *Bubo bubo*, Partridge *Alectoris barbara* and some species of raptors (Toschi, 1969; Bundy, 1976; Brehme et al., 2002a, b, 2003a, b, 2004).

Fezzan province is composed of many oases, cultivated areas, irrigated crop sites, urban and residential areas, these may provide roosting sites and shelters for many bird species, particularly, those who adapted to live within and adjacent to anthropological environments. This reflects the large numbers of sparrows that inhabit the urban areas

(Spanish sparrow and Desert sparrow; fig. 3), whilst those species were absent in Akakus.

Furthermore, there was a difference in species diversity among the study sites depending on habitat types. Five waterbirds species (*Ardea cinerea*, *Egretta garzetta*, *Ardeola ralloides*, *Anas querquedula* and *Gallinula chloropus*) were observed in Sebha (sewage site) and Ubari (oases); while the rest of species were found on plant covers (bushes, shrubs and trees; pers. obs.).

## Mammals

The province of Fezzan is reasonably characterized by good diversity of Mammal species. During this study a total of 11 species were recorded.

### Order *Erinaceomorpha* and *Chiroptera*

Two species of hedgehogs belong to the family Erinaceidae were observed: Long-eared hedgehog, *Hemiechinus auritus* S.G. Gmelin, 1770 and desert hedgehog, *Paraechinus aethiopicus* (Ehrenberg, 1832) close to the farmlands in Traghan and Murzuq. These two species are common in the area (Hufnagel, 1972).

A bat species from family Vespertilionidae (*Pipistrellus* sp.) was observed just after the sunset at all visited sites. As all species of mammals in the south of Libya, bats need to be addressed in a comprehensive study in order to identify the extant species and their relations to other bats populations in the north.

### Order *Carnivora*

Of this group of mammals, only two species were recorded, the Jackal *Canis aureus* Linnaeus, 1758 was only identified by tracks left in sites in Traghan. It usually inhabits areas with optimum food and shelter. This species is reported in different types of Libya habitats (Hufnagel, 1972). However, IUCN classified this species as Least Concern, due to its widespread range, but due to the urbanization and destruction of natural habitats, these animals were no longer seen in the nature (pers. observations). Furthermore, a caracas of Fennec, *Vulpes zerda* Zimmermann, 1780 was found on the road between Al-awenat and Ghat. Despite, this species is very common in the province; especially close to human dwellings.

	Scientific name	Common name	Wadi Al-shati	Sebha	Traghen	Murzuq	Ubari	Al-awenat	Ghat	Akakus	Status
1	<i>Ardea cinerea</i> Linnaeus, 1758	Grey heron	-	1	-	-	-	-	-	-	PV
2	<i>Egretta garzetta</i> (Linnaeus, 1766)	Little egret	-	6	-	8	-	-	-	-	PV
3	<i>Ardeola ralloides</i> Scopoli, 1769	Squacco Heron	-	5	-	-	-	-	-	-	PV
4	<i>Ciconia ciconia</i> Linnaeus, 1758	White stork	-	-	-	-	36	1 died	-	-	PV
5	<i>Anas querquedula</i> Linnaeus, 1758	Garganey	-	8	-	-	-	-	-	-	PV
6	<i>Circus aeruginosus</i> Linnaeus, 1758	Marsh harrier	-	-	-	-	2	-	-	-	PV
7	<i>Falco biarmicus</i> Temminck, 1825	Lanner Falcon	-	-	-	-	5	-	-	-	RB
8	<i>Gallinula chloropus</i> (Linnaeus, 1758)	Morhen	-	1	-	3	7	-	-	-	RB
9	<i>Pterocles coronatus</i> Lichtenstein, 1823	Crowned Sandgrouse	-	-	-	-	38	-	-	-	RB
10	<i>Columba livia</i> Gmelin, 1789	Rock dove	-	-	-	-	-	-	77	55	RB
11	<i>Streptopelia turtur</i> (Linnaeus, 1758)	Turtle dove	-	50	38	20	22	-	-	-	MB
12	<i>Streptopelia senegalensis</i> (Linnaeus, 1776)	Laughing Dove	60	17	70	30	50	42	28	-	MB
13	<i>Apus pallidus</i> Shelley, 1870	Pallid swift	-	65	-	-	30	-	-	-	MB
14	<i>Galerida cristata</i> (Linnaeus, 1758)	Crested lark	-	-	-	-	-	1	19	-	RB
15	<i>Ammomanes deserti</i> (Lichtenstein, 1823)	Desert lark	-	-	-	-	23	7	15	-	RB
16	<i>Riparia riparia</i> (Linnaeus, 1758)	Sand martin	-	-	-	-	-	-	33	14	PV
17	<i>Cercotrichas galactotes</i> (Temminck, 1820)	Rufous Bush Robin	18	-	-	10	17	14	18	-	PV
18	<i>Oenanthe leucopyga</i> (Brehm, 1855)	White-crowned Wheatear	18	-	17	11	22	36	14	2	RB
19	<i>Acrocephalus scirpaceus</i> (Hermann, 1804)	Reed warbler	-	18	-	18	-	-	-	-	PV
20	<i>Iduna pallida</i> (Hemprich et Ehrenberg, 1833)	Olivaceous Warbler	22	-	-	-	11	5	17	-	MB

Table 3. Numbers of birds species observed in Fezzan province and their status (continued).

	Scientific name	Common name	Wadi Al-shati	Sebha	Traghen	Murzuq	Ubari	Al-awenat	Ghat	Akakus	Status
21	<i>Lanius meridionalis</i> (Temminck, 1820)	Great grey shrike	17	29	-	12	2	-	-	-	RB
22	<i>Turdoides fulva</i> (Desfontaines, 1789)	Fulvous Babbler	28	-	14	13	9	-	-	-	RB
23	<i>Corvus ruficollis</i> Lesson, 1830	Brown-necked Raven	9	-	-	7	100	12	-	-	RB
24	<i>Passer hispaniolensis</i> Temminck, 1820	Spanish Sparrow	150	200	120	150	150	160	300	-	WV
25	<i>Passer simplex</i> (Lichtenstein, 1823)	Desert Sparrow	-	50	50	100	-	-	90	4	RB
26	<i>Emberiza sahari</i> Levaillant, 1850	House Bunting	-	-	-	-	-	-	25	-	RB
		<b>TOTAL</b>	<b>322</b>	<b>450</b>	<b>309</b>	<b>382</b>	<b>524</b>	<b>277</b>	<b>636</b>	<b>75</b>	<b>2975</b>

Table 3 (continued). Numbers of birds species observed in Fezzan province and their status.

### Order Hyracoidea

One of the most important findings of this study is the observation of Rock hyrax, *Procavia capensis* Pallas, 1766. It occurs throughout most of Africa from the southernmost tip north to a line from Senegal throughout southern Algeria, Libya and Egypt into the Middle East, except Congo and Madagascar (Olds & Shoshani, 1982). The rock hyrax is one of the four living species of the order Hyracoidea, and the only living species in the genus *Procavia* Storr, 1780. However, the distribution of this species in Libya is limited to the far southern mountains (Hufnagel, 1972). Study on distribution, density and biology of this species in Libya is needed. We had a visit to Akakus mountains, where usually this species had been found, but we could not observe any individuals in the area. However, our observation of this animal is based on four captives of this species kept in an old rocky house of a local family (Fig. 4).

### Order Artiodactyla

Even-toed ungulates are more or less rare in the province. In this study two species of family Bovidae were sighted; Barbary sheep, *Ammotragus lervia* Pallas, 1777 and Dorcas gazelle, *Gazella*

*dorcas* Linnaeus, 1758). Only horns of barbary sheep were recovered in Al-Awenat (Fig. 5a). It was a clear evidence of the presence of this species around the area. Moreover, locals emphasized that this species still exists in the region. A total of 12 Dorcas gazelle were observed in Al-jaza'a protected area in Al-Shati (Fig. 5b). This species cover a wide range in Libya (Bennett, 1970; Hufnagel, 1972; Essghaier, 1980), but population trend has recently declined due to overhunting and habitat destruction.

### Order Lagomorpha

Rabbit, *Lepus* sp. is the most common widely distributed species in Libya (Hufnagel, 1972); usually inhabits macchia-type vegetation, grassland, bushveld, and semi-desert areas. This species was observed in the most study sites (Wadi Al-shati, Sebha, Traghen, Murzuq and Ubari).

### Order Rodentia

Two species of rodents were reported by the present study, Jerboa *Jaculus jacuulus* (Linnaeus, 1758) of family Dipodidae and Gerbil, *Gerbillus* sp. of family Muridae, which is in accordance with the findings of Hufnagel (1972). A total of 5 specimens



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Figure 2. Desert agama *Trapelus mutabilis* (Akakus). Figure 3. A female of Desert sparrow. Figure 4. Rock hyrax in an old house in Al-Awenat.



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Figure 5. Horns of Barbary sheep. Figure 6. Dorcas gazelle in Aljaza'a protected area in Al-Shati.

of Gerbil were caught by life traps at the area between Wadi Al-shati and Sebha. However, the distribution of these species can be estimated by their wholes.

## CONCLUSIONS

In conclusion, the present study, conducted during summer 2006, documented some species from different orders of vertebrates. It is also highlighted the importance of biodiversity in Fezzan province. Although the survey was in summer, and thus few numbers of species and individuals were observed, nevertheless, it is emphasized the wild animal diversity and urged the need to implement a comprehensive study for the province in different seasons of the year.

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## Results of the eighth winter waterbird census in Libya in January 2012

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### ABSTRACT

After sporadic observations and reports on Libyan birds during the last century, a regular census of wintering birds at Libyan coastal wetlands started in January 2005. Results of each winter census till 2011 have been published. The survey of 2012 was carried out by the authors of the present paper. The general aim was to continue the census of wintering waterbirds in Libya, despite the difficulties that faced the team after the War of Liberation, and the fact that certain areas, very important for birds, have been declared military areas. A total of 29,314 individuals belonging to 69 waterbird species was counted. Comparatively, the number of sites covered in 2012 was less than that in previous years of the survey. The majority of individuals counted belong to seven gull species. This survey also observed a total of 56 individuals of *Aythya nyroca* Guldenstadt, 1770, a Near Threatened species, as well as, for the first time, a single individual of Canada Goose *Branta canadensis* (Linnaeus, 1758) in eastern Libya.

### KEY WORDS

Waterbirds; *Aythya nyroca*; Canada Goose; Libya.

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### INTRODUCTION

After sporadic observations and reports of Libyan birds during the last century, a regular census of wintering birds at Libyan coastal wetlands started in January 2005. Results of each winter census till January 2011 have been published (e.g. Azafzaf et al., 2005, 2006; Etayeb et al., 2007; Hamza et al., 2008).

These field surveys resulted in the publication of the Atlas of Wintering Waterbirds of Libya 2005–2010. In addition, 2005 and 2006 results were published in Wildfowl (Smart et al., 2006) and recently, results of the seventh winter waterbird

census in Libya (January–February 2011) were published (Bourass et al., 2013).

The Environment General Authority (EGA), the official Libyan body responsible for the implementation of international agreements relating to biodiversity, co-sponsored the previous ornithological surveys of wetlands in Libya, under a Memorandum of Agreement with the RAC/SPA and AEWA, and with support from Wetlands International, the Istituto Nazionale per la Fauna Selvatica INFS (Italy) and the Office National de la Chasse et de la Faune Sauvage ONCFS (France).

The survey of 2012 was carried out by the authors of the present paper. The general aim was to continue the census of wintering waterbirds in Libya, despite the difficulties that faced the team after the War of Liberation and the declaration of certain very important areas for birds as military areas. The study also aimed to compare the present results with the previous results (2005–2011) and to report on whether there were records of any new species.

## MATERIAL AND METHODS

The survey was principally focused on the far eastern and western regions, and very few sites in the middle region of the country were covered (Fig. 1). A total of 42 sites was covered (Table 1); the survey was carried out in two periods, 3rd–8th Jan and 22nd–31st Jan. Moreover, unlike previous years, the survey of 2012 excluded some important bird sites, because of their declaration as military sites during the Libyan War of Liberation.

Unfortunately, there was no access to the Tawergha complex (Qaser Ahmed, Tawergha Spring and Al Hisha; 32°00'12,9" N; 15°08'41,9" E) one of the most important sites for waterbirds, where numerous species and individuals were observed in previous years (2005–2011). In order to examine the population trend of waterbirds wintering in Libya from 2005 to 2012, the Living Planet

Index (LPI) was used. The use of LPI was started in 1997 by the World Wide Fund for Nature (WWF) to investigate the changes of global biodiversity over time, especially for measuring the average trends of vertebrate populations (Loh et al., 2005).

In this paper, the Chain method was used to calculate the index, where the logarithm of the ratio of the population of each pair of years was calculated using the formula:

$$d_t = \log(N_t/N_{t-1})$$

where N= population size and t= years (time). The specific values of  $d_t$  were generated for  $n_t$  as:

$$d_t = \frac{1}{n_t} \sum_{i=1}^{n_t} d_{it}$$

Finally, the index for waterbird populations in Libyan wetlands in a standard year t was calculated as:

$$I_t = I_{t-1} 10^{d_t}$$

## RESULTS AND DISCUSSION

The overall number of species and individuals of waterbirds and non-waterbirds was lower than



Figure 1. Sites included in the winter census in January 2012.

S.n	site name	N	E
1	Ajdabiyah GMMR reservoir	30.58	20.34694
2	Ajdabiyah sewage farm	30.69472	20.25889
3	Al Labadia	32.50472	20.89306
4	Al Mallahah	32.89972	13.28694
5	Al Maqarin karstic lakes	32.15917	20.13861
6	Assabri beach	32.13667	20.07278
7	Ayn Taqnit	32.125	12.80722
8	Ayn Zayyanah	32.21389	20.15556
9	Bab al Bahr coast	32.89667	13.16417
10	Benghazi harbours	32.10472	20.05778
11	Bin Jawwad dam	30.80028	18.06694
12	Bou Dzira	32.16833	20.13194
13	Coast Abu Kammash to Ras Ajdir	33.11139	11.63639
14	Farwah Lagoon	33.08806	11.76028
15	Sabkhat Abu Kammash	33.08389	11.59389
16	Sabkhat al Kuz	32.44083	20.43333
17	Sabkhat al Manqub	32.90944	12.12639
18	Sabkhat al Thama and Sabkhat Esselawi	32.14944	20.10278
19	Sabkhat ash Shuwayrib	30.72361	20.12972
20	Sabkhat at Tamimi	32.35917	23.07528
21	Sabkhat Ayn ash Shaqiqah	32.81444	21.47972
22	Sabkhat Ayn az Zarqa	32.80444	21.45917
23	Sabkhat Fairuz	32.04333	20.02222
24	Sabkhat Julyanah	32.09028	20.05944
25	Sabkhat Karkurah	31.40111	20.055
26	Sabkhat Millitah	32.83083	12.28278
27	Sabkhat Qaminis and Sabkhat Jaruthah	31.74528	19.93444
28	Sabkhat Qanfudhah	32.00028	19.98861
29	Sabkhat Ras at Tin	32.60917	23.12222
30	Sea off Farwah Island	33.11639	11.74861
31	Tajura coast	32.89583	13.37
32	Tobruk harbour	32.06861	23.98583
33	Tripoli harbour	32.90167	13.19194
34	Umm al Jarami	32.52444	23.09361
35	Wadi al Mujaynin dam	32.29	13.2525
36	Wadi al Qusaybat and Ain al Wahsh	32.31639	23.09694
37	Wadi at Tut dam	32.11722	12.42083
38	Wadi Ghan dam	32.23778	13.13083
39	Wadi Ka'am dam	32.39667	14.32917
40	Wadi Ka'am mouth	32.52667	14.44639
41	Wadi Zaret dam	32.10611	12.80333
42	Zuwarah harbour	32.92306	12.12139

that in all years between 2005 and 2011, as well as the number of sites covered (Table 2). A total of 29,314 individuals belonging to 69 species from 20 families of waterbirds and wetland-dependent raptors was recorded during January 2012 (Table 3). This survey was mainly focused on the eastern and western regions, but included some sites in the middle region of the country.

The population index of wintering waterbirds in Libya showed fluctuations throughout the years of census (2005–2012), with peaks of up to more than 50% in January of 2006, 2008 and 2010 (Fig. 2). Furthermore, the Living Planet Index showed a population decline in January 2012 of up to 0.3% for the above mentioned reasons.

#### Family PODICIPEDIDAE

Three species from this family were counted: Black-necked Grebe *Podiceps nigricollis*, Little Grebe *Tachybaptus ruficollis* and Great Crested Grebe *Podiceps cristatus* (Table 3). These species were reported in the previous surveys from 2005 to 2011 (Azafzaf et al., 2005, 2006; Etayeb et al., 2007; Hamza et al., 2008; Bourass et al., 2013). The largest number was of the Black-necked Grebe with a total of 495 individuals.

#### Family PROCELLARIIDAE

A total of fourteen Yelkouan Shearwater *Puffinus yelkouan* was counted during this survey. Since the start of wintering survey in 2005, Yelkouan Shearwater was only observed in winters 2005 (EGA-RAC/SPA Waterbird Census Team, 2012), and 2011 with a total of five individuals (Bourass et al., 2013).

#### Family SULIDAE

Six individuals of Gannet *Morus bassanus* were observed in winter 2012 (four in Wadi Ka'am, one at Tajura Coast and one at Farwah Island). The number of Gannets ranged from 3 to 40 individuals during the previous surveys 2005–2011, and the peak was in January 2011.

Table 1. Number of sites covered in January 2012, Libya.

Years	2005	2006	2007	2008	2009	2010	2011	2012
No. WB	29,996	51,698	39,303	53,632	40,369	51,652	34,842	29,314
No. WB sp.	79	85	92	79	65	86	81	69
No. NWB	301,60	146,621	39,130	13,378	13,047	60,000	506,155	2,054
No. NWB sp.	74	60	69	64	55	60	67	23
Covered sites	65	56	43	50	49	94	84	42
Period of census	3–17 Jan	19–31 Jan	3–15 Feb	20–31 Jan	26 Jan–7 Feb	24 Jan–3 Feb	29 Jan–13 Feb	3–8 Jan, 22 Jan–1 Feb

Table 2. Numbers of birds (species and individuals) counted during winters 2005 to 2012, Libya. WB=Waterbirds, NWB= Non-Waterbirds

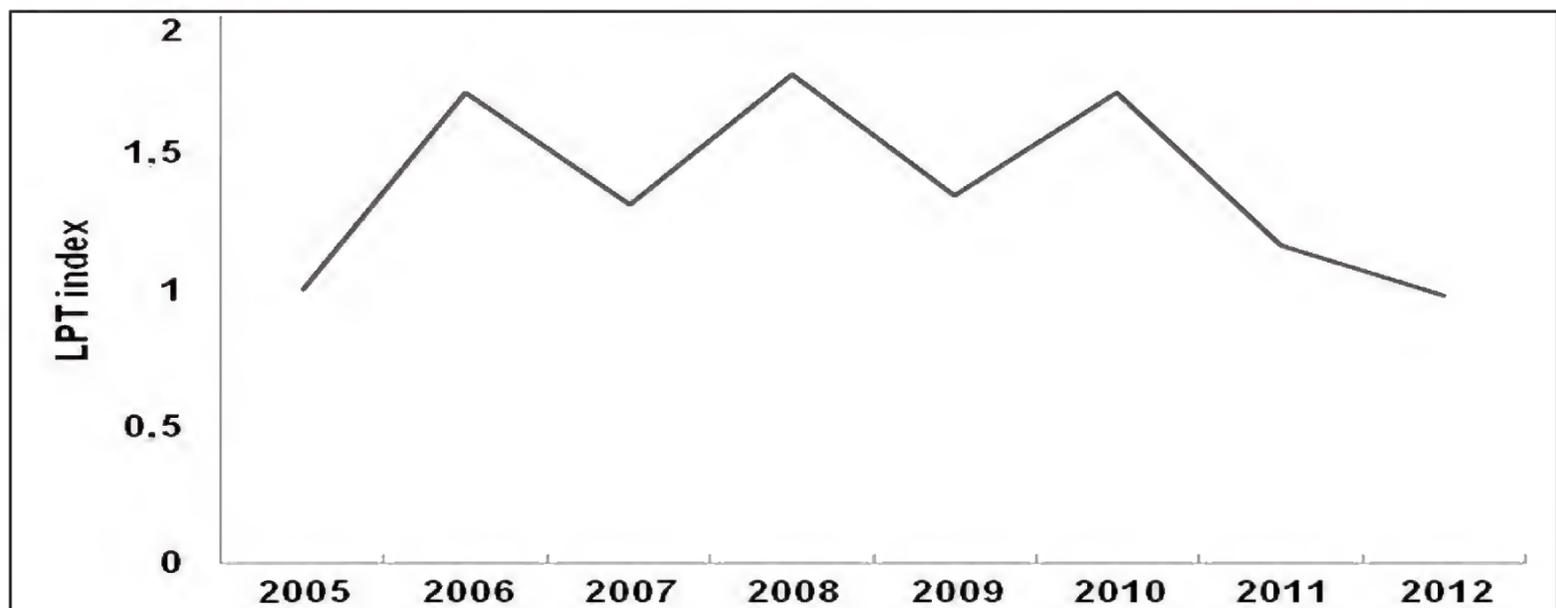


Figure 2. The index of waterbird populations wintering in Libyan wetlands from 2005 to 2012.

#### Family PHALACROCORACIDAE

In January 2012 this family was represented only by the Cormorant *Phalacrocorax carbo*, with a total of 1357 individuals counted in 25 different sites. The highest numbers were observed in Wadi Ka'am and Farwah Lagoon (313 and 236, respectively). Since winter 2005 the total has ranged from 987 to 2606, with a peak in 2010 (EGA-RAC/SPA Waterbird Census Team, 2012).

#### Family ARDEIDAE

Five species belonging to this family were observed during the current survey: Cattle Egret,

Squacco Heron, Little Egret, Great Egret and Grey Heron (Table 3). The highest number was of Cattle Egret, with a total of 611 individuals, and the lowest of Squacco Heron where only two individuals were observed in Wadi Ka'am. However, from 2005 to 2010 the number of Squacco Heron ranged from 2 to 5 (EGA-RAC/SPA Waterbird Census Team, 2012). Relatively, the numbers of the other species of this family were at the same levels for the years 2005 to 2011 (Bourass et al., 2013; EGA-RAC/SPA Waterbird Census Team, 2012).

#### Family CICONIDAE

Five individuals of White Stork *Ciconia ciconia*

were counted in Al Labadia in eastern Libya (Table 1). Bourass et al. (2013) reported a total of 86 individuals in winter 2011. From 2005 to 2010 numbers ranged from 4 to 50 (EGA-RAC/SPA Waterbird Census Team, 2012). However, White Storks are more common in farmland than in coastal wetlands (Bundy, 1976).

#### Family THRESKIORNITHIDAE

The current survey counted 61 Eurasian Spoonbills *Platalea leucorodia*, the lowest total so far; the peak was in 2011 with a total of 145 individuals (Bourass et al., 2013).

#### Family PHOENICOPTERIDAE

A total of 219 individuals of Greater Flamingo *Phoenicopterus roseus* was counted in six sites (Al Mallahah, Sabkhat Millitah, Sabkhat Abu Kamash, Sabkhat Qanfudhah, Sabkhat al Kuz and Farwah Lagoon). This observation is the lowest among the years from 2005 to 2011. Moreover, the highest number of Flamingos was observed in 2009 with a total of 3292 individuals (EGA-RAC/SPA Waterbird Census Team, 2012).

#### Family ANATIDAE

A total of 11 species belonging to this family was observed in this survey (Table 3). The highest numbers were of Shoveler *Anas clypeata* and Teal *Anas crecca*, with totals of 747 and 394 individuals, respectively. Other species of the family Anatidae numbered from 1 to 193 (Table 3). However, individual numbers of these species were the lowest recorded, in comparison to the numbers in previous surveys (2005–2011). Unexpectedly, during counting of birds in Al Labadia on 29th Jan 2012, members of the census team observed an individual of Canada Goose *Branta canadensis* with a flock of 177 Shoveler, seven Pintail *Anas acuta* and four individuals of Ferruginous Duck *Aythya nyroca*.

This is the first record of this species in Libya, although two other species of geese have been reported in Libya: White-fronted Goose *Anser albifrons* (Bundy, 1976) and Greylag Goose *Anser anser* (Bundy, 1976; EGA-RAC/SPA Waterbird Census Team, 2012). Description of Canada Goose: Larger than all species of duck, long neck, brownish body, black head and neck and white patches on the

face. This observation was in early morning. The team was able to observe this species at a distance of 100–120 m for more than one hour, using Swarovski Telescope and Svensson et al. (2010) guide.

#### Family PANDIONIDAE and ACCIPITRIDAE

A total of 20 Marsh Harriers *Circus aeruginosus* was observed in different wetlands along the coastline and inland. This observation is the lowest so far as the range was 21–74 individuals from 2005 to 2011 (EGA-RAC/SPA Waterbird Census Team, 2012; Bourass et al., 2013). Although it is mentioned as a winter and passage visitor (Bundy, 1976), and there is no evidence of breeding, our observations from field visits to different sites in Libya recorded the presence of Marsh Harrier in all months of the year. Furthermore, this species is reported as a resident breeder in Tunisia which is the neighbouring country to Libya (Isenmann et al., 2005). A solitary Osprey *Pandion haliaetus* has been observed during winter 2012 in Tajura Coast. However, a total of four individuals was observed in 2005 (Smart et al., 2006) and only one in 2008 (Hamza et al., 2008) and 2010 (EGA-RAC/SPA Waterbird Census Team, 2012). The Osprey is reported as a winter and passage visitor in Libya (Bundy, 1976).

#### Family RALLIDAE

Unlike previous years, Moorhen *Gallinula chloropus* was counted at only three sites (Al Mallahah, Wadi Ka'am and Al Labadia), with a total of 297 individuals (Table 3). However, this number was in the range of Moorhens (38–701) counted during the previous years 2005–2011; the peak was in 2009 (EGA-RAC/SPA Waterbird Census Team, 2012). Coot *Fulica atra* was observed in 13 sites, mostly freshwater wetlands. The total of 901 individuals is the highest among the previous winter surveys where the range was 211–763.

#### Family HAEMATOPODIDAE

A total of 22 Eurasian Oystercatcher *Haematopus ostralegus* was recorded, as usual, at the westernmost wetlands on the Libyan coastline. The previous annual maximum was 56 in 2011 (Bourass et al., 2013).

Family	Scientific name	Common name	Total
ANATIDAE	<i>Branta canadensis</i> (Linnaeus, 1758)	Canada Goose	1
	<i>Tadorna tadorna</i> (Linnaeus, 1758)	Shelduck	64
	<i>Anas platyrhynchos</i> Linnaeus, 1758	Mallard	26
	<i>Anas strepera</i> (Linnaeus, 1758)	Gadwall	1
	<i>Anas acuta</i> Linnaeus, 1758	Pintail	63
	<i>Anas clypeata</i> Linnaeus, 1758	Shoveler	747
	<i>Marmaronetta angustirostris</i> (Ménétriés, 1832)	Marbled Duck	10
	<i>Anas crecca</i> Linnaeus, 1758	Teal	394
	<i>Aythya ferina</i> (Linnaeus, 1758)	Pochard	193
	<i>Aythya nyroca</i> Guldenstadt, 1770	Ferruginous Duck	56
	<i>Anas</i> sp.	Duck sp.	22
PROCELLARIIDAE	<i>Puffinus yelkouan</i> Acerbi, 1827	Yelkouan Shearwater	14
SULIDAE	<i>Morus bassanus</i> Linnaeus, 1758	Gannet	6
PHALACROCORACIDAE	<i>Phalacrocorax carbo</i> (Linnaeus, 1758)	Cormorant	1357
ARDEIDAE	<i>Bubulcus ibis</i> Linnaeus, 1758	Cattle Egret	611
	<i>Ardeola ralloides</i> Scopoli, 1769	Squacco Heron	2
	<i>Egretta garzetta</i> (Linnaeus, 1776)	Little Egret	116
	<i>Casmerodius albus</i> (Linnaeus, 1758)	Great Egret	19
	<i>Ardea cinerea</i> Linnaeus, 1758	Grey Heron	83
CICONIDAE	<i>Ciconia ciconia</i> Linnaeus, 1758	White Stork	5
THRESKIORNITHIDAE	<i>Platalea leucorodia</i> Linnaeus, 1758	Spoonbill	61
PHOENICOPTERIDAE	<i>Phoenicopterus roseus</i> Pallas, 1811	Flamingo	219
PODICIPEDIDAE	<i>Podiceps nigricollis</i> Brehm, 1831	Black-necked Grebe	495
	<i>Tachybaptus ruficollis</i> (Pallas, 1764)	Little Grebe	88
	<i>Podiceps cristatus</i> Linnaeus, 1758	Great Crested Grebe	82
ACCIPITRIDAE	<i>Circus aeruginosus</i> Linnaeus, 1758	Marsh Harrier	20
PANDIONIDAE	<i>Pandion haliaetus</i> (Linnaeus, 1758)	Osprey	1
RALLIDAE	<i>Gallinula chloropus</i> (Linnaeus, 1758)	Moorhen	297
	<i>Fulica atra</i> Linnaeus, 1758	Coot	901
HAEMATOPODIDAE	<i>Haematopus ostralegus</i> Linnaeus, 1758	Oystercatcher	22
RECURVIROSTRIDAE	<i>Himantopus himantopus</i> Linnaeus, 1758	Black-winged Stilt	550
	<i>Recurvirostra avosetta</i> Linnaeus, 1758	Avocet	8
BURHINIDAE	<i>Burhinus oediconemus</i> Linnaeus, 1758	Stone Curlew	35
CHARADRIIDAE	<i>Charadrius hiaticula</i> Linnaeus, 1758	Ringed Plover	61

Table 3. Number of waterbird species and individuals counted in January 2012, Libya (continued).

Family	Scientific name	Common name	Total	
CHARADRIIDAE	<i>Charadrius alexandrinus</i> Linnaeus, 1758	Kentish Plover	339	
	<i>Pluvialis squatarola</i> Linnaeus, 1758	Grey Plover	44	
	<i>Pluvialis apricaria</i> Linnaeus, 1758	Golden Plover	430	
	<i>Vanellus vanellus</i> Linnaeus, 1758	Lapwing	263	
SCOLOPACIDAE	<i>Calidris alba</i> Pallas, 1764	Sanderling	12	
	<i>Arenaria interpres</i> (Linnaeus, 1758)	Turnstone	27	
	<i>Calidris alpina</i> Linnaeus, 1758	Dunlin	1781	
	<i>Calidris ferruginea</i> Pontoppidan, 1763	Curlew Sandpiper	3	
	<i>Calidris minuta</i> Leisler, 1812	Little Stint	231	
	<i>Tringa glareola</i> Linnaeus, 1758	Wood Sandpiper	8	
	<i>Tringa ochropus</i> Linnaeus, 1758	Green Sandpiper	16	
	<i>Actitis hypoleucos</i> Linnaeus, 1758	Common Sandpiper	22	
	<i>Tringa totanus</i> Linnaeus, 1758	Redshank	696	
	<i>Tringa erythropus</i> Pallas, 1764	Spotted Redshank	66	
	<i>Tringa nebularia</i> Gunnerus, 1767	Greenshank	68	
	<i>Tringa stagnatilis</i> Bechstein, 1803	Marsh Sandpiper	34	
	<i>Limosa limosa</i> Linnaeus, 1758	Black-tailed Godwit	3	
	<i>Limosa lapponica</i> Linnaeus, 1758	Bar-tailed Godwit	2	
	<i>Numenius arquata</i> Linnaeus, 1758	Curlew	340	
	<i>Numenius phaeopus</i> Linnaeus, 1758	Whimbrel	1	
	<i>Gallinago gallinago</i> Linnaeus, 1758	Snipe	110	
	<i>Philomachus pugnax</i> Linnaeus, 1758	Ruff	13	
	LARIDAE	<i>Chroicocephalus ridibundus</i> Linnaeus, 1776	Black-headed Gull	11981
		<i>Chroicocephalus genei</i> Breme, 1839	Slender-billed Gull	804
<i>Larus melanocephalus</i> Temminck, 1820		Mediterranean Gull	1035	
<i>Larus argentatus</i> Pontoppidan, 1763		Herring Gull	31	
<i>Larus michahellis</i> Naumann, 1840		Yellow-legged Gull	1398	
<i>Larus audouinii</i> Payraudeau, 1826		Audouin's Gull	87	
<i>Larus fuscus</i> Linnaeus, 1758		Lesser Black-backed Gull	2374	
<i>Larus</i> sp.		Gull sp.	9	
STERNIDAE	<i>Sterna sandvicensis</i> Latham, 1787	Sandwich Tern	362	
	<i>Hydroprogne caspia</i> Pallas, 1770	Caspian Tern	40	
	<i>Sterna bengalensis</i> Lesson, 1821	Lesser Crested Tern	1	
	<i>Chlidonias hybridus</i> Pallas, 1811	Whiskered Tern	43	

Table 3 (continued). Number of waterbird species and individuals counted in January 2012, Libya.

#### Family RECURVIROSTRIDAE

At eight Libyan coastal wetlands, 550 Black-winged Stilts *Himantopus himantopus* were counted (previous maximum 753 in 2011). This species is mentioned as a passage visitor (Bundy, 1976), but recently has been recorded as a breeder at Al Mallahah wetland (Etayeb et al., 2013). A total of eight Avocets *Recurvirostra avosetta* was observed in two sites in eastern Libya (Al Labadia and Ayn Zayyanah). The previous annual maximum was 193 in 2006 (EGA-RAC/SPA Waterbird Census Team, 2012).

#### Family BURHINIDAE

Eurasian Stone Curlew *Burhinus oedicephalus* was counted in two sites: Wadi Ka'am dam and Tajura Coast with totals of 10 and 25 individuals respectively. The total of 35 Stone Curlews is the highest so far, with the range in the previous years of 1–12 individuals.

#### Family CHARADRIIDAE

Five species belonging to this family were observed along the coastline: Ringed Plover 61 individuals (previous maximum 101 in 2011), Kentish Plover 339 individuals (previous maximum 1797 in 2007), Grey Plover 44 individuals (previous maximum 195 in 2006), Golden Plover 430 individuals (previous maximum 645 in 2006) and Lapwing 263 individuals (previous maximum 96 in 2011) (Table 3; Smart et al., 2006; Etayeb et al., 2007; EGA-RAC/SPA Waterbird Census Team, 2012; Bourass et al., 2013).

#### Family SCOLOPACIDAE

In different sites along the Libyan coast, particularly those with shallow water, we counted a total of 18 species belong the family Scolopacidae. This family was the largest during this survey (see Table 3). The number of individuals varied from species to species, and the highest was 1781 for Dunlin *Calidris alpina*, while the lowest was a solitary Whimbrel *Numenius phaeopus* in Farwah Lagoon. Moreover, Redshank *Tringa totanus* numbered 696 (previous maximum 1544 in 2010). Only three Black-tailed Godwits *Limosa limosa* (previous maximum 10 in 2005, 2006) and two Bar-tailed Godwits *Limosa lapponica* (previous maximum 17 in 2011) were observed at the westernmost part of

Libya (Coast Abu Kammash to Ras Ajdir). However, other species fluctuated in numbers through the years from 2005 to 2011, and showed a relative decrease in 2012, in relation to the reduced number of sites covered.

#### Family LARIDAE

A total of seven species of gull was observed (Table 3). In comparison to the previous years, the number of individuals was very low, for instance Black-headed Gull *Chroicocephalus ridibundus* in 2012 numbered 11,980 individuals, whereas the previous maximum was 25,352 in 2008. A total of 87 of the Near Threatened Audouin's Gull *Larus audouinii* (IUCN Red List) was counted in seven sites around Tripoli and Benghazi. However, this number was the lowest so far (previous maximum 670 in 2006).

#### Family STERNIDAE

Four species were observed from this family (Table 3). The highest number was for the Sandwich Tern *Sterna sandvicensis* with a total of 362 individuals. This number was in the range of the previous counts (83 in 2007 and 395 in 2010). Although this species existed in good numbers compared to the other *Sterna* species, there is no evidence so far of breeding in Libya. It is reported as a winter visitor (Bundy, 1976). Caspian Tern *Hydroprogne caspia* and Whiskered Tern *Chlidonias hybridus* were more or less in the range of previous counts (Table 3). A solitary individual of Lesser Crested Tern *Sterna bengalensis* was observed in Tajura Coast. This species is a summer breeder in some sites in eastern Libya. The population of Lesser Crested Tern can be seen in good numbers in Libya from late April till August (Hamza & Azafzaf, 2012).

#### Family ALCEDINIDAE

10 individuals of Kingfisher *Alcedo atthis* were observed at different sites along the coastline (previous maximum 19 in 2005).

#### *Non-waterbird species*

Although this census did not target non-waterbird species, some species were occasionally recor-

Family	Scientific name	Common name	Total
ACCIPITRIDAE	<i>Buteo rufinus</i> (Cretzschmar, 1827)	Long-legged Buzzard	2
FALCONIDAE	<i>Falco tinnunculus</i> Linnaeus, 1758	Kestrel	3
STRIGIDAE	<i>Bubo ascalaphus</i> (Savigny, 1809)	Pharaoh Eagle Owl	1
UPUPIDAE	<i>Upupa epops</i> Linnaeus, 1758	Hoopoe	7
ALAUDIDAE	<i>Galerida cristata</i> Linnaeus, 1758	Crested Lark	67
	<i>Melanocorypha calandra</i> (Linnaeus, 1766)	Calandra Lark	13
HIRUNDINIDAE	<i>Riparia riparia</i> (Linnaeus, 1758)	Sand Martin	3
	<i>Hirundo fuligula</i> (Lichtenstein, 1842)	Rock Martin	20
	<i>Hirundo rustica</i> Linnaeus, 1758	Barn Swallow	6
TURDIDAE	<i>Phoenicurus ochruros</i> (Gmelin, 1774)	Black Redstart	3
MOTACILLIDAE	<i>Motacilla alba</i> Linnaeus, 1758	White Wagtail	41
TURDIDAE	<i>Erithacus rubecula</i> (Linnaeus, 1758)	Robin	4
	<i>Saxicola torquata</i> (Linnaeus, 1766)	Stonechat	26
SYLVIIDAE	<i>Sylvia melanocephala</i> (Gmelin, 1789)	Sardinian Warbler	4
	<i>Acrocephalus scirpaceus</i> (Hermann, 1804)	Reed Warbler	5
	<i>Phylloscopus collybita</i> (Vieillot, 1817)	Chiffchaff	18
LANIIDAE	<i>Lanius excubitor</i> Linnaeus, 1758	Great Grey Shrike	11
TIMALIIDAE	<i>Turdoides fulvus</i> (Desfontaines, 1789)	Fulvous Babbler	5
CORVIDAE	<i>Corvus corax</i> Linnaeus, 1758	Raven	3
STURNIDAE	<i>Sturnus vulgaris</i> Linnaeus, 1758	Starling	1725
PASSERIDAE	<i>Passer domesticus</i> Linnaeus, 1758	House Sparrow	79
FRINGILLIDAE	<i>Carduelis carduelis</i> Linnaeus, 1758	Goldfinch	5
	<i>Serinus serinus</i> Linnaeus, 1766	Serin	3

Table 4. Number of non-waterbird species and individuals counted in January 2012, Libya.

ded in and around wetlands. A total of 2054 individuals belonging to 23 species from 16 families was observed during this survey (Table 4). However, these numbers were the lowest among the previous years (2005–2011, see Table 2).

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# New knowledge on diet and monitoring of a roost of the long-eared owl, *Asio otus* (Linnaeus, 1758) (Strigiformes Strigidae) on Mount Etna, Sicily

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## ABSTRACT

A study during autumn and winter in Monte Serra area (Mount Etna) was performed on the pellets of a roost of long-eared owl, *Asio otus* (Linnaeus, 1758) (Strigiformes Strigidae). Besides, in order to better understand the feeding habits of this species on Mount Etna, the data from Monte Serra were integrated with those from Linguaglossa Pineta (breeding period). The study was performed through the analysis of 1,724 preys. The species most preyed was the Mammalia Microtidae *Microtus savii* (de Selys-Longchamps, 1838). The average weight of the preys was 23.48 g, while the average meal was 36.63 g. Besides, the results of the yearly monitoring of the roost studied are given.

## KEY WORDS

*Asio otus*; trophic niche; roost; Sicily.

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## INTRODUCTION

The trophic niche of *Asio otus* (Linnaeus, 1758) (Strigiformes Strigidae) during autumn and winter in a site of Mount Etna was studied in order to better understand that niche during all the year. The literature data concerning Sicily consist only on the information by Siracusa et al. (1996) focalized on the diet during the reproductive period in two localities (Linguaglossa and Roccapalumba). Up to now, no information on the roost monitoring in Sicily are known.

## MATERIAL AND METHODS

The studied site lies on the "Monte Serra", one of the volcanic cones of Mount Etna, at an altitude of 450 m a.s.l., which originated on the side south-

east during 122 B.C. It has a characteristic shape of a horseshoe, as a result of the collapse of the summit of the crater and of the volcano slope.

In recent centuries the landscape, due to human settlement and agricultural activities, has been progressively modified and the natural vegetation was represented just by some residual strips unevenly distributed. After the abandonment of cultivation, has started a new and slow recolonisation of the Mediterranean natural vegetation. This vegetation consists mainly in the bushes of evergreen holm oak, *Quercus ilex* L., wild olive, *Olea europaea* L., and carob, *Ceratonia siliqua* L.

The slopes of Monte Serra are covered with a shrubby in which are present the common broom, *Spartium junceum* L., and the Etna broom, *Genista aetnensis* (Raf. ex Biv.) DC, as the predominant species (Fig. 1).

At the base of the mountain, lies a forest left in its natural state, the "Forest of Cyclamen" in which the essence most represented is the tree oak, *Quercus virgiliana* Tenore, followed by hornbeam, *Ostrya carpinifolia* Scopoli, and flowering ash, *Fraxinus ornus* L.

The climatic characteristics of the study area are derived on the data of the time series of the Viagrande termoplviometric station (Fig. 2), which is located on the slope most affected by rainfall (annual rainfall higher than the whole of Etna), because invested by the moisture deriving from the Ionian Sea, which it overlooks. The study area falls within the Mediterranean Biogeographical Region, in the range of the meso-Mediterranean

climate (Brullo et al., 1996). The data on diet of long-eared owl in autumn and winter were obtained from the analysis of pellets collected in a roost located at "Parco di Monte Serra", in the period between September 2012 and March 2013.

The pellets were weekly collected. The collected material was provided on-site of a label reporting a detailed tagging, as well as the date and time of collection, the GPS coordinates of individual roost sites, weather conditions, information on the presence/absence and number of specimens observed.

The pellets were dried in the open air for a few days, wrapped in polythene bags containing camphor (to prevent any damage caused by the attack

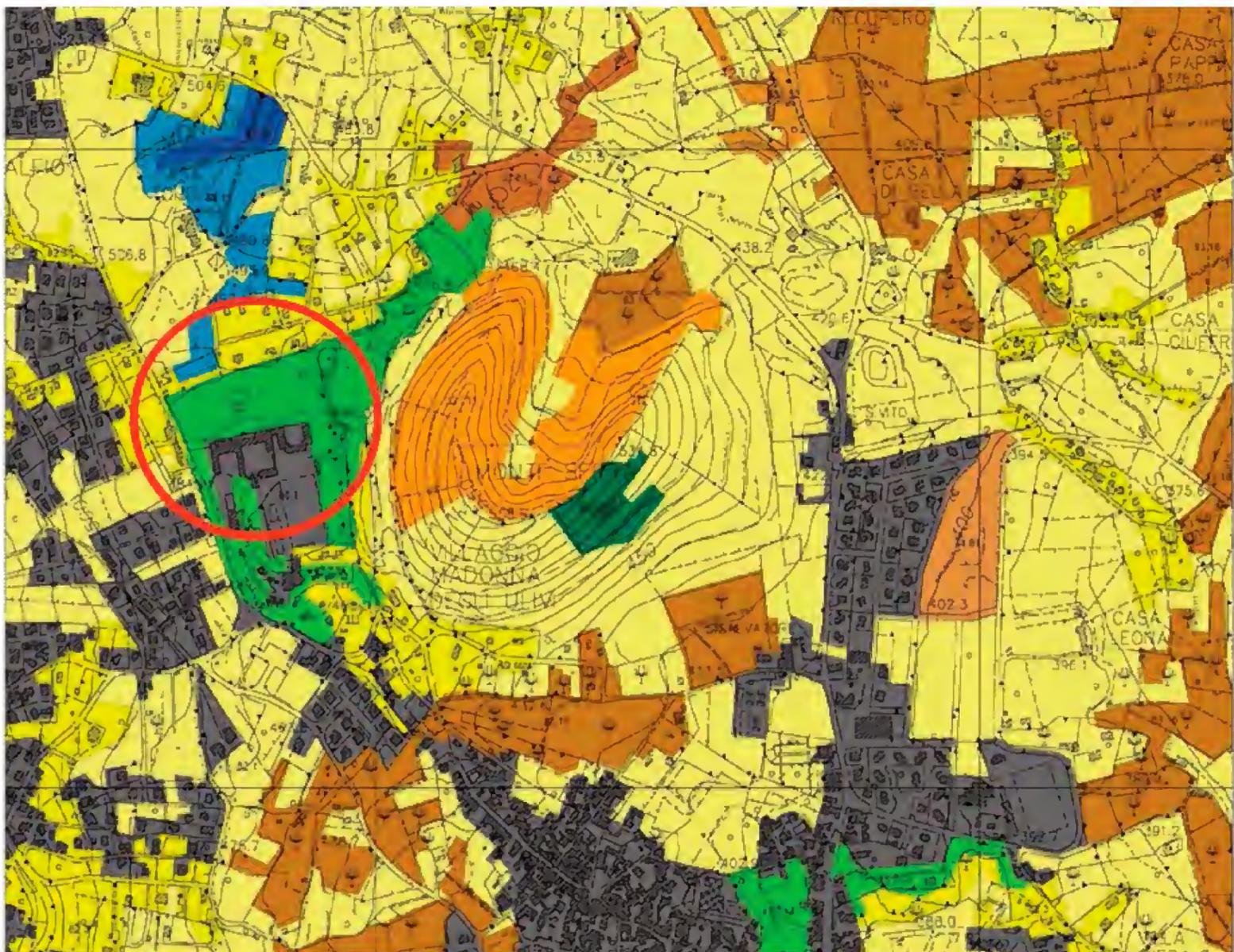


Figure 1. Land use in area of "Monte Serra" and neighboring areas (from Angelini et al., 2009, modified). Legend according to Corine Biotopes Code: 31.81 (brown) Middle-European scrubs; 32.215 (orange) low scrub with *Calicotome* sp.; 34.81 (light brown) Mediterranean subnitrophilous meadows; 41.732 (green) peninsular and insular Italy oak deciduous woods; 45.31A (light green) Southern Italy and Sicilian holm oak woods; 82.1 (light yellow) arable intensive and continuous; 82.3 (yellow) cultures of extensive type and complex agricultural systems; 83.11 (azure) groves; 83.21 (blue) vineyards; 83.322 (dark green) plantations of *Eucalyptus*; 83.16 (ocher brown) citrus orchards; 86.1 (gray) towns.

of scavenging arthropods) and then transported to the laboratory to be analyzed.

The content of each intact pellet was noted separately and the number of prey items concerned was taken to equal to the greatest number of identified fragments of one species (greatest number of lower jaws, etc.).

For the study of the pellets was used the pellets analysis technic (Contoli, 1980). The pellets were opened by dry technique, with the aid of a tweezers and of an entomological brush. For those too compact it was preferred the immersion in hot water for a few minutes in order to more easily separate the bones.

Before opening, were taken measures, with a digital gauge, relating to the length and the width of pellets. For the sorting of the content was used a stereoscopic microscope for better visibility of the alveoli of the molars and of the bones of small mammals.

To count the preyed specimens is considered their minimum number (Chaline et al., 1974). The jaws of the rats and the synsacrum of birds collected were measured with a digital caliper, in order to estimate the weight of the preyed specimens.

The identification of small mammals was based on the cranium features and dichotomous keys (Toschi & Lanza, 1959; Toschi, 1965; Chaline et al., 1974; Amori et al., 2008), while for the larger prey was used the morphology of the long bones.

The calculation of the biomass was carried out by assigning to each species an average weight, relative to the species of small mammals and Coleoptera in Sicily (Table 1), provided by Di Palma & Massa, 1981, and for savi's pine vole (*Microtus savii*) provided by Catalisano & Massa, 1987.

Using the equation of Di Palma & Massa (1981), the calculated average weight of the brown rat (*Rattus norvegicus* Berkenhout, 1769) results  $102.6 \pm 27.0$  (SD) g (number of sampled specimens  $n = 46$ ), and  $94.5 \pm 26.4$  (SD) g ( $n = 14$ ) regarding *Rattus* sp. The weight of 94.5 g, equivalent to that of *Rattus* sp., has been assigned also to *Rattus rattus* (Linnaeus, 1758), considering that only 2 specimens were collected and no measurable jaws were available.

Using the equation of Di Palma & Massa (1981), the calculated average weight of the birds results  $14.1 \pm 5.2$  (SD) gr ( $n = 187$ ) based on synsacrum found in the pellets.

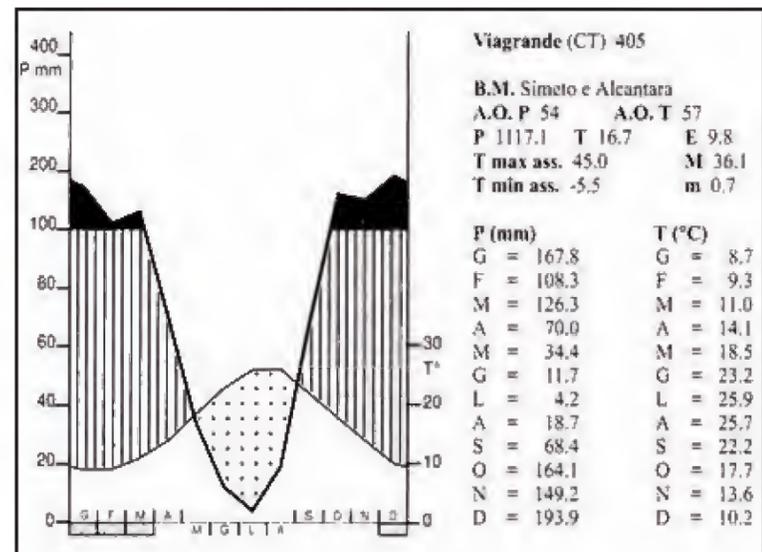


Figure 2. Climogramma of Viagrande termopluiometric station (from Zampino et al., 1997).

Taxa	Weight (g)	References
<i>Mus domesticus</i>	12.2	Di Palma & Massa, 1981
<i>Apodemus sylvaticus</i>	20.8	Di Palma & Massa, 1981
<i>Rattus norvegicus</i>	102.6	Equation of Di Palma & Massa, 1981
<i>Rattus</i> sp.	94.5	Equation of Di Palma & Massa, 1981
<i>Rattus rattus</i>	94.5	Same weight of <i>Rattus</i> sp.
<i>Microtus savii</i>	20	Catalisano & Massa, 1987
<i>Crocidura sicula</i>	6.7	Di Palma & Massa, 1981
<b>Coleoptera</b>	0.1	Di Palma & Massa, 1981
<b>Chiroptera</b>	10	( <i>Pipistrellus</i> sp.): average weight of sampled species
<b>Aves</b>	14.1	Equation of Di Palma & Massa, 1981 (synsacrum)
Not det.	34.1	Average weight of all categories of prey (excluding <i>Rattus norvegicus</i> and Coleoptera)

Table 1. Values used for the calculation of the biomass.

Besides the study of the trophic niche based on the collected pellets, the monitoring of the presence of the owls in the roost from May 2012 to June 2013 was performed (Fig. 3).

## RESULTS AND DISCUSSION

A total of entire 875 pellets were collected and examined in the Monte Serra area. The pellets have an average length of  $32.2 \pm 7.9$  (SD) mm and an average width of  $18.8 \pm 3.2$  (SD) mm. A total of 1,421 prey have been identified (Table 2, Fig. 4), with an average of 1.62 prey/pellet; 1 or 2 prey/pellet were found in most cases, 3 sometimes, 4

occasionally. During the study period, mammals are the most represented group (about 67% of the prey) followed by birds (about 32%). *Microtus savii* represents the most preyed species (50.2% of the catch), while *Apodemus sylvaticus* (Linnaeus,



Figure 3. Specimen of *Asio otus* on *Quercus* sp. (October 2012, photo by E. Musumeci).

Monte Serra					
Category of prey	n	%	weight (g)	biomass (g)	%
<i>Microtus savii</i>	714	50.25	20	14280	41.88
<b>Microtidae</b>	<b>714</b>	<b>50.25</b>		<b>14280</b>	<b>41.88</b>
<i>Mus domesticus</i>	19	1.34	12.2	231.8	0.68
<i>Apodemus sylvaticus</i>	108	7.60	20.8	2246.4	6.59
<i>Rattus rattus</i>	2	0.14	94.5	189	0.55
<i>Rattus norvegicus</i>	75	5.28	102.6	7695	22.57
<i>Rattus</i> sp.	26	1.83	94.5	2457	7.21
<b>Muridae</b>	<b>230</b>	<b>16.19</b>		<b>12819.2</b>	<b>37.6</b>
<b>Rodentia</b>	<b>944</b>	<b>66.43</b>		<b>27099.2</b>	<b>79.48</b>
<i>Crocidura sicula</i>	1	0.07	6.7	6.7	0.02
<b>Soricidae</b>	<b>1</b>	<b>0.07</b>		<b>6.7</b>	<b>0.02</b>
<b>Soricomorpha</b>	<b>1</b>	<b>0.07</b>		<b>6.7</b>	<b>0.02</b>
<b>Chiroptera</b>	<b>7</b>	<b>0.49</b>	<b>10</b>	<b>70</b>	<b>0.21</b>
<b>MAMMALIA</b>	<b>952</b>	<b>67</b>		<b>27175.9</b>	<b>79.66</b>
<b>AVES</b>	<b>452</b>	<b>31.81</b>	<b>14.1</b>	<b>6373.2</b>	<b>18.69</b>
<b>INSECTA Coleoptera</b>	<b>1</b>	<b>0.07</b>	<b>0.1</b>	<b>0.1</b>	<b>0</b>
<b>Not det.</b>	<b>16</b>	<b>1.13</b>	<b>34.1</b>	<b>545.6</b>	<b>1.6</b>
<b>Total prey</b>	<b>1421</b>				
<b>Pellets</b>	<b>875</b>				
<b>Prey/pellets</b>	<b>1.62</b>				
<b>Total biomass (g)</b>	<b>34094.8</b>				
<b>Average weight prey (g)</b>	<b>23.99</b>				
<b>Average meal (g)</b>	<b>38.86</b>				

Table 2. Results of the pellets analysis in the study area.

1758), generally the main trophic resource in wooded areas, shows the frequency of only 7.6%. Although Monte Serra is a suburban park in a discretely anthropized area, *Mus domesticus* Linnaeus, 1758 is very little represented (only 1.3%), but about 7.2% of prey (about 30% of biomass) belongs to *Rattus* spp. (Table 2): this latter result could be justified with the energetic advantage obtained by long-eared owl feed on rats, because these have a greater weight than other prey and owls could save energy by reducing the hunting with an equal gain of biomass. Soricomorpha and Chiroptera, as well as Insecta, are present in very low percentages of prey, less than or equal to 0.5%. The only found specimen of Soricidae, *Crocidura sicula* Miller, 1900, could be due to a selective choice of prey as well as environmental factors, like the pressure of the human presence in the area of Monte Serra. It should be emphasized that, although it is uncommon the predation of birds, in the examined site the percentage of this prey is significant and this is in agreement with some studies conducted on wintering sites in Northern Italy and in Spain (Albufera de Valencia) which recorded a presence of birds even higher, 50% of the total number of individuals preyed (Mastrorilli, 2000; Escala et al., 2009). The discrepancy between these results is likely attributable to the opportunistic habits of the long-eared owl that, when possible, implements group hunting strategies able to ferret out and in some cases cut off entire dormitories of passerines (Mikkola, 1983).

The data of the present study were compared with those of the long-eared owl diet during the reproductive period, detected always by the pellets analysis technic, in two sicilian sites, Pineta di Linguaglossa and Roccapalumba, characterized by different environmental features (Siracusa et al., 1996): an old pinewood and a cultivated area respectively.

A total of 191 pellets were collected and examined in Linguaglossa Pineta station (Table 3). Mammals are the most represented group (about 94% of the prey) followed by birds (about 6%). *Apodemus sylvaticus* was the most preyed species (60% of the catch) and with *Microtus savii* (32.67% of prey) represent about 93% of the preys. *Mus domesticus* is very little represented (only 0.66%), while no species of *Rattus* were collected. Soricomorpha and Chiroptera were present in very low percentages equal to 0.33% (Siracusa et al., 1996).

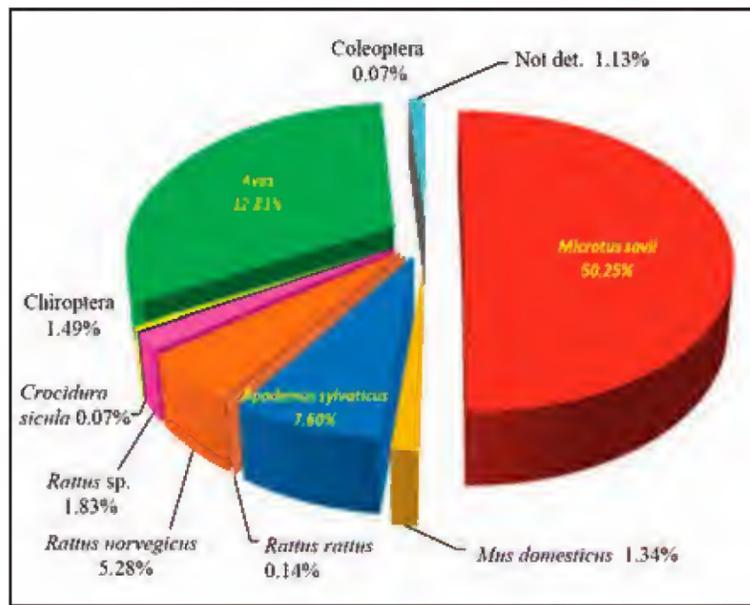


Figure 4. Graphical results of the pellets analysis in the study area.

A total of 21 pellets were collected and examined in Roccapalumba station (Table 3). Mammals are the most represented group (about 93% of the prey) followed by birds (more than 3%), arthropods (more than 2%) and amphibians and reptiles (about 1.5%). *Microtus savii* was the most preyed species (89.42% of the catches), while the other species of mammals (*Apodemus sylvaticus*, *Mus domesticus*, *Rattus rattus* and *Crocidura sicula*) were present in very low percentages, less than 2% (Siracusa et al., 1996).

In order to identify the trophic niche of the species in the piedmont areas of the Etna eastern slope, the stations of Monte Serra and Linguaglossa (a pinewood), were considered as a single sample

Category of prey	MONTE SERRA				LINGUAGLOSSA				ROCCAPALUMBA			
	n	%	biomass (g)	%	n	%	biomass (g)	%	n	%	biomass (g)	%
<i>Microtus savii</i>	714	50.25	14280	41.88	99	32.67	1683	26.34	245	89.42	4165	89.93
<i>Mus domesticus</i>	19	1.34	231.8	0.68	2	0.66	25	0.39	3	1.09	37.50	0.81
<i>Apodemus sylvaticus</i>	108	7.60	2246.4	6.59	182	60.07	4277	66.94	1	0.36	23.50	0.51
<i>Rattus rattus</i>	2	0.14	189	0.55	-	-	-	-	1	0.36	118	2.55
<i>Rattus norvegicus</i>	75	5.28	7695	22.57	-	-	-	-	-	-	-	-
<i>Rattus sp.</i>	26	1.83	2457	7.21	-	-	-	-	-	-	-	-
<i>Crocidura sicula</i>	1	0.07	6.7	0.02	1	0.33	6.5	0.10	5	1.82	32.50	0.70
Chiroptera	7	0.49	70	0.21	1	0.33	20	0.31	-	-	-	-
<b>MAMMALIA</b>	<b>952</b>	<b>67</b>	<b>27175.9</b>	<b>79.66</b>	<b>285</b>	<b>94.06</b>	<b>6011.5</b>	<b>94.08</b>	<b>255</b>	<b>93.06</b>	<b>4376.50</b>	<b>94.50</b>
<b>AVES</b>	<b>452</b>	<b>31.81</b>	<b>6373.2</b>	<b>18.69</b>	<b>18</b>	<b>5.94</b>	<b>378</b>	<b>5.92</b>	<b>9</b>	<b>3.28</b>	<b>189</b>	<b>4.08</b>
<b>AMPHIBIA + REPTILIA</b>	-	-	-	-	-	-	-	-	<b>4</b>	<b>1.46</b>	<b>60</b>	<b>1.30</b>
<b>ARTHROPODA</b>	<b>1</b>	<b>0.07</b>	<b>0.1</b>	<b>0</b>	-	-	-	-	<b>6</b>	<b>2.19</b>	<b>6</b>	<b>0.13</b>
Not det.	16	1.13	545.6	1.6	-	-	-	-	-	-	-	-
<b>Total</b>	<b>875</b>				<b>303</b>				<b>274</b>			

LINGUAGLOSSA		ROCCAPALUMBA	
Total prey	303 (243 on entire pellets)	Total prey	274 (66 on entire pellets)
Pellets	191	Pellets	21
Prey/pellets	1.27*	Prey/pellets	3.14*
Total biomass (g)	6389.50**	Total biomass (g)	4631.5 **
Average weight prey (g)	21.09**	Average weight prey (g)	16.9 **
Average meal (g)	26.78*	Average meal (g)	53.07*

Table 3. Comparison of results of pellets analysis during winter period (Mt. Serra) and during breeding period of long-eared owl from Pineta di Linguaglossa and from Roccapalumba (\* calculated only on prey on entire pellets; \*\* calculated on total prey) (from Siracusa et al., 1996, modified).

(Table 4), although the first case concerns the diet in the autumn and winter, while the second case regards the trophic niche in the reproductive period. It must be emphasized that the two sites, with different vegetations, are located both in the foothill region of Etna Mountain.

A total of 1,066 pellets were processed (Table 4). Also in this case, mammals are the most represented group (about 72% of the prey) followed by birds (about 27%), while arthropods are almost absent. *Microtus savii* is the most preyed species (more than 47% of the catches), while the Muridae provide the greatest contribution in terms of biomass (42.30% of total). Soricomorpha and Chiroptera are present in very low percentages less than or equal to 0.46%. The average weight of the preys is 23.48 g, while the average meal is 36.63 g.

The roost of Mt Serra was observed by the end of May 2012, when a young specimen has been

sighted among *Genista*, at the end of June 2013 (Fig. 5). Although traces of their presence (as plumage and very few pellets) were evident from June to August, only in early September 2012 were observed 7 specimens on an oak near the structure used by the Butterfly House as Information Point. This same roost was used by the group for most of the autumn season. During the sightings were counted from 1 to a maximum of 7 specimens, with greater presence during the afternoon hours. The owls were quite confident and they tolerated human presence. In November sporadic observations of owls were recorded and no pellets were found. The causes of this absence could, at least partially, be attributed to human disturbance or it might have been a time of reorganization of the roost. In late November (29th), after many days of absence, a roost of more than 11 specimens occupied the pines located inside the playground for children of the butterfly house. This roost, that throughout the winter period was composed of about 20 specimens, was present until the end of February. From late February to mid-March, were observed no more than 7 specimens as to restore the situation of September-November. No specimens were spotted from middle March to the end of June.

This study has allowed us to integrate knowledge about the trophic niche of the long-eared owl in Sicily for which was known a single study that refers to the diet of this species in the breeding season; however, were not known data concerning the trophic niche during the autumn-winter period and concerning the roost in wintering period. The data obtained from the pellets analysis of about 20 specimens and the analysis of the characteristics of the study area, have confirmed the selective behavior of *Asio otus* in the choice of prey, specifically the Microtids (as shown by the high percentage of *Microtus savii* found). It also highlighted a certain plasticity of the species that, if necessary, takes advantage of favorable situations such as the presence of dormitories of birds that are flushed out with a technique of group hunting. The above explains the significant number of birds found in the pellets, which is not a data usually reported in bibliography. This study is also useful for the increase of knowledge on the wintering sites of the long-eared owl in Italy and can be inserted in the national register of the roosts, set up by the project: "Gufiamo: count the long-eared owls wintering in

TOTAL MS+L				
Category of prey	n	%	biomass (g)	%
<i>Microtus savii</i>	813	47.16	15963	39.43
<b>Microtidae</b>	<b>813</b>	<b>47.16</b>	<b>15963</b>	<b>39.43</b>
<i>Mus domesticus</i>	21	1.22	256.8	0.63
<i>Apodemus sylvaticus</i>	290	16.82	6523.4	16.11
<i>Rattus rattus</i>	2	0.12	189	0.47
<i>Rattus norvegicus</i>	75	4.35	7695	19
<i>Rattus sp.</i>	26	1.51	2457	6.07
<b>Muridae</b>	<b>414</b>	<b>24.01</b>	<b>17121.2</b>	<b>42.30</b>
<b>Rodentia</b>	<b>1227</b>	<b>71.17</b>	<b>33084.2</b>	<b>81.72</b>
<i>Crocidura sicula</i>	2	0.12	13.2	0.03
<b>Soricidae</b>	<b>2</b>	<b>0.12</b>	<b>13.2</b>	<b>0.03</b>
<b>Soricomorpha</b>	<b>2</b>	<b>0.12</b>	<b>13.2</b>	<b>0.03</b>
<b>Chiroptera</b>	<b>8</b>	<b>0.46</b>	<b>90</b>	<b>0.22</b>
<b>MAMMALIA</b>	<b>1237</b>	<b>71.75</b>	<b>33187.4</b>	<b>81.97</b>
<b>AVES</b>	<b>470</b>	<b>27.26</b>	<b>6751.2</b>	<b>16.68</b>
<b>INSECTA Coleoptera</b>	<b>1</b>	<b>10.06</b>	<b>0.1</b>	<b>0</b>
<b>Not det.</b>	<b>16</b>	<b>0.93</b>	<b>545.6</b>	<b>1.35</b>
<b>Total prey</b>	<b>1724 (1664 on entire pellets)</b>			
<b>Pellets</b>	<b>1066</b>			
<b>Prey/pellets</b>	<b>1.56*</b>			
<b>Total biomass (g)</b>	<b>40484.30**</b>			
<b>Average weight prey (g)</b>	<b>23.48**</b>			
<b>Average meal (g)</b>	<b>36.63*</b>			

Table 4. Sum of results of the pellets analysis of long-eared owl during breeding period in Pineta di Linguaglossa and during autumn in Monte Serra. \* calculated only on prey on entire pellets (n=1664); \*\* calculated on total prey (n=1724).

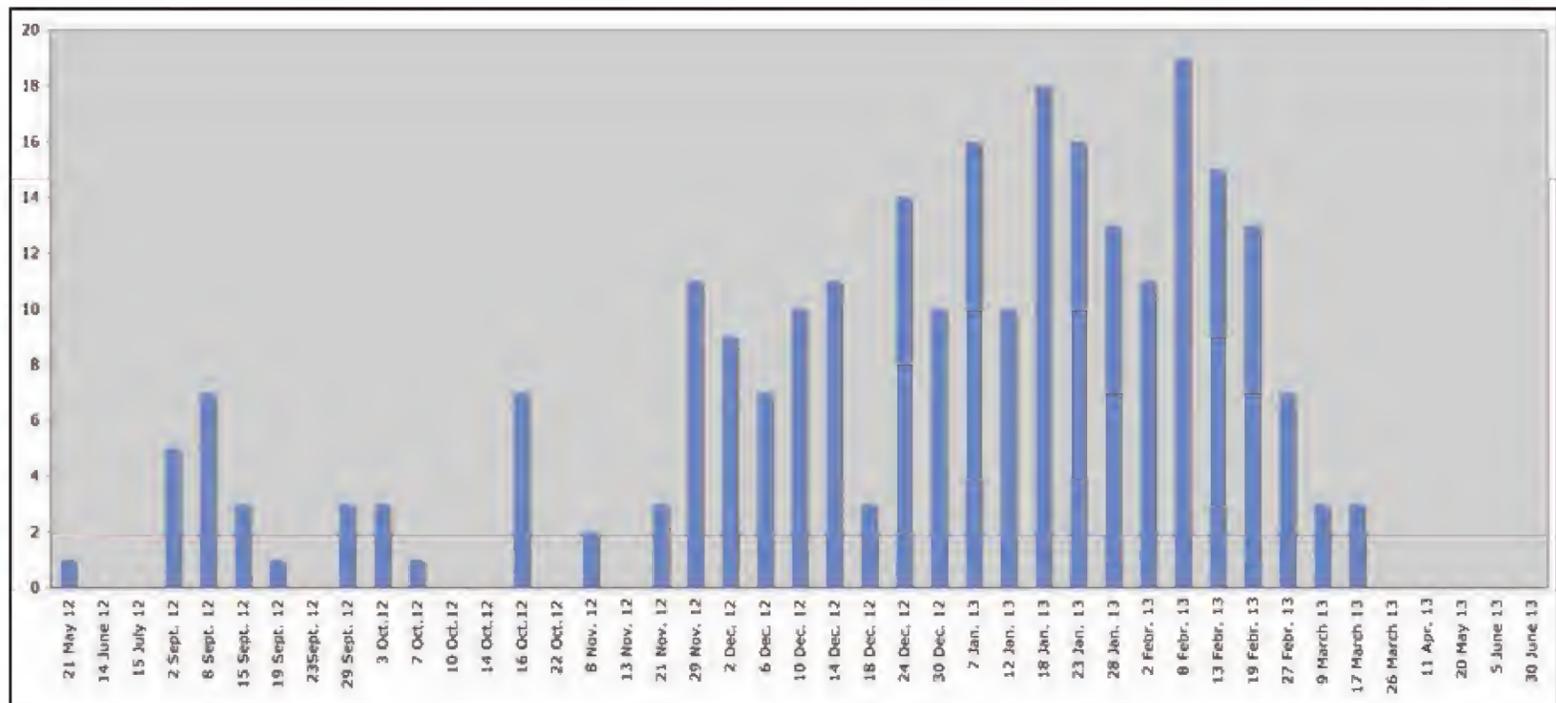


Figure 5. Histogram date/number of long-eared owl specimens observed.

Italy", started a few years ago from the collaboration of GIC & EBN Italy, with the Global owl project that provides for the establishment of a network containing data on the presence of the roosts in Italy. From the analysis of the monitoring of the roost of Monte Serra, one might assume the presence of two different populations. The first one, in the Park throughout the year, although with changes in the choice of the roost and possibly with nesting site located not many miles away.

The other population, more numerous, would take advantage of the Monte Serra Park as a wintering site. Specimens of this second population may be resident in the territory of Etna and make seasonal vertical migrations or could be migratory specimens that stop to winter. The hypothesis of two different populations is supported by the owl attitude observed in the days of collecting pellets. Whenever the collector approached at the roost, systematically, part of specimens are alerted and receding in flight; however, remained always 5-7 specimens, very confident, as if they were already accustomed to the environment and the presence of visitors to the park. Because the site is regularly occupied, this would allow regular long-term monitoring of the roost; furthermore, the use of molecular studies of feathers collected throughout the year could also clarify the phenology of the species in Sicily, whose presence as a nesting species has been established only recently.

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# Morphological differences between two subspecies of Spotted Flycatcher *Muscicapa striata* (Pallas, 1764) (Passeriformes Muscicapidae)

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## ABSTRACT

Four subspecies of Spotted Flycatcher (*Muscicapa striata* Pallas, 1764) (Passeriformes Muscicapidae) are usually recognized within the Western Palaearctic. We carefully analysed two of these in order to determine and quantify their morphological differences: *M. striata striata* (inhabiting most of continental Europe east to the Ural mountains and a small portion of north-western Africa) and *M. striata tyrrhenica* Schiebel, 1910 (breeding on the Tyrrhenian islands of Corsica, Sardinia and the Tuscan Archipelago). We examined total of 58 Spotted Flycatcher specimens from Italian museums (of which 18 *M. striata tyrrhenica*) and obtained data about morphological features such as wing point, length and formula, and bill length, width and depth; furthermore, we investigated plumage colour using a spectrometer. Biometric measurements and an analysis of plumage streaking confirmed the presence of important differences between the two taxa; the colorimetric analysis did not produce the expected results, although it had some interesting implications concerning the preservation of museum specimens and their use in studies of plumage colour.

## KEY WORDS

Spotted Flycatcher; *Muscicapa striata tyrrhenica*; morphology; museum specimens.

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## INTRODUCTION

The Spotted Flycatcher (*Muscicapa striata* Pallas, 1764) is a songbird in the family Muscicapidae and is the only member of its genus in Europe, with at least twenty more species in Asia and Africa. The Spotted Flycatcher is found through most of the Palaearctic, with a continuous distribution from the Iberian peninsula to the Mongolia-China border. It is a long-distance, trans-Saharan migrant, and most of the population winters south of the Equator (Cramp & Perrins, 1993).

Seven subspecies are currently recognized in this extensive range (del Hoyo et al., 2006): *M. striata striata* (Pallas, 1764) (Figs. 1, 2) breeds in

Europe east to the Ural mountains and in north-western Africa, and winters south of the Sahara; *M. striata balearica* von Jordans, 1913 (Fig. 1), breeds in the Balearic islands and winters in western and south-western Africa; *M. striata tyrrhenica* Schiebel, 1910 (Figs. 1, 2), breeds in Corsica and Sardinia and presumably winters in Africa; *M. striata inexpectata* Dementiev, 1932, breeds in Crimea and winters in Africa; *M. striata neumanni* Poche, 1904, breeds in the islands of the Aegean Sea east to the Caucasus and northern Iran and south to Cyprus and the Levant, in addition to central Siberia, and winters in eastern and southern Africa; *M. striata sarudnyi* Snigirewski, 1928, breeds from eastern Iran to northern and western

Pakistan and presumably winters in southern and eastern Africa; *M. striata mongola* Portenko, 1955, breeds from the south-eastern Altai mountains to northern Mongolia, and presumably winters in southern and eastern Africa.

Only two (*M. striata striata* and *M. striata tyrrhenica*) of these seven subspecies are regularly found in Italy, while *M. striata neumanni*, which could potentially occur in migration, has not yet been confirmed (Corso, 2005; Bricchetti & Fracasso, 2008). The nominate subspecies breeds throughout continental Italy and Sicily, where it is considered common and widespread, although its distribution is somewhat patchy with gaps in high mountain areas. The core breeding range of *M. striata tyrrhenica* comprises Corsica and Sardinia, but contra del Hoyo et al. (2006) and Cramp & Perrins (1993), it also breeds in the Tuscan Archipelago (Bricchetti & Fracasso, 2008), while its presence along a narrow band of the Tyrrhenian coast remains to be confirmed (Bricchetti & Fracasso, 2008; Tellini et al., 1997). The authors provide some interesting information on the abundance of Spotted Flycatcher subspecies in Italy.

Although the nominate subspecies breeds almost throughout continental Italy, it is never abundant, with population densities that rarely exceed 0.2

pairs/hectare. On the other hand, as many as 0.6 pairs/hectare have been found in *M. striata tyrrhenica* (VV. AA. in Thibault & Bonaccorsi, 1999); so the species seems to fit the usual pattern on islands of density inflation due to lower species richness (eg MacArthur & Wilson, 1967; George, 1987; Blondel et al., 1988). Interestingly, high population densities have been recorded along the Tyrrhenian coast in Tuscany; densities are far lower only 50 km inland (Tellini et al., 1997).

There are currently no reliable data on the wintering range of *M. striata tyrrhenica* (Cramp & Perrins, 1993, del Hoyo et al., 2006). The *M. striata tyrrhenica* subspecies of the Spotted Flycatcher was described for the first time by Schiebel (1910) in a paper on the Corsican avifauna and a syntype taken in Aitone, Corsica, on 19 May 1910 is currently held at the Zoologisches Forschungs institut und Museum Alexander Koenig in Bonn, Germany. The identification of this subspecies is generally dealt with very superficially in the ornithological literature, with limited discussion of its distinguishing characteristics. Several examples are below:

- Arrigoni degli Oddi (1929): “similar to the previous species [authors’ note: the subspecies

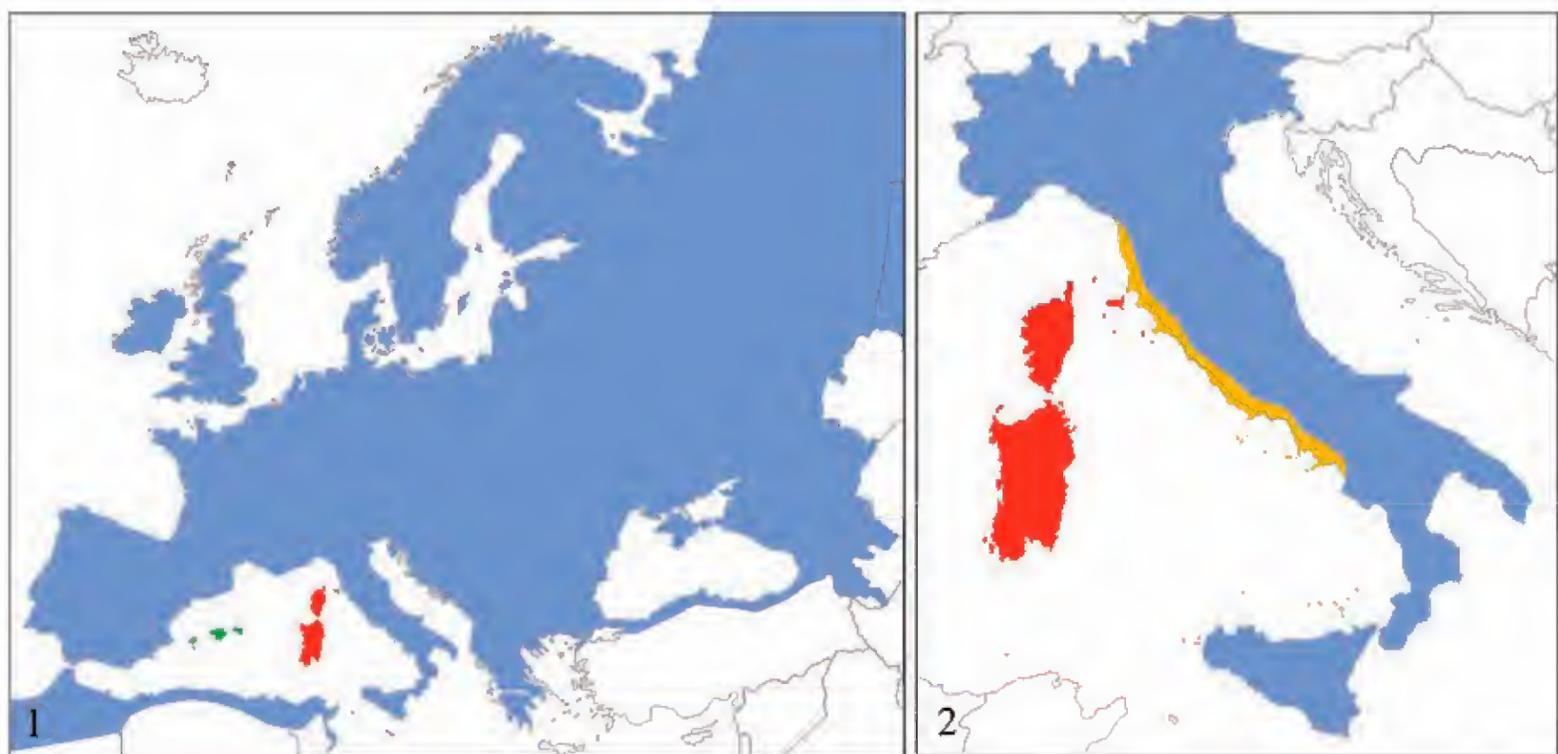


Figure 1. In Western Europe three subspecies of Spotted Flycatcher are found: *Muscicapa striata striata* (blue), *M. striata tyrrhenica* (red) and *M. striata balearica* (green). Figure 2. Two subspecies of Spotted Flycatcher breed in Italy: *M. striata striata* (blue) and *M. striata tyrrhenica* (red); *M. striata tyrrhenica* could be present in the yellow area too, but further research is needed.

*striata*]; central spots on the cervix and streaking on breastless distinct”;

- Cramp & Perrins (1993): “more warm brown on upperparts, distinctly less streaked on breast, streaks replaced by broader, coalescing spots”;

- Bricchetti & Fracasso (2008): “upperparts browner and warmer-toned, and streaking on the underparts less well-defined and tending to merge into spots”;

- van Duivendijk (2010): “Primary-projection slightly shorter than *striata*; upperparts warmer brown, underparts almost unstreaked but with broad, faint spots”.

Over the last ten years we have carried out in-depth field and museum studies on the morphological differences between the two taxa in question (Figs. 3–6). In the field, the immediate impression given by *M. striata tyrrhenica* is of a paler bird with warmer tones to the back and more homogeneous underparts. The breast markings, which are generally well defined streaks in *M. striata striata*, appear faded and more spot-like. The streaking on the nape is also less well defined compared to the nominate subspecies, due to the lower contrast between the streaks and the nape’s background colour. Primary projection is one of the most important characters: while the primary projection beyond the tertials is longer than the tertials themselves in continental birds, individuals from Corsica and Sardinia have a primary projection that is shorter than, or at most equal to the length of the tertials.

This paper mainly reports the results of our museum studies, while an article on field identification criteria is forthcoming (Viganò et al., personal data).

## MATERIAL AND METHODS

Our first observations on the morphological differences between the two subspecies were made in the field: *M. striata tyrrhenica* was studied in southern Sardinia near Villasimius (Cagliari) in July 2004, August 2005, July 2006, and May 2011 and on the island of Elba in July 2014. We have studied this taxon in Corsica as well, in the area of the Gulf of Calvi, in July 2007, July 2008, and May 2012. Our studies of *M. striata striata* have taken place continuously during the breeding season since 2005

in northern Italy; additionally, we have studied this taxon during spring migration on various small islands off central and southern Italy, especially Ventotene (Latina) in April 2010 and 2011 and Linosa (Agrigento) in May 2006, April 2007, and April 2009, where on good days hundreds or even thousands of individuals can be seen.

Other observations took place opportunistically elsewhere in the Western Palearctic, both during the breeding season and in migration. Studies of museum skins complemented our field observations and were of fundamental importance for this paper (Figs. 7, 8; Table 1). There are very few specimens of *M. striata tyrrhenica* in Italian and foreign museums; indeed, there are none at all in the largest bird collection in Europe at the Natural History Museum at Tring, U.K. We arranged for all of the *M. striata tyrrhenica* specimens held at the Museo Civico di Storia Naturale in Milan, Italy (MCSM), Museo Civico di Zoologia in Rome, Italy (MCZR), and Museo di Scienze Naturali in Forlì, Italy (MSNF) to be sent on short-term loan to the Museum of the Institute for Environmental Protection and Research (Istituto Superiore per la Protezione e la Ricerca Ambientale - ISPRA) in Ozzano dell’Emilia (Bologna, Italy) so that they could be studied side-by-side along with the specimens held in the last-named institution.

We took the following measurements: wing chord, longest primary (P3), distance of each primary from P3, bill length from the nostrils, bill height and thickness at the nostrils. Measures that are generally taken during ringing activities such as tail, tarsus, and bill-to-cranium length were not taken since they vary depending on the way the specimen was prepared (Winker, 1998; Eck et al., 2011; Kuczynski, 2003). The measurements considered here are also subject to some degree of variation depending on specimen preparation; measurements taken on live animals may add a degree of precision and some additional information, but we felt that museum specimens were better suited to taking biometrical and plumage colour data together.

As concerns wing chord length, one study that looked at the wings of Rooks (*Corvus frugilegus*) measured upon capture, after 8 weeks, and again after 144 weeks found a difference in length between fresh and dried wings of about 1.84% (Knox, 1980). Measurements were taken using a stopped ruler (to the nearest 0.5 mm), callipers (to



3



4



5



6

Figures 3, 4. Spotted Flycatcher (*Muscicapa striata tyrrhenica*), Villasimius (Cagliari), Sardinia, May 2011. Note the quite pale and warm general colour, the subtle head and breast markings and the short primary projection compared to tertials length. Figures 5, 6. Spotted Flycatcher (*Muscicapa striata striata*), Ventotene, Latina, Italy, April 2011 (Fig. 5) and Pantelleria, Trapani, Sicily, May 2009 (Fig. 6, photo by Igor Maiorano). The overall impression is of a colder and less homogeneous bird, with bold markings on breast and head; primary projection is longer than tertials length.

the nearest 0.1 mm) and a thin strip of graph paper (to the nearest 0.5 mm) strengthened by an equally thin strip of transparent plastic.

The latter tool was necessary to measure P3: this feather is usually measured using a special ruler, but due to the specimens' age, their rigidity, and their historic value, some are from the prized Arrigoni degli Oddi collection, we decided to use graph paper as it is thinner and less invasive. Colour analysis of the upperparts of Spotted Flycatcher specimens was undertaken using an Ocean Optics USB 2000 spectrometer at ISPRA.

Before proceeding with the spectrometer analysis of Spotted Flycatcher plumage we had to calibrate the instrument and its associated software, Ocean Optics Spectrasuite, which is provided by the manufacturer of the spectrometer and the lamp. The spectrometer was calibrated by reading and recording on the software two values that were to correspond with white and black. In order to do so we used Ocean Optics' WS1 Diffuse Reflectance Standard for white, while for black we placed the lighting fibreover the black square on X-Rite's Color Checker's colour scale.

Once the programme was launched, only two parameters needed to be set. Scan-to-average was set at 5: for each colour reading of a given point, five scans are automatically made, and their average is recorded as the final value. Integration time was set at 300 in order to prevent peaks in the graph

above the upper margin when the scanner was placed above the white standard; in other words, to ensure that reflectance on a white standard would not return excessively high values that would have led to a loss of information on the portion of the graph falling outside the margins.

Once calibration was completed, we sampled colours on each specimen as follows: three measurements were taken from the mantle (usually two from the right-hand side and one from the left) and three more from the rump (by moving the scanner along a vertical line from the top to the bottom of the rump).

This means that for each specimen, the data reported in the Table 2 comprises the averages of 15 measurements on the mantle and 15 on the rump. In accordance with the instructions reported by Hill & McGraw (2006) we selected and ranked the data before analyzing them: we only considered values with wavelengths between UV and red ( $299.74 \leq \lambda \leq 700.28$ ), then sub-divided them into intervals of approximately 10 nm, e.g. from 410nm to 420nm.

The values we calculated (for both mantle and rump) are as follows:

- Total Reflectance: the sum of all intervals
- UV Component: the sum of values falling between 300nm and 400nm

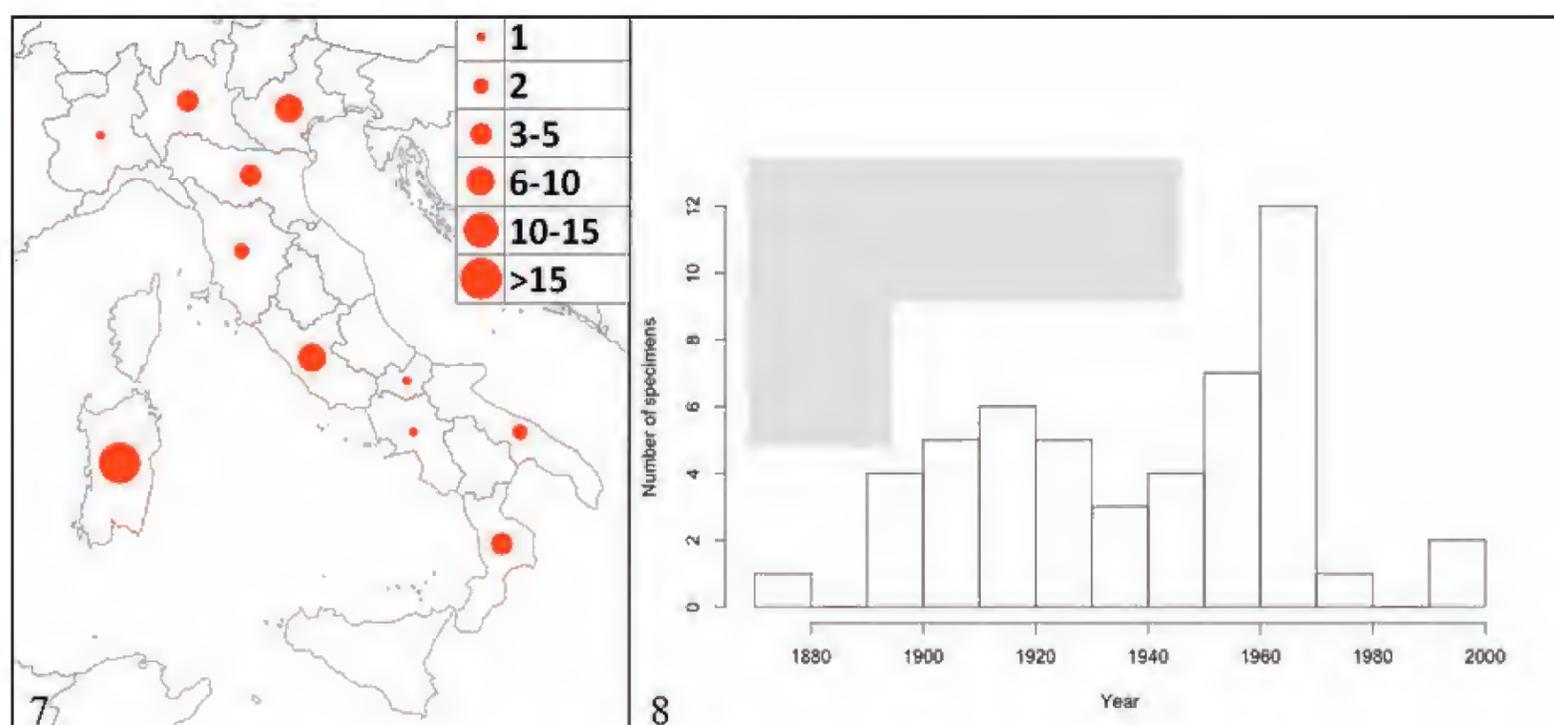


Figure 7. The provenience of the museum specimens analysed. Figure 8. The number of birds collected per decade.

Museum	<i>M. striata striata</i>	<i>M. striata tyrrhenica</i>
MCSM	10	7
MCZR	15	6
MSNF	5	4
ISPRA	8	1
<b>Total</b>	<b>38</b>	<b>18</b>

Table 1. This table summarizes the number of specimens studied, the museum they belong and their subspecific identification.

- UV Chroma: UV Component to Total Reflectance ratio

- RED Component: the sum of values falling between 600nm and 700nm

- RED Chroma: RED Component to Total Reflectance ratio

The results are reported in the Tables 2 and 3 in the following chapter. In order to better investigate the results obtained with the colorimeter, we made subsets of the original data (Figs. 9–20): we began by removing from the sample of *M. striata striata* all individuals from the narrow strip of Tyrrhenian coastline in Tuscany, Latium, and Campania where *M. striata tyrrhenica* may be breeding; we did not remove two individuals captured on Ventotene Island (Latina) and Capri (Naple) because they matched *M. striata striata* in every regard and we considered them to be spring migrants of *M. striata striata* with a reasonable degree of certainty. A second subset was made comparing the usual sample of Sardinian specimens with a subset (n=6) of *M. striata striata* specimens that show particularly cold plumage tones on visual inspection. We also divided the sample into old “pre-1960” and recent “post-1960” subsets, meaning that ‘recent’ specimens were no more than fifty years old, following Armenta et al. (2008).

In order to evaluate the differences in nape and breast streaking between the two subspecies, we compared the specimens visually (see, for example, Galeotti et al. 2009). After an initial evaluation of all specimens, we established categories that could

represent in sufficient detail the variability present in the two taxa. We scored breast streaking on a 0 to 6 scale (0 indicating no streaking and 6 the heaviest streaking) and nape streaking on a 0 to 5 scale. We assigned those values to each specimen; when necessary, we compared the specimen under observation directly with the reference specimens.

## RESULTS

Biometric analyses found significant differences in wing morphology. Differences in maximum wing chord were found to be statistically significant using a t-test ( $t = 9.4407$ ,  $p = 6.079e-12$ ), confirming our field observations of a shorted primary projection in *M. striata tyrrhenica*.

Similar wing measurement data are reported in the literature (e.g. Cramp & Perrins, 1993; Brichetti & Fracasso, 2008). On the other hand, in a study of birds ringed between mid-April and mid-May at Capo Caccia, Sardinia (Marchetti & Baldaccini, 1995) did not report such a difference, although the authors themselves suggested that such comparisons were better made using birds caught on their breeding grounds during the reproductive season in order to ensure correct subspecific identification. In addition to the wing chord, significant differences were found in the wing formula as well. The values calculated for each primary are summarized in figure 22, which shows wing formula for each taxon. The most significant difference concerns the relative distance between the longest primary (P3) and P2; this characteristic is also depicted in figure 21, which shows the distance (in mm) between P2 and P3 in each taxon. The t-test reveals significant differences between the two subspecies concerning this character ( $t = -5.1674$ ,  $p = 6.536e-06$ ), as well as in the distance between P3 and P4 ( $t = 5.8634$ ,  $p = 6.768e-07$ ). Differences in wing shape of this type and extent are highly interesting. Similar discrepancies have been found between sister species in which one is a short-distance migrant and the other a long-distance migrant (Chandler & Mulvihill, 1988; Mönkkönen, 1995), or where there is a gradient between more or less migratory subspecies of the same species (Arizaga et al., 2006; Winkler et al. 2010) or again in similar species where one is migratory and the other sedentary (Chandler & Mulvihill, 1990; Milá et al., 2008).



Figures 9–14. A value for underpart markings was given to each specimen; seven categories were determined (one central category not depicted), ranging from least marked (value 0) to boldly marked (value 6).



15



16



17



18



19



20

Figures 15–20. A value for head streakings was given to each specimen; six categories were determined, ranging from least marked (value 0) to boldly marked (value 5).

This phenomenon is known as “Seebohm’s rule” and can be summed up as follows: long-distance migrants have more pointed wings (shorter inner primaries and longer outer primaries) compared to short-distance migrants or non-migratory species, since longer and more pointed wings make for more powerful flight compared to shorter, more rounded wings (Seebohm, 1901; Calmaestra & Moreno, 2001).

We also found differences in bill length measured from the distal end of the nostrils to the tip of the bill, with  $p = 0.01582$  and  $t = 2.5203$ , with *M. striata striata* showing on average a longer bill; we did not use the commonest bill measurement method, from the tip of the bill to the base of the skull, because for museum specimens it is less reliable than the parameter used in this study (Winker, 1998; Kuczynski et al., 2003). Our scores for breast and nape streaking also confirmed our field observations, namely that nape and breast streaking is less well defined in Sardinian and Corsican birds.

Colour analysis did not reveal any statistically significant differences except in the sum of  $\lambda$  falling between 300 and 400nm, or within the UV

spectrum. These differences fade away if one considers the UV chroma, namely by dividing the UV value by total reflectance. In order to better understand the reasons for this, we carried out a number of tests by modifying the data sample used in the analysis in an attempt to remove the effect of certain parameters that may have generated background noise and muddled the results. The first subset excludes all individuals from the narrow strip of Tyrrhenian coastline where *M. striata tyrrhenica* may breed: using this sample, differences in mantle UV are no longer significant, but differences emerge in terms of total reflectance and the red component of the mantle, with *M. striata tyrrhenica* slightly redder and paler than *M. striata striata*, albeit with low statistical significance. However, further manipulation of the sample for colorimetric analysis, comparing *M. striata tyrrhenica* specimens with six particularly cold plumaged *M. striata striata* specimens did not find statistically significant differences for any variable.

This unexpected result, involving *striata* specimens that showed clear differences in mantle tones compared to *M. striata tyrrhenica* on visual inspec-

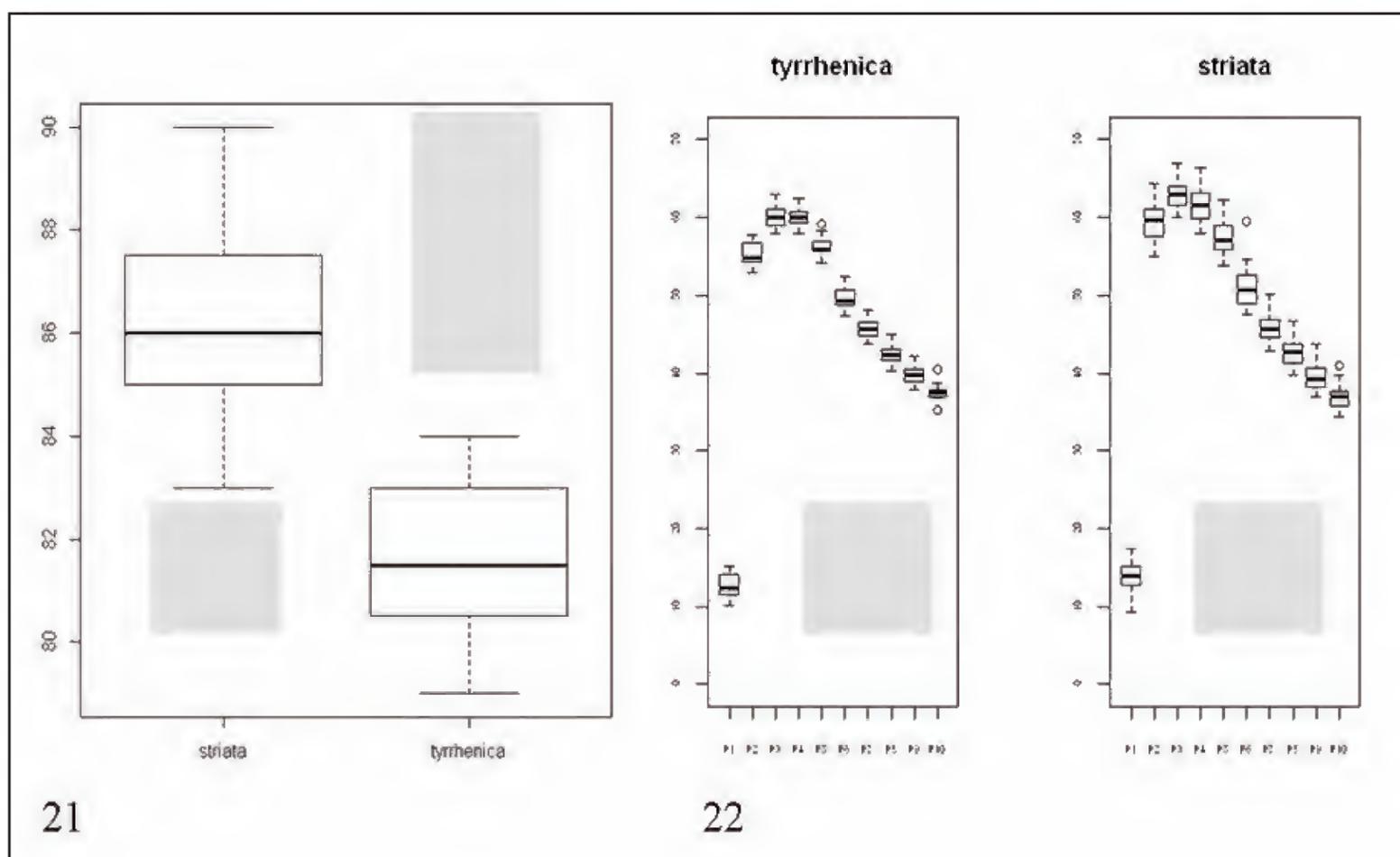


Figure 21. Chord values (in mm) recorded on *Muscicapa striata striata* and *M. striata tyrrhenica* specimens.  
Figure 22. Wing formula for both subspecies; note the rounder shape of *M. striata tyrrhenica* birds.

	<i>Muscicapa striata striata</i>			<i>Muscicapa striata tyrrhenica</i>				
variable	mean + sd	n	range	mean + sd	n	range	t	p
P1	13.75926 ± 1.931572	27	9.3-17.4	12.67500 ± 1.438286	16	10.2-15.1	1.9448	0.05868
P2	<b>59.57778 ± 2.469247</b>	27	<b>55.0-64.4</b>	<b>55.33125 ± 1.520841</b>	16	<b>52.9-57.8</b>	<b>6.2002</b>	<b>2.245e-07</b>
P3	<b>62.96429 ± 1.914509</b>	28	<b>60-67</b>	<b>60.12500 ± 1.258306</b>	16	<b>58-63</b>	<b>5.3003</b>	<b>3.996e-06</b>
P4	<b>61.64074 ± 2.176670</b>	27	<b>58.0-66.5</b>	<b>60.06250 ± 1.223043</b>	16	<b>58.0-62.5</b>	<b>2.6544</b>	<b>0.01126</b>
P5	57.36667 ± 2.300000	27	53.8-62.2	56.26154 ± 1.413352	13	54.2-59.1	1.5879	0.1206
P6	50.97407 ± 2.695094	27	47.5-59.5	49.61250 ± 1.433353	16	47.4-52.4	1.8645	0.06943
P7	45.86667 ± 1.840568	27	42.9-50.2	45.67333 ± 1.258381	15	43.7-48.1	0.3616	0.7195
P8	42.66296 ± 1.784581	27	39.7-46.6	42.35625 ± 1.175284	16	40.2-44.9	0.6118	0.544
P9	39.69259 ± 1.836369	27	36.9-43.8	39.73125 ± 1.151068	16	36.9-43.8	-0.0757	0.9401
P10	36.84074 ± 1.727662	27	34.3-40.9	37.56000 ± 1.136913	15	35.2-40.4	-1.444	0.1565
chord	<b>86.14286 ± 1.603567</b>	28	<b>83-90</b>	<b>81.50000 ± 1.505545</b>	16	<b>79-84</b>	<b>9.4407</b>	<b>6.079e-12</b>
bill L	<b>8.392593 ± 0.2758566</b>	27	<b>8.0-8.9</b>	<b>8.140000 ± 0.3680062</b>	15	<b>7.2-8.6</b>	<b>2.5203</b>	<b>0.01582</b>
bill W	3.496429 ± 0.1990387	28	3.1-3.9	3.420000 ± 0.1373213	15	3.2-3.7	1.3244	0.1927
billT	4.357143 ± 0.2379365	28	3.6-4.8	4.353333 ± 0.3888934	15	3.6-5.1	0.0399	0.9683
breast	<b>4.096774 ± 0.7897189</b>	31	<b>3-6</b>	<b>1.466667 ± 0.9904304</b>	15	<b>0-3</b>	<b>9.7384</b>	<b>1.504e-12</b>
head	<b>3.586207 ± 0.7327659</b>	30	<b>2-5</b>	<b>1.333333 ± 0.8164966</b>	15	<b>0-3</b>	<b>9.2998</b>	<b>9.361e-12</b>
f_R_tot_refl	385.2981 ± 74.04245	36	263.55-603.68	397.1140 ± 55.03810	15	316.97-486.38	-0.556	0.5807
f_R_UV	59.08778 ± 15.51324	36	36.00-99.42	61.77267 ± 13.38254	15	41.97-85.83	-0.5849	0.5613
f_R_CROM A UV	0.151982 ± 0.0151761	36	0.11943-0.18782	0.154283 ± 0.0155461	15	0.1324-0.1910	-0.49	0.6263
f_R_RED	141.8281 ± 22.45401	36	100.9-200.3	148.8973 ± 20.66444	15	114.11-181.89	-1.0476	0.3
f_R_CHRO MA RED	0.370492 ± 0.0201814	36	0.331798-0.41221	0.375287 ± 0.0162703	15	0.35564-0.4098	-0.815	0.419
f_M_tot_refl	303.9143 ± 33.40160	36	236.78-344.78	329.1888 ± 40.71543	16	290.13-405.80	-1.5784	0.1302
f_M_UV	<b>44.53722 ± 6.774240</b>	36	<b>31.52-57.73</b>	<b>49.10250 ± 7.547965</b>	16	<b>39.27-65.49</b>	<b>-2.1659</b>	<b>0.03512</b>
f_M_CHRO MA UV	0.144340 ± 0.0137475	36	0.11600-0.171272	0.147015 ± 0.0119409	16	0.13113-0.1696	-0.6728	0.5042
f_M_RED	112.1264 ± 9.672242	36	92.18-126.12	120.3400 ± 11.764493	16	108.76-141.91	-1.773	0.09145
f_M_CHRO MA RED	0.376839 ± 0.0175326	36	0.338173-0.40683	0.375442 ± 0.0206807	16	0.34161-0.4047	0.2508	0.803

Table 2. All the statistical results from our study are here summarized; the variables highlighted in boldface are those for which the t-test found values <0.05.

	<i>Muscicapa striata striata</i>			<i>Muscicapa striata tyrrhenica</i>				
variable	mean + sd	n	range	mean + sd	n	range	t	p
M_tot_refl	<b>309.2468 ± 31.11327</b>	<b>29</b>	<b>236.78-365.09</b>	<b>329.1888 ± 40.71543</b>	<b>16</b>	<b>290.13-405.80</b>	<b>-2.2777</b>	<b>0.0279</b>
M_UV	45.6875 ± 6.037829	29	35.20-56.61	49.10250 ± 7.547965	16	39.27-65.49	-1.6468	0.1071
M_CHROMA_UV	0.1476630 ± 0.0113407	29	0.123644-0.171272	0.147015 ± 0.0119409	16	0.13113-0.1696	0.179	0.8588
M_RED	<b>115.6518 ± 10.24447</b>	<b>29</b>	<b>92.18-126.12</b>	<b>120.3400 ± 11.764493</b>	<b>16</b>	<b>108.76-141.91</b>	<b>-2.5046</b>	<b>0.01623</b>
M_CHROMA_RED	0.3748562 ± 0.0180199	29	0.338173-0.399920	0.375442 ± 0.0206807	16	0.34161-0.4047	-0.0983	0.9222
R_tot_refl	388.8814 ± 78.95214	29	263.55-603.68	397.1140 ± 55.03810	15	316.97-486.38	-0.3589	0.7215
R_UV	60.81893 ± 16.22125	29	36.00-99.42	61.77267 ± 13.38254	15	41.97-85.83	-0.1947	0.8466
R_CHROMA_UV	0.1549453 ± 0.0141347	29	0.121704-0.187822	0.154283 ± 0.0155461	15	0.1324-0.1910	0.1413	0.8884
R_RED	141.9193 ± 23.99409	29	100.9-200.3	148.8973 ± 20.66444	15	114.11-181.89	-0.9519	0.3468
R_CHROMA_RED	0.3674105 ± 0.0197631	29	0.331798-0.408994	0.375287 ± 0.0162703	15	0.35564-0.4098	-1.3203	0.1941

Table 3. Same colorimetric variables analyzed in the previous table, but with a different subset of data: birds collected from the narrow strip of Tyrrhenian coastline in Tuscany, Latium, and Campania, where *M. striata tyrrhenica* could occur, were removed.

tion, suggests that the method we used for our colorimetric analysis is not ideal for detecting such subtle differences in plumage pigmentation.

Additional comparisons looked at the effects of time on the state of preservation of specimen. In accordance with other works that tested colour deterioration in museum specimens (Armenta et al., 2008; Doucet & Hill, 2009), we found highly significant differences between old (pre-1960) and recent (post-1960) specimens.

We used this data to build a linear model to identify the variables that most affected colour variation. As expected, taxon did not have a stat-

istically significant effect, while year of collection did ( $F(1,46) = 7, P = 8.408e-05$ ). In other words, specimens that were more than fifty years old showed a statistically-significant higher total reflectance, and thus appeared paler.

The biometric and colorimetric data collected in this study is summarized in Table 2, which also indicates sample size (n), the minimum and maximum values recorded (range) and the t and p values for the t-test as applied to each variable for the two taxa. The variables highlighted in boldface are those for which the t-test found values  $<0.05$ , meaning that the differences between the two taxa for

the variable in question were statistically significant. The variables “P1” to “P10” indicate primary length from the outermost to the innermost; “chord” indicates the length of the maximum wing chord, namely the closed wing measured from the carpal joint; “bill L, H, and T” respectively indicate bill length, height, and thickness; “breast” and “head” indicate the amount of streaking in these two areas scored after a visual examination.

Colorimetric data follows: variables initialed with an M refer to the mantle, and those with an R to the rump; tot\_refl refers to total reflectance, UV and RED respectively refer to the sum of  $\lambda$  falling between 300 and 400 and between 600 and 700; UV\_CHROMA and RED\_CHROMA indicate the ratio between these two variables and total reflectance.

## DISCUSSION AND CONCLUSIONS

The objective of this study was to test the differences observed in the field between the *M. striata striata* and *M. striata tyrrhenica* subspecies of Spotted Flycatcher as objectively as possible, by using methods that would not be influenced by differences in perception of colour and proportions on the part of different observers. The results confirmed the morphological differences observed in the field and cited in the literature, and the different intensity and extent of streaking on the underparts and the nape. Nevertheless, to better assess these parameters a larger sample, in both quantitative and qualitative terms, would be preferable, and would ideally include a larger number of birds captured on their breeding grounds. Differences in wing-shape are important not only from an identification perceptible, but also in light of the relationship between wing morphology and migratory distance (Baldwin et al., 2010; Mönkkönen, 1995).

The shorter, more rounded wings of *M. striata tyrrhenica* suggest that birds breeding in Corsica and Sardinia may have a shorter migration compared to birds from continental Italy and Europe. This is all the more interesting given that there is no solid data in the literature on the non-breeding range of *M. striata tyrrhenica* (Cramp & Perrins, 1993; del Hoyo et al., 2006), that should anyway be sub-saharan, given the absence of evidence of winter sightings north of the Sahara. On the other

hand, our colorimetric analyses failed to confirm the differences observed in the field and reported in the literature. To conclude, biometric measurements and an analysis of plumage streaking confirmed the presence of some important differences between the two taxa, including characters that can be seen in the field, while the colorimetric analysis did not produce the expected results, although it had some interesting implications concerning the preservation of museum specimens and their use in studies of plumage colour.

There are several other instances of taxa that have similar distributions to *M. striata tyrrhenica* Spotted Flycatchers and are morphologically very similar to the taxa breeding elsewhere in Italy and Europe being recognized as full species after in-depth analyses of morphology, voice, ecology and DNA: examples include Corsican Finch (*Carduelis corsicana*) (Cramp & Perrins, 1993; Sangster, 2000; Förschler & Kalko, 2007, Förschler et al. 2009) and Moltoni's Warbler (*Sylvia subalpina*) (Brambilla et al., 2008), both recently recognized as full species; further research on *M. striata tyrrhenica* Spotted Flycatcher is needed.

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# A quantitative morphological geographical study from a widely distributed raptor: the Lesser Kestrel *Falco naumanni* Fleischer, 1818 (Falconiformes Falconidae)

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## ABSTRACT

Lesser Kestrel *Falco naumanni* Fleischer, 1818 (Falconiformes Falconidae) is considered a monotypic species. *F. naumanni pekinensis* Swinhoe, 1870 was described from Beijing, China. Although considered valid for most of the 20th century, some authors treated *F. naumanni pekinensis* as a synonym of *F. naumanni naumanni*, and subsequent authors have since regarded “*pekinensis*” as an invalid taxon. Recent field observations in Asia and Europe and museum studies have confirmed diagnosable differences in (fresh) adult males. Comparing morphology between nominate “*naumanni*” and “*pekinensis*”, with the latter invariably showing more extensive grey on the wing coverts and darker and more saturated colours on both the underparts and upperparts, with all grey areas, including the hood, being a darker, deeper lead-grey. Females often have more extensive dark markings and a better-defined dark eye-line but apparently are indistinguishable in most cases. This study aims to re-evaluate *F. naumanni pekinensis* and to discuss geographic variation in the subspecies in a widely distributed raptor.

## KEY WORDS

Lesser Kestrel; *pekinensis*; *naumanni*; subspecies; geographical variation.

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## INTRODUCTION

Today, Lesser Kestrel *Falco naumanni* Fleischer, 1818 (Falconiformes Falconidae) is considered a monotypic species (cf. Cramp & Simmons, 1980; Snow & Perrins, 1998; Forsman, 1999; Clark, 1999; Corso, 2000, 2001a; Ferguson-Lees & Christie, 2001). After a few years, was described *F. chenchris pekinensis* Swinhoe, 1870 from two birds (adult male and immature male) (cf. Swinhoe, 1870; Dresser, 1871-1881). Currently, *F. naumanni pekinensis* is regarded as a synonym of *F. naumanni naumanni* (cf. Vaurie, 1965; Dickinson & van Remsen, 2013).

In September-October 2003, two authors (AC, JJ) were at Chokpak Ornithological Station, Jambyl Province, Kazakhstan together with Wim Nap and Arend Wassink, studying raptors and other birds in collaboration with Andrei and Edward Gavrillov as Vladimir Kolbinsev. AC was intrigued by the upperwing pattern of several adult male Lesser Kestrels that were caught in the large Heligoland-traps onsite (and subsequently ringed) as in birds observed in the field. They appeared consistently different from birds AC observed within the Western Palearctic. The past twelve years, in addition to our field studies of Lesser Kestrel, we have studied

skins from museums worldwide and photos from throughout their breeding range. We have found that eastern populations, especially the well-isolated breeding grounds in China, are phenotypically strikingly different from western populations. This suggests that *F. naumanni pekinensis* may be a well identifiable taxon, although its breeding and wintering distribution remains to be fully elucidated. This paper reports the preliminary results of our studies concerning western and eastern populations, with a focus on the latter, particularly “*pekinensis*”. In this paper we describe plumage colour and pattern, in special fresh adult males, of both Western (*F. naumanni naumanni*) and Eastern Lesser Kestrel (Chinese Lesser Kestrel *F. naumanni pekinensis* and intermediate populations). Their field identification and plumage variability will be discussed separately (Corso et al., personal data).

## MATERIAL AND METHODS

In this study we investigated in detail adult birds in the field within the borders of the Western Palearctic, and to a more limited extent in Asia. Between 2003 and 2014, we studied birds from Africa (Egypt, Eritrea, Kenya, Morocco, Somalia, Sudan, Tanzania and Tunisia), Asia (Armenia, Azerbaijan, Burma, China, Georgia, India, Israel, Kazakhstan, Laos, Mongolia, Russia, Oman, Turkey, Turkmenistan, Saudi Arabia and Yemen) and Europe (France, Greece, Portugal, Spain and Italy) in field, museum or photographs. During fall 2003, AC and JJ studied tens of Lesser Kestrels in the hand during ringing operations in Kazakhstan as in the field (up to 1.000 birds were observed during their stay). Particular attention was given to the adult males and to a lesser extent to adult females. Juveniles were not studied in much detail.

The skins we studied are held in the following museums and bird collections: American Museum of Natural History, New York, U.S.A. (AMNH); Institute of Zoology, Almaty, Kazakhstan (IZA); Museo Civico di Scienze Naturali “Angelo Priolo”, Randazzo, Italy (MCR); Museo Civico di Storia Naturale of Milan, Italy (MCSM); Museo Civico of Terrasini, Italy (MCT); Museo Civico dell’Università di Scienze Naturali of Catania, Italy (MCUCT); Museo Civico di Zoologia of Rome, Italy (MCZR); Muséum National d’Histoire Naturelle, Paris,

France (MNHN); Museo Regionale di Scienze Naturali of Turin, Italy (MRSN); Museo di Storia Naturale “Giacomo Doria”, Genoa, Italy (MSNGD); Museo di Storia Naturale “La Specola”, Florence, Italy (MSNLS); National Zoological Museum of China, Beijing, China (NZMC); Naturalis Biodiversity Center, Leiden, the Netherlands (NBC); Natural History Museum, Tring, England (NHM); Naturhistorisches Museum Wien, Vienna, Austria (NMW); Peabody Yale Museum of Natural History, New Haven, U.S.A. (PMNH); Museo Civico di Storia Naturale di Carmagnola, Italy (SNCa); Museum für Naturkunde, Berlin, Germany (ZMB) and in thirteen private collections.

Other abbreviations: AC: Andrea Corso; JJ: Justin J.F.J. Jansen; MV: Michele Viganò.

The list of the specimens (both skins and mounted) examined from the museums and private collections were, after objective examination, divided into four groups (Figs. 1, 2):

Group A: *Falco naumanni pekinensis*: one of two syntypes of the subspecies (Figs. 8, 9); 20 adult males and 8 adult females (China). For Figs. 3, 4, 5 and 6 we used only fresh breeding plumage males from China (N=13).

Group B: *Falco naumanni* ssp.: 28 adult males, 25 females (age combined) (Asia: Mongolia, Altai Mountains breeding area as well as Burma, India and Laos wintering area). For Figs. 3, 4, 5 and 6 we used only fresh breeding plumages males from Mongolia (N=13).

Group C: *Falco naumanni* ssp.: 87 adult males; 60 (age combined) females (Asia: Arabian Peninsula (unspecified countries), Afghanistan, Azerbaijan, Iraq, Kazakhstan, Pakistan, Turkmenistan; Africa: Eritrea, Kenya, Somalia, Tanzania). For Figs. 3, 4, 5 and 6 we used only fresh breeding plumage males from Kazakhstan (N=9), Turkmenistan (N=6), Azerbaijan (N=7) and Afghanistan (N=4).

Group D: *Falco naumanni naumanni*: 349 adult males; 172 (age combined) females (Europe: Albania, Czech Republic, France, Greece, Italy, Macedonia, Portugal, Slovenia, Spain; Africa: Algeria, Angola, Botswana, Egypt, Ethiopia, Libya, Mauritania, Morocco, Niger, Senegal, South Africa, Tanzania, Tunisia; Asia: Armenia, Georgia, Iran, Iraq, Israel, Jordan, Kyrgyzstan, Lebanon, Palestine, Syria, Turkey). For Figs. 3, 4, 5 and 6 we used only fresh breeding plumage males from Turkey (N=5), Greece (N=12), Albania (N=5), France (N=5) and Spain (N=29).

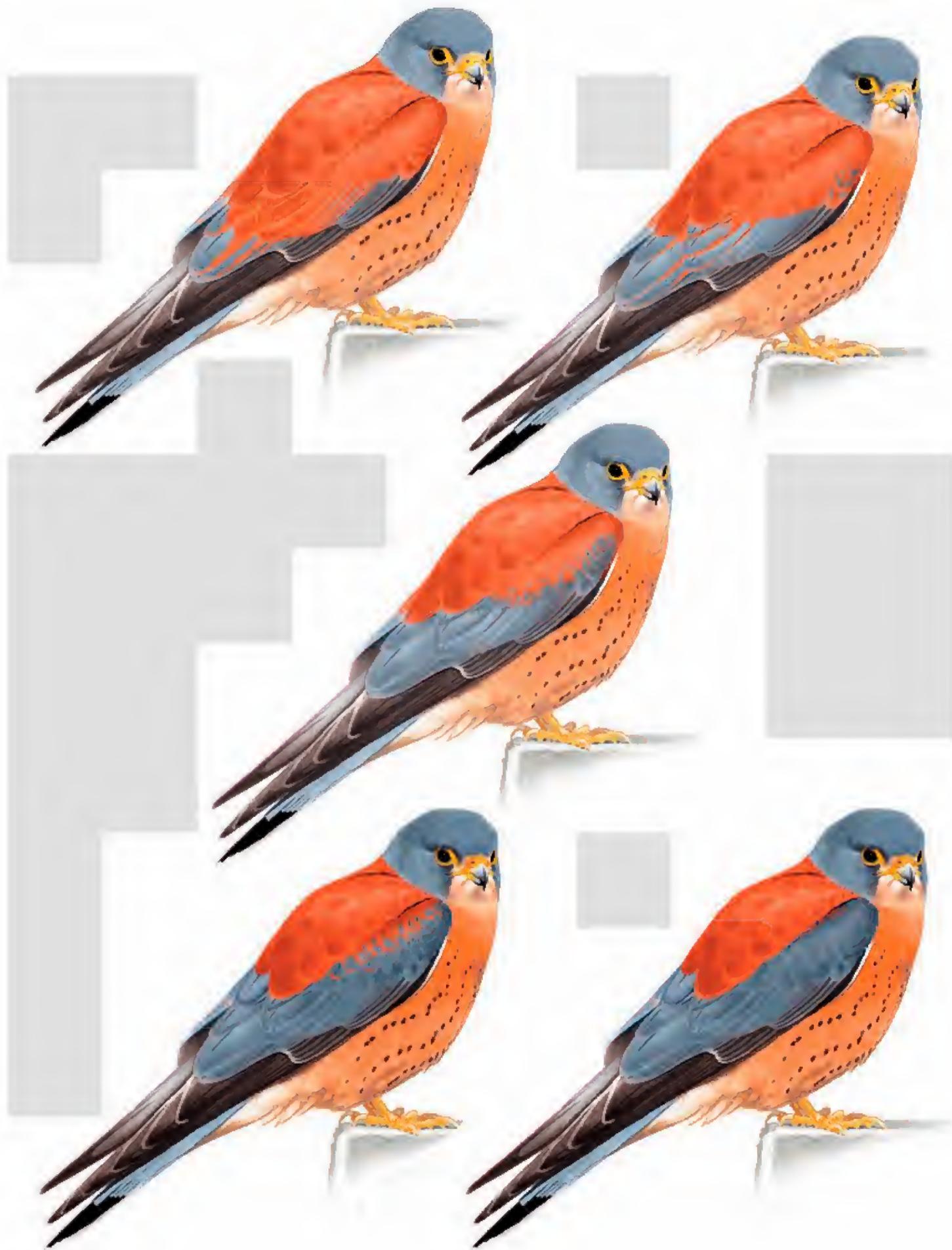


Figure 1. Plumage types as indicated in the text: upper 2 birds (group D), ssp. *naumanni*, among this group, left bird is an example with least grey extension on upperwing coverts and tertials, and on the right typical nominate *naumanni*. Note the grey extension on wing, plumage colour saturation and bare parts colour. Central bird, intermediate bird, plumage group B and C in the text. Lower 2 birds, classic “*pekinensis*”, plumage group A, from China breeding populations and allegedly from India, Laos and Burma during winter and on passage. The slight variation found is shown (artwork by Lorenzo Starnini). Note on *pekinensis* that the plumage colour, chiefly mantle and grey tones, is darker, more saturated than nominate *naumanni*, and that the upperwing coverts are entirely grey as well as the bare parts are more orange-ochre.

Additionally, to test the reliability of plumage colour and pattern in discriminating between populations, we took four photographs of each Lesser Kestrel skin. We sampled: upperside, underside and lateral sides (in order to check if there were differences between upperwing pattern of both wings) (Figs. 10-19). We only used indirect sunlight. All specimens were photographed with the same camera at a fixed distance, with a Kodak Gray Scale (Kodak, 2007) in the background (a standard scale of grey values ranging from 0, white to 19, jet black) (Fig. 7). This is an objective way of measuring the grey colours in bird plumages (cf. Adriaens et al., 2010; Bot & Jansen, 2013). The grey card in the background enabled us to calibrate the colours in the photograph, using Adobe Photoshop 10.0.1. We used brightness as a measure to assess the grey and red parts in adult males. To quantify the brightness of the red parts we measured its median spectral reflectance of red, green and blue (RGB) by using Photoshop. To assess the amount of grey and red on the head and upperparts, we measured the saturation. This was calculated by using the formula:  $\text{saturation} = 100 \times ((\text{MAX} - \text{MIN}) / \text{MAX})$ , where MAX and MIN are the maximum and minimum of the median RGB values as measured by Photoshop. A low saturation value corresponds to much grey in the head and upperparts and vice versa. For the analysis of colours we used the plates in Ridgway (1912: plate II and III). In particular, we compared the following:

1. Grey value of rump and tail;
2. Grey value of head (hood);
3. Percentage of grey coloured upperwing coverts.

To sample the upperwing coverts, we measured the percentage of grey coloured coverts (versus russet-brown coverts), therefore, how many coverts (median MC+ greater GC+ lesser LC) were grey. On skins, we considered the coverts visible on closed wing by using Photoshop to calculate the percentages. All statistical analysis was performed using R version 2.15.1 (R Development Core Team 2013). Numerical variables (Grey hood and % of grey UPW covers) were tested for normality using the Shapiro-Wilk test. Tests were significant which indicates that these variables do not come from a normally distributed population. Therefore we used a non-parametric approach (Kruskal-Wallis test) to test for a significant difference between groups for

these 2 variables. To test for differences between groups in the other 2 variables (colour\_of\_upperparts and deep\_intensity\_of\_underparts) we used generalized linear models (GLM).

Regarding the specimens and photos of adult females under investigation, we focused on the boldness, width and distribution/demarcation of the dark markings on the head, underwing, tail, mantle and breast. We arbitrarily divided specimens on the basis of the extent and boldness of these marking without looking at the label (no geographical pre-indication), and subsequently checked if these features were related to the classified groups (Fig. 2). After that, we assigned a numerical code to the presence, definition and boldness of the dark markings on the face:

1. no dark eye-line and weak moustache mark;
2. weak eye-line and bolder moustache;
3. obvious and bold dark eye-line as well as moustache.

#### The *Falco naumanni pekinensis* syntypes

Swinhoe (1870: 442) described "*pekinensis*" using an adult male collected on September 18th 1868 at the hills overlooking the Ming Tombs (40° 25' 05" N, 116° 22' 41" E) (42 kilometres north-northwest of Beijing) (Figs. 8, 9) and a juvenile male collected at the Western Hills (roughly in Miyun County about 93 kilometres northeast of Beijing (indicative 40°31'40.8"N, 116°48'02.5"E) between 10-12 August 1868 (Swinhoe, 1870: 436).

Specimens from Swinhoe became spread, and the syntype now present in NHM, arrived as part of a load of 480 Accipitres and Striges in three loads in 1886 (Sharpe 1906) donated by Henry Seebohm. Amongst these specimens is the adult male, now labelled as BMNH.1886.3.25.272, and regarded as syntype (Warren 1966: 222). This specimen has been collected according to Warren (1966) and it is labelled as collected on October 18th (sic!) 1868. Henry E. Dresser noted that both specimens in his '*A history of the birds of Europe*' (1871-82, VI: 135) were still in Swinhoe's private collection, and collected in August and September 1868 near Beijing.

A request at electronic Bulletin for European Avian Curators (EBEAC - September 2014) and requests elsewhere did not help in locating the immature male. By chance, a juvenile and adult Amur Falcon *Falco amurensis* Radde, 1863 were collected near Beijing by Swinhoe in August 1868 (Tri-

stram Collection Liverpool T2824 (Tristram, 1889: 67) was reported (Clem Fisher in litteris). Their plumage is notably different, but strangely enough not reported by Swinhoe (1870).

Description: Swinhoe described the types rather briefly: "Large numbers of Kestrels were flying and hovering about. Their movement struck me as peculiar; and on shooting a male we found the species to be a race of *Falco cenchris*, Naumann. We procured on this occasion an adult male, and in the Western Hills a young male. They agree in size and form with *Falco cenchris* of Europe; but the adult male has all the wing-coverts grey right up to the scapulars, most of them narrowly edged with rufous. The adult has the inner or short primaries

broadly bordered at their tips with whitish, rufous in the immature, and wanting in the European bird. Both adult and immature have the white on the under quills 3 ¼ inches short of their tips; in the European bird it advances one inch nearer the tips. I will note this Eastern race as var. *pekinensis*. It will probably be the bird that winters in India."

## RESULTS

We sampled 108 fresh adult males from the breeding ranges for this analysis. We sampled the percentage of grey upperwing coverts, grey value in the hood as for the colouration of the colour of

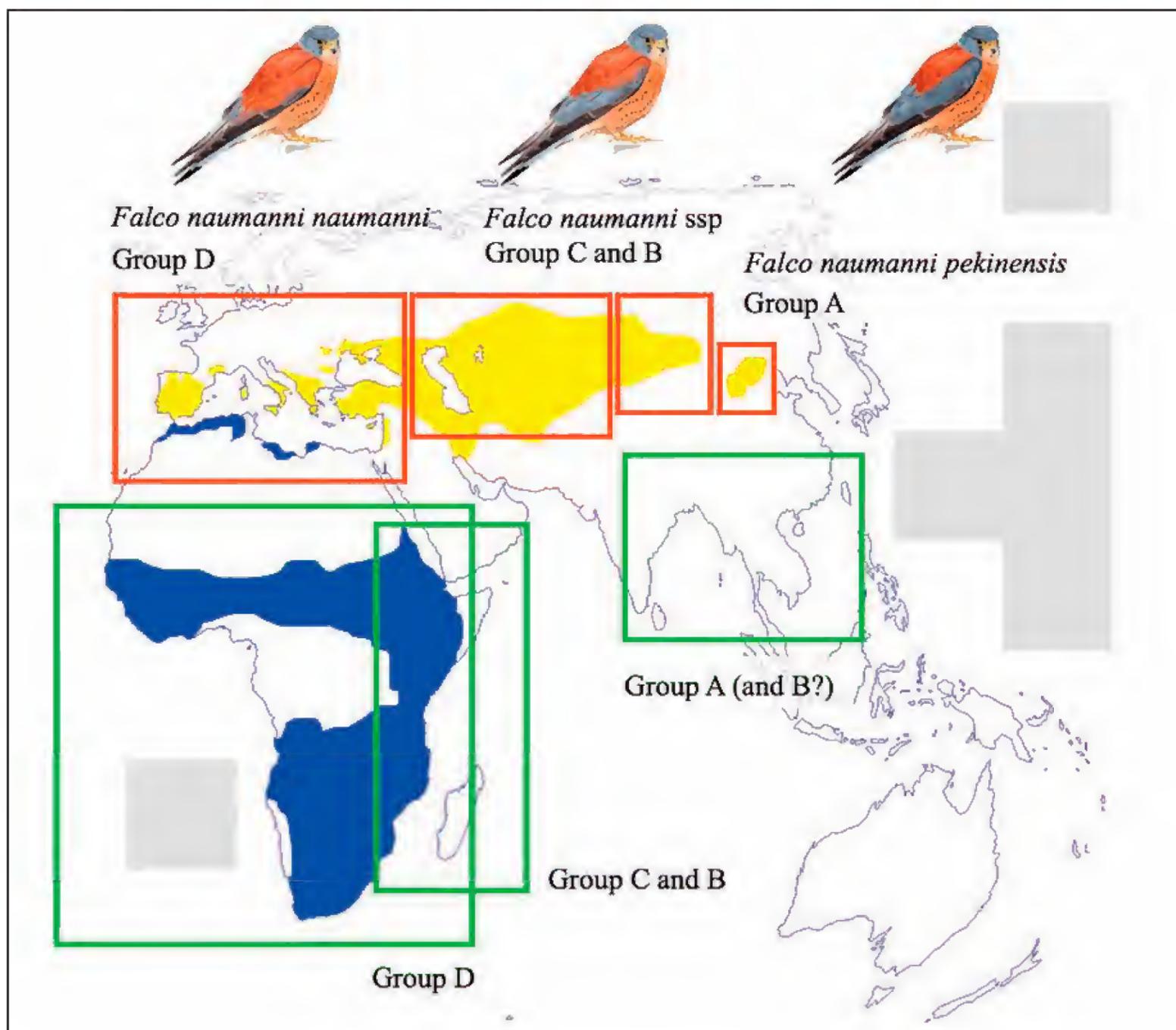


Figure 2. World distribution (breeding range - red, wintering area - green) of the two subspecies discussed in this paper (plumage group A and D), and of intermediate populations and pekinensis-type birds (B/C) as found during this study and according to past literature. Delimitation of the range is roughly indicated and should be considered as solely indicative.

the upperparts and intensity of underparts. The proportion of Group A is 12 %, group B 12 %, group C 24 % and for group D 52 %. Although the proportion of group D is well out of proportion we think the number is sufficiently large to allow good comparison as shown in the results. The results of testing four characters among the four defined areas is summarized in Fig. 2 and also outlined below.

Group A. The adult males collected in China (N=13) show a mean of 11.46 (min. 10; max. 12) on the Kodak Grey Scale (Kodak, 2007) in hood colouration (Figs. 3, 7). For grey in the upperwing coverts the mean is 93.5 % (min. 85; max. 99) of grey (Figs. 4, 8, 10, 11, 13, 15, 16). The intensity of underparts is 100 % Mikado-orange mars yellow (Fig. 5). The colouration in upperparts varies slightly as shown in Fig. 6, but the mean colouration was Burnt Sienna (8 out of 13 birds). Breeding adult females: 62.5% of the specimens from China (N=8) showed a well-defined dark eye-line (code 3). The remaining (N=3) showed a weaker marking (code 2). However, juveniles of both "*pekinensis*" and "*naumanni*" show a bolder and better-marked moustache and eye-line, compared to adult female, making any relevant use in the field to identify "*pekinensis*" from "*naumanni*" of these characters extremely hard. Concerning the underwing pattern, the outer primaries (wing-tip) as well as the trailing edge of the wing (inner primaries and secondaries) are more extensively and conspicuously dark in all Chinese females than in adult female "*naumanni*" in group D. Also, although rather variable, on average the black bar-like marks on the mantle were wider and more conspicuous than in typical adult female "*naumanni*". Birds from photographs shown a higher amount of variability, with several individuals lacking dark eye-line thus being almost identical to European females but a little darker and more patterned. As for adult male, also in adult female, the cere and the bare skin of the eye-ring, is brighter, deeper coloured and more orange-ochreous than in adult female "*naumanni*".

Group B. The adult males collected in Mongolia (N=13) shows a mean of 8.8 (min. 7; max. 10) on the Kodak Grey Scale (Kodak, 2007) in hood colouration (Fig. 3, 7). For the wing coverts the mean is 71.9 % (min. 50 %; max. 90 %) of grey (Fig. 4) (Kodak, 2007). The intensity of underparts is mixed, as 7 birds are mikado-orange-mars-yellow and 6 are orange-buff (Fig. 5). The colouration in upperparts is mixed, as seen in Fig. 6.

Group C. The adult males collected in Kazakhstan, Turkmenistan, Azerbaijan and Afghanistan (N=26) show a mean of 8.07 (min. 7; max. 10) on the Kodak Grey Scale in hood colouration (Fig. 3, 9) (Kodak, 2007). For the wing coverts the mean is 56.5 % (min. 40 %; max. 86 %) of grey (Fig. 4). The intensity of underparts is mainly orange-buff (20 out of 26) (Fig. 5). The colouration in upperparts varies as shown in Fig. 6.

Group D. The adult males collected Turkey, Greece, Albania, France and Spain (N=56) show a mean of 7.14 (min. 6; max. 10) on the Kodak Grey Scale in hood colouration (Figs. 3, 7) (Kodak, 2007). For the wing coverts the mean is 30.2 % (min. 15; max. 45) of grey (Figs. 1, 4, 17). Notable is the differentiation in western and eastern birds of the distribution area of this population. As we found a certain variability on the extension of the grey coloured upperwing coverts. Some as typical birds as shown in every field guide and handbooks as well as birds showing almost no grey on coverts or only some tinged grey (Figs. 1, 17) in the western part of the distribution area. The intensity of underparts is mostly buff-yellow or capucine-yellow (46 out of 56) (Fig. 5). The colouration in upperparts varies as shown in Fig. 6.

For what concern the female, only 5% of adult females showed a dark eye-line (code 3) (higher percentage when looking at juvenile; Corso, 2000, 2001a; AC pers. obs.). Dark markings on the mantle were on average narrower and less striking than in the most marked adult female *pekinensis*. However, we failed to find relevant differences. In juvenile *naumanni* we found them being darker and with bolder/wider dark markings than adult females, adding to the difficulty to separate them. Bare parts were less orange and paler, and always yellower than "*pekinensis*".

## DISCUSSION

The four groups (adult males in fresh plumage) were significantly different when considering the features: hood and % of grey UPW covers (Kruskal-Wallis test) (Table 1). This can be seen in Figs. 3, 4. These figures report averages and standard errors (SE) for each group. The four groups were also significantly different when considering the other two variables (Table 2). Figures 5 and 6 represent

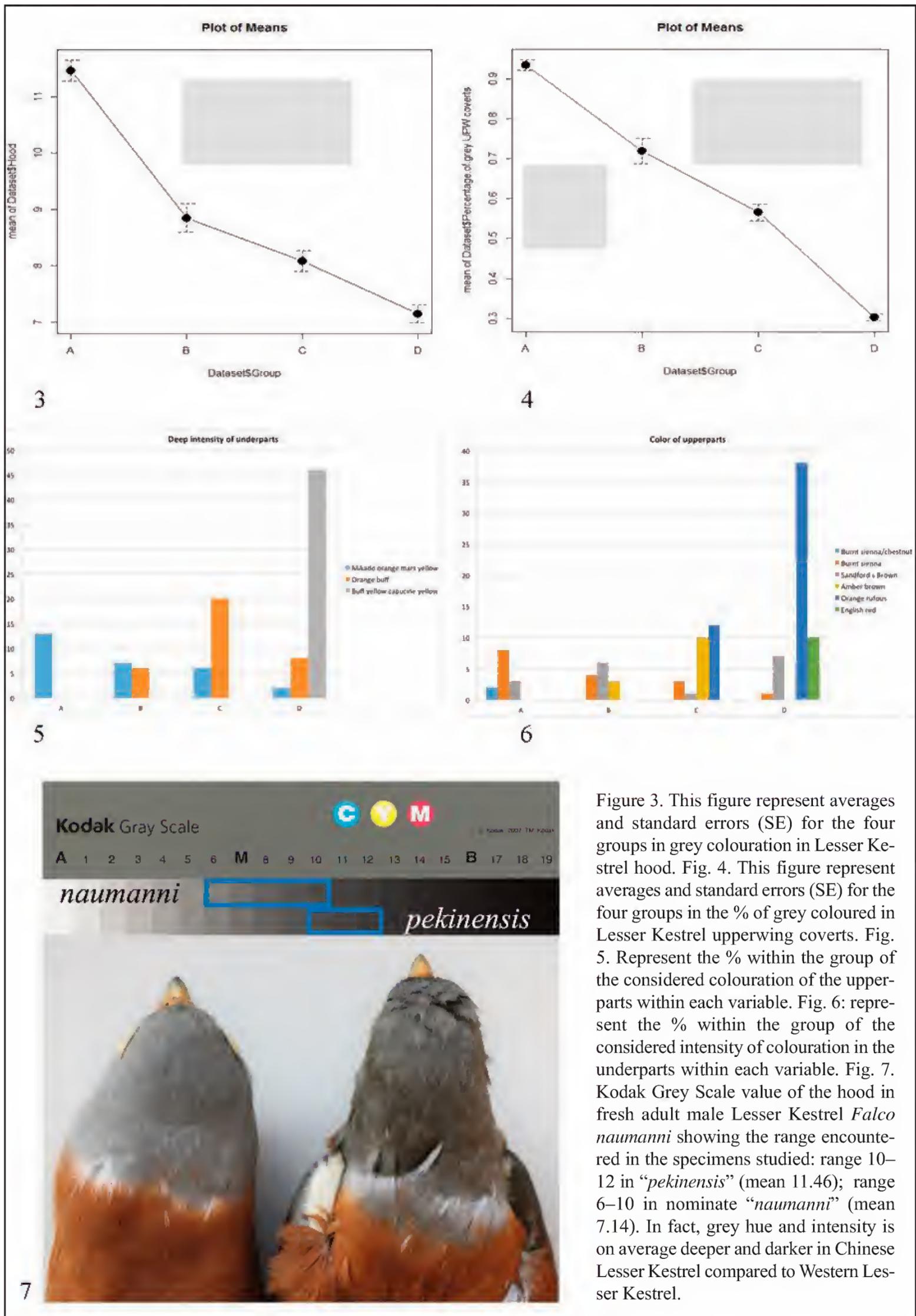


Figure 3. This figure represent averages and standard errors (SE) for the four groups in grey colouration in Lesser Kestrel hood. Fig. 4. This figure represent averages and standard errors (SE) for the four groups in the % of grey coloured in Lesser Kestrel upperwing coverts. Fig. 5. Represent the % within the group of the considered colouration of the upperparts within each variable. Fig. 6: represent the % within the group of the considered intensity of colouration in the underparts within each variable. Fig. 7. Kodak Gray Scale value of the hood in fresh adult male Lesser Kestrel *Falco naumanni* showing the range encountered in the specimens studied: range 10–12 in “*pekinensis*” (mean 11.46); range 6–10 in nominate “*naumanni*” (mean 7.14). In fact, grey hue and intensity is on average deeper and darker in Chinese Lesser Kestrel compared to Western Lesser Kestrel.



Figure 8. *Falco naumanni pekinensis*, adult male Reg. no. BMNH.1886.3.25.272. Near Ming Tombs, north of Peking, 18.X.1868, syntype, R. Swinhoe leg. (H. van Grouw, NHM, Tring). No illustration in any modern field guide is available of such a plumage, with no description or illustration reporting these characters. Fig. 9. *F. naumanni pekinensis*, same bird as plate 5 (H. van Grouw, NHM, Tring). Note the very richly coloured underparts, much richer than any nominate “*naumanni*”. Fig. 10. *F. naumanni pekinensis*, adult male, Hebei, China, 27.IV.1937 (He Peng, NZMC). A fresh adult male “*pekinensis*” from the typical breeding range of the taxon, showing very intense brick-red (Burnt Sienna) mantle and sooty-led grey plumage areas. Fig. 11. *F. naumanni pekinensis*, adult male, Hebei, China, 27.IV.1937 (He Peng, NZMC). Same bird of Figs. 10, 12. Note that the entire upperwing coverts are typically solidly dark sooty led-grey, as never shown by any nominate “*naumanni*”. Fig. 12. *F. naumanni pekinensis*, adult male from Hebei, China, 27.IV.1937 (He Peng, NZMC). Same bird of Figs. 10, 11. Note the very richly coloured underparts, more saturated and extensively coloured than in typical nominate “*naumanni*”.

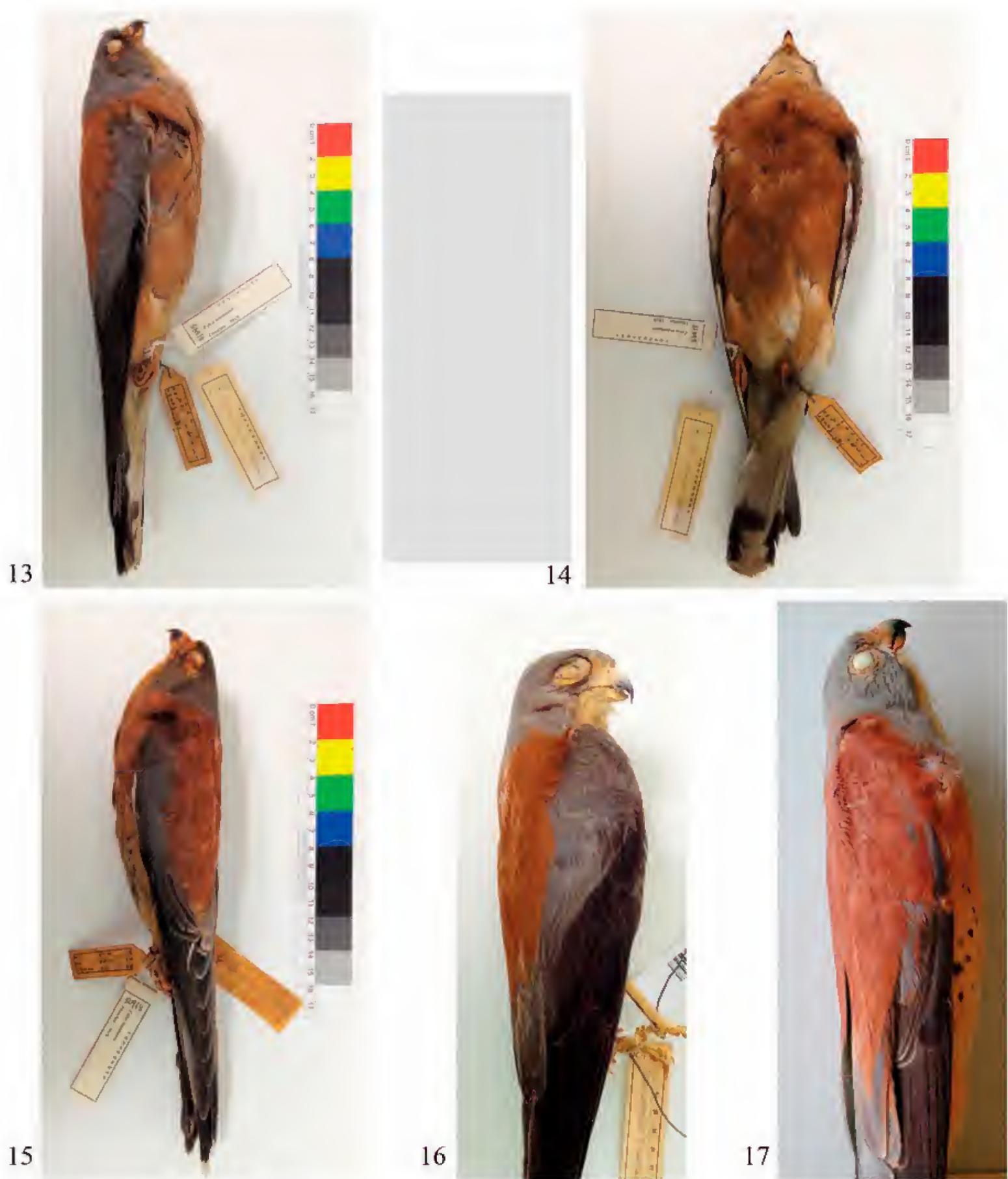


Figure 13. *Falco naumanni pekinensis*, adult male, Beijing, China, 4.IV.1961 (He Peng, NZMC). Note the typically entirely grey upperwing coverts of this male from the terra typica of the *pekinensis* taxon. Fig. 14. *F. naumanni pekinensis*, adult male, Beijing, China, 4.IV.1961 (He Peng, NZMC). Same bird of Fig. 15. Note intensely coloured underparts, with very saturated colour. Fig. 15. *Falco naumanni pekinensis*, adult male, Hebei, China, 8.X.1965 (He Peng, NZMC). Note that the entire upperwing coverts are typically solidly dark sooty led-grey, as never shown by any nominate *naumanni*. Fig. 16. *F. naumanni pekinensis*, adult male, Hebei, China, 27.IV.1937 (He Peng, NZMC). Same bird of Figs. 10,12 to show a close up view of the upperwing coverts pattern. Compare to Fig. 17. Fig. 17. *F. naumanni pekinensis*, ad. male, Spain (A. Corso, NHM, Tring). Plumage type D according to description given in the text. Note that in many European birds (ca.20%) the grey on wing coverts is very limited and pretty hard to be seen in the field or even in the hands. Note that the plumage is paler, less intense and less deep in both the grey of hood and wing-coverts and of the mantle and underparts.

the percentage within group of the considered category within each variable. The analyses showed that the groups are significantly different. The largest difference was found between group A and D (Tables 1, 2).

These groups, possibly, connect in winter/migration areas, but more study is necessary. Also the wintering areas for the individual groups are unknown, but in Fig. 2 we displayed the supposed wintering areas. The differences between group A and D is large and both phenotypes differ 86.2% taken into account the four sampled morphological features. We did not investigate whether there are genetic differences among “*naumanni*” and “*pekinensis*”, something that surely should be the target of future studies. The mean differences between other groups are A vs. B 49 %, A vs. C 75 %, B vs. C 14.7%, B vs. D 67.8% and C vs. D 39.3 %.

According to the criteria to show discrete character differences (Rolán-Alvarez & Rolán, 1995; Corbet, 1997; Johnson et al., 1999; Garnett & Christidis, 2007; Rising, 2007; Winker et al., 2007; Cicero, 2010; Remsen, 2010) 86.2 % fall well in the criteria set by Amadon (1949), Simpson & Roe (1939) and Mayr (1969) (George Sangster in littoris). We advise that the Chinese population known under the synonym “*pekinensis*” should be considered valid, despite the apparent intermediate zone between this and nominate “*naumanni*”. For the Lesser Kestrel the same applies as for other polytypic species of raptor with a wide breeding distribution area that it has a certain amount of clinal variation (Ferguson-Lees & Christie, 2001). Examples are Common Buzzard *Buteo buteo* ssp., Black Kite *Milvus migrans* ssp., Saker Falco *cherrug* and Peregrine Falco *peregrinus* ssp. (Vaurie, 1961; Ellis & Garat, 1983; Brosset, 1986; Dixon et al., 2012; White et al., 2013). The distributional areas are often poorly defined and a large variability applies in subspecies (Dementiev, 1957; Corso, 2001b; Eastham et al., 2001; Bricchetti & Fracasso, 2003; Eastham & Nicholls, 2005; Karyakin & Pfeffer, 2009; Pfeffer, 2009; Zuberogitia et al., 2009; Karyakin, 2011; Rodriguez et al., 2011). To meet the criteria as set by Amadon (1949), Simpson & Roe (1939) and Mayr (1969) most currently recognised subspecies fall short when assessed on the overlap between phenotypes.

To simplify, we are faced with two choices: 1) we consider the currently recognized subspecies of

Variable	Chi squared	df	Pr(>Chi)
Kodak_hood	53,62	3	<0.01***
percentage_of_grey_UP W_coverts	89,2	3	<0.01***

Table 1. Showing the Kruskal-Wallis test at all four groups, considering hood and % of grey upperwing coverts.

Variable	Chi squared	df	Pr(>Chi)
colour_of_upperparts	30,73	3	<0.01***
deep_intensity_of_ underparts	94,79	3	<0.01***

Table 2. Showing GLM test, on the colouration of upperparts and the intensity of underparts.

a forementioned raptor species and other wide-ranging raptors as representatives of clinal variation only. And therefore unworthy of taxonomic rank, in which case we would not consider “*pekinensis*” as a valid taxon in light of the intermediate birds found; 2) we believe all these taxa, including “*pekinensis*”, to be worthy of taxonomic rank. In any case, as the Chinese population of Lesser Kestrel is always identifiable, and geographically isolated. It is therefore worthy of taxonomic rank, which will also help focus attention on its conservation (Patten, 2015).

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## Current knowledge on the Sicilian tardigrade fauna

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### ABSTRACT

Based on the literature, and adding personal contribution, the author takes stock of the knowledge about the species of limno-terrestrial tardigrades present in Sicily and the main small islands around it (Aeolian Islands, Ustica, Egadi Islands). In total 111 species are reported: 108 from Sicily (main island), 35 from the Aeolian Islands, 17 from Ustica and 11 from the Egadi Islands. Two species are new records only for the respective islands, 13 are new records for the whole studied area, four of which are new also for the Italian fauna. A good 13 species (11.7%) are at present endemic for the studied area. The zoogeographic spread of the 111 Sicilian tardigrade species confirms the modern ideas about tardigrade zoogeography.

### KEY WORDS

Tardigrada; Sicilian fauna; zoogeography; taxonomy.

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### INTRODUCTION

In the Surveys on the Sicilian tardigrade fauna (Ustica, Aeolian and Aegadean archipelagos included) until 2009 allowed to recognize 94 terrestrial and freshwater species (Arcidiacono, 1962; 1964, Binda, 1969; 1978; Binda & Pilato, 1969a,b, 1971, 1972, 1984, 1985, 1987; Binda et al., 1980; Pilato, 1969, 1971a,b,c, 1973, 1974, 2009; Pilato & Catanzaro, 1988, 1989; Pilato et al., 1982, 1989, 2000).

Though that a number may have appeared high, the variety of Sicilian environments considered, the composition of Sicilian tardigrade fauna may be considered far away from being completely known; for this reason, I have recently carried out, in collaboration with G. Pilato and G. Sabella, new studies that until now have led us to describe four species new to science (Pilato et al., 2014; Lisi et al., 2014). The total number of limno-terrestrial tardigrade species up to now reported from Sicily (and surrounding small islands) is 98.

### MATERIAL AND METHODS

The current study has been based only on the re-examination of abundant old material, from the Pilato and Binda collection (Museum of the Department of Biological, Geological and Environmental Sciences, section of Animal Biology “Marcello La Greca”, University of Catania), collected and partially identified in the far past but the results had remained unpublished; in some cases the old diagnosis had to be updated revealing new records, and even new species, which is not surprising considering that past tardigrade taxonomy was based on less strict criteria and some wrong convictions, so that little differences between populations, when noticed, were more easily attributed to individual variability within a single species rather than considered as an indication that the two populations belonged to distinct species. About the new records reported in Table 2, all the data about localities and samples are the only available, due to the fact that

at the time of collection it was not in use to take note of more detailed information.

All the studied specimens were mounted in polyvinyl lactophenol. Specific diagnosis was based on the original descriptions and eventual redescrptions (Plate, 1889; Cuénot, 1929; Marcus, 1936; Binda, 1971; Pilato & Sperlinga, 1975; Dastyh, 1984; Binda & Rebecchi, 1992; Bertolani & Rebecchi, 1993; Pilato & Binda, 1997/1998; Pilato et al., 2003; Tumanov, 2006; Pilato et al., 2011) and on the monograph by Ramazzotti e Maucci (1983); by comparison, specimens of the Pilato and Binda collection of the following species were examined: *Hypsibius scabropygus* Cuénot, 1929, *Diphascon pingue* (Marcus, 1936), *D. higginsi* Binda, 1971 and *D. chilense* Plate, 1889. All observations and measurements were made under x100 oil immersion using a Leica Phase Contrast Microscope equipped with a micrometer.

## RESULTS

The progression of those studies has led to recognise other 13 species that represent new records for the studied area, and four of them are new records for the Italian fauna as well. The total number of limno-terrestrial tardigrade species for that area then raises to 111.

The updated checklist of limno-terrestrial tardigrade species present in Sicily (and surrounding small islands) is reported in Table 1, where the island in which each species was found is reported; I found it interesting to take into consideration also the presence of each species in north Africa, for having an idea of the faunal affinity with that region.

In total 111 species are reported (98 already known, plus 13 new findings): 108 from Sicily (main island), 35 from the Aeolian Islands, 17 from Ustica and 11 from the Egadi Islands. Two species are new records only for the respective islands, 13 are new records for the whole studied area, four of which are new also for the Italian fauna (Table 2).

A special mention has to be made about the tardigrade fauna of North Africa, with which a remarkable affinity has come out: it shares with Sicily 40 species, representing a good 36.0% of the Sicilian species.

Thirteen species (11.7%) today result to be endemic for the studied area. Nine "terrestrial" more or less recently described, and 4 already reported

freshwater species: *Carphania fluviatilis* Binda, 1979 (the only freshwater species of the class Heterotardigrada), *Isohypsibius tuberciculatus* Pilato et Catanzaro, 1990, *I. verae* Pilato et Catanzaro, 1990, and *Macroversum mirum* Pilato et Catanzaro, 1989.

As regards possible biogeographic evaluations, the geographic distribution of the 111 Sicilian tardigrade species seems to confirm the modern ideas about tardigrade biogeography. It was very hard in the past to make biogeographic evaluations about the species of this group, due to wrong convictions about species individual variability and poorly strict criteria for specific diagnosis, and an overestimated effect of passive dispersal; these had great impact on the believed geographic distribution of the species creating great confusion and making very difficult to study tardigrade species from a biogeographic point of view. However, thanks to a change in the evaluation of individual variability and the taxonomic criteria for specific diagnosis (eg. Pilato, 1975; 1979), as well as a reevaluation of the possibility of passive dispersal (Pilato, 1979) which reflected into a reconsideration of the geographic distribution of the species, many old diagnosis mistakes have been corrected (and this correction still continues today), and starting with McInnes (1994) and Pilato & Binda (2001), it is today universally accepted to consider tardigrade species from the biogeographic point of view.

Limiting myself to use the available data from the literature, in which old diagnosis mistakes very probably still hide, it is possible to notice that tardigrade species tend to have a limited geographic distribution, at the level of zoogeographic region, not cosmopolitan, or nearly such, as believed in the far past. In Table 3 the zoogeographic spread of the 111 Sicilian tardigrade species is reported and the data confirms the above expressed idea.

As regards the relatively high number of species reported from the literature as present in 7 zoogeographic regions, it must be stressed that those 17 species are mostly represented by species described in the far past (even about a century ago), so that there had been all the time, before the "revolution" of the last decades, for various authors to report the same species from all over the world; as a matter of fact, the correction of such diagnosis mistakes has been in the last decade one of the great goals of tardigrade taxonomists, and much still remains to be done.

	rank	Sicily	Aeolian Archipel.	Ustica	Aegadean Archipel.	North Africa
<b>CARPHANIIDAE</b>						
<i>Carphania fluviatilis</i> Binda, 1978	E	*				
<b>ECHINISCIDAE</b>						
<i>Bryodelphax tatrensis</i> Weglarska, 1959		*		*		*
<i>Bryodelphax weglarskae</i> Pilato, 1972					*	
<i>Cornechiniscus lobatus</i> (Ramazzotti, 1943)		*				
<i>Echiniscus blumi</i> Richters, 1903		*	*			*
<i>Echiniscus trisetosus</i> Cuenot, 1932		*	*			*
<i>Echiniscus mediantus</i> Marcus, 1930		*	*			
<i>Echiniscus bisetosus</i> Heinis, 1908		*	*			*
<i>Echiniscus canadensis</i> Murray, 1910		*	*			*
<i>Echiniscus testudo</i> (Doyère, 1840)		*	*			*
<i>Echiniscus merokensis</i> Richters, 1904		*	*	*		*
<i>Echiniscus granulatus</i> (Doyère, 1840)		*	*			*
<i>Echiniscus quadrispinosus</i> (Richters, 1902)		*nr	*			
<i>Echiniscus carusoi</i> Pilato, 1972	E	*			*	*
<i>Echiniscus ramazzottii</i> Binda et Pilato, 1969	E		*			
<i>Parechiniscus chitonides</i> Cuénot, 1926		*				*
<i>Pseudechiniscus pseudoconifer</i> Ramazzotti, 1943		*				
<b>MILNESIIDAE</b>						
<i>Milnesium almatyense</i> Tumanov, 2006	NRI	*				
<i>Milnesium tardigradum</i> Doyère, 1840		*	*	*	*	*
<b>EOHYPYSIBIIDAE</b>						
<i>Bertolanus weglarskae</i> (Dastych, 1972)		*				
<b>HYPYSIBIIDAE</b>						
<i>Astatumen trinacriae</i> (Arcidiacono, 1962)		*				*
<i>Bindius triquetrus</i> Pilato, 2009	E	*				
<i>Diphascon belgicae</i> Richters, 1911		*				*
<i>Diphascon brevipes</i> Marcus, 1936		*				
<i>Diphascon carolae</i> Binda et Pilato, 1969		*				
<i>Diphascon chilense</i> Plate, 1888	NRS	*				
<i>Diphascon higginsi</i> Binda, 1971	NRS	*				*
<i>Diphascon nelsonae</i> Pilato, Binda, Bertolani et Lisi, 2005			*			
<i>Diphascon nobilei</i> Binda, 1969		*	*			
<i>Diphascon patanei</i> Binda et Pilato, 1971		*	*			
<i>Diphascon pingue</i> Marcus, 1936	NRS	*	*			
<i>Diphascon procerum</i> Pilato, Sabella et Lisi, 2014	E	*				
<i>Diphascon recamieri</i> (Richters, 1911)		*				
<i>Diphascon serratum</i> Pilato, Binda, Bertolani et Lisi, 2005	E	*				
<i>Diphascon scoticum</i> Murray, 1905		*				

Table 1. Limno-terrestrial tardigrade species from Sicily; Ranks: NRS = new record for the whole studied area (Sicily and surrounding islands); NRI = new record also for the Italian fauna; E = endemic. In the geographic region column, "nr" indicates new record only for the single island/arcipelago. Taxonomy according to Bertolani et al. (2014).

	rank	Sicily	Aeolian Archipel.	Ustica	Aegadean Archipel.	North Africa
<b>HYPYSIBIIDAE</b>						
<i>Diphascon serratum</i> Pilato, Binda, Bertolani et Lisi, 2005	E	*				
<i>Diphascon scoticum</i> Murray, 1905		*				
<i>Diphascon ziliense</i> Lisi, Sabella et Pilato, 2014	E	*				
<i>Hypsibius convergens</i> (Urbanowicz, 1925)		*	*	*		*
<i>Hypsibius conifer</i> Mihelcic, 1938		*				
<i>Hypsibius dujardini</i> (Doyère, 1840)		*	*			*
<i>Hypsibius microps</i> Thulin, 1928		*	*			*
<i>Hypsibius pallidoides</i> Pilato, Kiosya, Lisi, Inshina et Biserov, 2011	NRI	*				
<i>Hypsibis pallidus</i> Thulin, 1911		*				
<i>Hypsibius ragonesei</i> Binda et Pilato, 1985	E	*				
<i>Hypsibius scabropygus</i> Cuénot, 1929	NRS	*				
<i>Mixibius saracenus</i> (Pilato, 1973)		*				
<i>Mixibius parvus</i> Lisi, Sabella et Pilato, 2014	E	*				
<i>Platicrista angustata</i> (Murray 1905)		*				*
<b>RAMAZZOTTIIDAE</b>						
<i>Ramazzottius oberhaeuseri</i> (Doyère, 1840)		*		*		
<i>Ramazzottius thulini</i> (Pilato, 1970)		*				
<b>ISOHYPYSIBIIDAE</b>						
<i>Doryphoribius doryphorus</i> (Binda et Pilato, 1969)		*		*		*
<i>Doryphoribius macrodon</i> Binda, Pilato et Dastych, 1980		*				
<i>Doryphoribius zappalai</i> Pilato, 1971		*				
<i>Eremobiotus alicatai</i> (Binda, 1969)		*				*
<i>Hexapodibius micronyx</i> Pilato, 1969		*				
<i>Isohypsibius arbiter</i> Binda, 1980	NRS	*				
<i>Isohypsibius austriacus</i> (Iharos, 1966)		*				*
<i>Isohypsibius dastychi</i> Pilato, Bertolani et Binda, 1982		*				
<i>Isohypsibius deconincki</i> Pilato, 1971		*				*
<i>Isohypsibius elegans</i> Binda et Pilato, 1971		*	*	*	*	*
<i>Isohypsibius granulifer</i> Thulin, 1928		*				
<i>Isohypsibius kristenseni</i> Pilato, Catanzaro et Binda, 1989		*				
<i>Isohypsibius longiunguis</i> Pilato, 1974		*				
<i>Isohypsibius lunulatus</i> (Iharos, 1966)		*	*			*
<i>Isohypsibius marcellinoi</i> Binda et Pilato, 1971		*				
<i>Isohypsibius monoicus</i> Bertolani, 1981		*				
<i>Isohypsibius nodosus</i> (Murray, 1907)		*				
<i>Isohypsibius pappi</i> (Iharos, 1966)		*			*	
<i>Isohypsibius prosostomus</i> Thulin, 1928		*				
<i>Isohypsibius reticulatus</i> Pilato, 1973		*				

Table 1. Limno-terrestrial tardigrade species from Sicily; Ranks: NRS = new record for the whole studied area (Sicily and surrounding islands); NRI = new record also for the Italian fauna; E = endemic. In the geographic region column, “nr” indicates new record only for the single island/arcipelago. Taxonomy according to Bertolani et al. (2014).

	rank	Sicily	Aeolian Archipel.	Ustica	Aegadean Archipel.	North Africa
<i>Isohypsibius ronsisvallei</i> Binda et Pilato, 1969		*				
<i>Isohypsibius sattleri</i> Richters, 1902		*	*	*		*
<i>Isohypsibius silvicola</i> (Iharos, 1966)		*				
<i>Isohypsibius tetractyloides</i> Richters, 1907		*				
<i>Isohypsibius tuberculatus</i> Pilato et Catanzaro, 1990	E	*				
<i>Isohypsibius verae</i> Pilato et Catanzaro, 1989	E	*				
<i>Parhexapodibius lagrecai</i> (Binda et Pilato, 1969)		*	*	*		*
<i>Pseudobiotus matici</i> (Pilato, 1971)		*				
<i>Pseudobiotus kathmanae</i> Nelson, Marley et Bertolani, 1999		*				
<i>Thulinus ruffoi</i> (Bertolani, 1982)		*				
<i>Thulinus stephaniae</i> (Pilato, 1974)		*				
<b>MACROBIOTIDAE</b>						
<i>Macrobiotus diffusus</i> Binda et Pilato, 1987		*	*	*	*	*
<i>Macrobiotus echinogenitus</i> Richters, 1904		*	*			*
<i>Macrobiotus harmsworthi</i> Murray, 1907		*	*	*	*	*
<i>Macrobiotus hufelandi</i> Schultze, 1834		*	*	*	*	*
<i>Macrobiotus insuetus</i> Pilato, Sabella et Lisi, 2014	E	*				
<i>Macrobiotus islandicus</i> Richters, 1904		*				*
<i>Macrobiotus macrocalix</i> Bertolani et Rebecchi, 1993	NRS	*				
<i>Macrobiotus nuragicus</i> Pilato et Sperlinga, 1975	NRS	*				*
<i>Macrobiotus pallarii</i> Maucci, 1954		*	*			*
<i>Macrobiotus patiens</i> Pilato, Binda, Napolitano et Moncada, 2000		*nr	*	*		
<i>Macrobiotus persimilis</i> Binda et Pilato, 1972		*	*	*		*
<i>Macrobiotus pilato</i> Binda et Rebecchi, 1992	NRS	*				
<i>Macrobiotus polonicus</i> Pilato, Kaczmarek, Michalczyk et Lisi, 2003	NRI	*				
<i>Macrobiotus sapiens</i> Binda et Pilato, 1984		*				
<i>Macrobiotus simulans</i> Pilato, Binda, Napolitano et Moncada, 2000		*	*			
<i>Macrobiotus terminalis</i> Bertolani et Rebecchi, 1993	NRS	*				
<i>Paramacrobiotus areolatus</i> (Murray, 1907)		*	*		*	*
<i>Paramacrobiotus csotiensis</i> (Iharos, 1966)		*				
<i>Paramacrobiotus richtersi</i> (Murray, 1911)		*	*	*	*	*
<i>Minibiuotus furcatus</i> (Ehrenberg, 1859)		*	*			
<i>Minibiotus intermedius</i> (Plate, 1889)		*	*	*		*
<i>Minibiotus pseudofurcatus</i> (Pilato, 1972)		*			*	
<i>Minibiotus weinerorum</i> (Dastyk, 1984)	NRI	*				
<i>Richtersius coronifer</i> (Richters, 1903)		*				*
<i>Tenuibiotus tenuis</i> (Binda et Pilato, 1972)		*				
<i>Xerobiotus pseudohufelandi</i> (Iharos, 1966)		*	*	*		*

Table 1. Limno-terrestrial tardigrade species from Sicily; Ranks: NRS = new record for the whole studied area (Sicily and surrounding islands); NRI = new record also for the Italian fauna; E = endemic. In the geographic region column, “nr” indicates new record only for the single island/arcipelago. Taxonomy according to Bertolani et al. (2014).

	rank	Sicily	Aeolian Archipel.	Ustica	Aegadean Archipel.	North Africa
<b>MURRAYIDAE</b>						
<i>Dactylobiotus parthenogeneticus</i> Bertolani, 1982		*				
<i>Dactylobiotus dispar</i> (Murray, 1907)		*				
<i>Macroversum mirum</i> Pilato et Catanzaro, 1989	E	*				
<i>Murrayon pullari</i> (Murray, 1907)		*				
<b>NECOPINATIDAE</b>						
<i>Necopinatum mirabile</i> Pilato, 1971		*				

Table 1. Limno-terrestrial tardigrade species from Sicily; Ranks: NRS = new record for the whole studied area (Sicily and surrounding islands); NRI = new record also for the Italian fauna; E = endemic. In the geographic region column, “nr” indicates new record only for the single island/arcipelago. Taxonomy according to Bertolani et al. (2014).

<b>MILNESIIDAE</b>	<i>Milnesium almatyense</i> Tumanov, 2006 <b>NRI</b> Cesarò (Messina) “Portella Femmina Morta”; moss sample. Ramacca (Catania); moss sample.
<b>HYPYSIBIIDAE</b>	<i>Diphascon chilense</i> Plate, 1889 Belpasso (Catania) “Contrada Milia”; chestnut leaf litter <i>Diphascon higginsii</i> Binda, 1971 Belpasso (Catania) “Contrada Milia”; chestnut leaf litter <i>Diphascon pingue</i> (Marcus, 1936) Belpasso (Catania) “Contrada Milia”; chestnut leaf litter <i>Hypsibius pallidoides</i> Pilato, Kiosya, Lisi, Inshina et Biserov, 2011 <b>NRI</b> Belpasso (Catania) “Contrada Milia”; chestnut leaf litter <i>Hypsibius scabropygus</i> Cuénot, 1929 Isnello (Palermo) “Pizzo Antenna” Madonie Mountains; lichens on tree trunk.
<b>ISOHYPYSIBIIDAE</b>	<i>Isohypsibius arbiter</i> Binda, 1980 Belpasso (Catania) “Contrada Milia”; chestnut leaf litter. Bronte (Catania) “Contrada Rinazzo”; moss sample.
<b>MACROBIOTIDAE</b>	<i>Macrobiotus macrocalix</i> Bertolani et Rebecchi, 1993 Contessa Entellina (Palermo), Contrada Mazzaporro, - Nebrodi Mountains; moss sample <i>Macrobiotus nuragicus</i> Pilato et Sperlinga, 1975 Mandanici (Messina), Madonie Mountains; moss sample <i>Macrobiotus pilatoii</i> Binda et Rebecchi, 1992 Madonie Mountains; <i>Sphagnum</i> sample <i>Macrobiotus polonicus</i> Pilato, Kaczmarek, Michalczyk et Lisi, 2003 <b>NRI</b> Maletto (Catania) “Sciara St. Venera”; moss sample - Catania; moss sample <i>Macrobiotus terminalis</i> Bertolani et Rebecchi, 1993 Cesarò (Messina), Mt. Soro (Nebrodi Mountains); moss sample <i>Minibiotus weinerorum</i> Dastych, 1984 <b>NRI</b> Isnello (Palermo) “Pizzo Antenna” Madonie Mountains; lichens on tree trunk.

Table 2. New records of limno-terrestrial tardigrade species for Sicily and surrounding islands.  
NRI = new record also for the Italian fauna.

Palearctic (of which endemic)	Present in 2 zoogeographic regions	Present in 3 zoogeographic regions	Present in 4 zoogeographic regions	Present in 5 zoogeographic regions	Present in 6 zoogeographic regions	Present in 7 zoogeographic regions	Total
40 (13)	19	15	5	11	4	17	111
36.0% (11.7%)	17.1%	13.5%	4.5%	9.9%	3.6%	15.3%	100%

Table 3. Zoogeographic spread of the limno-terrestrial tardigrade species of Sicily.

## CONCLUSIONS

As it can be seen, a limited study of old material may reveal new records and even new species, also with the change of old diagnoses, not correct in the light of the modern criteria; this, as well as improving knowledge in general, allows to go ahead in the progress of tardigrade taxonomy and biogeography. The current study, thanks to the promising results obtained, still goes on and intends to proceed with the correction of very old literature mistakes (which affect the correct knowledge of tardigrade biodiversity and species geographic distribution), enrich faunistic and biogeographic knowledge, and put in evidence the variety and eventual peculiarity of Sicilian tardigrade fauna, with repercussions on general knowledge of Sicilian biodiversity.

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## On the presence of *Campodea majorica sicula* Condé, 1957 (Diplura Campodeidae) in the "Abisso della Pietra Selvaggia" cave (Mount Pellegrino, Palermo, Italy)

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### ABSTRACT

We report for the first time the presence of *Campodea majorica sicula* Condé, 1957 (Insecta, Diplura, Campodeidae) in the "Abisso della Pietra Selvaggia", a vertical karst cave situated in the southern slope of Mount Pellegrino, adjacent to the city of Palermo (Sicily). This hypogean subspecies is considered endemic of Sicily and up to now it was known only for the "Addaura Caprara" cave, located at the opposite slope (north-east) of Mount Pellegrino. During a speleological excursion in the "Abisso della Pietra Selvaggia" cave, organized by "Centro Speleologico Etneo" (Catania, Italy), 14 specimens of this subspecies were collected in the bottom of the cave, at -170 m. The bottom is one of the few humid areas of the cave, whereas the rest is very dry, dusty and apparently without Diplura. In addition to *C. majorica sicula*, currently are known the following *C. majorica* subspecies, all hypogean: *C. majorica majorica* Condé, 1955, *C. majorica interjecta* Condé, 1955, both endemic of some caves of Majorca Island (Balearic Islands, Spain) and *C. majorica valentina* Sendra et Moreno, 2004, found inside 7 caves located in the karstic area of Mount Mondúver and Sierra de Corbera (SE of Valencia, Spain).

### KEY WORDS

Diplura; biospeleology; karst cave; hypogean fauna; Sicily.

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### INTRODUCTION

Diplura is a poorly investigated order which contains small and wingless species. They are unpigmented and eyeless. The antennae are long and moniliform. The abdomen ends with a pair of cerci that can be long and thin or short and pincer-like. The majority of the species usually are 2-5 mm long, although some species can reach 50 mm. There are about 94 known species in Italy, 19 of which occur

in Sicily (Thibaud, 2013). The most part of the species belong to the Campodeidae family, that includes epigeal and hypogean species.

*Campodea majorica sicula* Condé, 1957 was described on 4 specimens collected by P. Strinati on 21 August 1956 in the Addaura Caprara III cave (Condé, 1957), located in the NE slope of Mount Pellegrino, near the city of Palermo (Sicily). Until now this was the only record in Sicily for the taxon. In the present paper we report for the first time the

presence of this subspecies also in the "Abisso della Pietra Selvaggia", a vertical karst cave situated in the southern slope of Mount Pellegrino.

Up to now, in addition to *C. majorica sicula*, other three subspecies are known: *C. majorica majorica* Condé, 1955, *C. majorica interjecta* Condé, 1955, both endemic of some caves of Majorca Island (Balearic Islands, Spain) and *C. majorica valentina* Sendra et Moreno, 2004, found inside 7 caves located in the karstic area of Mount Mondúver and Sierra de Corbera (SE of Valencia, Spain). All these taxa are strictly hypogean (Condé, 1955b, 1957; Sendra, 1985, Sendra & Moreno, 2004).

## MATERIAL AND METHODS

During the sampling in the "Abisso della Pietra Selvaggia" cave, 14 specimens of this subspecies were collected by hand and preserved in 70% ethanol.

The "Abisso della Pietra Selvaggia" cave is located in the Mount Pellegrino massif, within the "Riserva Naturale Orientata Regionale Monte Pellegrino" (managed by Rangers d'Italia), in the North-West Sicily, at the northern side of Palermo (Figs. 1, 2). The Reserve covers about 1020 ha and was created in 1996 to protect the Mount Pellegrino massif and the "Tenuta Reale della Favorita". It is

also a Site of Community Importance (SCI) ITA020014. Mount Pellegrino is a carbonatic massif (606 m a.s.l.) made up of rocks originated in shallow seas from Trias to Eocene. The mount is subject to karst phenomena and counts 134 caves of both marine and karst origin.

The "Abisso della Pietra Selvaggia", is a vertical karst cave situated in the southern slope of Mount Pellegrino at an elevation of 425 m a.s.l. It is 171 m deep (Fig. 3) and it consists of a sequence of four shaft, respectively of 31 m, 6 m, 38 m, 62 m (Mannino, 1985).

The specimens were collected in the bottom of the cave (-157/-171 m), on the moist soil, among the stones and near stalagmites (Fig. 4). The bottom is one of the few humid areas of the cave, the rest is very dry, dusty and apparently without Diplura.

The specimens were examined in laboratory using a Leica M 205A stereomicroscope equipped with a Leica DFC450 digital camera and a multi-focus image acquisition software (Leica Application Suite v.4.2.0). Moreover some macrophotos have been made on-site using digital SLR camera. Taxonomical reference are based on the checklist of "Fauna Europaea", version 2.6 (Thibaud, 2013).

ABBREVIATIONS: ma: medial anterior macrochaeta; la: lateral anterior macrochaeta; lp: lateral posterior macrochaeta.



Figure 1. Location of Mount Pellegrino (Palermo, Sicily). Figure 2. Satellite image of Mount Pellegrino, with location of the investigated caves. Red square: Addaura Caprara; yellow square: Abisso della Pietra Selvaggia (from Google Earth)

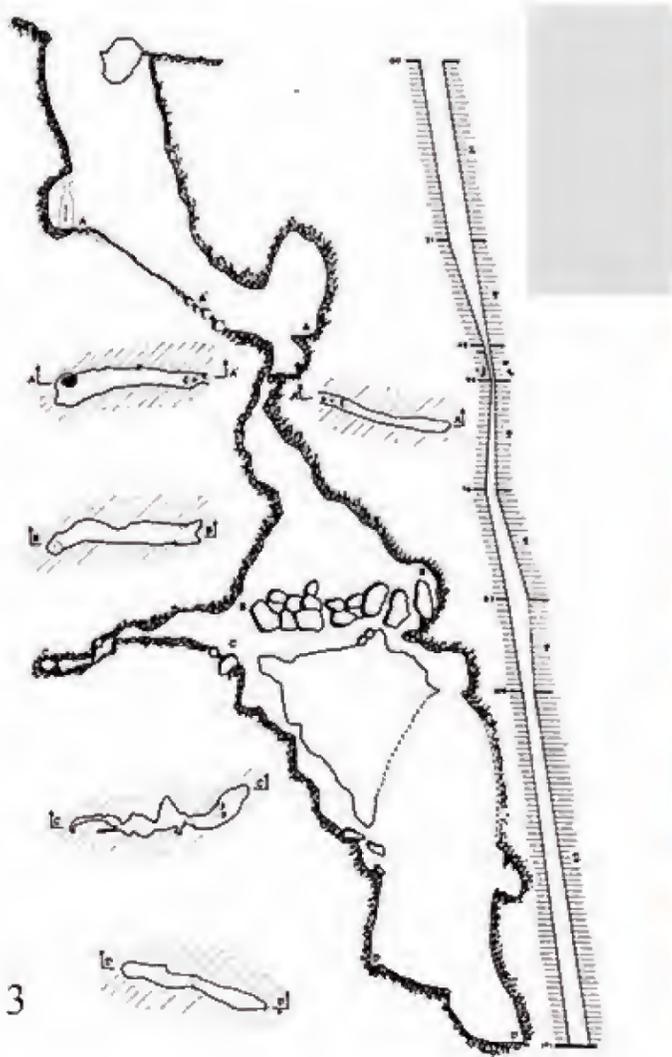


Figure 3. Longitudinal section and plan of "Abisso della Pietra Selvaggia" cave (M. Panzica survey, from Mannino, 1985).  
Figure 4. Bottom of "Abisso della Pietra Selvaggia" (Photo by F. Fiorenza).



Figure 5. *C. majorica sicula* adult female from "Abisso della Pietra Selvaggia", body length 8 mm (Photo by F. Fiorenza).

### *Campodea majorica sicula* Condé, 1957

EXAMINED MATERIAL. Italy, Sicily, Palermo, "Abisso della Pietra Selvaggia" cave, 38°09'33.2"N; 13°21'25.6"E; 16.III.2014, 3 females, 2 males; 11.V.2014, 5 females and 4 males, Marletta A., Nicolosi G., Grech T. legit.

DESCRIPTION. Body length: 7 mm male; 8 mm female (Fig. 5). Head (Fig. 6): Antennae with 41-43 antennomeres, cupuliform organ with 9-12 sensilla. Insertion line of antennae bordered by 3+3 macrochaetae. Sensillum of third antennomere bacilliform and in latero-sternal position. Thorax: the typical notal macrochaetae distribution is similar to the other *C. majorica* subspecies with 3+3 (ma, la, lp) pronotal macrochaetae, 3+3 (ma, la, lp) mesonotal macrochaetae and 1+1 (ma) metanotal macrochaetae (Fig. 7). Notal macrochaetae and setae similar to the other *C. majorica* subspecies, but slightly longer and thinner. The posterior-marginal setae are thick and crenellated. Mesonotal macrochaetae lp/ma ratio is 1.74-2.21. Abdomen (Fig. 8): urotergite VI with 1+1 la macrochaetae, lp macrochaetae absent. Urotergite VII with 1+1 la macrochaetae and 1+1 lp macrochaetae. Urotergite VIII with la macrochaetae absent and 3+3 lp macrochaetae. Posterior margin of urosternite I of males with 2-3 rows of glandular setae. Cerci 1.5 times longer than body length, with about 20 elongated articles with long macrochaetae and setae (Condé, 1957; Sendra & Moreno, 2004).

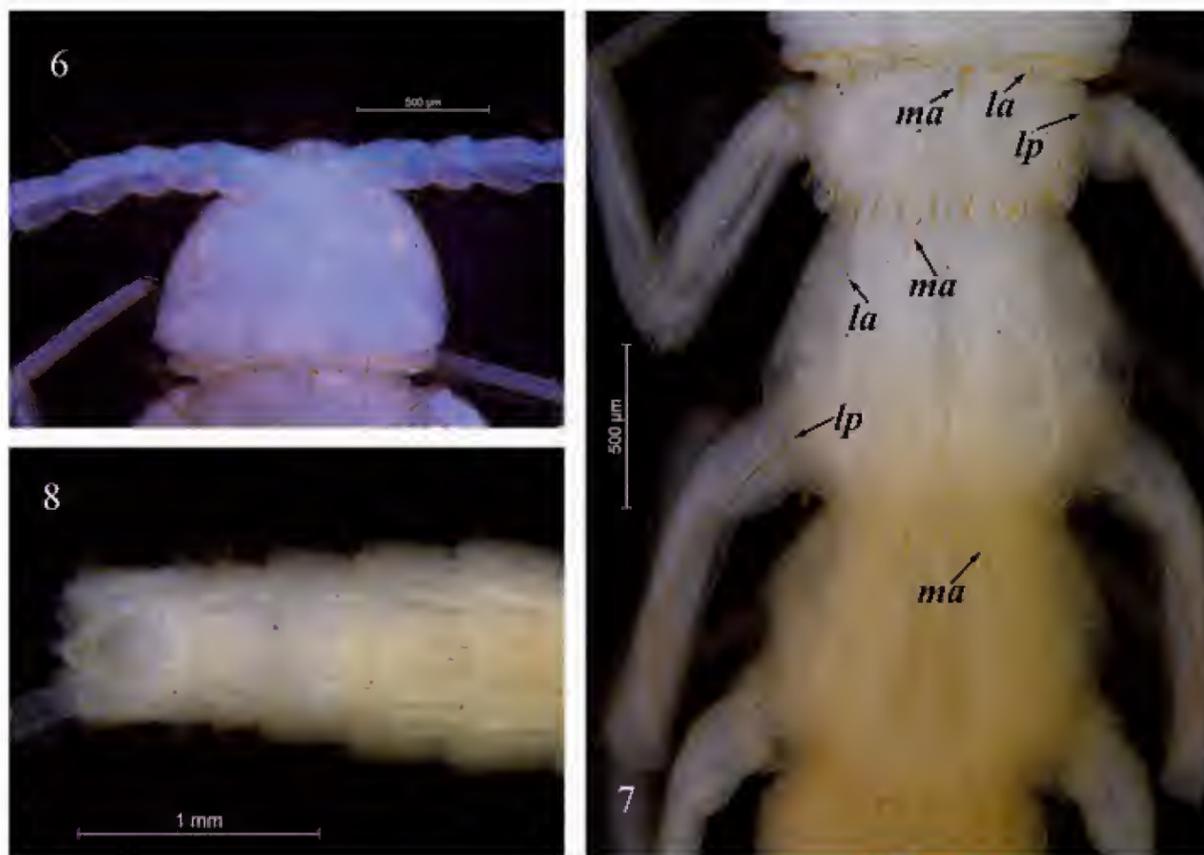


Figure 6. *Campodea majorica sicula*: head (dorsal view).

Figure 7. Thorax (dorsal view).

Figure 8. Abdomen, urotergites V-X (for abbreviations see text).

REMARKS. According to Condé (1948, 1955a, 1957) and Sendra & Moreno (2004), *C. majorica* subspecies, together with *C. cyrnea* Condé, 1948 and *C. blandinae* Condé, 1948 (both hypogean species endemic of Corsica island), are considered closely related with *C. grassi* Silvestri, 1912, an epigeal species widespread in the western Mediterranean area (Italy mainland, Corsica, Sicily, Tunisia, Algeria and north-eastern of Iberian Peninsula) (Silvestri, 1912). They form a group of related species that share following common characters: elongated appendages, hypertrophic cupuliform organ of antennae, robust and short notal macrochaetae, lateral posterior (lp) macrochaetae absent or reduced, short clothing setae, body surface densely covered with thin microdenticles and abdomen with 1+1 lateral anterior (la) macrochaetae from urotergites V or VI, 1+1 lp from VII and 3+3 lp in VIII. The phylogenetic history of these species and their adaptation process in the hypogean environment are still uncertain, thus more investigation would be necessary, also with mitochondrial DNA-based analysis.

#### ACKNOWLEDGEMENTS

We would like to thank Dr. Alberto Sendra (Valencia, Spain) for his precious advices on identification of this taxon; Dr. Salvatore Palascino (Director of Mount Pellegrino Natural Reserve)

for allowing us to conduct this study. And also the speleologists of "Centro Speleologico Etneo" for their technical support into the cave.

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## Remarks on the composition of the Auchenorrhyncha fauna in some moist areas in Southern Apulia (Italy)

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### ABSTRACT

A list of 84 Auchenorrhyncha species collected from field excursions in the province of Lecce (Southern Apulia) in June 2011 and April 2012 is given. Prevalently three areas were studied: the Regional Natural Park “Bosco e Paludi di Rauccio”, the Protected Oasis “Laghi Alimini” and the State Natural Reserve “Le Cesine”. Four species (*Delphax meridionalis* (Haupt, 1924), *Delphacodes capnodes* (Scott, 1870), *Parapotes reticulatus* (Horváth, 1897) and *Calamotettix taeniatus* (Horváth, 1911)) are recorded for the first time for Italy, five (*Stenokelisia angusta* Ribaut, 1934, *Euides basilinea* (Germar, 1821), *Chloriona glaucescens* Fieber, 1866, *Hecalus storai* (Lindberg, 1936) and *Melillaia desbrochersi* (Lethierry, 1899)) are new records for the Apennine Peninsula (“S” in the checklist of the Italian fauna) and 26 new for Apulia. For some species of special interest their ecology and distribution is discussed. The investigated areas are of high relevance for nature conservation as they constitute small relics of formerly vastly extended coastal marshes, where several stenotopic Auchenorrhyncha species occur, associated particularly with moist vegetation. Interesting is a group of taxa that are known only from the Balkan region and South Italy. Possibly the isolated occurrence of some other Auchenorrhyncha taxa in Apulia is connected rather with the Balkan Peninsula than with Central Europe.

### KEY WORDS

Faunistics; Ecology; Biogeography.

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### INTRODUCTION

As the knowledge on the distribution of many species of Auchenorrhyncha in Italy is still rather fragmentary, and recent data for the southern regions of the peninsula are almost completely lacking, it may be useful to publish some data deriving from two sampling trips in June 2011 and April 2012, respectively, in some moist areas in the province of Lecce in Southern Apulia (Fig. 1).

Especially three zones of notable naturalistic importance were investigated: the Regional Natural Park “Bosco e Paludi di Rauccio”, the State Natural

Reserve “Le Cesine” and the Protected Oasis “Laghi Alimini”.

The Regional Natural Park “Bosco e Paludi di Rauccio” (Figs. 2–5) comprises many different habitats: forest of *Quercus ilex* L. (residue of the “Foresta di Lecce”, a forest area that in the Middle Ages extended between Lecce, the Adriatic coast, Otranto and Brindisi), a swampy area named Specchia della Milogna, small ponds and moist areas, two coastal basins (Idume and Fetida), sandy seashore, some zones of Mediterranean maquis and garigue, ruderal areas and pastures. The State Natural Reserve “Le Cesine” (Figs. 6, 7) is an area of extreme environmental value. Even if prevalently a

humid area, it includes in addition a large variety of habitats and transitional zones, which create a vast ecological mosaic. A part from extended reed areas, numerous canals, swamps and marshes and the basins of Pantano Grande and Salapi, there are many other habitats as pine forest, Mediterranean maquis, *Quercus ilex* forest and ruderal areas. The reserve includes 620 ha, defined as “moist zone of international value” (RAMSAR convention, 1971); out of these 620 ha, 348 are “natural reserve of animal repopulation” administered by the WWF-Italy. The Alimini lakes (Fig. 8) consist of two basins: Alimini Grande and Alimini Piccolo, named also Fontanelle, with the former being a salt water, the latter a fresh water lake. The oasis includes valuable areas of Mediterranean maquis and coastal retrodunal lagoons of great naturalistic interest. The protected area is one of the most important natural sites of the Salento region, with an ecosystem rich of plant and animal species. It constitutes a “Zone of Special Protection” (ZPS), proposed as Site of European Community Importance (pSIC). The protected Oasis of Alimini lakes is a very important place where birds can rest and winter.

## MATERIAL AND METHODS

The samplings were carried out in June 2011 and April 2012 at 18 localities (two of them sampled twice).

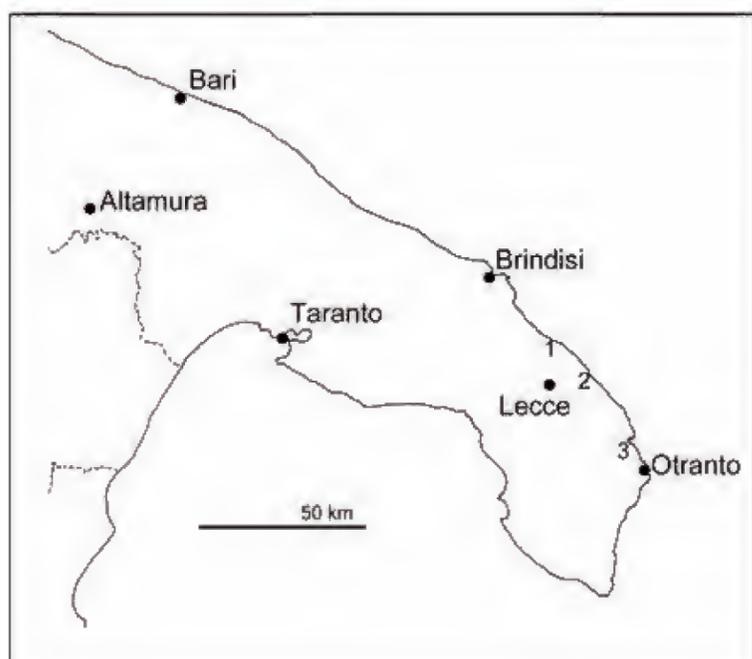


Figure 1. Map of the investigated areas in South Apulia. 1 = Bosco e Paludi di Rauccio; 2 = Le Cesine; 3 = Laghi Alimini.

We applied two collection methods: a) by entomological net and aspirator, b) directly by sight of single specimens by means of the aspirator.

### List of collecting sites

In order to facilitate the comparison of data in our different papers on the Italian Auchenorrhyncha fauna we maintain the number system of collecting localities applied already in other publications.

- St. 552: Torre Chianca, Bosco di Rauccio; N40°27'52.4" E18°10'00.4"; 3 m; 19/06/2011; ruderal area with shrubs of *Pistacia lentiscus* L. and *Phillyrea* L. (Fig. 2).

- St. 553: Torre Chianca, Bosco di Rauccio; N40°28'11.8" E18°10'10.7"; 2 m; 20/06/2011; *Phragmites australis* (Cav.) Trin. on the margin of a field and moist areas with *Juncus* L., *Bolboschoenus maritimus* (L.) Palla, Cyperaceae (Fig. 3).

- St. 554: Torre Chianca, Bosco di Rauccio; N40°28'02.0" E18°10'19.8"; 6 m; 20/06/2011; margin of *Quercus ilex*-forest, *Pistacia lentiscus*, *Phillyrea* and open areas.

- St. 555: Torre Chianca, south of Bosco di Rauccio; N40°27'09.0" E18°11'57.6"; 3 m; 20/06/2011; moist area with *Carex* L., *Juncus*, Cyperaceae, Poaceae (Fig. 4).

- St. 556: Torre Chianca, Bosco di Rauccio; Specchia della Milogna; N40°28'09.6" E18°10'29.9"; 3 m; 21/06/2011; moist area with *Bolboschoenus* (Asch.) Palla in Hallier & Brand, *Carex*, *Tamarix* L., *Phragmites* Adans, *Juncus*, and dry ruderal area.

- St. 557: Torre Chianca, Bosco di Rauccio; N40°27'56.5" E18°10'07.8"; 7 m; 21/06/2011; forest of *Quercus ilex* with *Pistacia lentiscus*, *Phillyrea*, *Clematis* L., *Hedera* L. etc.

- St. 558: Torre Chianca, Bacino Idume; N40°28'08.0" E18°11'21.8"; 5 m; 21/06/2011; vegetation near the sea and the basin with *Elymus* L., *Phragmites*, etc.

- St. 559: Laghi Alimini, north of Lago Grande; N40°12'31.6" E18°25'41.4"; 10 m; 22/06/2011; moist area with *Juncus*, *Phragmites*, *Cyperus* L.

- St. 560: Laghi Alimini, Lago Piccolo; N40°10'50.9" E18°27'04.7"; 4 m; 22/06/2011; moist area with *Carex* (Fig. 8).

- St. 561: Torre Chianca, south of Bosco di Rauccio; N40°27'08.9" E18°11'57.4"; 6 m;



Figure 2. Bosco e Paludi di Rauccio: St. 552. Figure 3. Bosco e Paludi di Rauccio: St. 553. Figure 4. South of Bosco e Paludi di Rauccio: St. 555. Figure 5. South of Bosco e Paludi di Rauccio: St. 561. Figure 6. Le Cesine: St. 563. Figure 7. Le Cesine: St. 562. Figure 8. Laghi Alimini: St. 560. Figure 9. Porto Badisco: St. 564.

22/06/2011; open dry stony area, *Phillyrea*, Poaceae, *Carex*, *Rubus* L., thistles (Fig. 5).

- St. 562: Natural Reserve "Le Cesine"; N40°21'16.7" E18°20'26.2"; 4 m; 23/06/2011; shore of lagoon, *Phragmites*, *Bolboschoenus*, *Carex*, *Tamarix* (Fig. 6).

- St. 563: Natural Reserve "Le Cesine"; N40°21'03.9" E18°21'05.4"; sea level; 23/06/2011; shore of lagoon, *Bolboschoenus*, *Carex*, Cyperaceae (Fig. 7).

- St. 564: between Porto Badisco and Santa Cesarea; N40°04'08.0" E18°28'44.8"; 45 m; 24/06/2011; dry rocky area and small pine forest with *Brachypodium* P. Beauv., *Carex*, Poaceae (Fig. 9).

- St. 622: Natural Reserve "Le Cesine"; sea level; 17/04/2012; forest, shore of lagoon, shrubs, herbaceous vegetation.

- St. 623: West of Natural Reserve "Le Cesine"; N40°20'50.3" E18°19'33.8"; 20 m; 17/04/2012; olive grove, herbaceous vegetation with prevalently Fabaceae, Poaceae.

- St. 624: road S. Cataldo - Frigole; N40°23'38.6" E18°15'23.4"; 20 m; 17/04/2012; open dry area with Poaceae and maquis vegetation.

- St. 625: Torre Chianca, Bosco di Rauccio; N40°27'23.6" E18°10'00.7"; 6 m; 18/04/2012; meadow, herbaceous vegetation.

- St. 626: Torre Chianca, Bosco di Rauccio; N40°27'56.5" E18°10'07.8"; 7 m; 18/04/2012; forest of *Quercus ilex* with *Pistacia lentiscus*, *Phillyrea*, *Clematis*, *Hedera* etc.

- St. 627: Torre Chianca, south of Bosco di Rauccio; N40°27'09.0" E18°11'57.6"; 3 m; 18/04/2012; moist area with *Mentha* L., *Carex*, *Juncus*, Cyperaceae, Poaceae.

- St. 628: coast between Frigole and Torre Chianca; N40°27'33.8" E18°12'50.9"; 2 m; 18/04/2012; open area near seashore with Poaceae, *Carex*, herbaceous vegetation.

In the "List of collected specimens" are indicated for each species: the collection locality and in parentheses the number of males, females and (if present) nymphs, separated by semicolon, respectively. For some species brachypterous (b) and macropterous (m) specimens are listed separately; if both forms were present they are divided by comma. New records for Italy are indicated by NI, new records for peninsular Italy ("S" in D'Urso, 1995a) by NPI, and new records for Apulia by NRA.

## RESULTS

### List of collected specimens

#### Familia CIXIIDAE

*Pentastiridius suezensis* (Matsumura, 1910)  
555 (1; 0) 558 (1; 0) 562 (26; 13) 563 (1; 1)

#### Familia DELPHACIDAE

*Asiraca clavicornis* (Fabricius, 1794)  
552 (0; 1) 627 (0; 1)

*Kelisia guttula* (Germar, 1818)  
556 (1; 1)

*Kelisia guttulifera* (Kirschbaum, 1868)  
552 (1; 0) - NRA

*Kelisia* gr. *ribauti* Wagner, 1938  
559 (2; 3) 628 (1; 0) - NPI

*Stenocranus fuscovittatus* (Stål, 1858)  
556 (1; 1) - NRA

*Stenokelisia angusta* Ribaut, 1934  
554 (1; 0) 555 (7; 3; 9) 556 (0; 1) 560 (6; 0; 2)

*Eurysanoides rubripes* (Matsumura, 1910)  
624 (3b; 5b) - NRA

*Delphax inermis* Ribaut, 1934  
555 (0; 1b) - NRA

*Delphax meridionalis* (Haupt, 1924)  
556 (1; 0) - NI

*Euides basilinea* (Germar, 1821)  
562 (1m; 0) - NPI

*Chloriona glaucescens* Fieber, 1866  
558 (2m; 0) 562 (3m; 1m) - NPI

*Chloriona sicula* Matsumura, 1910  
553 (8m; 3b, 4m) 554 (4m; 2b) 555 (14m; 4b, 2m; 1) 558 (1m; 0) 559 (11m; 2m) 627 (12m; 2b) - NRA

*Laodelphax striatella* (Fallén, 1826)  
552 (0; 2m) 553 (1m; 0) 559 (2m; 3m) - NRA

***Delphacodes capnodes*** (Scott, 1870)

555 (1m; 0) - NI

***Muirodelphax aubei*** (Perris, 1857)

556 (2b, 1m; 1b, 2m), 558 (7b; 3b; 2) 624 (0; 1b) 628 (0; 1b)

***Florodelphax leptosoma*** (Flor, 1861)

556 (0; 1b) 559 (4b, 2m; 4b, 2m) - NRA

***Toya obtusangula*** (Linnavuori, 1957)

553 (1m; 1m)

***Toya propinqua*** (Fieber, 1866)

552 (1m; 1m) 559 (3m; 2m) 564 (3m; 0) 623 (1m; 0) - NRA

***Flastena fumipennis*** (Fieber, 1866)

559 (1b; 1b) - NRA

Fam ilia TROPIDUCHIDAE

***Trypetimorpha*** sp.

556 (0; 0; 1) - NRA

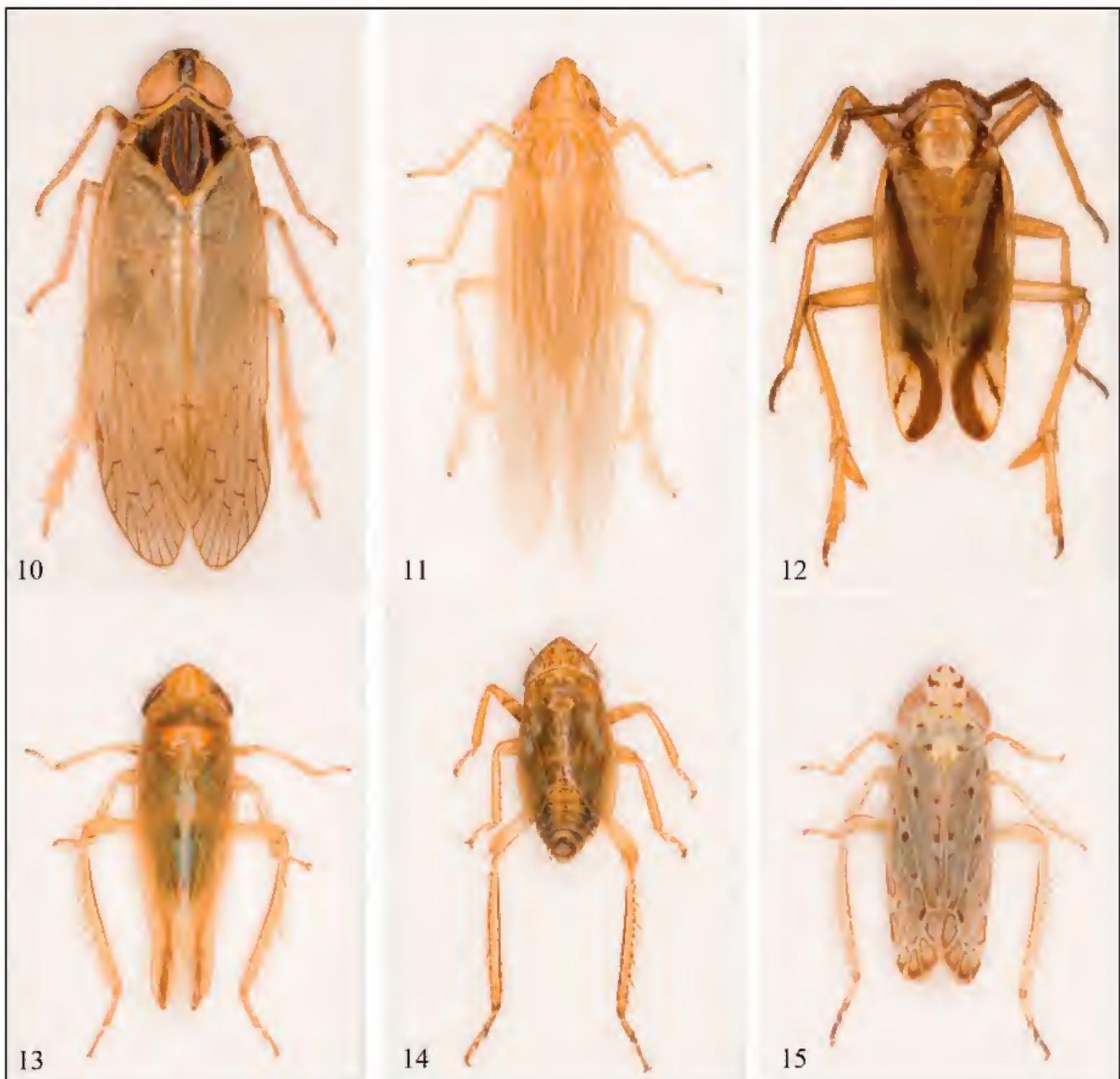


Figure 10. *Pentastiridius suezensis*. Figure 11. *Stenokelisia angusta*. Figure 12. *Delphax meridionalis*. Figure 13. *Mocydiopsis oranensis*. Figure 14. *Melillaia desbrochersi*. Figure 15. *Adarrus reductus*. Photos by Massimo Vollaro.

## Fam ilia CALISCELIDAE

*Caliscelis bonellii* (Latreille, 1807)

561 (1; 0)

*Homocnemia albovittata* A. Costa, 1857

556 (0; 0; 1)

*Peltonotellus quadrivittatus* (Fieber, 1876)

564 (0; 1)

*Ommatidiotus dissimilis* (Fallén, 1806)

556 (0; 0; 1) 628 (0; 0; 2) - N R A

## Fam ilia ISSIDAE

*Agalmatium bilobum* (Fieber, 1877)

552 (1; 0)

*Agalmatium flavescens* (Olivier, 1791)

552 (2; 1) 561 (1; 0)

*Issus lauri* Ahrens, 1818

552 (0; 1) 554 (6; 1) 557 (2; 4) 622 (2; 0; 2)

*Latissus dilatatus* (Fourcroy, 1785)

557 (2; 1)

## Fam ilia CERCOPIDAE

*Cercopis sanguinolenta* (Scopoli, 1763)

624 (2; 0) 625 (3; 1)

## Fam ilia APHROPHORIDAE

*Lepyronia coleoptrata* (Linnaeus, 1758)

553 (1; 1) 554 (2; 0) 555 (0; 1) 556 (1; 0) 562 (2; 0)

*Neophilaenus campestris* (Fallén, 1805)

552 (0; 1) 557 (0; 1) 564 (1; 1)

*Neophilaenus lineatus* (Linnaeus, 1758)

559 (9; 1) 561 (5; 1) 564 (1; 0) 622 (0; 1)

*Philaenus spumarius* (Linnaeus, 1758)

552 (0; 2) 554 (1; 0) 557 (1; 0) 624 (0; 1) 625 (2; 3)

## Fam ilia CICADELLIDAE

*Agallia consobrina* Curtis, 1833

552 (0; 1) 557 (3; 13)

*Anaceratagallia laevis* (Ribaut, 1935)

552 (2; 2) 556 (3; 4) 559 (3; 0) 562 (3; 0) 564 (2; 2)

*Austroagallia sinuata* (Mulsant et Rey, 1855)

552 (0; 2) 553 (1; 1) 558 (8; 3) 564 (0; 5) 625 (0; 2)

*Bugraia ocularis* (Mulsant et Rey, 1855)

552 (1; 1) 554 (1; 2) 557 (2; 2; 1) 622 (2; 13) 626 (0; 7)

*Hecalus storai* (Lindberg, 1936)

561 (2; 0) - N P I

*Stegelytra* cf. *erythroneura* Haupt, 1924

557 (0; 0; 1) - N R A

*Empoasca alsiosa* Ribaut, 1933

628 (1; 2) - N R A

*Lindbergina (Youngiada)* sp.

557 (0; 9) - N R A

*Ribautiana tenerrima* (Herrich-Schäffer, 1834)

554 (0; 1) - N R A

*Eupteryx thoulessi* Edwards, 1926

622 (1; 0) - N R A

*Eupteryx zelleri* (Kirschbaum, 1868)

564 (1; 6) 622 (0; 1) 624 (1; 0)

*Zyginidia adamczewskii* Dworakowska, 1970

564 (2; 0) - N R A

*Zyginidia* gr. *ribauti* Dworakowska, 1970

552 (20; 18) 553 (2; 4) 554 (2; 2) 556 (1; 2) 561 (0; 1)

559 (7; 13) 562 (2; 1) 564 (9; 0) 624 (1; 1) 628 (7; 3)

*Arboridia parvula* (Boheman, 1845)

552 (1; 1)

*Grypotes staurus* Ivanoff, 1885

557 (3; 4; 2)

*Opsius lethierryi* Wagner, 1942

556 (3; 0) 562 (1; 3)

*Opsius stactogalus* Fieber, 1866

555 (1; 5) 556 (2; 0)

*Nealiturus fenestratus* (Herrich-Schäffer, 1834)

552 (0; 1) 553 (0; 1) 556 (1; 0) 559 (0; 2)

*Circulifer* sp.

552 (0; 1)

*Balclutha nicolasi* (Lethierry, 1876)

559 (6; 10; 1) - N R A

*Balclutha rosea* (Scott, 1876)

553 (0; 1) 562 (0; 1) - N R A

*Macrosteles ossiannilssoni* Lindberg, 1954  
555 (1; 3) - N R A

*Macrosteles quadripunctulatus* (Kirschbaum, 1868)  
623 (2; 1)

*Maiestas* sp.  
557 (0; 2) 559 (0; 1)

*Varta rubrostriata* (Horváth, 1907)  
554 (7; 4) - N R A

*Doratura* gr. *paludosa* Melichar, 1897  
556 (1; 2) 564 (2; 1; 1)

*Fieberiella florii* (Stål, 1864)  
552 (0; 1) 554 (0; 1) 557 (1; 0; 1)

*Synophropsis lauri* (Horváth, 1897)  
557 (1; 0) - N R A

*Anoplotettix* sp.  
552 (0; 1)

*Selenocephalus stenopterus* Signoret, 1880  
561 (1; 0)

*Cicadula lineatopunctata* (Matsumura, 1908)  
559 (4; 7) - N R A

*Mocydia crocea* (Herrich-Schäffer, 1837)  
627 (0; 1)

*Mocydiopsis oranensis* (Matsumura, 1908)  
561 (4; 4)

*Thamnotettix dilutior* (Kirschbaum, 1868)  
557 (1; 0)

*Thamnotettix zelleri* (Kirschbaum, 1868)  
623 (7; 8; 7)

*Conosanus obsoletus* (Kirschbaum, 1858)  
552 (1; 0) 553 (2; 5) 555 (2; 4) 556 (2; 3) 559 (0; 2)

*Euscelis alsius* Ribaut, 1952  
553 (1; 0) - N R A

*Euscelis lineolatus* Brullé, 1832  
552 (10; 10) 553 (5; 0) 554 (2; 4) 555 (1; 0) 556 (1; 2)  
557 (5; 6) 559 (7; 5) 564 (3; 1)

*Streptanus josifovi* Dlabola, 1957  
624 (5; 11) 626 (2; 2)

*Artianus manderstjernii* (Kirschbaum, 1868)  
556 (2; 0)

*Melillaia desbrochersi* (Lethierry, 1889)  
623 (32; 17) 624 (0; 1) 626 (1; 5) - N P I

*Paramesus obtusifrons* (Stål, 1853)  
553 (9; 3) 555 (1; 2) 556 (2; 3) 562 (8; 2; 1) 563 (5; 2)

*Parapotes reticulatus* (Horváth, 1897)  
563 (10; 3) - N I

*Paralimnus phragmitis* (Bohemán, 1847)  
555 (1; 2) 556 (1; 2) 562 (2; 14) - N R A

*Psammotettix alienus* (Dahlbom, 1850)  
552 (6; 6) 553 (2; 9) 554 (0; 7) 556 (0; 2) 558 (2; 3) 559  
(11; 0) 562 (2; 0) 564 (7; 8) 622 (7; 7) 623 (5; 2) 624 (3;  
2) 625 (3; 1) 627 (1; 0) 628 (18; 18; 18)

*Psammotettix confinis* (Dahlbom, 1850)  
559 (4; 0)

*Adarrus reductus* (Melichar, 1897)  
561 (25; 22) 564 (17; 9) 627 (0; 1)

*Jassargus latinus* (Wagner, 1942)  
624 (0; 1)

*Arthaldeus striifrons* (Kirschbaum, 1868)  
556 (0; 3) - N R A

*Calamotettix taeniatus* (Horváth, 1911)  
562 (2; 14) - N I

### *The investigated areas*

1. Bosco di Rauccio and adjacent areas (St. 552-558, 561, 625-627) (Figs. 2-5): 67 taxa collected.

The high number of collected species is due to the major collecting intensity in relation to the other two investigated areas. Ten localities with different ecological features were studied, two of them in two different seasons. Particular importance have the reed areas with six species of *Phragmites* feeders, among them *Pentastiridius suzeensis*, *Chloriona glaucescens*, *Delphax inermis* and *D. meridionalis*.

In other moist areas, characterized by Cyperaceae and Juncaceae, further interesting species were discovered: *Stenokelisia angusta*, *Delphacodes capnodes*, *Ommatidiotus dissimilis* (all on *Carex* spp.), *Florodelphax leptosoma* (on *Juncus*), *Toya*

*obtusangula* (on Poaceae?) and *Eupteryx thoulessi* (on *Mentha aquatica* L.). *Varta rubrostriata* lives on tussocks of a tall Poaceae species (probable *Erianthus ravennae*) which is present on field margins west of Specchia della Milogna. In the central forest area nine (unfortunately female) specimens of an interesting Typhlocybinae species, *Lindbergina (Youngiada)* sp., were collected on *Quercus ilex*, and the brachypterous Deltocephalinae *Melillaia desbrochersi* on the low vegetation of small clearings. The dry areas south of the Natural Reserve with a garigue like vegetation furnished very interesting results as well. Among other species there were found *Adarrus reductus*, *Hecalus storai* and *Mocydiopsis oranensis*.

2. Le Cesine and adjacent areas (St. 562, 563, 622, 623) (Figs. 6, 7): 22 taxa collected.

Only four localities in this area were investigated. Again, the reed areas along the lagoons are particularly rich of interesting Auchenorrhyncha: on *Phragmites* the following species were collected: *Pentastiridius suezensis*, *Euides basilinea*, *Chloriona glaucescens*, *Paralimnus phragmitis* and *Calamotettix taeniatus*. *Parapotes reticulatus* was found not far from the *Phragmites* sites on *Schoenoplectus lacustris*, *Eupteryx thoulessi* on *Mentha aquatica*. A rich population of *Melillaia desbrochersi* was collected in spring on the herbaceous vegetation of an olive grove.

3. Laghi Alimini (St. 559, 560) (Fig. 8): 18 taxa collected.

Only two sites were studied in this area. A rich population of *Stenokelisia angusta* was observed on tall sedges near the reed belt around Lago Piccolo. *Kelisia* gr. *ribauti* (on *Carex* sp.), *Florodelphax leptosoma* (on *Juncus*), *Flastena fumipennis* and *Balclutha nicolasi* (on *Cyperus*) were collected in a moist area with different small Cyperaceae and Juncaceae.

### Observations on some taxa of special interest

***Pentastiridius suezensis*** (Matsumura, 1910)  
(St. 555, 558, 562, 563) (Fig. 10)

All *Pentastiridius* specimens collected in 2011/2012 in Apulia (and a population found some years before in northern Apulia, province of Foggia, Lago di Lesina) belong to this taxon. Their aedeagus

shape corresponds to the figures given by Van Stalle (1991), and by Wagner (1954), who probably had seen the type material. The species shares apparently the ecological preferences with *P. leporinus* (Linnaeus, 1761) and was found in abundance on *Phragmites australis* in coastal lagoon areas and similar habitats.

In D'Urso (1995a) the presence of this species in Italy is regarded as doubtful with records of *Oliarus pallens* (Germar, 1821) possibly referring to *P. suezensis*. All *Pentastiridius* Kirschbaum, 1868 specimens we collected in other parts of Italy including Sardinia and all *Pentastiridius* specimens in the Servadei collection under the name *Oliarus leporinus* L. and *O. pallens*, which were checked by the authors, belong to *P. leporinus*. Thus, it seems that *P. suezensis* is present only in a part of southeastern Italy, where it replaces *P. leporinus*, which is present and common in all other regions of peninsular Italy. *P. suezensis* is described from Egypt, and has a wide distribution primarily in many parts of southern, southeastern and eastern Europe, but also in Africa and Asia until India and Philippines (Van Stalle, 1991).

Until now, there are unresolved taxonomical problems in this species group (see Holzinger et al., 2003, Webb et al., 2013).

***Kelisia* gr. *ribauti*** Wagner, 1938  
(St. 559, 628)

There are some doubts about the identity of *Kelisia ribauti* in Central Europe and the populations in the Mediterranean regions (see Guglielmino et al., 2005). Italian populations of this species group were found in many different habitats from localities near the seashore until moderately high mountain areas, always in moist environments on different small *Carex* species. At least at low altitude they hibernate in the adult stage.

***Stenocranus fuscovittatus*** (Stål, 1858)  
(St. 556) (Fig. 16) - NRA

Species widely distributed in the Palaearctic region. In Italy it is recorded from Trentino Alto Adige (Servadei, 1967), Veneto (Minelli & Mannucci, 1979), Lazio (Castellani, 1953). The record for Lazio is doubtful and may refer rather to *S. major* (Kirschbaum, 1868). In Apulia the species is found in marshes on tall sedges. This is in congruence with the observations in Nickel (2003).



Figure 16. *Stenocranus fuscovittatus*. Figure 17. *Euides basilinea*. Figure 18. *Chloriona glaucescens*. Figure 19. *Delphacodes capnodes*. Figure 20. *Ommatidiotus dissimilis*. Figure 21. *Varta rubrostriata*. Figure 22. *Parapotes reticulatus*. Figure 23. *Calamotettix taeniatus*. Photos Gernot Kunz.

***Stenokelisia angusta*** Ribaut, 1934

(St. 554, 555, 556, 560) (Fig. 11) - NPI

The species is recorded from Sicily (Asche, 1985) and Sardinia (Guglielmino et al., 2000). It is indicated in Della Giustina & Remane (1991) as thermo-xerophilous and feeding possibly on *Carex flacca* Schieber. Habitat and host plant of the populations found in Apulia do not coincide with this characterization. The host plant in Apulia is a tall sedge like *Carex acutiformis* Ehrh., the habitats are moist areas in marshes. In Sardinia the species was found in a spring fen at an altitude of about 1000 m.

***Delphax inermis*** Ribaut, 1934

(St. 555) - NRA

The species is widely distributed in the Mediterranean area. In Italy it seems to be rather rare and is recorded only from Lazio and Sicily (Servadei, 1968; D'Urso, 1995a). The record for Lazio should be confirmed. The host plant is *Phragmites australis*.

***Delphax meridionalis*** (Haupt, 1924)

(St. 556) (Fig. 12) - NI

This species is recorded until now only from Greece. In Italy it is replaced apparently by the close related *D. ribautianus* Asche et Drosopoulos, 1982. The new record for Italy represents one of several examples in which taxa present on the Balkan Peninsula occur also in southern or south-eastern Italy. The specimen in Apulia was collected on *Phragmites australis* in a marsh area.

***Euides basilinea*** (Germar, 1821)

(St. 562) (Fig. 17) - NPI

Also this species is a *Phragmites* feeder. In Italy it was recorded until now only from Trentino Alto Adige (Servadei, 1968) and Veneto-Lombardia (Osella, Pagliano-Osella, 1989). The specimen from Apulia was found on the shore of a lagoon together with *Pentastiridius suezensis*, *Chloriona glaucescens* and *Calamotettix taeniatus*.

***Chloriona glaucescens*** Fieber, 1866

(St. 558, 562) (Fig. 18) - NPI

The species is distributed in Europe (except for the Iberian Peninsula) and in Central Asia. In Italy it is recorded by Servadei (1967) from Trentino Alto Adige. This record is dubious in view of the preference of this *Chloriona* Fieber, 1866 species for

brackish habitats. The habitats in Apulia were reeds on the seashore or along the shore of lagoons. Host plant is *Phragmites australis*.

***Delphacodes capnodes*** (Scott, 1870)

(St. 555) (Fig. 19) - NI

The species is widely distributed in central and southeastern Europe. Tall sedges are recorded as host plants. This coincides with our observations in Apulia.

***Trypetimorpha*** sp.

(St. 556) - NRA

Only one nymph was collected from this genus, the identification of which at species level is at present impossible. In the past there was some nomenclatural confusion in this genus (see Huang & Bourgoïn, 1993; Guglielmino et al., 2005). In Italy, two *Trypetimorpha* Costa 1862 species are present: *T. occidentalis* Huang et Bourgoïn, 1993 widespread and common in Central Italy, and *T. fenestrata* Costa, 1862 described from Campania and recorded also from Basilicata by Servadei (1967; as *T. pilosa* Horváth, 1907 now a synonym of *T. fenestrata*). We checked the specimens from Basilicata in the Servadei-collection and confirmed the identification as *T. fenestrata*.

***Ommatidiotus dissimilis*** (Fallén, 1806)

(St. 556, 628) (Fig. 20) - NRA

The species is widespread in the Palaearctic region. In the past it was considered tyrophophilous and monophagous on *Eriophorum vaginatum* L. (Nickel, 2003). However, in the meantime it was found also on other *Eriophorum* L. taxa and on several *Carex* species in quite diverse habitats. In Italy it is recorded from Trentino Alto Adige and Veneto (Servadei, 1967), Toscana (Mazzoni, 2005), Abruzzo and Lazio (Guglielmino et al., 2005). Host plants in Apulia are small sedges in moist areas near the coast. This coincides with the habitats in Lazio. In Abruzzo, however, the species was found on dry mountain pastures at an altitude of 1900 m (on *Carex* cf. *kitaibeliana* Degen ex Bech.). No morphological differences were observed between these different populations.

***Hecalus storai*** (Lindberg, 1936)

(St. 561) - NPI

The species is described from the Canary Islands and recorded also from France. Our identi-

fication is based on Ribaut's description and figures. In Italy there is only a record from Sicily (Pantelleria) (D'Urso & Guglielmino, 1995). *Hecalus* Stål, 1864 species may be rather variable in size and vertex shape, whereas there are only slight differences in the genital morphology. Therefore it is difficult to define specific characters. Linnavuori (1975) made an important contribution to the knowledge of the genus, but many problems are left. The specimens in Apulia were found in a dry and stony habitat south of Bosco di Rauccio.

***Stegelytra* cf. *erythroneura* Haupt, 1924**

(St. 557) - NRA

Until now this genus was not recorded for Apulia. We found only one nymph (on *Quercus ilex*). The authors collected in central and Southern Italy (and Sardinia) only *S. erythroneura* (on *Quercus ilex* and *Q. cerris* L.). Probably also the nymph from Bosco di Rauccio belongs to this taxon. The other *Stegelytra* Ghauri 1972 taxon present in Italy, *S. putoni* (Mulsant et Rey, 1875), was collected by the authors in Liguria (on *Q. ilex*) (Guglielmino & Bückle, 2007), and was later recorded by Mazzoni (2005) from Toscana.

***Lindbergina (Youngiada)* sp.**

(St. 557) - NRA

No species of *Youngiada* Dlabola, 1959 was recorded before from Apulia. We collected only females, an identification of which on species level is not possible. They present the same colouration as a female collected in Southern Lazio (Guglielmino et al., 2005) and were found like the specimen from Lazio on *Quercus ilex*. In Italy until now two species of this subgenus are recorded: *Lindbergina loewi* (Lethierry, 1884), a doubtful record from Friuli Venezia Giulia, (see D'Urso, 1995a) and *L. chobauti* (Ribaut, 1952) (Vidano & Arzone, 1987; Mazzoni, 2005).

***Zyginidia adamczewskii* Dworakowska, 1970**

(St. 564) - NRA

The species is described from Croatia and recorded also from Greece (Drosopoulos et al., 1986). The first and only record in Italy is from Campania (Vidano, 1982). Vidano (1982) indicates *Cynodon dactylon* (L.) Pers., *Agropyron repens* (L.) P. Beauv. and other Poaceae as host plants. The specimens in Apulia were collected in a dry rocky garigue like habitat.

***Zyginidia* gr. *ribauti* Dworakowska, 1970**

(St. 552–554, 556, 5559, 561, 562, 564, 624, 628)

Very common taxon throughout peninsular Italy; it is replaced in Sardinia by *Z. scutellaris* (Herrich-Schäffer, 1838), and in Northern Italy partly by *Z. pullula* (Boheman, 1845). The relationships between *Z. ribauti*, *Z. serpentina* (Matsumura, 1908) and *Z. italica* (Ribaut, 1947) should be clarified (see also Guglielmino et al., 2005). *Z.* gr. *ribauti* displays a remarkable variability in its aedeagus morphology, not only between different populations, but also within the same population.

***Circulifer* sp.**

(St. 552)

Only one female of this genus was collected in a maquis like area of Bosco di Rauccio. The genus (often inserted in *Neoliturus* Distant, 1918) is very problematic in respect of species discrimination. Italian populations are quite diverse in colouration and size. However, no distinct differences in the genital morphology of males and females were observed. In males, the shape of the genital plates corresponds to that given by Ribaut (1952) for *C. haematoceps* (Mulsant et Rey, 1855). The habitats are generally dry places in low and median altitude, also sandy seashores. The host plants are in some cases apparently *Cistus* sp., in others Chenopodiaceae. In Germany *Circulifer* cf. *haematoceps* was found on *Sedum* L. (Crassulaceae) (Nickel, pers. comm.).

***Maiestas* sp.**

(St. 557, 559)

The females of this genus found during our study in Apulia belong with great probability to *M. schmidtgeni* (Wagner, 1939), which is very widespread and common in dry ruderal lowland places in peninsular Italy.

***Varta rubrostriata* (Horváth, 1907)**

(St. 554) (Fig. 21) - NRA

After the revision of the *Varta-Stymphalus* generic complex (Viraktamath, 2004) the distribution of *V. rubrostriata* should be checked. In Italy it is recorded from Lazio and Basilicata (Servadei, 1967). The presence in both regions was confirmed by the authors. The host plants in Italy are apparently *Erianthus ravennae* (L.) P. Beauv. and *Imperata cylindrica* (L.) P. Beauv., in Bulgaria and Greece it occurs also on *Sorghum halepense* (L.) Pers.

***Doratura* gr. *paludosa*** Melichar, 1897  
(St. 556, 564)

The group of species close to *D. paludosa* is in need of revision. A paper on the topic is in preparation. The *Doratura* J. Sahlberg, 1871 populations found in southern Apulia belong to the same species that is found in other Adriatic parts of peninsular Italy. In the past those populations were recorded sometimes as *D. paludosa*, sometimes as *D. veneta* Dlabola, 1959.

***Mocydiopsis oranensis*** (Matsumura, 1908)  
(St. 561) (Fig. 13)

Westmediterranean species, in Italy recorded only from Apulia (Gargano) and Sicily (Guglielmino, 1993). A small localized population was found during the recent study in Apulia in a dry and stony garigue like habitat together with *Adarrus reductus* (Melichar, 1897).

***Melillaia desbrochersi*** (Lethierry, 1889)  
(St. 623, 624, 626) (Fig. 14) - NPI

Mediterranean species, in Italy recorded only from Sicily (D'Urso, 1995b). In Apulia, we collected it only in spring. It was found in an olive grove near the Natural Reserve "Le Cesine", and in the Natural Park "Bosco e Paludi di Rauccio" in a ruderal place and on some small clearings. Probably the species is widespread and not uncommon in southern Italy, but until now it was never found because of its particular life cycle: adults occur only in the early (and late?) parts of the year.

***Parapotes reticulatus*** (Horváth, 1897)  
(St. 563) (Fig. 22) - NI

The discovery of this species in Apulia was quite unexpected. It is distributed in several countries of central, northern and southeastern Europe, including Ex-Yugoslavia. As host plants are recorded *Schoenoplectus lacustris* (L.) Palla and possibly *S. tabernaemontani* (Gmel.) Palla (Nickel, 2003). A quite abundant population of this species was found in the lagoon area of the Natural Reserve "Le Cesine", on *Schoenoplectus lacustris*.

***Adarrus reductus*** (Melichar, 1897)  
(St. 561, 564, 627) (Fig. 15)

The species is described from Croatia. In Italy it is recorded only from Apulia (Servadei, 1967). It was collected in two very dry stony garigue like sites (south of Bosco di Rauccio and near Porto Badisco).

***Calamotettix taeniatus*** (Horváth, 1911)  
(St. 562) (Fig. 23) - NI

The species is recorded from central and eastern Europe. In Apulia, it was found on the shore of the Pantano Grande in the Natural Reserve "Le Cesine" on its host plant, *Phragmites australis*, in moderately high abundance.

## CONCLUSIONS

During our research in Apulia 84 Auchenorrhyncha species were found on the whole. Four species (*Delphax meridionalis*, *Delphacodes capnodes*, *Parapotes reticulatus* and *Calamotettix taeniatus*) are recorded for the first time for Italy, five (*Stenokelisia angusta*, *Euides basilinea*, *Chloriona glaucescens*, *Hecalus storai* and *Melillaia desbrochersi*) are new records for the Apennine Peninsula ("S" in the checklist of the Italian fauna), and 26 are new records for Apulia (*Kelisia guttulifera*, *Stenocranus fuscovittatus*, *Eurysanoides rubripes*, *Delphax inermis*, *Chloriona sicula*, *Laodelphax striatella*, *Florodelphax leptosoma*, *Toya propinqua*, *Flastena fumipennis*, *Trypetimorpha* sp., *Ommatidiotus dissimilis*, *Stegelytra* cf. *erythroneura*, *Empoasca alsiosa*, *Lindbergina* (*Youngiada*) sp., *Ribautiana tenerrima*, *Eupteryx thoulessi*, *Zyginidia adamczewskii*, *Balclutha nicolasi*, *B. rosea*, *Macrosteles ossiannilssoni*, *Varta rubrostriata*, *Synophropsis lauri*, *Cicadula lineatopunctata*, *Euscelis alsius*, *Paralimnus phragmitis*, *Arthaldeus striifrons*).

The high number of new records for Apulia, and the fact that some of these records regard species that are widespread and quite common throughout Italy, show that the knowledge on this region is presently very scarce. In addition to the here presented data, many further research is necessary to achieve to a sufficient understanding of the Auchenorrhyncha fauna in southeastern Italy.

Even if the three studied areas furnished very important results, we are far from an approximately complete knowledge on the Auchenorrhyncha of these areas. Additional investigations should include more localities, biotopes and collecting seasons.

The distribution of some taxa collected during our recent study in Apulia is particularly interesting: Apparently these species are present only in the Balkan region and in South Italy. *Delphax meridionalis* was considered an endemic species of

Greece before it was discovered in Apulia; *Adarrus reductus* is recorded only from Croatia and Apulia; and *Zyginidia adamczewskii* is known from Croatia, Greece and South Italy (Campania, Apulia). In contrast to these three cases, other taxa display a wide distribution in Europe. In Italy, however, they were found until now only in Apulia and not in the central and northern parts of this country. This group includes *Pentastiridius suezensis*, *Calamotettix taeniatus*, *Parapotes reticulatus* and *Delphacodes capnodes*. We may add *Chloriona glaucescens* as well, a halophilous species, the record of which from Trentino Alto Adige (Servadei, 1967) is probably erroneous. A molecular study of these species in order to clarify the relationships between populations from central Europe, southern Italy and the Balkan region would be very interesting.

Unlike most other regions of Italy, a great part of Apulia consists of plains and low hills, which nowadays are almost completely cultivated. Thus, moist habitats (freshwater lakes or springs and brackish lagoons), and the dry maquis and garigue areas, have become extremely rare and harbour the last relics of a flora and fauna, which in former times were typical for the whole region, but are now nearly extinct. The protection at least of the few natural sites left is therefore of particular importance. Each of the three investigated areas has its own special characteristics, each is unique but fragile and vulnerable.

In the case of the Natural Park of "Bosco e Paludi di Rauccio" we observed some negative impact of agricultural activity on the protected area. Whereas the central *Quercus ilex* forest and the Specchia della Milogna area in the northeastern sector of the reserve display more or less safe conditions, there are other zones around the forest and above all in the southwestern part of the Natural Park that seem to be conspicuously compromised. Apparently, the main problem consists in frequent arsons of vast extension, easily visible in recently burnt *Carex* meadows, but also in green areas where a glance at the soil between the fresh grasses revealed everywhere the black charred remnants of the plants burnt in the years before. The almost completely black colouration of populations of *Lepyronia coleoptrata* specimens in these areas may be interpreted as adaptive character to these particular conditions (a similar case is documented in *Philaenus spumarius* from Great Britain (Wilson, pers. comm.).

Finally we point out the interesting area south of Bosco di Rauccio, off the Natural Park (St. 555, 561, 627). This site, consisting of quite extended wet meadows and reeds along a central channel and adjacent dry garigues, has a great value for plants, birds and insects. We think it very important to warrant the conservation of this habitat as a highly valuable addition to the nearby located Natural Park.

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## Presence's mapping of *Brachytrupes megacephalus* (Lefebvre, 1827) (Orthoptera Gryllidae) within the Natural Reserve of Vendicari (Noto, Siracusa, Italy)

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### ABSTRACT

*Brachytrupes megacephalus* (Lefebvre, 1827) (Orthoptera Gryllidae) is a species included in the Annexes II and IV of EU Directive 92/43 as taxon requiring strict protection. The authors summarize the researches aimed to recognize the localization of this species within the natural reserve of Vendicari, protected area along the south eastern Sicilian coast in the territory of Noto (province of Siracusa). The presence of the specimens was ascertained by detecting its holes on the soil surface. The holes position was recorded using GPS and utilized for mapping the presence of the species as tool for its protection management in the reserve territory.

### KEY WORDS

monitoring; wildlife management; protected areas; mapping.

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### INTRODUCTION

The *Brachytrupes megacephalus* (Lefebvre, 1827) (Orthoptera Gryllidae) (Figs. 1, 2), described on specimens from Sicily, is a South-Mediterranean species widespread in the sandy environments of Sicily, Aeolian Islands, Maltese Islands, southern Sardinia, Northern Africa (included the Saharan oases): it is an exclusively sandy adapted cricket.

This species is considered as a biodiversity element of particular interest thanks to its complex eco-biology. Previous works (see Conti et al., 2014) investigated the biological cycle, swimming ability and digging technique, reproductive mode, coupling pattern and more. Due to its current rarefaction in Europe, this species has been included

in the Annexes II and IV of EU Directive 92/43 as a species requiring strict protection.

The reserve of Vendicari lies in the south-eastern extremity of Sicily and is part of a vast wetlands system that is one of the most important of the island; it extends for about 8 km of coastline and 0.3-1.5 km inland and includes a series of different environments (sweet-water wetlands, coastal lagoons, garrigue scrubland, Mediterranean maquis) and a very rich biodiversity: a wide description of the reserve was edited by Petralia (2010). *B. megacephalus*, having been already monitored in Vendicari a little bit more than ten years ago (Petralia et al., 2003), is one of the main component of the arthropodological fauna in the reserve (Petralia & Russo, 2010).

This research was aimed to map the localization of the species in order to provide basic information useful to manage the protection of the species itself.

The study was carried out during the breeding season (from March to early May of 2012) when the digging activity of the specimens (surface active again after the winter suspension, for mate) is particularly intense and easily detectable: the location of individuals was carried out by detecting the position of the holes that the animals burrow into the sand and where the animals remain for most of their life, also where they die after spawning. The traces that indicate the presence of the animals are two (Figs. 3, 4): the mouths of the burrows and the little sandy cones occluding those; also the piercing sound-calls emitted by the males to attract the females provide further information about the presence of individuals.

The survey in the reserve was conducted in the sandy sectors of the A zone (integral reserve) in the potential habitats for the presence of *B. megacephalus* (Figs. 5, 6). The concerned areas are: 1, the

mouth of the Tellaro river (Eloro) at the extreme north of the reserve; 2, the sandy dunes of Calamosche; 3, the sandy south western area of the Vendicari island; 4, the southern dune belt where the GPS position of each detected burrow was recorded.

## RESULTS AND COMMENTS

The presence of the species was ascertained within the areas marked with numbers 1 and 4 (Fig. 6).

In the latter the GPS burrow records (290 in 18 ha) allowed to obtain the representation of the area where the species localizes (Fig. 7) using gvSIG program: the animals dwell exclusively on the sandy belt and do not intrude both the sandy beach (seaward) and inland; it is also possible to observe particular concentrations of burrows in the extreme north of the sandy belt (Fig. 8).

In the Vendicari island were not found specimens of the monitored species. Probably that is due



Figures 1, 2. Specimens of *B. megacephalus* photographed before their release: on the male's forewings (Fig. 1) is visible the stridulatory organ, absent on the female (Fig. 2). Figures 3, 4. Examples of burrow's mouth of *B. megacephalus* (Fig. 3) and little sandy cone that close the burrow on the soil surface (Fig. 4) (Photos by A. Petralia).

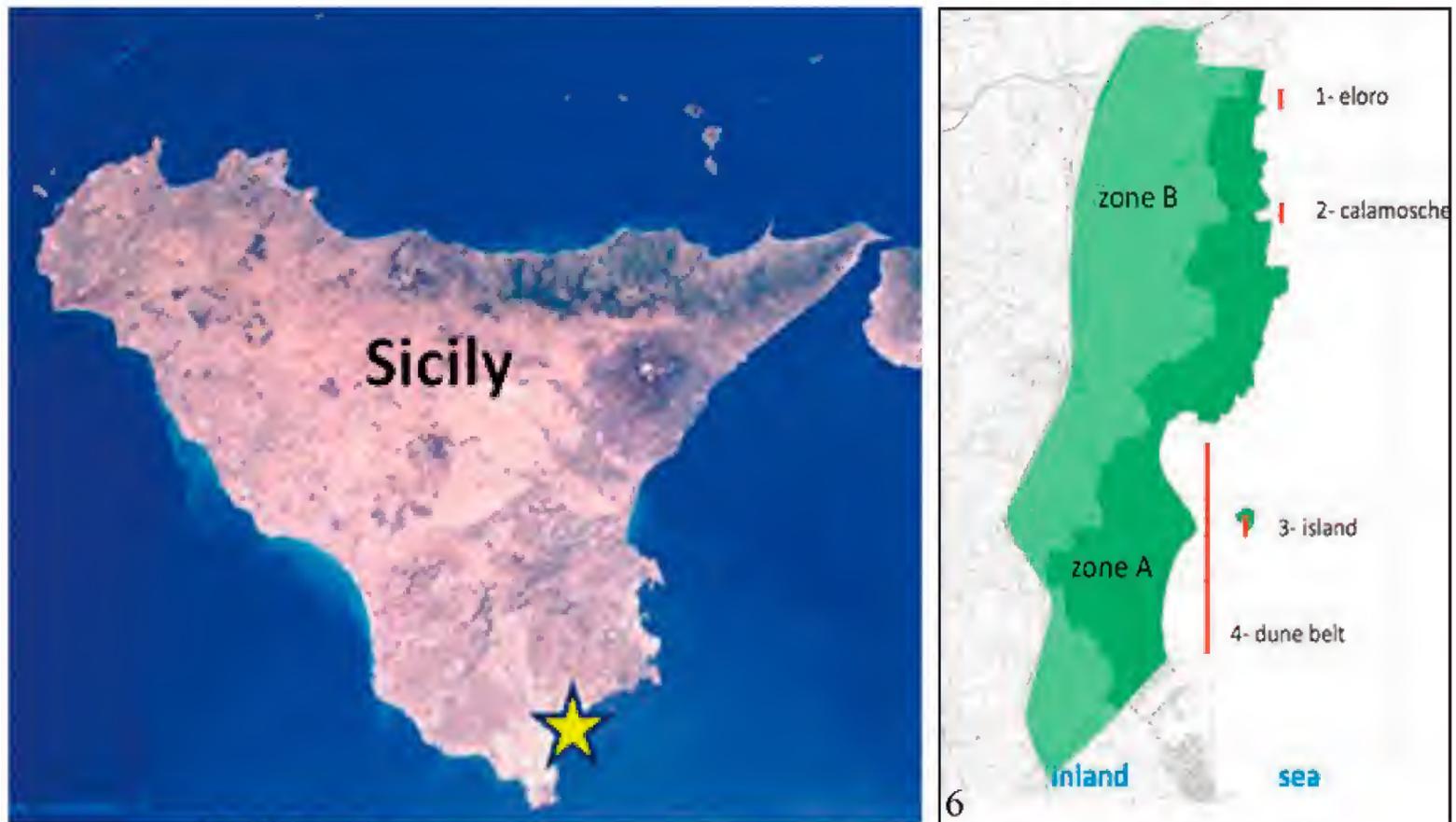


Figure 5. Localization (yellow star) of the reserve of Vendicari along the south western Sicilian coast. Figure 6. In dark-green the A zone of the reserve, in light-green the B zone; 1 to 4 the potential habitats of *B. megacephalus*.

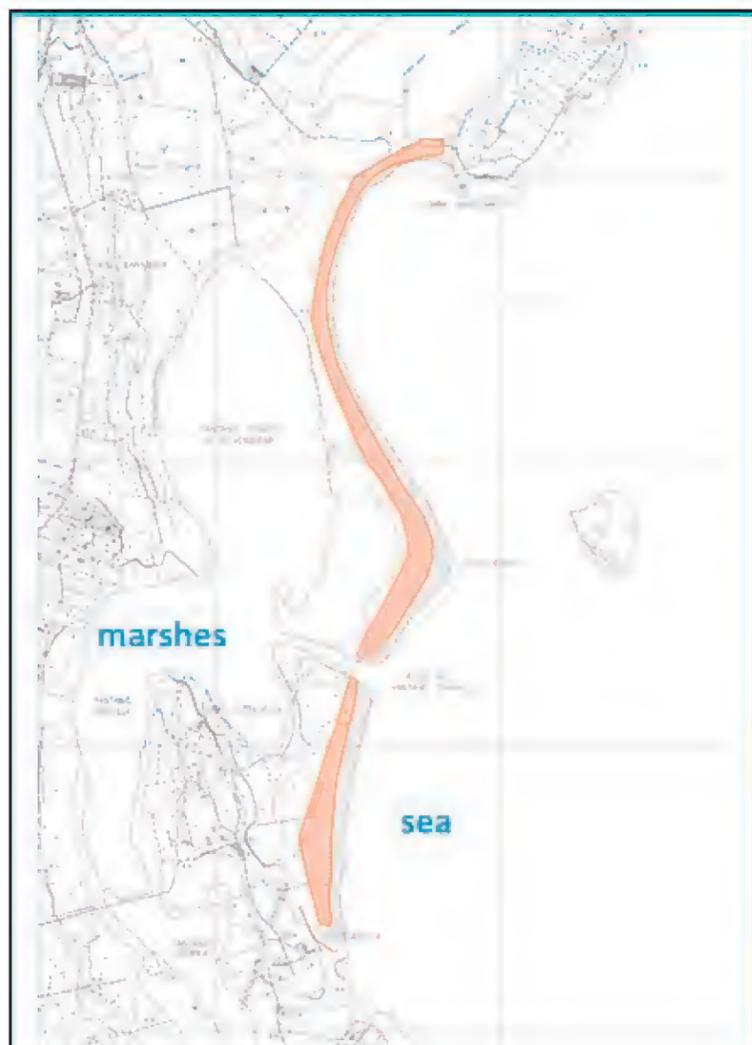


Figure 7. Mapping of the *B. megacephalus* presence along the dune belt in the southern part of the reserve of Vendicari.

to the not good condition of the sandy habitat: too narrow extension of the sandy surface in the island, too windy and not protected because of scarce vegetation, too brackish.

Also in the area marked with number 2 (Calamosche) the species was not detected: it is important to emphasize that in the previous monitoring carried out in 2003 (Petralia et al., 2003) the species was present in these sandy dunes. Probably the disappearance here of this species can be related with the strong anthropic pressure on the dunes just behind the beach of Calamosche: in particular the anarchic trampling on the sand (and the consequent destruction of nests, eggs and young specimens of *B. megacephalus* especially during the early stages of development) to reach the beach for swimming in the summer months, which increased over time, could have acted as a decisive factor in habitat degradation and, as consequence, in disappearance of the species.

We can conclude that the protection of *B. megacephalus* depends on a very severe protection of the stability of his habitat. The results of the mapping here described, indicate the areas in which is opportune to concentrate the actions aimed to ensure the safeguard of the species: firstly a very strict prevention

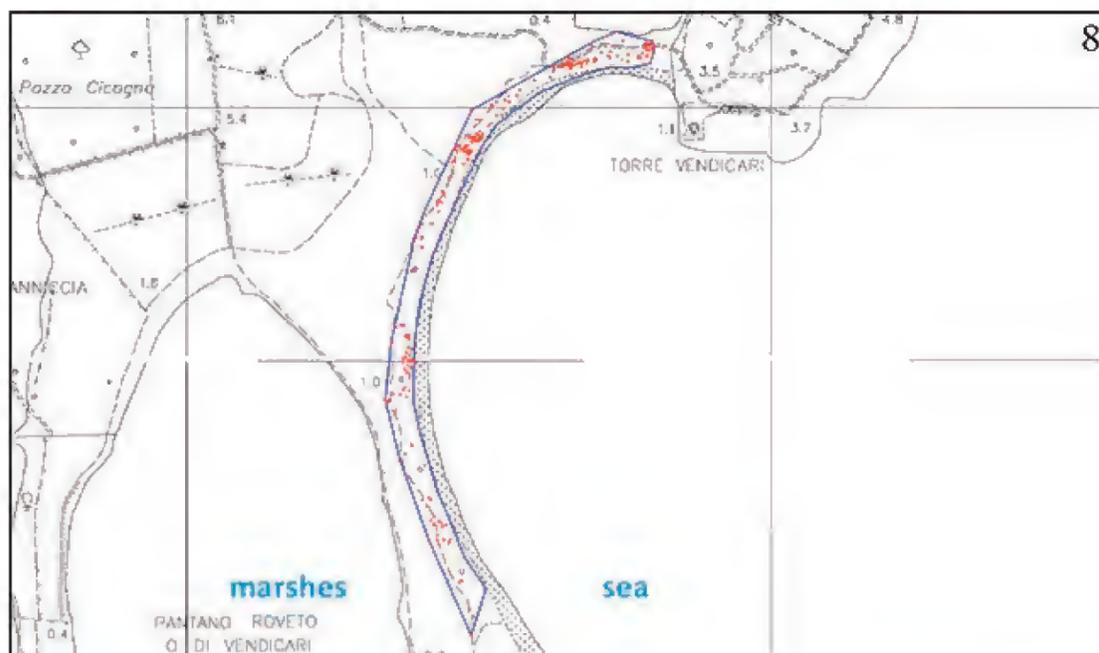


Figure 8. Northern sector of the dune belt referred to the Fig. 4 to show the particular concentrations of burrows highlighted by red dots.

Figure 9. Calamosche in winter (photo by [www.ternioggi.it](http://www.ternioggi.it)) and in summer (Figure 10, photo by [www.itineraricamper.it](http://www.itineraricamper.it)): the very heavy human pressure on the beach in summer could have generated negative effects on the conditions for the survival of *B. megacephalus* in the back dunes, from which the species has disappeared.



of the trampling (by humans and by cars) on the dune, given its destructive effects on the sandy habitat integrity.

The Calamosche situation (Figs. 9, 10) (in particular the disappearance of the species in this area) represents in this sense a clear warning signal that induces a very careful control in the Eoro area (number 1 in Fig. 6) and along the dune belt also exposed to trampling in violation of the protection rules provided for the A area where the dunes are located.

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## First purposive study of beetles (Coleoptera) from endogean environments in Bulgaria: collection sites and preliminary results

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### ABSTRACT

So far, special attention to the endogean and MSS (Mesovoid Shallow Substratum) fauna was not paid in Bulgaria, though typical subterranean species of the Coleoptera have been described. The aim of present study is to put on record the results of a broad-scale study of the coleopteran fauna from the MSS and lower (euedaphic) soil horizons in the country. We carried out investigations in the period April 2006–July 2014, mainly in the Vitosha Mt., Pirin Mt., Stara Planina Mts., Slavyanka Mt., Belasitsa Mt., Erma and Kresna Gorge, Western Rhodopes Mts., and Srednagora Mts. For the time being, material from the following families was identified to the genus and species levels: Anobiidae, Aphodiidae, Carabidae, Clambidae, Corylophidae, Curculionidae, Endomychidae, Histeridae, Leiodidae, Monotomidae, Scyrtidae, Silvanidae, Silphidae, Staphylinidae (Pselaphinae) and Zopheridae. We report for the first time the subgenus *Antisphodrus* Schaufuss, 1865 (Carabidae) and *Zustalestus* Reitter, 1912 (Curculionidae) from Bulgaria. *Blemus discus discus* (Fabricius, 1792) is recorded for the second time from the country.

### KEY WORDS

Coleoptera; endogean and MSS fauna; Bulgaria; news records.

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### INTRODUCTION

The superficial, cave and hemiedaphic invertebrate fauna in Bulgaria has been an object of comprehensive investigations for almost 120 years already. In the same time still very little is known about invertebrates living in the lower soil layers (so called euedaphic or endogeic environments) and especially in the network of fissures and crevices in the maternal rock below the soil horizon.

The latter environment is usually referred to as Mesovoid Shallow Substratum (MSS), according to the works of Juberthie et al. (1980, 1981), or superficial subterranean habitats (SSHs), according

to Culver & Pipan (2008). In regard to the Coleoptera, it seems that this specific environment has been widely discussed by southwest Europe authors (Ruffo, 1959; Laneyrie, 1960; Coiffait, 1963) prior to its formal introduction by Juberthie et al. (1980). At present, at least four basic types of MSS habitats are discriminated (Juberthie, 2000, Ortuño et al., 2013), based on different combinations of abiotic and biotic factors.

Typical endogeic species can be found in most of the soil-dwelling groups of Arthropoda: the Lower insects (Japygidae), beetles (Carabidae, Leiodidae), myriapods (Diplopoda, Chilopoda), isopods (Isopoda), spiders (Araneae), etc.

Undoubtedly, one of the most interesting groups among them are the beetles represented by a relatively high number of endemic species. Special attention to the endogean and MSS fauna in Bulgaria has been paid only recently (Deltchev et al., 2011; Langourov et al., 2014). Typical endogean or hypogean beetles, excluding those collected in caves and precipices, were found occasionally (Knirsh, 1930; Genest & Juberthie, 1983; Genest, 1983; Hurka, 1990; Janák & Moravec, 2008).

The aim of present study is to put on record the results of a broad-scale study of the coleopteran fauna inhabiting MSS and lower (euedaphic) soil horizons in Bulgaria. Here we give a list of the collecting localities and a register of the taxa found in the different sites.

#### MATERIAL AND METHODS

The investigation was carried out in the period April 2006-July 2014, mainly in the Vitosha Mt.,

Pirin Mt., Stara Planina Mts., Slavyanka Mts., Belasitsa Mt., Erma and Kresna Gorge, Western Rhodopes Mts., and Sredna gora Mts (Fig. 1., Table 1).

The traps were made from PVC pipe with diameter of the holes 8 cm and length of 60 and 80 cm. One hundred and eight holes were drilled on each pipe, at 10 cm distance from its end. Traps were put into 60 or 80 cm deep hole dug as deep as the limestone or silicate layer. Ten centimeters high plastic cup tied to polythene rope, and filled with solution of ethilenglycol or ethilenglycol with few drops of formalin was put into the end of the pipe. Traps were covered by solid plastic covers in order to avoid penetration of superficial fauna into the pipe and infiltration of water during heavy rains. In some cases we also used olfactory attractant (fish).

The identification of the taxa has been made as follows: Curculionidae (Luigi Magnano), Histeridae (Evgeni Chehlarov), Pselaphinae (first author), and all other families (second author).



Figure 1. Distribution of localities with MSS traps in Bulgaria.

TRAP NO.	DATE OF SETTING	SITE DESCRIPTION	LENGTH OF TUBE
V-N-1	29.IV.2006	Vitosha Mts., northern slope, above Boyana, Boyanski kamak place, at the bottom of a 4-5 m deep microcave; dry, alt. 847 m.	70 cm
V-N-2&3	30.IV.2006	Vitosha Mts., northern slope, two traps set ca. 30-35 m above Boyanski kamak, in a scree in mixed forest of <i>Fagus sylvestris</i> and <i>Carpinus betulus</i> ; alt. 847 m.	60 cm
V-E-1	13.V.2006	Vitosha Mts., eastern slope, approx. 28 km south of Sofia, on the road Sofia-Samokov, Yarema place; forest of <i>Fagus sylvatica</i> , in a brown soil, humid, close to a small river, alt. 1363 m	80 cm
V-W-1	10.VI.2006	Vitosha Mts., western slope, village of Bosnek, near the cave Duhlata, karst, stony substrate mixed with clay, alt. 964 m	80 cm
V-W-2	24.VI.2006	Vitosha Mts., western slope, village of Bosnek, near the cave Duhlata, karst, stony substrate, clay, alt. 992 m	60 cm
V-W-3	24.VI.2006	Vitosha Mts., western slope, village of Bosnek, near the cave Duhlata, karst, stony substrate, clay, alt. 992 m	70 cm
V-SL-1-2	06.VI.2013	Vitosha Mts., Bosnek Vill., near Akademik cave, N 42°29'28.28" E 23°11'18.28"	60 cm
V-SL-3	06.VI.2013	Vitosha Mts., Bosnek Vill., scree on the road to Chuipetlyovo	60 cm
V-SL-4	06.VI.2013	Bosnek Vill., Popov Izvor Karst spring	60 cm
V-SL-5	02.X.2013	Bosnek Vill., near Pepelyankata Cave	60 cm
V-SL-6	02.X.2013	Bosnek Vill., near Duhlata Cave	80 cm
BK-mss1	29.IV.2006	Vitosha Mt., above Boyana, Boyanski kamak place, at the bottom of a 4-5 m deep microcave; dry, alt. 847 m.	80 cm
Du-mss4	24.VI.2006	Vitosha Mt., near Bosnek Village, near Duhlata Cave, karst, stony substrate, clay, alt. 992 m	80 cm
P-W-2	7.V.2006	Pirin Mts., western slope, above village of Ilindentsi, Zandana Area, karst, in a scree, dry soil/ sandy substrate, alt. 492 m	70 cm
P-W-4	14.V.2006	Pirin Mts., western slope, village of Gradeshnitsa, near Gradeshnichka banya, at the base of stony/sandy cliff, dry, sandy/ stony substrate, alt. 312 m	60 cm
P-N-1	24.V.2006	Pirin Mts., northern slope, approx. 6 km before Predela Area, humid ravine, <i>Fagus sylvatica</i> forest, at the base of <i>Fagus</i> tree, thick layer of leaf litter, humid soil mixed with stones, alt. 676 m,	60 cm
P-N-2	24.V.2006	Pirin Mts., northern slope, approx. 6 km before Predela Area, humid ravine, <i>Fagus sylvatica</i> forest, humid soil and gravel, alt. 676 m	80 cm
P-E-1&2	25.V.2006	Pirin Mts., eastern slope, 3 km before village of Gospodintsi, Gotse Deltshev District, approx. 30 m away of the main road Bansko-Gotse Deltshev and approx. 5-6 m of a small river; in scree at the base of a limestone rocks, close to broad-leaf tree; alt. 585 m	60 cm
P-S-1	25.V.2006	Pirin Mts., southern slope, approx. 900 m after Popovi livadi Hut on the main road Gotse Deltshev-Katuntsi, ca. 40-50 m away of the road, marble stone debris on a small meadow; alt. 1367 m	50 cm
P-S-2&3	18.VI.2006	Pirin Mts., southern slope, approx. 1700 m away of the main road Gotse Deltshev-Katuntsi, on the secondary road to Orelyak Peak; in a small valley, <i>Fagus</i> forest, alt. 1560 m	60 cm

Table 1. Distribution of localities with MSS traps in Bulgaria (continued).

TRAP NO.	DATE OF SETTING	SITE DESCRIPTION	LENGTH OF TUBE
P-S-4&5	8.VI.2006	Pirin Mts., southern slope, St. Iliya Site near village of Kalimantsi; close to the chapel, under the venerable <i>Quercus coccifera</i> trees, alt. 494 m	60 cm
P-S-6	27.VI.2006	Pirin Mts., southern slope, Peshternik Site near village of Kalimantsi; against the large travertine, under the double willow, alt. 380 m	70 cm
P-S-7	27.VI.2006	Pirin Mts., southern slope, Peshternik Site near village of Kalimantsi; close to the large travertine, in a smaller travertine, under a hazel bush	60 cm
WR-1	23.IV.2006	West Rhodopes Mts., central parts, approx. 1100 m after the crossroad to village of Borovo towards village of Belitsa; on the left side of the road, in a small rocky valley, overgrown with bushes and <i>Pinus nigra</i> , ca. 50 m of the road, alt. 657 m	55 cm
WR-2	23.IV.2006	West Rhodopes Mts., central parts, approx. 1100 m after the crossroad to village of Borovo towards village of Belitsa; on the left side of the road, in a small rocky valley, overgrown with bushes and <i>Pinus nigra</i> , ca. 100 m of the road, alt. 666 m	80 cm
WR-3&4	23.IV.2006	West Rhodopes Mts., central parts, on the way to village of Belitsa; narrow valley on the right side of the road, ca. 80 m of the road, <i>Pinus nigra</i> and deciduous bushes, alt. 666-668 m	60 cm
WR-5	14.VII.2007	West Rhodopes Mts., southern parts, near village of Koshnitsa, below the cave Uhlovitsa; right slope, above the trek, at the foot of hornbeam bushes, not far from a old beech tree, humid and shady place, gravels in the soil, alt. 928 m	80 cm
EG-1&2	11.VI.2006	Rui Mts., Erma Gorge, ca. 30 m before the tunnel, on the slope overgrown with hazel bush, ash-trees; rocky substrate, at the foot of rocks; 685 m	60 cm
SP-1	6.VI.2006	Stara Planina Mts., Topya Site near village of Golyama Zhelyazna; ca. 20 m of the entrance of Topya Cave; ca. 25-30 m of the river; karst slope overgrown with scarce bushes and deciduous trees; 460 m	70 cm
SP-2	7.VI.2006	Stara Planina Mts., Topya Site near village of Golyama Zhelyazna; ca. 5 m of the entrance of Yalovitsa Cave; karst slope in ca. 25-30 m of the river; karst slope in young <i>Quercus</i> forest; 608 m	50 cm
S-1	4.VII.2006	Slavyanka Mts., Livade Site near village of Goleshevo in Alibotush Reserve; karst slope in <i>Pinus</i> forest; ca. 1700 m, N 41°23'532" E 23°36'307"	60 cm
SG-1	29.IV.2006	Sredna gora Mts., St. Ivan Site near Panagyurishte, abandoned vineyard overgrown with scattered Prune trees and blackberries in close proximity to forest of <i>Pinus nigra</i> ; deep soil layer, lower horizon mixed with stones, 584 m	100 cm
SG-2	29.IV.2006	Sredna gora Mts., same coordinates and site description; situated ca. 30 m apart of SG-1.	60 cm
SG-3	29.IV.2006	Sredna gora Mts., situated ca. 30 m apart of SG-1. Trap set in young artificial forest of <i>Pinus nigra</i> ; brown forest soil mixed with stones; 5-7 cm thick layer of pine needles	80 cm
SG-4	29.IV.2006	Sredna gora Mts., same coordinates and site description; trap is situated ca. 10 m apart of SG-3. Trap set in young artificial forest of <i>Pinus nigra</i> ; brown forest soil mixed with stones; 5-7 cm thick layer of pine needles	60 cm
DH-1&2	10.V.2007	Derventsky Heights, village of Dennitsa, crossroad to Stefan Karadzovo, Yambol District, sink-hole in <i>Quercus</i> forest, at the base of a big stone; alt. 365 m	60 cm

Table 1 (continued). Distribution of localities with MSS traps in Bulgaria.

## RESULTS

Up to now, material from the following families was identified to genus and/or species level: Anobiidae, Aphodiidae, Carabidae, Clambidae, Corylophidae, Curculionidae, Endomychidae, Histeridae, Leiodidae, Monotomidae, Scyrtidae, Silvanidae, Silphidae, Staphylinidae (Pselaphinae), and Zopheridae (Table 2).

## DISCUSSION

### *Carabidae*

Thirty one ground-beetle taxa at the species level were collected in the traps. Eight of them, including one undescribed species from the genus *Laemostenus*, are Balkan endemic species. The subgenus *Antisphodrus* Schaufuss, 1865 is a new taxon to the fauna of Bulgaria. So far, no species of this group was known from the core area of the Balkan Peninsula. *Antisphodrus* display scattered distribution in the Northern Mediterranean as its species occur from Spain in the west to Iran in the east. They have restricted distribution by loci and are confined to endogean and hypogean, primarily limestone habitats. The only female specimen we collected from this subgenus belongs to a new species for the science. Currently, the description of this form is prevented for the lack of enough material.

The ground-beetles collected might be divided conditionally in three categories in view of their degree of specialization to underground way of life. The first group includes three true endogean species. *Trechus subacuminatus* and *Laemostenus* (*Antisphodrus*) sp. are hither to found only in the MSS-niche in Bulgaria. The two species are partly depigmented, and possess small, but functioning eyes. With certainty, both are very rare and strictly localized everywhere since they were not caught before using the standart methods of collecting. To the same group belongs also *Duvalius regisborisi*, which formerly was found only in caves. It is an eyeless beetle well-adapted to life in the underground environment. The second group contains seven species (*Blemus discus discus*, *Laemostenus cimmerius weiratheri*, *L. plasoni*, *L. terricola punctatus*, *Trechus austriacus*, *T. irenis*, and *T. subnotatus*), the most of them found repeatedly in caves but now also caught in MSS-traps. That category

occupies an intermediate position between the eu-eadiphic (endogean) species and the soil-inhabiting species.

The separation of this group is evidenced from their frequency and number of individuals found in the MSS-traps we put. The third group includes edaphic (or soil) species, which are primarily forest dwellers. This species complex is the dominant one with respect to the number of species—twenty species from fifteen genera (Table 2). Most of those species are forest dwellers, except for *Bembidion dalmatinum* and *Syntomus pallipes*, which are characteristic of open and ecotone habitats. It is worth noting that the dominant species in the MSS-traps in the Vitosha Mt. is *Aptinus bombardia*. We did not find it in the traps put in other places. *Blemus discus discus* is recorded here for the second time for the country (see Hieke & Wrase, 1988).

### *Leiodidae*

Twenty three taxa of the species level from Leiodidae have been identified till now. This figure excludes the species of *Colon* Herbst, 1797 and *Leiodes* Latreille, 1796 which identification is still unaccomplished. The most typical example of the MSS-environment is the endogean *Guerguievella petrovi*. This very small, blind and depigmented beetle belongs to a monotypic genus and species that was discovered not long ago (Giachino & Guéorguiev, 2007). The type series of this species includes three dozens of specimens made available by hand-collecting in six separate visits of the "Kraypatnata Peshtera" Cave near Smilyan Village. The visits were carried out in the period 1962-2004.

Recently, we collected *Guerguievella petrovi* twice in MSS-traps in a mass, as the samples significantly differ to each other in the number of individuals. The first sample, exposed in the dry summer-autumn season, contained three specimens, while the next one, exposed in the wet autumn-winter season, contained more than 60 specimens. The cholevine species, like *Choleva angusara*, *C. glauca*, *Nargus badius*, *Ptomaphagus sericatus*, and *Sciodrepoides watsoni*, are detritophagous. They are sometimes collected in caves in Bulgaria and now they were found in MSS-traps. Other species, such as the leiodines (*Agathidium* spp., *Hydnobius* spp., *Leiodes* spp.), eat fungi and live above the ground or underground (Newton, 1998).

	Family	Species and subspecies	Trap No.	Collection date	References
1	Familia ANOBIIDAE	<i>Ptinus</i> sp.	V-N-1 P-W-2 P-S-4&5	30.4-3.6.2006 7.5.-18.6.2006 7.12.2006-19.4.2007	Present paper
2	Familia APHODIIDAE	<i>Ataenius horticola</i> Harold, 1869 - Fig. 2.	P-W-2	14.05.-6.07.2006	Guéorguiev & Bekchiev, 2009
3		<i>Oxyomus sylvestris</i> (Scopoli, 1763)	P-W-4	7.05.-18.06.2006	Present paper
4	Familia CARABIDAE	<i>Abax (Abacopercus) carinatus carinatus</i> (Duftschmid, 1812)	SP-2; V-N-2 P-N-1; V-SL-4	6.6.-6.9.2006; 30.4.- 3.6.2006; 7.9.2006; 6.6-02.10.2013	Langourov et al., 2014; present paper
5		<i>Amara</i> (s.str.) <i>saphyrea</i> Dejean, 1828	SG-1 SG-2	29.4.-29.5.2006 28.12.2006-20.04.2007	Present paper
6		<i>Aptinus</i> (s.str.) <i>bombarda</i> (Illiger, 1800)	V-N-1 V-N-2&3	3.6.-25.7.2006; 30.4.- 3.6.2006; 5.11.2006- 6.6.2007	Langourov et al., 2014
7		<i>Bembidion (Peryphanes) dalmatinum dalmatinum</i> Dejean, 1831	V-SL-3	6.6-2.10.2013	Langourov et al., 2014
8		<i>Blemus discus discus</i> (Fabricius, 1792) - Fig. 3	V-SL-4	6.6-2.10.2013	Langourov et al., 2014
9		<i>Carabus (Procrustes) coriaceus cerisyi</i> Dejean, 1826	SG-1	6.8.2006-18.11.2006	Present paper
10		<i>Cychrus semigranosus balcanicus</i> Hopffgarten, 1881	V-SL-3	6.6-2.10.2013	Langourov et al., 2014
11		<i>Duvalius (Paraduvalius) regisborisi</i> (Buresch, 1926)	SP-1	6.6.-6.9.2006	Present paper
12		<i>Harpalus</i> (s.str.) <i>atratus</i> Latreille, 1804	SP-2	6.6.-6.9.2006	
13		<i>Laemostenus (Actenipus) plasoni</i> (Reitter, 1885)	P-N-1 P-S-1 P-S-2&3	7.9.2006-3.7.2007; 9.2006-4.7.2007; 4.7.-17.10.2007	Present paper
14		<i>Laemostenus (Antisphodrus) sp.</i>	EG-1&2	25.06.-2.12.2006	Present paper; new subgenus to the fauna of Bulgaria
15		<i>Laemostenus (Pristonychus) cimmerius weiraetheri</i> J. Müller, 1932	V-SL-1-2 V-SL-4	6.6-2.11.2013; 6.6-2.10.2013	Langourov et al., 2014
16		<i>Laemostenus (Pristonychus) terricola punctatus</i> (Dejean, 1828)	V-N-1; V-N-1; V-W-2; V-W-3; SG-4; BK-mss1 Du-mss4	3.06.-25.7.2006; 5.11.2006-6.6.2007; 26.8.-3.12.2006; 26.8.2006; 6.8.-18.9.2006; 3.06.-25.07.2006 26.08.-3.12.2006	Langourov et al., 2014 and present paper
17		<i>Leistus (Pogonophorus) rufomarginatus</i> (Duftschmid, 1812)	V-SL-4	6.6-2.10.2013	Langourov et al., 2014

Table 2 (1/6). List of the registered edaphicolous and hypogeicolous Coleoptera from MSS- traps.

	Family	Species and subspecies	Trap No.	Collection date	References
18	Familia CARABIDAE	<i>Leistus (Pogonophorus)</i> <i>spinibarbis rufipes</i> Chaudoir, 1843	V-SL-5	2.11.2013-26.6.2014	Present paper
19		<i>Molops (s.str.)</i> <i>alpestris rhilensis</i> Apfelbeck, 1904	P-N-1 P-S-1 WR-2	7.9.2006-3.7.2007; 9.2006-4.7.2007; 3.4.-9.6.2006	Present paper
20		<i>Molops (s.str.) dilatatus</i> <i>dilatatus</i> Chaudoir, 1868	WR-1	23.4.2006-9.6.2006	Present paper
21		<i>Molops (s.str.) piceus</i> <i>bulgaricus</i> Mařan, 1938	V-N-2&3	5.11.2006-6.6.2007	Langourov et al., 2014
22		<i>Myas (s.str.) chalybaeus</i> (Palliard, 1825)	SP-2	6.6.-6.9.2006	Present paper
23		<i>Platynus proximus</i> (J. Frivaldszky, 1879)	SP-1	06.06.-06.09.2006	Present paper
24		<i>Pterostichus (s.str.) mer-</i> <i>klii</i> (J. Frivaldszky, 1879)	SP-1	6.6.-6.9.2006	Present paper
25		<i>Pterostichus (Petrophi-</i> <i>lus) melanarius melana-</i> <i>rius</i> (Illiger, 1798)	V-SL-4 V-SL-5 V-SL-6	6.6-2.10.2013; 2.10-2.11.2013; 2.10-2.11.2013	Langourov et al., 2014
26		<i>Pterostichus (Platysma)</i> <i>niger</i> (Schaller, 1783)	V-N-1 V-N-2&3	3.6.-25.7.2006; 5.11.2006-6.6.2007	Langourov et al., 2014
27		<i>Syntomus pallipes</i> (Dejean, 1825)	SG-1	29.4.-29.5.2006	Present paper
28		<i>Synuchus vivalis</i> (Illiger, 1798)	SG-4	6.8.-18.9.2006	Present paper
29		<i>Tapinopterus (s.str.)</i> <i>balcanicus</i> Ganglbauer, 1891	V-N-1 V-N-2 V-N-2 & 3 WR-1 WR-3 & 4	3.6.-25.07.2006; 30.4.-3.6.2006; 5.11.2006-6.6.2007; 9.6.-17.7.2006; 23.4.-9.6.2006	Langourov et al., 2014: present paper
30		<i>Tapinopterus (s.str.)</i> <i>cognatus kalofirensis</i> Mařan, 1933	SP-2	6.6.-6.9.2006	Present paper
31		<i>Trechus (s.str.)</i> <i>austriacus</i> Dejean, 1831	V-W-1 P-E-2 SG-1 SG-2 V-SL-1-2 V-SL-4 V-SL-5	24.6.-3.12.2006; 7.9.2006-4.7.2007; 29.4.-29.5.2006; 18.9.-28.12.2006; 6.6-2.11.2013; 2.10-02.11.2013; 2.10-02.11.2013	Langourov et al., 2014; present paper
32		<i>Trechus (s.str.) irenis</i> Csiki, 1912	V-SL-4	6.6-2.10.2013	Langourov et al., 2014
33		<i>Trechus (s. str.)</i> <i>subacuminatus</i> A. Fleischer, 1898	EG-1&2	11.06.-25.06.2006/ 2.12.2006-18.04.2007	Present paper New species for Bulgaria.
34		<i>Trechus (s. str.) subnotatus</i> Dejean, 1831	SG-3	18.11.-28.12.2006	Present paper

Table 2 (2/6). List of the registered edaphicolous and hypogeicolous Coleoptera from MSS- traps.

	Family	Species and subspecies	Trap No.	Collection date	References
35	Familia CLAMBIDAE	<i>Clambus</i> sp.	EG-1&2 P-S-4&5	2.12.2006-8.4.2007; 7.12.2006-9.4.2007	Present paper
36	Familia CORYLOPHIDAE	<i>Sericoderus lateralis</i> (Gyllenhal, 1827)	SG-3	20.4.-1.5.2007	Langourov et al., 2014
37	Familia CURCULIONIDAE	<i>Acalles</i> sp.	P-E-1&2	7.9.2006-4.7.2007	Present paper
38		<i>Brachysomus</i> sp.	WR-1	1.4.-25.11.2007	Present paper
39		<i>Dodecastichus geniculatus</i> (Germar, 1817)	EG-1&2	25.6.-2.7.2006	Present paper
40		<i>Dodecastichus obsoletus</i> (Stierlin, 1861)	EG-1&2	25.6.-2.7.2006	Present paper
41		<i>Otiorhynchus</i> (s.str.) <i>albidus</i> Stierlin, 1861	P-S-4&5	19.8.-15.11.2007; 19.5.-13.7.2007	Present paper
42		<i>Otiorhynchus</i> (s.str.) <i>balcanicus</i> Stierlin, 1861	V-W-3 P-S-4&5	26.8.2006; 23.6.- 7.7.2006; 7.12.2006- 19.4.2007; 13.7.-19.8.2007; 19.8.-15.11.2007	Langourov et al., 2014; present paper
43		<i>Otiorhynchus</i> (s.str.) <i>bisulcatus</i> (Fabricius, 1781)	V-W-2 EG-1&2	26.7-26.8.2006; 25.6.-2.7.2006	Langourov et al., 2014; present paper
44		<i>Otiorhynchus</i> (s.str.) <i>coarctatus</i> Stierlin, 1861	V-W-2	26.7.2006	Langourov et al., 2014
45		<i>Otiorhynchus</i> (s.str.) <i>corneolus</i> Weise, 1906	V-W-1 V-W-2 V-W-3 EG-1&2	24.6.-3.12.2006; 26.7-26.8.2006; 4-16.6.2007; 25.6.-2.7.2006	Langourov et al., 2014; present paper
46		<i>Otiorhynchus</i> (s.str.) <i>crataegi</i> Germar, 1824	V-W-2	26.7.2006	Langourov et al., 2014
47		<i>Otiorhynchus</i> (s.str.) <i>juglandis</i> Apfelbeck, 1895	V-W-2; V-W-3 SG-1 SG-2 P-E-1&2 P-S-2&3 P-S-4&5 WR-3&4	26.7.2006; 26.8.2006; 5-20.8.2007; 29.5- 17.6.2006; 7.9.2006- 4.7.2007; 4.7.-17.10.2007; 23.6.-7.7.2006; 1.4.-25.11.2007	Langourov et al., 2014; present paper
48		<i>Otiorhynchus</i> (s.str.) <i>ovalipennis</i> Boheman, 1843	P-S-4 & 5	23.6.-7.07.2006; 7.12.2006-19.4.2007; 19.5.-13.7.2007; 19.8.-15.11.2007	Present paper
49		<i>Otiorhynchus</i> ( <i>Podoro-</i> <i>pelmus</i> ) aff. <i>metsovensis</i> Magnano, 1999	P-S-2 & 3	4.7.-17.10.2007	Present paper; probably new species
50		<i>Otiorhynchus</i> ( <i>Zustalestus</i> ) <i>consobrinus</i> Reitter, 1913	P-S-1	4.7.-17.10.2007	Present paper; new subgenus for Bulgaria

Table 2 (3/6). List of the registered edaphicolous and hypogeicolous Coleoptera from MSS- traps.

	Family	Species and subspecies	Trap No.	Collection date	References
51	Familia CURCULIONIDAE	<i>Stomodes rotundicollis</i> Frivaldszky, 1880	P-S-2&3	4.7.-17.10.2007	Present paper
52		<i>Sitophilus oryzae</i> (Linnaeus, 1763)	P-S-2&3	4.7.-17.10.2007	Present paper
53		<i>Tychius</i> sp.	P-S-4&5	23.6.-7.7.2006	Present paper
54	Familia ENDOMYCHIDAE	<i>Hylaea reissi</i> Csiki, 1911	WR-2 EG-1&2 P-S-2&3 V-N-1; V-SL-3	9.06.-19.07.2006 25.06.-2.12.2006 4.07.-17.10.2007 5.11.2006-6.06.2007 02.11.2013-30.07.2014	Present paper
55		<i>Lycoperdina pulvinata</i> Reitter, 1884	S-1	9.6.2007	Present paper
56	Familia HISTERIDAE	<i>Abraeus perpusillus</i> (Marsham, 1802)	DH-1&2	10-20.5.2007	Present paper
57	Familia LEIODIDAE	<i>Agathidium</i> (s.str.) <i>bohemicum</i> Reitter, 1884	EG-1&2	25.6.-2.12.2006	Guéorguiev & Bekchiev, 2009
58		<i>Apocatops nigrita</i> (Erichson, 1837)	EG-1&2	25.6.-2.12.2006	Present paper
59		<i>Catops chrysomeloides</i> (Panzer, 1798)	V-SL-4	6.6 - 2.10.2013	Langourov et al., 2014
60		<i>Catops fuliginosus</i> Erichson, 1837	V-W-3 P-N-2 P-S-4&5 EG-1&2 V-SL-4	26.8.-3.12.2006; 16.6.2006; 27.06.-7.12.2006; 25.6.-2.12.2006; 2.10-2.11.2013	Langourov et al., 2014; present paper
61		<i>Catops grandicollis</i> Erichson, 1837	SG-1; SG-2	29.04.-29.05.2006; 1.05.-25.05.2007	Present paper
62		<i>Catops neglectus</i> Kraatz, 1852	P-N-2 WR-2 EG-1&2 SG-3 V-N-2&3	7.9.2006-3.7.2007; 23.4.-9.6.2006; 25.6.-2.12.2006; 18.11.-28.12.2006; 5.11.2006-6.6.2007	Guéorguiev & Bekchiev, 2009; Langourov et al., 2014
63		<i>Catops picipes</i> (Fabricius, 1792)	V-SL-4	2.10-02.11.2013	Langourov et al., 2014
64		<i>Catops subfuscus</i> Kellner, 1846	P-N-2	24.5.-16.6.2006	Guéorguiev & Bekchiev, 2009
65		<i>Catops tristis</i> (Panzer, 1794)	P-N-1 P-S-1	7.9.2006-3.7.2007; 9.2006-4.7.2007	Present paper
66		<i>Choleva</i> (s.str.) <i>agilis</i> (Illiger, 1798)	V-SL-4	6.6 - 2.10.2013	Langourov et al., 2014
67		<i>Choleva</i> (s.str.) <i>angustata</i> (Fabricius, 1781)	SG-1 V-SL-4	29.4.-29.5.2006; 6.6 - 2.10.2013	Langourov et al., 2014; present paper
68		<i>Choleva</i> (s.str.) <i>glauca</i> Britten, 1918	P-S-1 V-SL-4	9.2006-4.7.2007; 6.6 - 2.10.2013	Langourov et al., 2014 and present paper
69		<i>Choleva</i> (s.str.) <i>macedonica</i> Karaman, 1954 - Fig. 4	V-SL-4	6.6 - 2.10.2013	Langourov et al., 2014

Table 2 (4/6). List of the registered edaphicolous and hypogeicolous Coleoptera from MSS- traps.

	Family	Species and subspecies	Trap No.	Collection date	References
70		<i>Choleva</i> (s.str.) <i>oblonga</i> Latreille, 1807	SG-2	20.4.-1.5.2007	Present paper
71		<i>Choleva</i> (s.str.) <i>reitteri</i> Petri, 1915	EG-1&2 V-SL-4	25.6.-2.12.2006; 6.6-2.10.2013	Langourov et al., 2014 and present paper
72		<i>Choleva</i> ( <i>Cholevopsis</i> ) <i>paskoviensis</i> Reitter, 1913	P-E-2; P-S-2; SG-1	7.09.2006-4.07.2007; 11.2006-4.07.2007; 6.08.-18.09.2006	Present paper
73		<i>Colon</i> sp.	P-E-2; P-S-4&5; EG-1&2	7.9.2006-4.7.2007; 7.12.2006-19.4.2007; 25.6.-2.12.2006;18.4.- 17.6.2007	Present paper
74		<i>Guerguievella petrovi</i> Giachino et Guéorguiev, 2007	WR-5	14.7.-13.10.2007	Present paper
75		<i>Hydnobius punctatus</i> Hampe, 1861	EG-1&2	25.6.-2.12.2006	Guéorguiev & Bekchiev, 2009
76		<i>Leiodes</i> sp.	P-W-2 P-S-4&5 EG-1&2	7.5.-18.6.2006; 7.12.2006-19.4.2007; 25.6.-2.12.2006	Present paper
77		<i>Liocyrtusa nigriclavis</i> (Hlisnikovský, 1967)	EG-1&2	25.6.-2.12.2006	Guéorguiev & Bekchiev, 2009
78		<i>Nargus</i> (s.str.) <i>badius rotundus</i> Karaman, 1954	V-E-1 P-N-1 EG-1&2 V-SL-4	16.4.-15.7.2007; 7.9.2006-3.7.2007; 17.6.-9.7.2007; 6.6-2.10.2013	Langourov et al., 2014 and present paper
79		<i>Nargus</i> ( <i>Demorchus</i> ) sp.	V-W-3	26.08.-3.12.2006	Present paper
80		<i>Ptomaphagus</i> (s.str.) <i>sericatus</i> (Chaudoir, 1845)	P-S-1 EG-1&2 V-SL-4	11.06.-25.06.2006; 9.2006-4.07.2007; 25.06.-2.12.2006; 17.06.- 9.07.2007; 02.10- 02.11.2013	Langourov et al., 2014; present paper
81		<i>Sciodrepoides watsoni</i> <i>watsoni</i> (Spence, 1815)	EG-1&2 V-N-2 P-N-1 P-N-2 SG-3	25.6.-2.12.2006; 30.4.- 3.6.2006; 7.9.2006- 3.7.2007; 7.9.2006- 3.7.2007; 29.05.- 17.6.2006; 17.6.- 6.8.2006	Langourov et al., 2014 and present paper
82	Familia MONOTOMIDAE	<i>Rhizophagus</i> ( <i>Rhizophagus</i> ) <i>ferrugineus</i> (Paykull, 1800)	DH-1&2	6.09-3.11.2007	Present paper
83		<i>Rhizophagus</i> ( <i>Rhizophagus</i> ) <i>perforatus</i> Erichson 1845	V-SL-4	6.6-2.10.2013	Langourov et al., 2014
84	Familia SCIRTIDAE	<i>Cyphon</i> sp.	SG-1	29.04.-29.05.2006	Present paper
85	Familia SILVANIDAE	<i>Oryzaephilus surinamen-</i> <i>sis</i> (Linnaeus, 1758)	V-SL-4	6.6-2.10.2013	Langourov et al., 2014

Table 2 (5/6). List of the registered edaphicolous and hypogeicolous beetle (Coleoptera) taxa from MSS- traps.

	Family	Species and subspecies	Trap No.	Collection date	References
86	Familia SILPHIDAE	<i>Silpha obscura orientalis</i> Brullé, 1832	P-S-2&3	4.07.-17.10.2007	Present paper
87	Familia STAPHYLINIDAE (PSELAPHINAE)	<i>Batrisodes elysius</i> Reitter, 1884	P-W-4	6.7.2006	Present paper
88		<i>Bryaxis dalmatinus</i> (Reitter, 1881)	P-S-4&5 V-SL-1-2	27.6.-7.12.2006; 6.6-2.11.2013	Bekchiev, 2008; Langourov et al., 2014
89		<i>Bryaxis beroni</i> Karaman, 1969 - Fig. 5	EG-1&2	23.06.2008	Present paper
90		<i>Bryaxis islamitus</i> (Reitter, 1885)	P-N-2	4.07.-16.11.2007	Present paper
91		<i>Bryaxis roumaniae</i> Raffray, 1904	P-E-1&2; P-N-2; V-SL-3	4.07.-17.10.2007; 4.07-16.11.2007/P.S; 02.10-02.11.2013	Langourov et al., 2014; present paper
92		<i>Bryaxis nodicornis</i> Aubé, 1833	V-SL-4	06.06-02.10.2013	Langourov et al., 2014
93		<i>Bythinus acutangulus</i> <i>lunifer</i> Karaman, 1948	P-N-2	4.07-16.11.2007	Present paper
94		<i>Claviger</i> cf. <i>elysius</i> Reitter, 1884	P-E-1	07.09.2006- 04.07.2007	Present paper
95		<i>Trimium caucasicum</i> Kolenati, 1846	P-S-4&5 P-S-6	19.04.-19.06.2007 15.11.2007	Present paper
96		<i>Trimium puncticeps</i> Reitter, 1880	V-SL-6	07.2014	Present paper
97		<i>Trimium expandum</i> Reitter, 1884	P-S-4&5	27.06.-7.12.2006	Bekchiev, 2008
98		<i>Tychus apfelbecki</i> Karaman, 1955	P-E-1	7.9.2006- 4.7.2007	Bekchiev, 2008
99	Familia ZOPHERIDAE	<i>Langelandia</i> sp.	P-W-2 P-E-1&2 P-S-4&5 DH-1&2	6.7.2006 7.9.2006-4.7.2007 7.12.2006-19.4.2007 10-20.5.2007	Present paper

Table 2 (6/6)285-296. List of the registered edaphicolous and hypogeicolous Coleoptera from MSS- traps.

*Choleva macedonica* is worth mentioning. It has been described by a single male specimen collected from the cave of Bela Voda (Karaman, 1954), in the south of Republic of Macedonia. The cave lies on the left bank of Vardar River, close to the archeological site Prosek at the Demir-Kapija Canyon. Szymczakowski (1976) expressed doubts about the status of *C. macedonica* and listed it as questioned synonym of *C. sturmi* Brisout de Barneville, 1863. Subsequently the species status of the former was confirmed (Nonveiller et al., 1999) and since then it is considered distinct species (Perreau, 2004). *C. macedonica* was recently announced from Bulgaria (Langourov et al., 2014). Based on two male speci-

mens (one of them without head and pronotum), the record at Popov Izvor Karst Spring (see Table 2) represents the second finding of the species after the description and the first one out of Republic of Macedonia. The study of the aedeagus supports the view of Karaman (ibid.) that it is a distinct species, not synonym of *C. sturmi*.

From an ecological point of view, the most striking fact to us seems the coexistence of five species of *Choleva* (s. str.) at the same place and probably in the same time (Popov Izvor Karst spring, N42.50275 E23.15317, 06.VI-02.X.2013): *Choleva agilis*, *Ch. angustata*, *Ch. glauca*, *Ch. macedonia*, and *Ch. reitteri*.

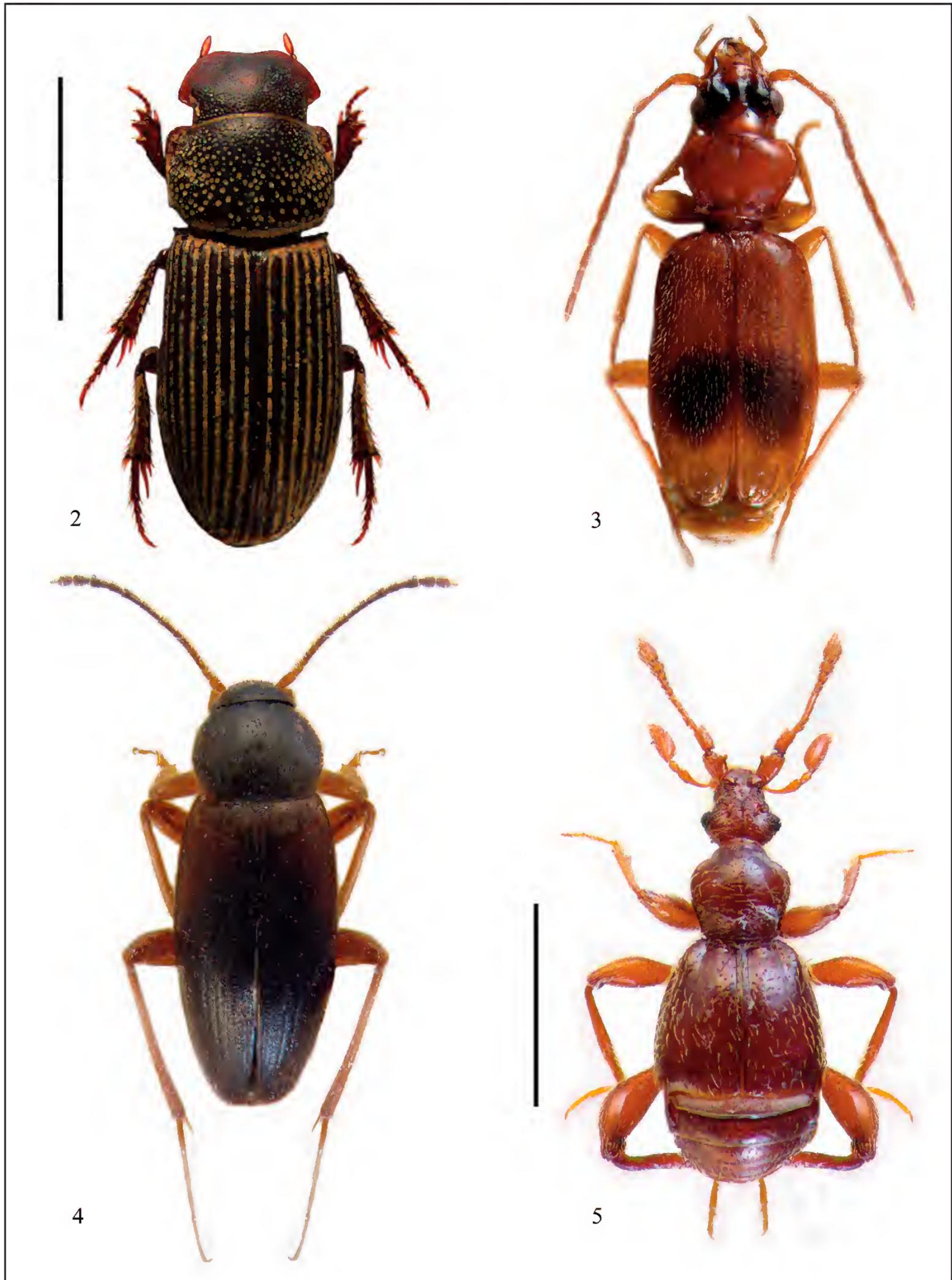


Figure 2. Habitus of *Ataenius horticola*; Figure 3. Habitus of *Blemus discus*; Figure 4. Habitus of *Choleva macedonica* (scale figs. 2–4: 2.5 mm); Figure 5. Habitus of *Bryaxis beroni* (scale: 1.0 mm).

### *Staphylinidae (Pselaphinae)*

All species that were captured with MSS traps usually can be found in leaf litter, rotten wood or under bark of trees and under stones. Apparently these species penetrate deep in the soil and some of them (*Bryaxis islamitus*, *Batrisodes elysius*) can be found also in caves (Besuchet, 1978, 1993; Bekchiev, 2011). We could suppose that the reason for this vertical migration is the alteration of appropriate microclimatical conditions (temperature, humidity) on the surface of the soil during the different seasons. Interesting fact is the founding of *Bryaxis beroni* in MSS, up to now this species was known only from caves (Bekchiev, 2008; Hlaváč et al., 2008).

### *Curculionidae*

Seventeen species of weevils have been caught in the MSS-trap as eleven of them belong to the genus *Otiorhynchus* Germar, 1822. The representatives of this genus are usually known as wingless rhizophagous. It is worth noting the finding of two taxa. The first of them is *Otiorhynchus consobrinus*. It belongs to the Balkan endemic subgenus *Zustalestus* Reitter, 1912 and is new to the Bulgarian fauna. So far, this species was known only from Croatia. The second species deserving attention is *Otiorhynchus (Podoropelmus)* sp. aff. *metsovensis* Magnano, 1999. This taxon might belong to a new species for the science, but additional material and works are needed to prove it.

### *other families*

Besides species of the above discussed four families, we found in the traps also representatives of other twelve families (Table 2).

Among the last species, the most characteristic endogean element seems to be the genus *Langelandia* Aubé, 1842. The species from this genus are always blind and partially depigmented, and they are collected sometimes sifting soil litter. We have distinguished at least three morphospecies of *Langelandia* as only *L. anophtalma* Aubé, 1842 was hitherto reported for Bulgaria. The material from this genus will be object of a separate study.

The representatives of *Hylaia* Guérin-Ménéville, 1857 and *Lycoperdina* Latreille, 1807 (both

endomychids) have been collected also in Bulgaria shifting leaf litter, and rarely they fall in the pitfall traps “Barber”. These beetles eat fungi and live in the ground, so their finding in the MSS-traps was not a surprise. An interesting fact is the collection of *Ataenius horticola*. The only species from subfamily Euparinae in continental Europe was only recently recorded from Bulgaria with detailed data (Guéorguiev & Bekchiev, 2009).

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## Ground beetles (Coleoptera Carabidae) diversity patterns in forest habitats of high conservation value, Southern Bulgaria

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### ABSTRACT

The study presents a comparison between the diversity of the carabid beetles taxocoenoses and their spatial distribution in different forest types of high conservation value in Strandzha (8 sites), the Rhodopes (4 sites) and Belasitsa (6 sites) mountains. The diversity indices have demonstrated the highest species richness and the highest diversity values in the riverside sites of Strandzha Mountain. The lowest species richness has been found in the tertiary relict forest of oriental beech with undergrowth of rhododendron (Strandzha Mountain) and in the century-old sweet chestnut forest (Belasitsa Mountain). The lowest values of diversity and evenness have been found in the beech forest sites in Strandzha and the Rhodopes due to the prevalence of the *Aptinus* species. This low diversity is a natural condition for the studied sites. The classification of the ground beetles complexes from the studied sites by similarity indices and TWINSpan has been made. A high level of dissimilarity among the sites has been found, showing unique species composition and abundance models in each site. Carabid beetles taxocoenoses in the forests of Strandzha Mountain have shown a low similarity level by species composition and abundance even in the range of the same mountain. Indicator species have been shown. The ordination of the carabid complexes has showed that the sites have been distributed continuously along two significant gradients. The first gradient has been found to be the altitude (probably due to the temperature conditions) in a combination with the hydrological regime. The second significant gradient probably has been under the complex influence of the climate conditions and vegetation type.

### KEY WORDS

Carabidae; diversity; conservation; Bulgaria.

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### INTRODUCTION

The present study is a part of the pilot studies of some indicator species groups as a basis for a long term monitoring in different forest types of high conservation value (Natura 2000 sites) in the Rhodopes, Belasitsa and Strandzha Mountains.

In order to assess the ecosystems before taking some management decisions there is a need of basic knowledge of the species compositions and succes-

sional processes of the species assemblages occupying the habitats (Szyszko et al., 2000).

Ground beetles could be a very useful group as an indicator of the habitat disturbance as well: they are abundant in most ecosystems; some species possess strong habitat preferences; most of the ground beetle species are associated with specific landscapes and microclimate conditions; they show rapid response to environmental changes (Pearsal, 2007). Until this study there was scarce information

about carabid beetles' fauna of Strandzha and Belasitsa Mountains (Gueorguiev & Gueorguiev, 1995). The diversity patterns and spatial structure of the ground beetles communities from these habitats have been unknown as well.

## MATERIAL AND METHODS

### *Study area and sampling methods*

The studied sites have been chosen in order to be representative habitat types for the Rhodopes, Belasitsa and Strandzha Mountains. The total number of the studied sites has been eighteen (Table 1, Fig.1). The description of the sample sites and their code according to Habitats Directive (Directive 92/43 EEC, EC, 1992) are given in Table 1.

At each site 10 pitfall traps (diameter = 80 mm, length = 110 mm) were set in a line. The conserving fluid in the traps was propylene glycol. The material was collected from May to October in the corresponding years shown in Table 2.

### *Data Analysis*

The species richness-number of collected species in each sample site (S); Shanon's (H) and Evenness

indexes have been calculated to compare alfa-diversity. Chao 1 procedure has been applied to calculate the expected species richness in the studied sites (Chao, 2005).

The dominance of the species has been determined using Pesenco's logarithmic scale (Pesenko, 1982) and the categories names have been adapted to Tischler's dominance categories, (1949): eudominants (very high abundance), dominants (high abundance), subdominants (average abundance), recedents (low abundance) and subrecedents (single individuals) (Kostova, 2009). Multidimensional non-parametric scaling (MDS) has been applied to visualize is similarity distances between the dominance curves of the studied taxocoenoses (Clarke, 1993). Chi-square test has been used to test the goodness of fit of the studied taxocoenoses' abundance models to the theoretical ones.

Czekanowski-Sørensen and Bray-Curtis similarity coefficients have been used to calculate similarity between carabid taxocoenoses, by species composition and by relative abundance of the species respectively. UPGMA method for clustering has been applied for constructing the dendrograms (Krebs, 1999). Two way indicator species analysis (TWINSPAN) for classification of the carabid beetle complexes has also been performed.

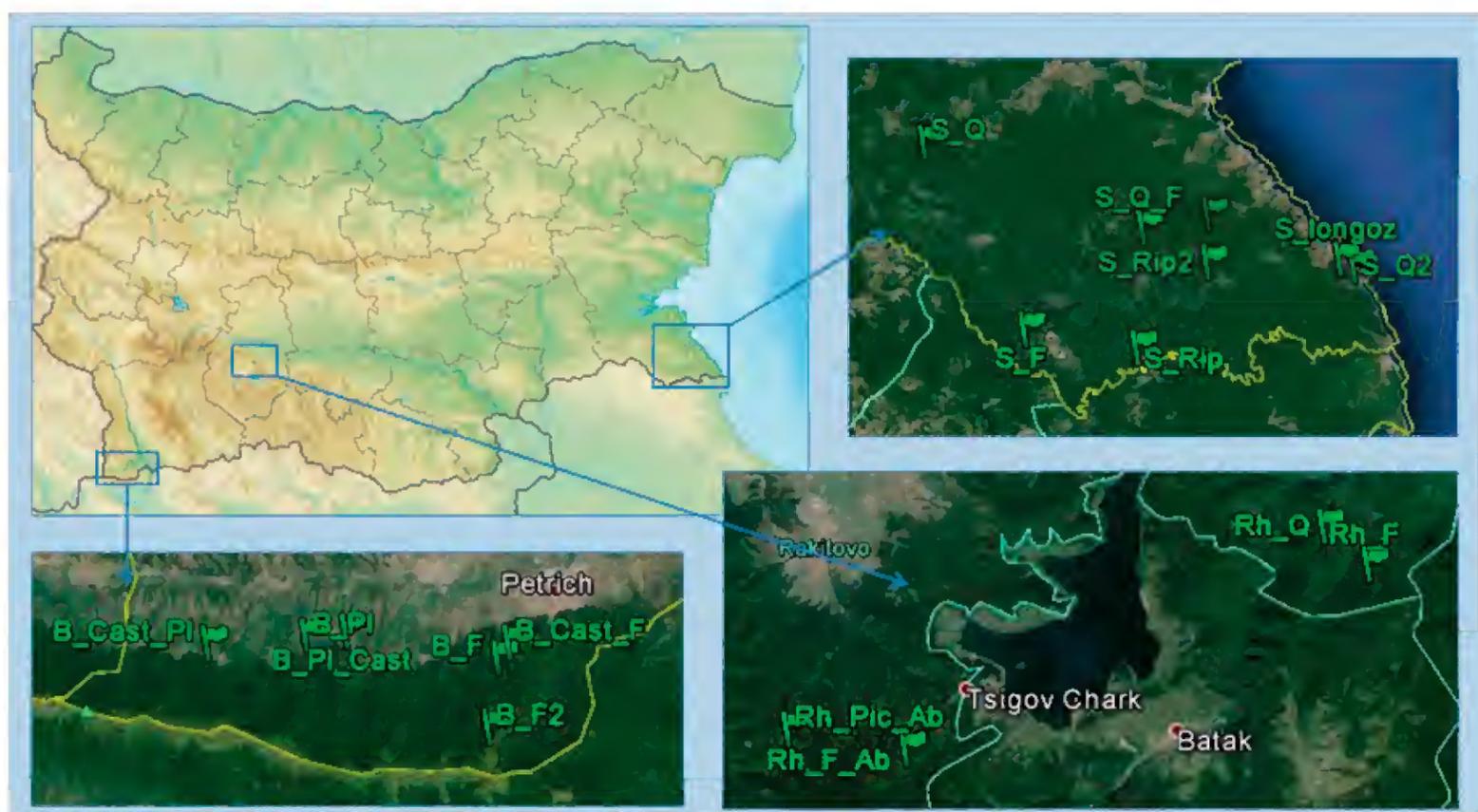


Figure 1. A map of the location of the study sites, S-Bulgaria (Source: Google Earth, 2014).

Mountain	Site	Altitude	Characteristic trees	Code HD92/43
Belasitsa	B_Pl	450	<i>Platanus orientalis</i> Linnaeus	92C0 - <i>Platanus orientalis</i> and <i>Liquidambar orientalis</i> woods
	B_Pl_Cast	400	<i>Platanus orientalis</i> Linnaeus, <i>Castanea sativa</i> Miller	92C0 - <i>Platanus orientalis</i> and <i>Liquidambar orientalis</i> woods
	B_Cast_Pl	400	<i>Platanus orientalis</i> Linnaeus, <i>Castanea sativa</i> Miller	92C0 - <i>Platanus orientalis</i> and <i>Liquidambar orientalis</i> woods
	B_Cast	750	<i>Castanea sativa</i> Miller, <i>Fagus sylvatica</i> Linnaeus	9260 <i>Castanea sativa</i> woods
	B_F	700	<i>Fagus sylvatica</i> Linnaeus (along waterfall)	9110 <i>Luzulo-Fagetum</i> beech forests
	B_F2	1500	<i>Fagus sylvatica</i> Linnaeus	9110 <i>Luzulo-Fagetum</i> beech forests
Rhodopes	Rh_Q	1054	<i>Quercus dalechampii</i> Tenore	91M0 Pannonian-Balkan turkey oak-sessile oak forests
	Rh_F	1133	<i>Fagus sylvatica</i> Linnaeus	9130 <i>Asperulo-Fagetum</i> beech forests
	Rh_F_Ab	1401	<i>Fagus sylvatica</i> Linnaeus, single trees <i>Picea abies</i> Karsten, <i>Abies alba</i> Miller	9130 <i>Asperulo-Fagetum</i> beech forests
	Rh_Pic_Ab	1596	<i>Picea abies</i> Karsten, <i>Abies alba</i> Miller	9410 Acidophilous <i>Picea</i> forests of the montane to alpine levels
Strandzha	S_Q	324	<i>Quercus hartwissiana</i> Steven, <i>Quercus cerris</i> Linnaeus	91M0 *Pannonian-Balkan turkey oak-sessile oak forests
	S_Q2	15	<i>Quercus frainetto</i> Tenore, <i>Quercus cerris</i> Linnaeus	91M0 *Pannonian-Balkan turkey oak-sessile oak forests
	S_Q_F	271	<i>Quercus polycarpa</i> Schur, single trees <i>Fagus orinetalis</i> Lipsky	91M0 *Pannonian-Balkan turkey oak-sessile oak forests
	S_F	401	<i>Fagus orientalis</i> Lipsky	91S0 *Western Pontic beech forests
	S_F_Rhod	183	<i>Fagus orientalis</i> Lipsky, undergrowth <i>Rhododendron ponticum</i> Linnaeus	91S0 *Western Pontic beech forests
	S_Rip	224	<i>Alnus glutinosa</i> Gaertn., <i>Quercus cerris</i> Linnaeus	91E0 *Alluvial forests with <i>Alnus glutinosa</i> and <i>Fraxinus excelsior</i>
	S_Rip2	35	meadow with single trees <i>Alnus glutinosa</i> Gaertn., <i>Salix sp.</i> , <i>Uglans regia</i> Linnaeus, <i>Rubus sp.</i> near <i>Quercus sp.</i> forest	91E0 *Alluvial forests with <i>Alnus glutinosa</i> and <i>Fraxinus excelsior</i>
	S_Longoz	6	<i>Fraxinus angustifolia</i> subsp. <i>oxycarpa</i> (M.Bieb. ex Willd.), <i>Alnus glutinosa</i> Gaertn.	91F0 Riparian mixed forests of <i>Quercus robur</i> , <i>Ulmus laevis</i> and <i>Ulmus minor</i> , <i>Fraxinus excelsior</i> or <i>Fraxinus angustifolia</i> , along the great rivers

Table 1. Description of the sample sites, S-Bulgaria.

This method makes classification of the samples, and then uses this classification to obtain a classification of the species according to their ecological preferences. It also makes a dichotomy based on ordination identifying the direction of variation. It gives an indicator pseudospecies, i.e. transforms abundance into pseudospecies (Hill & Šmilauer, 2005).

Detrended correspondence analysis (DCA) has been applied for ordination of the beetle complexes by sample sites. Data standardization has been applied for the analysis due to the different duration of the collecting time. The relative abundance (proportion of the total number of caught individuals) of the species from a given sample site has been used to calculate alpha-diversity indices, two way indicator species analysis and dominant structure analysis. Mean number of caught individuals per 100 trap/days has been used for cluster and ordination analysis. The following statistical softwares were used: Microsoft Excel (Office 2010), Past 3.01 (Hammer & Harper, 2001), Estimate S9.1.0 (Colwell, 2013), Primer 6 (Clarke & Gorley, 2006), WinTWINS 2.3 (Hill & Šmilauer, 2005).

## RESULTS

Eleven thousand eight hundred and seventy-six individuals belonging to one hundred twenty-eight species have been collected (Tables 2, 3). Only six species have been common to the three mountains: *Calosoma sycophanta*, *Carabus convexus*, *C. intricatus*, *C. coriaceus*, *Pterostichus niger* and *Myas chalybaeus* (Fig. 2).

The highest species richness of ground beetles has been shown in the riparian site with meadow and single trees (Strandzha)- 45 species. Relatively high species richness has also been demonstrated in the riparian sites of Strandzha with rich herbaceous undergrowth. The lowest species number has been found in the tertiary relict forest of *Fagus orientalis* with undergrowth of *Rhododendron ponticum* (Strandzha), 8 species and in the centuries-old forest of *Castanea sativa* (Belasitsa), 9 species. Relatively low species richness has also been found in the carabid taxocoenoses from the sample sites with altitude above 1400 m (the Rhodopes and Belasitsa Mountains) (Fig. 3). The species number of the ground beetles at each site has been actually

Mountain	Year of study	N_exemplars	N_Species
Rhodopes	2006, 2007	5062	29
Belasitsa	2008, 2009	1810	46
Strandzha	2009	5004	92
Total	-	11876	128

Table 2. A summary table of the collected material, S-Bulgaria.

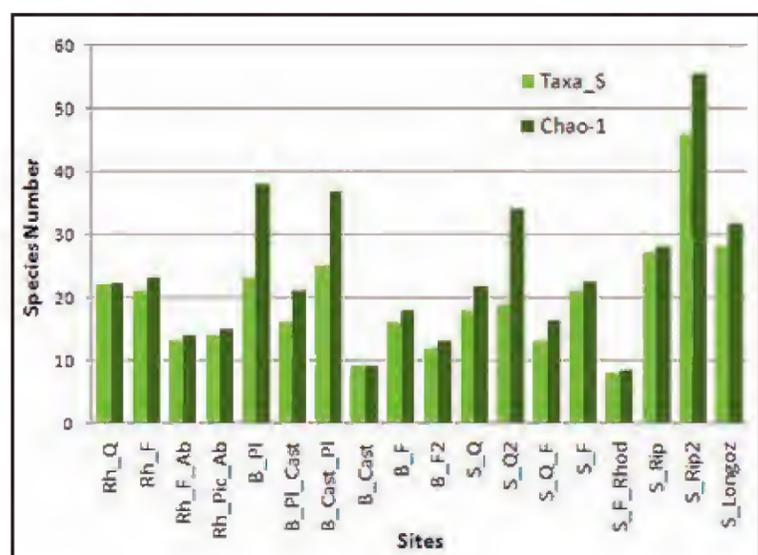


Figure 2. Species richness (empirical and estimated by Chao 1 procedure) of the ground beetle complexes in the studied sites.

greater, because there have been species that do not fall into the traps. The estimated species number by Chao 1 procedure has been almost the same only for four of the carabid taxocoenoses with relatively low species richness. The highest species number has been estimated for the riparian sites, the oak forests at the seashore in Strandzha and for the oriental plane forests in Belasitsa (Fig. 3).

Shanon's diversity index, fairly sensitive to actual site differences (Krebs, 1999), has demonstrated relatively high ground beetles diversity for all of the studied sites (Figs. 4, 5). An exception has been the beech forests of the Rhodopes and Strandzha Mountains due to the prevalence of one species: *Aptinus bombardata* and *A. cordicollis* respectively. The carabid taxocoenose of the century-old sweet chestnut forest in Belasitsa has shown the highest value of evenness -0.8. The lowest evenness has been estimated for the carabid taxocoenoses from the beech forest of Strandzha and the Rhodopes due to the above mentioned prevalence of the *Aptinus* species (Fig. 6).

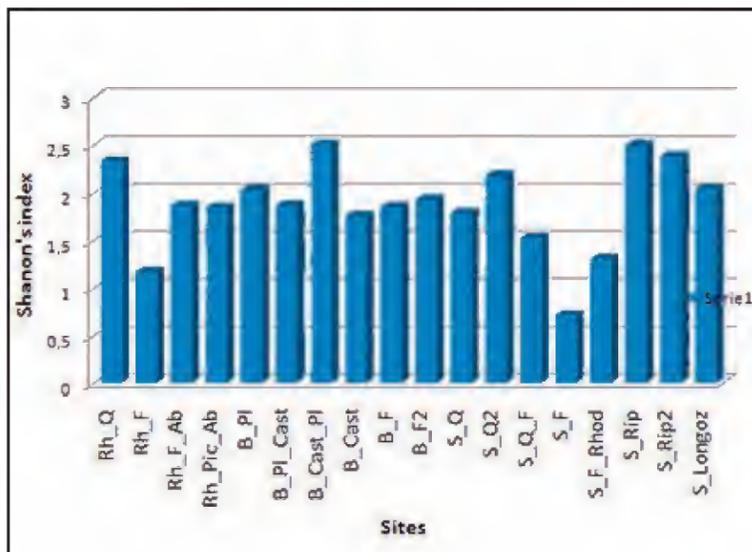


Figure 3. Diversity of the ground beetle complexes in the studied sites, estimated by Shannon's index.

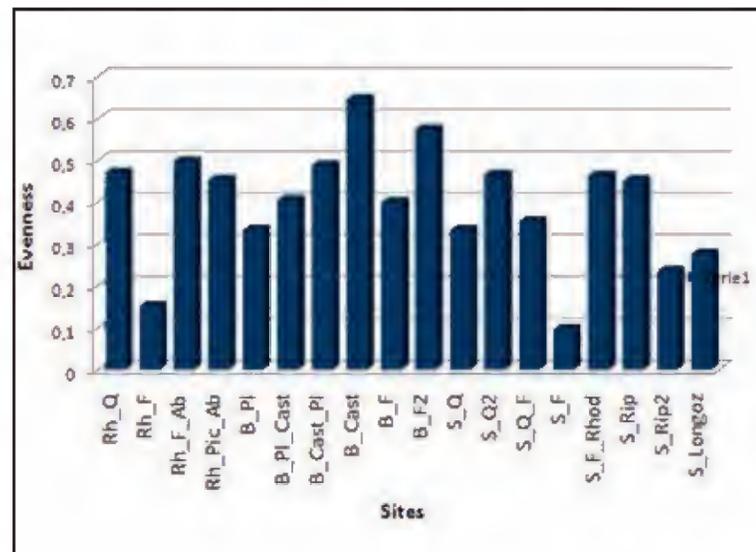


Figure 4. Evenness of the ground beetle complexes in the studied sites.

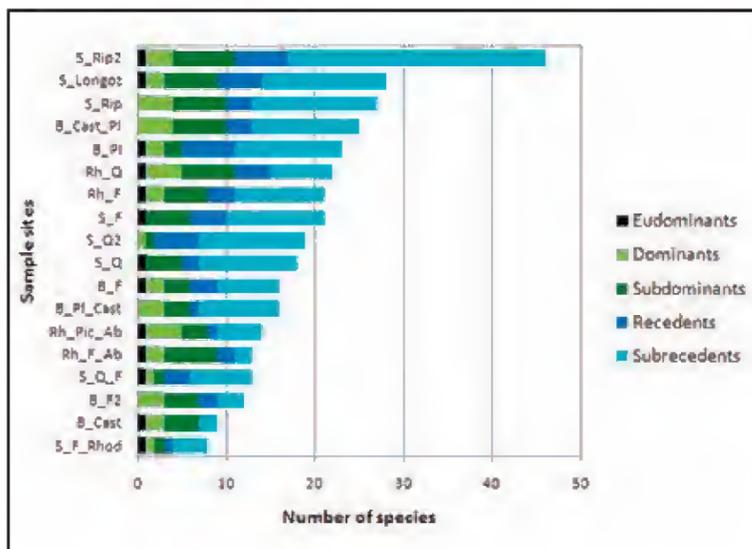


Figure 5. Dominance structure of the ground beetle complexes, based on Pesenko's logarithmic scale.

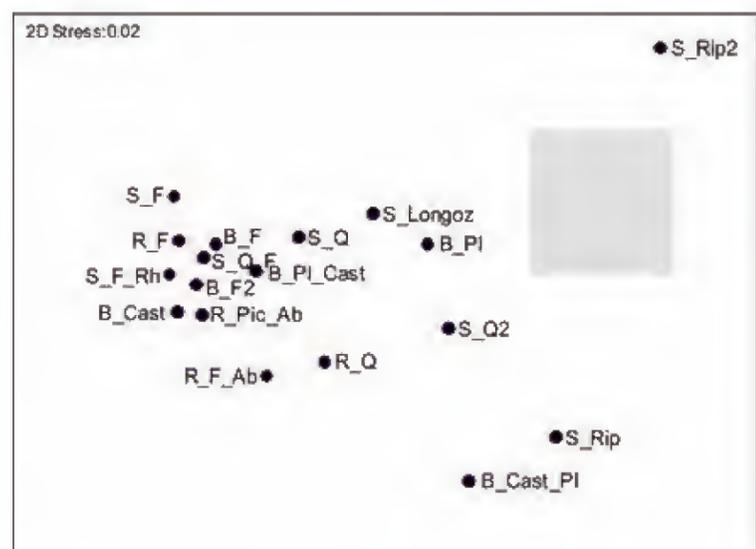


Figure 6. Dissimilarity distances between the dominance curves of the studied taxocoenoses, an MDS method.

The dominance structure of the riparian site with meadow in Strandzha has differed strongly from all the other with many species represented by single individuals (Figs. 7, 8). The riparian forest of Strandzha (S\_Rip) has showed a dominance structure close to the chestnut with oriental plane trees in Belasitsa (B\_Cast\_PI) without eudominants and more species as dominants and subdominants. These two sites have one thing in common- through both of them pass eco-trails. They have demonstrated Log-series model of the abundance, characteristic for disturbed habitats (B\_Cast\_PI: Chi square = 0.97,  $p = 0.94$ ; S\_Rip: Chi square = 0.98,  $p = 0.91$ ). The beech woods with prevalence of the *Aptinus* species have also represented a close dominant structure, so as the century-old and the tertiary relict forests with a small number of species and high evenness. The classification of the carabid

beetles' taxocoenoses by qualitative and quantitative similarity coefficients has demonstrated low levels of similarity for the mountains in general. Four main clusters have been formed by species composition (Fig. 9). The similarity by species composition has been relatively high for the studied carabid assemblages from the Rhodopes where they have formed a separate cluster. A separate cluster, although with low similarity, has been formed by the periodically flooded riparian sites of Strandzha with thick herbaceous undergrowth (S\_Rip; S\_Longoz). The beech and the chestnut forests of Belasitsa have also represented a separate cluster. The rest of the studied ground beetle assemblages have formed a cluster with low to average similarity between them. The picture of the clustering based on Bray-Curtis coefficient has shown more differences between the studied carabid assemblages.

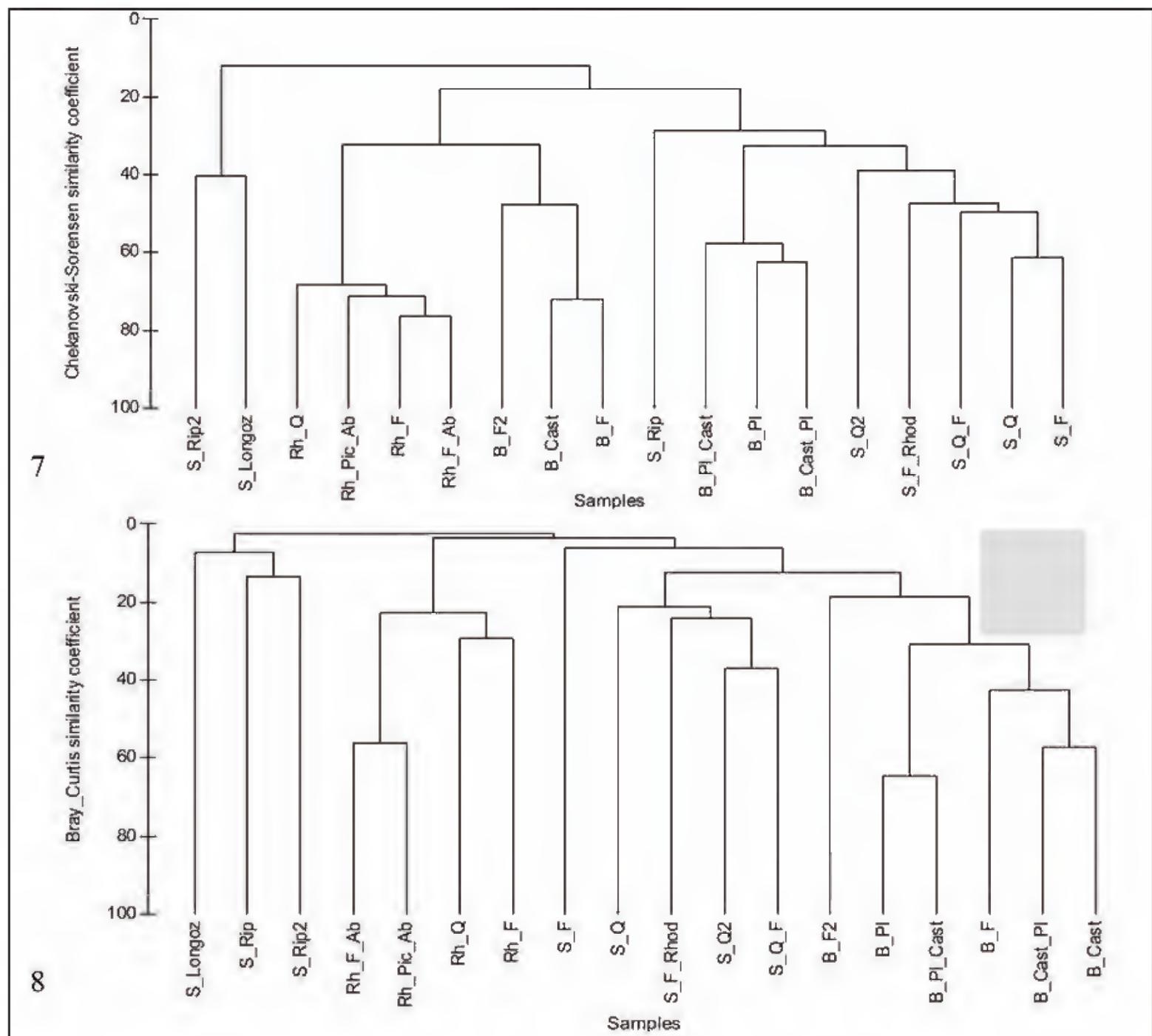


Figure 7. A dendrogram for hierarchical clustering of the similarity by species composition of the carabid beetles' complexes, an UPGMA method, based on Chekanovski- Sørensen coefficient of similarity. Figure 8. A dendrogram for hierarchical clustering of the similarity by species abundance of the carabid beetles' complexes, an UPGMA method, based on Bray-Curtis coefficient of similarity.

The levels of similarity have been much lower than by species composition only. There have been three main clusters: one of the riparian sites of Strandzha; one of the sites of the Rhodopes and one of all the other sites. At first level of division TWIN-SPAN analysis of the ground beetles' taxocoenoses by sample sites has shown separation of the Strandzha and Belasitsa low altitude sites from the other sample sites. The following groups of sites have been formed at second level of division: 1. the Rhodopes sites with altitude above 1000 m and Belasitsa sites above 700 m; 2. Belasitsa and Strandzha forest sites up to 450m; 3. the period-

ically flooded riparian sites of Strandzha. The classification of the species based on their habitat preferences has also been obtained (Table 3).

The ordination of the carabid assemblages by DCA has demonstrated two significant gradients (Eigenvalues: first axis = 0.97, second axis = 0.63, third axis = 0.34, fourth axis = 0.15). The sample sites have been arranged along the first axis as follows: the sites from the Rhodopes (above 1000 m) have been followed by the sites from Belasitsa in direction higher to lower altitude sites, then the forest sites from Strandzha and the riparian sites from the same mountain ending with the period-

ically flooded forest along the estuary of Veleka river with altitude almost at the sea level. The arrangement along the second axis (gradient) has separated the Norway spruce forests with altitude above 1400 meters from all the other sites (Fig. 11).

## DISCUSSION

The studied carabid beetles' taxocoenoses have demonstrated high species richness and diversity as a whole. There have been some exceptions like the low species richness of ground beetles in the old stable forest ecosystems, which is a natural condition. The higher species number of carabids in the open area habitats and cleared forests than in the old forests is typical for the temperate zone (Kryzhanovsky, 1983). The low values of diversity indices and evenness of the beech forests of the Rhodopes and Strandzha Mountains have been due to the prevalence of one species: *Aptinus bombarda* and *A. cordicollis*, respectively. This natural condition had also been found for the beech forests in Vitosha Mountain, Bulgaria (Popov et al., 1998).

The dominance structure and the abundance models of the carabid beetles' associations could be important indicators for the statement of succession and disturbance (Hill & Hamer, 1998). Only two of the studied habitats have shown disturbance by this estimators, probably due to an anthropogenic disturbance of the often visited by tourists eco-trails in

them. However, the use of the abundance models for assessment of the ground beetles status, respectively habitat status, is controversial. One of the reasons is that there are taxocoenoses with natural conditions differing from log-normal abundance model, which is an indicator of natural undisturbed communities.

When chi-square test is used for estimating goodness of fit to the theoretical models, there appears another problem. This test has low power and cannot be used for small samples (for example sites with low species number cannot be tested), so as for the different abundance models it has a different power, and the results of p - value should not be used for comparisons between the goodness of fit to the different models (Hammer et al., 2001). Then Kolmogorov-Smirnov one sample test could also be used. The classification of the studied sites has shown unique species composition and abundance of the ground beetle assemblages even within the range of one mountain. The unique indicator carabid species and pseudospecies (with transformed abundance) for the studied sites have been estimated by TWINSpan analysis. An indicator pseudospecies could be those with category above 2 (abundance above 5 %), they have to be abundant enough to be easily found and collected.

As a result, the following indicator species could be used for the studied taxocoenoses: *Cychrus semigranosus balcanicus* and *Carabus hortensis* have been found as indicators for the high altitude beech and Norway spruce forests, *Calathus metal-*

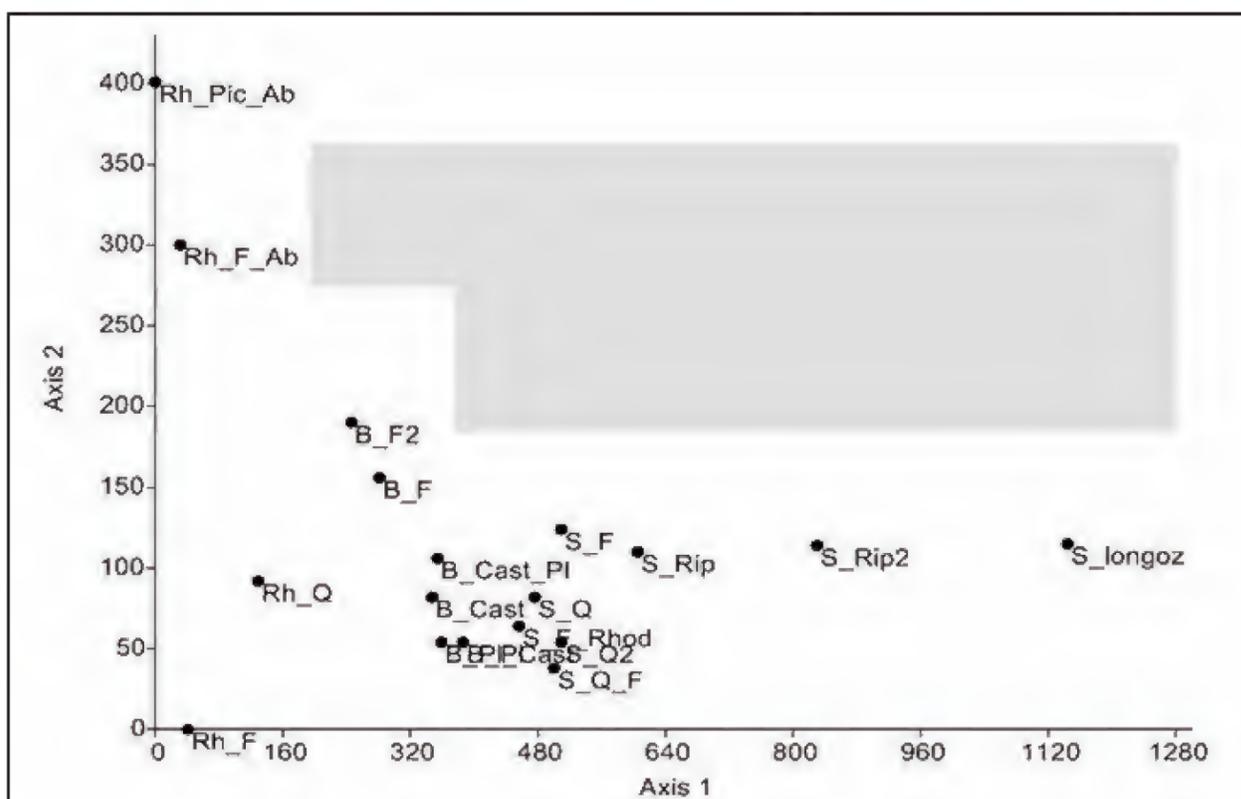


Figure 9. Detrended correspondence analysis (DCA) ordination diagram of the carabid beetles' complexes.

Species	Sample sites															Species division levels			
	Rh_Q	Rh_F	Rh_F_Ab	Rh_Pic_Ab	B_Cast_PI	B_Cast	B_F	B_F2	B_PI	B_PI_Cast	S_Q	S_Q_F	S_F	S_F_Rhod	S_Q2		S_Rip	S_Rip2	S_Longoz
<i>Platyderus rufus</i> Duftschmid, 1812	-	-	-	-	4	-	-	-	1	3	-	-	-	-	-	-	-	-	*11
<i>Ophonus laticollis</i> Mannerheim, 1825	-	-	-	-	4	-	-	-	2	-	-	-	-	-	-	-	-	-	*11
<i>Carabus intricatus</i> Linnaeus, 1761	3	1	1	-	4	5	4	-	4	5	2	-	2	-	-	-	-	*11	
<i>Tapinopterus balcanicus belasicensis</i> Maran, 1933	-	-	-	-	5	4	5	5	3	2	-	-	-	-	-	-	-	*10111	
<i>Laemostemus terricola punctatus</i> Dejean, 1828	-	-	-	-	3	-	-	-	1	-	-	-	-	-	-	-	-	*10111	
<i>Pterostichus vecors</i> (Tschitscherine, 1897)	-	-	-	-	-	-	4	1	-	-	-	-	-	-	-	-	-	*10110	
<i>Pterostichus brucki</i> Schaum, 1859	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	*10110	
<i>Pterostichus brevis</i> (Duftschmid, 1812)	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	*10110	
<i>Platymus scrobiculatus</i> (Fabricius, 1801)	-	-	-	-	5	4	5	-	2	-	-	-	-	-	-	-	-	*10110	
<i>Ophonus schaubergerianus</i> (Puel, 1937)	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	*10110	
<i>Molops rufipes belasicensis</i> Mlynar, 1977	-	-	-	-	5	5	5	5	3	-	-	-	-	-	-	-	-	*10110	
<i>Leistus magnicollis</i> Motschulsky, 1866	-	-	-	-	-	-	1	3	-	-	-	-	-	-	-	-	-	*10110	
<i>Lebia cyanocephala</i> (Linnaeus, 1758)	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	*10110	
<i>Harpalus triseriatus</i> Fliischer, 1897	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	*10110	
<i>Harpalus griseus</i> (Panzer, 1797)	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	*10110	
<i>Synuchus vivalis</i> (Illiger, 1798)	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	*101011	
<i>Cychrus semigranosus balcanicus</i> Hopffgarten, 1881	4	5	5	5	2	1	2	5	-	-	-	-	-	-	-	-	-	*101011	
<i>Pterostichus oblongopunctatus</i> (Fabricius, 1787)	-	2	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	*101010	
<i>Carabus violaceus azureus</i> Dejean, 1826	2	4	5	5	-	2	4	2	-	-	-	-	-	-	-	-	-	*101010	
<i>Carabus hortensis</i> Linnaeus, 1758	5	5	5	5	-	-	1	5	-	-	-	-	-	-	-	-	-	*101010	
<i>Xenion ignitum</i> (Kraatz, 1875)	5	5	5	5	-	-	-	-	-	-	-	-	-	-	-	-	-	*101001	
<i>Apinopterus balcanicus</i> Ganglbauer, 1891	4	5	5	4	-	-	-	-	-	-	-	-	-	-	-	-	-	*101001	
<i>Notiophilus biguttatus</i> (Fabricius, 1779)	4	2	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	*101001	
<i>Molops rhodopensis</i> Apfelbeck, 1904	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	*101001	
<i>Molops dilatatus</i> Chaudoir, 1868	5	5	5	5	-	-	-	-	-	-	-	-	-	-	-	-	-	*101001	
<i>Molops alpestris</i> (Dejean, 1828)	4	5	5	1	-	-	-	-	-	-	-	-	-	-	-	-	-	*101001	
<i>Microlestes minutulus</i> (Goeze, 1777)	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*101001	
<i>Laemostemus terricola</i> Herbst, 1784	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*101001	
<i>Clivina fossor</i> (Linnaeus, 1758)	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*101001	
<i>Carabus montivagus bulgaricus</i> Csiki, 1927	5	2	4	2	-	-	2	-	-	-	-	-	-	-	-	-	-	*101001	
<i>Calathus mollis</i> (Marsham, 1802)	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*101001	
<i>Calathus metallicus</i> Dejean, 1828	-	2	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	*101001	
<i>Aptinus bombardata</i> (Illiger, 1800)	5	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*101001	
<i>Abax ovalis</i> (Duftschmid, 1812)	2	5	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*101001	

Table 3. TWINSpan analysis' table of the studied ground beetles' taxocoenoses. Species abundance has been represented by pseudospecies. Doubled line has shown the first level of division, dotted line has shown the second level of division (continued).

Species	Sample sites															Species division levels			
	Rh_Q	Rh_F	Rh_F_Ab	Rh_Pic_Ab	B_Cast_PI	B_Cast	B_F	B_F2	B_PI	B_PI_Cast	S_Q	S_Q_F	S_F	S_F_Rhod	S_Q2		S_Rip	S_Rip2	S_Longoz
<i>Pterostichus niger</i> (Schaller, 1930)	2	2	5	5	1	-	-	-	1	-	-	-	2	-	-	-	-	1	*101000
<i>Amara communis</i> (Panzer, 1797)	2	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	*101000
<i>Harpalus rufipes</i> (De Geer 1774)	4	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	3	1	*100
<i>Calathus fuscipes</i> (Goeze, 1777)	2	-	-	1	1	-	-	-	-	-	-	-	-	-	3	2	5	-	*011
<i>Anisodactylus binotatus</i> (Fabricius, 1787)	-	-	-	-	2	-	-	-	-	1	-	-	-	-	-	-	-	4	*011
<i>Amara aenea</i> (De Geer, 1774)	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	*011
<i>Trechus quadristriatus</i> (Schrank, 1781)	-	-	-	-	1	-	2	5	-	-	3	-	3	-	1	2	2	-	*0101
<i>Myas chalybaeus</i> (Palliard, 1825)	4	-	-	-	5	5	3	-	5	5	4	3	4	4	3	-	-	-	*0101
<i>Carabus convexus</i> Fabricius, 1775	5	3	-	-	5	5	2	-	5	5	5	2	5	2	2	3	2	-	*0101
<i>Abax carinatus</i> (Duftschmid, 1812)	-	-	-	-	5	-	-	-	4	4	2	-	-	-	-	-	-	-	*0101
<i>Notiophilus rufipes</i> Curtis, 1829	-	-	-	-	4	-	-	-	2	1	4	1	-	-	-	5	-	-	*0100
<i>Carabus coriaceus</i> Linnaeus, 1758	3	4	3	1	-	5	3	-	2	4	3	5	5	4	5	-	2	2	*0100
<i>Calosoma sycophanta</i> (Linnaeus, 1758)	1	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	*0100
<i>Harpalus atratus</i> Latreille, 1804	-	-	-	-	5	-	-	-	3	4	1	4	4	-	-	4	-	-	*0011
<i>Amara saphyrea</i> Dejean, 1828	-	-	-	-	1	-	-	-	1	2	-	-	-	-	-	-	-	-	*0011
<i>Amara convexior</i> Stephens, 1828	-	-	-	-	1	-	1	-	-	-	-	-	2	-	-	5	-	-	*0011
<i>Trechus crucifer</i> Brulerie, 1875	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	*001011
<i>Pterostichus properans</i> (Chaudoir, 1868)	-	-	-	-	-	-	-	-	-	-	2	-	3	2	-	2	-	-	*001011
<i>Harpalus calceatus</i> (Duftschmid, 1812)	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	*001011
<i>Molops piceus byzantinus</i> Apfelbeck, 1902	-	-	-	-	-	-	-	-	-	-	-	-	5	-	2	2	-	-	*001011
<i>Licinus cassideus</i> (Fabricius, 1792)	-	-	-	-	-	-	-	-	-	-	1	1	-	-	1	-	-	-	*001011
<i>Laemostenus venustus</i> (Dejean, 1828)	-	-	-	-	-	-	-	-	-	-	2	-	3	-	-	-	1	-	*001011
<i>Laemostenus cimmerius</i> (Fischer-Waldheim, 1823)	-	-	-	-	-	-	-	-	-	-	5	1	5	-	4	-	-	-	*001011
<i>Harpalus sulphuripes</i> Germar, 1824	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	*001011
<i>Harpalus smaragdinus</i> (Duftschmid, 1812)	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	*001011
<i>Harpalus honestus</i> (Duftschmid, 1812)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	*001011
<i>Harpalus froelichi</i> Sturm, 1818	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	*001011
<i>Chlaenius aenocephalus</i> Dejean, 1826	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	*001011
<i>Carabus marietti</i> Cristofori et Jan, 1837	-	-	-	-	-	-	-	-	-	-	2	3	5	5	-	-	-	-	*001011
<i>Carabus scabrosus</i> Olivier, 1795	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	*001011
<i>Calosoma inquisitor</i> (Linnaeus, 1758)	-	-	-	-	-	-	-	-	-	1	-	2	-	-	-	-	-	-	*001011
<i>Calathus longicollis</i> Motschulsky, 1864	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	*001011
<i>Amara tricuspis</i> <i>tricuspis</i> Dejean, 1831	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	*001011
<i>Pterostichus nigrita</i> (Paykull, 1790)	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	*001010
<i>Harpalus tardus</i> (Panzer, 1797)	-	-	-	-	1	-	-	-	5	2	1	5	2	2	3	4	3	-	*001010
<i>Dromius quadrimaculatus</i> (Linnaeus, 1758)	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	*001010

Table 3. TWINSpan analysis' table of the studied ground beetles' taxocoenoses. Species abundance has been represented by pseudospecies. Doubled line has shown the first level of division, dotted line has shown the second level of division (continued).

Species	Sample sites															Species division levels			
	Rh_Q	Rh_F	Rh_F_Ab	Rh_Pic_Ab	B_Cast_PI	B_Cast	B_F	B_F2	B_PI	B_PI_Cast	S_Q	S_Q_F	S_F	S_F_Rhod	S_Q2		S_Rip	S_Rip2	S_Longoz
<i>Acupalpus suturalis</i> Dejean, 1829	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	*001010
<i>Trechus sp. (subnotatus group)</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	*001001
<i>Parophonus maculicornis</i> (Duftschmid, 1812)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	*001001
<i>Ophonus similis</i> (Dejean, 1829)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	*001001
<i>Ophonus nitidulus</i> Stephens, 1828	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	2	-	-	*001001
<i>Notiophilus palustris</i> (Duftschmid, 1812)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	*001001
<i>Leistus rufomarginatus</i> Duftschmid, 1812	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	*001001
<i>Harpalus flavicornis</i> Dejean, 1829	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	*001001
<i>Aptinus cordicollis</i> Chaudoir, 1843	-	-	-	-	-	-	-	-	-	-	1	-	5	-	1	5	1	-	*001001
<i>Amara anthobia</i> Villa, 1833	-	-	-	-	-	-	-	-	-	1	-	2	-	-	-	2	-	-	*001001
<i>Harpalus rubripes</i> (Duftschmid, 1812)	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	1	-	*001000
<i>Nebria brevicollis</i> (Fabricius, 1792)	-	-	-	-	-	-	-	2	-	-	1	-	-	-	-	5	5	3	*0001
<i>Carabus wiedemanni</i> Ménériés, 1836	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	3	-	*0001
<i>Amara ovata</i> (Fabricius, 1792)	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	1	2	-	*0001
<i>Harpalus serripes</i> (Quensel, 1806)	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	2	-	*000011
<i>Harpalus dimidiatus</i> (Rossi, 1790)	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	4	-	*000011
<i>Syntomus pallipes</i> (Dejean, 1825)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	*000010
<i>Harpalus albanicus</i> Reitter, 1900	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	*000010
<i>Bembidion lampros</i> (Herbst, 1784)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	5	2	*000010
<i>Agonum assimile</i> (Paykull, 1790)	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	2	2	5	*000010
<i>Asaphidion flavipes</i> (Linnaeus, 1761)	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	4	5	4	*000001
<i>Agonum dorsalis</i> (Pontopippidian, 1763)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	5	4	*000001
<i>Trechus obtusus thracicus</i> Pawlowski, 1973	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	*000000
<i>Tachys bistriatus</i> (Duftschmid, 1812)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	*000000
<i>Syntomus obscuroides</i> (Duftschmid, 1812)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	*000000
<i>Stenolophus smixtus</i> (Herbst, 1784)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	*000000
<i>Pterostichus strenuus</i> (Panzer, 1797)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	*000000
<i>Pterostichus melas</i> (Creutzer, 1799)	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	5	1	*000000
<i>Pterostichus melanarius bulgaricus</i> Lutshnik, 1915	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	*000000
<i>Pterostichus leonisi</i> Apfelbeck, 1904	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	*000000
<i>Pterostichus anthracinus</i> (Illiger, 1798)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	5	*000000
<i>Poecilus cupreus</i> (Linnaeus, 1758)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	5	*000000
<i>Parophonus complanatus</i> (Dejean, 1829)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	*000000
<i>Panagaeus cruxmajor</i> (Linnaeus, 1758)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	*000000
<i>Ophonus sabulicola</i> (Panzer, 1796)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	*000000
<i>Ophonus melleti</i> (Heer, 1837)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	*000000
<i>Oodes gracilis</i> Villa, 1833	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	*000000
<i>Harpalus tenebrosus</i> Dejean, 1829	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	*000000

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Species	Sample sites																Species division levels		
	Rh_Q	Rh_F	Rh_F_Ab	Rh_Pic_Ab	B_Cast_PI	B_Cast	B_F	B_F2	B_PI	B_PI_Cast	S_Q	S_Q_F	S_F	S_F_Rhod	S_Q2	S_Rip		S_Rip2	S_Longoz
<i>Harpalus cupreus</i> Dejean, 1829	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	*000000
<i>Harpalus autumnalis</i> (Duftschmid, 1812)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	*000000
<i>Harpalus affinis</i> (Schrank, 1781)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	*000000
<i>Gynandromorphus etruscus</i> (Quensel, 1806)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	*000000
<i>Dyschirius globosus</i> (Herbst, 1783)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	*000000
<i>Diachromus germanus</i> (Linnaeus, 1758)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	*000000
<i>Chlaenius nigricornis</i> (Fabricius, 1787)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	*000000
<i>Carabus granulatus</i> Linnaeus, 1758	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	*000000
<i>Calathus melanocephalus</i> (Linnaeus, 1758)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	*000000
<i>Brachinus elegans</i> Chaudoir, 1842	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	*000000
<i>Brachinus crepitans</i> (Linnaeus, 1758)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	*000000
<i>Bembidion inoptatum</i> Schaum, 1857	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4	*000000
<i>Bembidion elongatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	*000000
<i>Bembidion andreae</i> (Fabricius 1787)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	*000000
<i>Bembidion tethys</i> Netolitzky 1926	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	*000000
<i>Badister bipustulatus</i> (Fabricius, 1792)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	*000000
<i>Anisodactylus signatus</i> (Panzer, 1797)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	*000000
<i>Agonum viduum</i> (Panzer, 1797)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	*000000
<i>Agonum nigrum</i> Dejean, 1828	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	*000000
<i>Agonum mulleri</i> Herbst, 1785	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	*000000
Division levels of the sites	*00	*00	*00	*00	*01	*01	*01	*01	*1000	*1000	*10010	*10010	*10010	*10010	*10011	*101	*11	*11	

Table 3. TWINSPLAN analysis' table of the studied ground beetles' taxocoenoses. Species abundance has been represented by pseudospecies. Doubled line has shown the first level of division, dotted line has shown the second level of division.

*licus* has been an indicator for the Norway spruce forest above 1500 m, *Molops rhodopensis* has been found as an indicator species only for the high altitude Norway spruce forest of the Rhodopes, *Pterostichus brucki*, for the high altitude beech forest of Belasitsa, *Platyderus rufus* has been unique for the low altitude oriental plane woods, *Pterostichus melanarius bulgaricus*, *Bembidion andreae*, *Calathus melanocephalus*, *Harpalus cupreus* and *Ophonus sabulicola* have been an indicator species for the open area grassy habitats (S\_Rip2), *Bembidion andreae* has also been an indicator species only for the riparian meadow,

*Poecilus cupreus* has also been found as an indicator species for wet grassy habitats like the periodically flooded riparian sites of Strandzha, *Leistus rufomarginatus* and *Trechus* sp. (*subnotatus* group) have been indicator species for the riparian forest of Strandzha (S\_Rip), *Carabus granulatus*, *Chlaenius nigricornis*, *Dyschirius globosus* and *Oodes gracilis* have been found as indicator species for the periodically flooded estuary forest of Strandzha (S\_Longoz), *Calathus longicollis* has been an indicator species for the Black sea coastal oak forest, *Carabus scabrosus*, for the oriental beech woods of Strandzha.

The ordination of the carabid beetles' taxocoenoses has demonstrated continuous arrangement of the sites along the first axis (the first gradient). The first gradient has been found to be the altitude (probably due to the temperature conditions) in combination with the hydrological regime (for example, the periodically flooding of the last two sites). On this gradient, probably there is a complex influence of the climate conditions and the vegetation type. Continuous arrangement according the temperature conditions had also been found for the carabid associations of different altitude in Vitosha Mountain by Popov et al. (1998).

The high conservation value of the studied sites in the Rhodopes, Belasitsa and Strandzha Mountains has also to be concerned due to the great diversity of the ground beetles that should be preserved and monitored. Only the Rhodopes sites have been under high level of protection as a part of natural reserves, so as two of the sites in Strandzha as a part of protected localities. The rest of the studied habitats from Strandzha and Belasitsa Mountains have been with low protection status and therefore threatened by logging.

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## Mollusc assemblages of hard bottom subtidal fringe: a comparison between two coastal typologies

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### ABSTRACT

The mollusc assemblages of subtidal fringe from two different coastal typologies are described in their qualitative and quantitative features. The large-scale spatial investigation has been carried out in the lava cliffs of Catania and the conglomerate “beach-rocks” of Capo Peloro (Messina), whose assemblages have been compared by fourteen shallow sampling stations, spaced out hundred/thousand meters apart. The similarity/dissimilarity levels of the two assemblages have been evaluated throughout a set of eighty-six species, exclusive or common between the two areas. Both the assemblages were characteristic of an impoverished and highly variable photophilic taxocoenosis. The area was the main discriminating factor that determined the highest richness and abundance in the rough lava surface. The Catania assemblage was more constant in species composition, with presence of exclusive bivalves, cue of a micro-sedimentary environment. The Messina assemblage was very variable in species composition, and its structure, dominated by motile gastropods, was evidence of a high energy environment. Differences in the structure and micro-topography of the natural substratum from the two areas, besides possible secondary influence of freshwater inputs and wave exposure, were factors mainly responsible for the observed patterns. The whole data set, with dominant and accessory taxa, involves a relevant contribution from the deeper subtidal assemblage; despite of their ephemeral character, these assemblages contribute to maintain the local biodiversity on a broader spatial scale.

### KEY WORDS

Biodiversity; Geographical trend; Mediterranean Sea; Molluscs; Rocky shores.

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### INTRODUCTION

It is known that species distribution and related biodiversity levels are stressed by the interaction between biotic and abiotic factors, which determine a hierarchy of processes that operate at different spatio-temporal scales (Underwood & Chapman, 1996). Spatial patterns of intertidal hard bottom assemblages have been widely investigated in the past, both on a broad geographic (Blanchette et al., 2008) and local scale (Reichert et al., 2008). In the

Mediterranean basin, despite of the prevalent microtidal regime, the intertidal zone has received much attention (Benedetti-Cecchi, 2001; Fraschetti et al., 2001). By contrast, rocky subtidal assemblages have been investigated to a lesser extent, except for the impacted sessile communities (Fraschetti et al., 2001) and few groups of vagile invertebrates, such as polychaetes (Giangrande, 1988; Giangrande et al., 2003).

The mollusc taxocoene, notwithstanding its relevant diversification and wide geographic and

ecological distribution, has been poorly investigated in its quantitative aspects, and patterns of spatial distribution have been rarely described (Chemello & Milazzo, 2002; Terlizzi et al., 2003). Mollusc spatial patterns and relationships with substratum complexity have been locally investigated, for example in the Aegean Sea (Antoniadou et al., 2005). Within the subtidal zone, the upper level (the fringe) has received a scanty interest in the past, and the associated mollusc assemblages are probably the less known from the Mediterranean phytal zones.

The subtidal fringe, characterized by strong environmental constraints and high levels of environmental disturbance, shows different degrees of substratum complexity which might affect the spatial patterns of flora and fauna (Guichard et al., 2001). Furthermore, the ephemeral character of the algal covering might accentuate the spatial and temporal dynamics of the associated vagile fauna, as proved for shallower as well as deeper subtidal assemblages (Benedetti-Cecchi & Cinelli, 1992). In this respect, the Ionian coasts of Sicily might represent an appropriate case-study, due to rocky cliff typologies that are quite different from the northern coastline (of metamorphic and sedimentary origin) to the central (of mainly volcanic origin) and southern (carbonatic origin) coastlines. In this paper mollusc assemblages of subtidal fringe are investigated from two rocky coasts of different origin, volcanic and sedimentary, respectively located in the Strait of Messina and in the northern side of the Gulf of Catania.

Aims of the present investigation are: i) to describe the mollusc assemblages, which characterise the upper subtidal fringe from two different coastal typologies; ii) to investigate their similarity/dissimilarity at different spatial scales (kilometers, hundreds of kilometers); iii) to highlight the main (a)biotic constraints which may affect the assemblage composition and structure.

## MATERIAL AND METHODS

### *Study areas*

The study area, which corresponds to the northern segment of the Ionian coast of Sicily (Fig. 1), has a regular N 30°-trending shoreline, extending for a total length of 107 km from Capo Peloro

(North) to Catania (South). On the basis of geological and morphological characters, two sub-provinces can be distinguished. The northern segment, consisting of the Ionian side of the Peloritani chain from Capo Peloro to the city of Riposto (first 75 km), is characterized by Kabilo-Calabride terraces; the southern segment, made up of the volcanites from the eastern flank of Mt Etna, reaches the city of Catania (Longhitano & Zanini, 2006).

Since it represents a microtidal oceanographic framework, coastal dynamics are mainly influenced by waves that approach the coast obliquely, and by long-shore southward currents, controlled by the complex hydrological dynamics of the Messina Strait. Such hydrodynamics interact with clockwise, offshore circulation of the Ionian Sea.

Wave energy affects the coastline differently, since northwards it is mitigated by the action of the Messina Strait tidal currents, whilst southwards the near shore circulation is often diffracted and inhibited by the great complexity of the volcanic shoreline, marked by small coastal promontories and indentations (Figs. 2, 3). In the Sicily side of the Messina Strait the coastline is almost homogeneous with a mid-Pleistocene conglomerate outcrops, along almost two kilometers of shoreline (Bottari et al., 2005). Such so-called "beach-rock", which represents the sole hard substratum of natural origin, is frequently connected to artificial breakwaters and other concrete structures (Figs. 4, 5).

Rivers, as the main points of sedimentary input, are localized in the southern part and don't affect the Messina Strait. Freshwater inputs are mostly of phreatic origin in Catania, whilst in Messina stations they are mediated by the Capo Peloro Lagoon, throughout the two canals "Faro" and "Due Torri".

### *Sampling and analysis*

The sampling strategy has been based on two levels at different spatial scale (Fig. 1). The first level (100 km scale) distinguished the two areas of Messina (Capo Peloro) and Catania (Ognina). At the second level, seven stations per area have been located along 1.9 km (Messina) and 5 km of coast (Catania) respectively, according to the two main substratum typologies (natural vs. artificial), wave exposures (exposed vs. sheltered), slope (vertical vs. horizontal). The presence or absence of freshwater inputs was also considered. In spring 2002

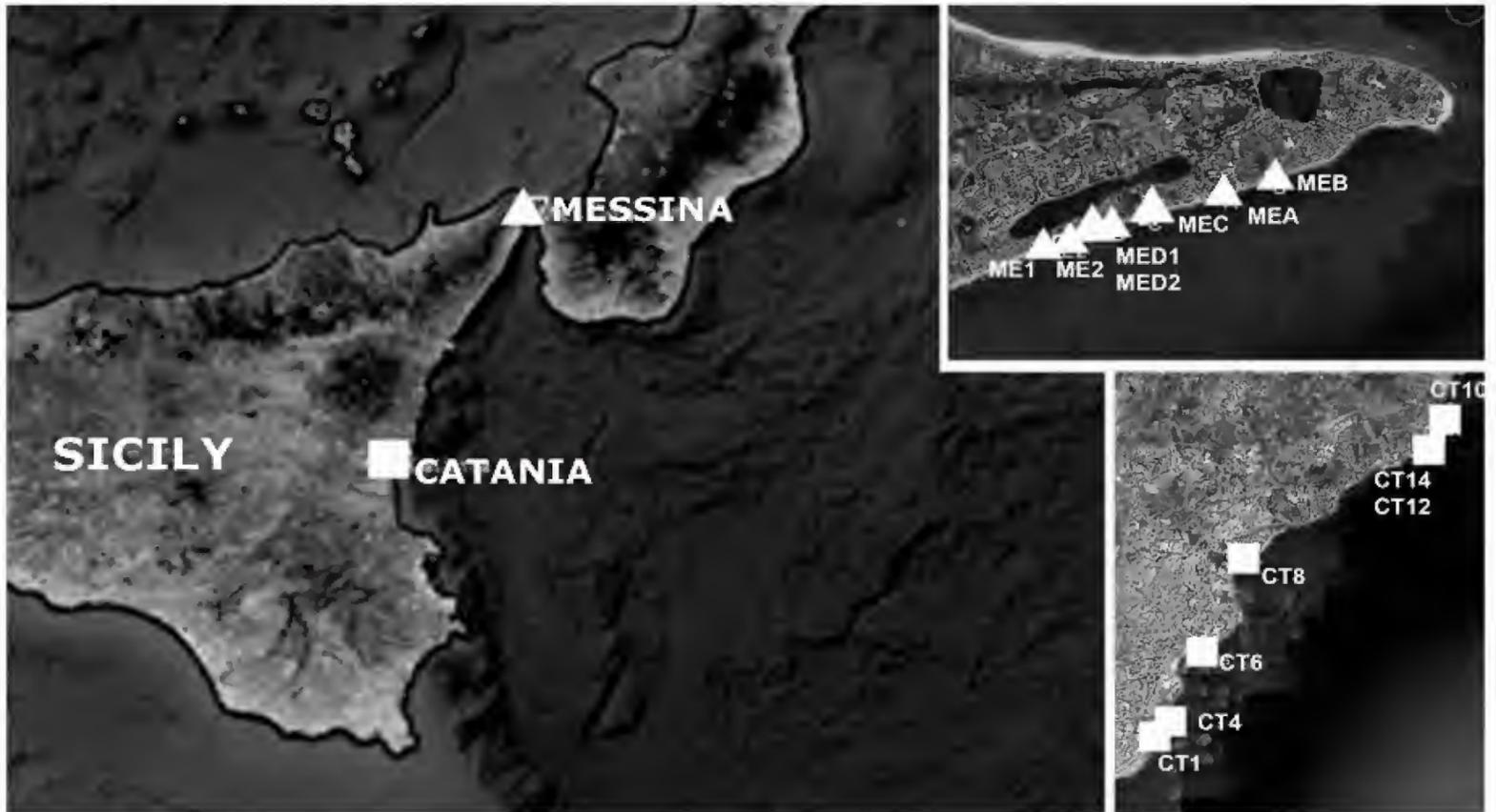


Figure 1. Study area. Messina (upper pane) and Catania (lower pane) coastlines with sampling distribution.



Figures 2-5. Study site. Figs. 2, 3. Messina shoreline with conglomeratic "beach-rocks".  
Figs. 4, 5. Catania shoreline with basaltic rocks.

two random replicates of 25x25 cm scraped surface were carried out for each station, ten meters spaced out (pooled data), in a shallow subtidal fringe from 0 to 0.3 m depth. Substratum typology and algal covering were preliminarily recorded on field. In laboratory, samples were washed throughout a 0.250 mm mesh sieve and the retained macrobenthic fauna was separated from algae throughout a manual centrifuge. Particles smaller than 0.250 mm were considered as "sediment" and their amount evaluated as volume and dry weight (80°C/24 h). Algae were investigated in their structure by dominant taxa, fresh and dried total biomass, total fresh volume and degree of branching, in accordance with Edgar (1983). Besides, the characterising algae were distinguished in the main functional groups of encrusting, thread-like and branched thallii, according to Littre & Arnold (1982).

The macro-zoobenthos (>0.250 mm sieved fraction) has been sorted out under the stereomicroscope at the Phylum/Classis/Ordo levels. Molluscs have been determined at the species level, and respective abundances evaluated. The univariate and multivariate statistical parameters have been elaborated by means of PRIMER 6.0 software package. Main factors potentially affecting assemblage composition and structure were selected a priori and tested by the analysis of similarity procedure (ANOSIM) for one way and two way crossed designs. The selected abiotic factors were the sampling area (two fixed levels), the sampling station (six random levels), the site exposure (two fixed levels), the substratum typology (two fixed levels), slope (two fixed levels), freshwater inputs (two random levels), entrapped sediment (two random levels).

The selected biotic factors were the algal covering (three fixed levels), algal volume (three random levels), dominant algal taxa (seven random levels) and the algal functional groups (three random levels). The similarity percentage analysis (SIMPER) highlighted for those species that were more responsible for dissimilarity between areas.

## RESULTS

The whole examined sample set provided a total of 86 species, 46 of which were exclusively collected in Catania and 21 were exclusively recorded in

Messina, while 22 species were common to the two areas (Table 1). Gastropod species were the most numerous, with 63 species, 34 of which were collected only in Catania and 18 only in Messina, plus 11 shared species; half of the 18 bivalve species were exclusively found in Catania, with respect to the two species exclusively recorded in Messina, whilst other 7 species were collected in both areas. Polyplacophora accounted one shared species plus three taxa exclusively found in Catania and one in Messina (Fig. 6).

The number of species found in each station ranged from 7 (MEB) to 24 (MEE1) in Messina with a tendential north-to-south increase; such trend was more irregular in Catania, with 15 species in CT12 up to 37 species in CT6. Likewise the number of species, the abundances per station were higher in Catania (min 244, max 1960 individuals) than in Messina (min 27, max 1349), but they were irregularly distributed and not clearly related to the number of species, except for MEE1 where the peaks of the two parameters matched (Fig. 7).

The trend of Margalef's richness agrees with the number of species. Univariate diversity indexes showed different trends between the two areas. Shannon diversity and species equitability had more remarkable fluctuations in Messina, ranging from 0.52 (MEE1) to 2.04 (MEC) and from 0.16 to 0.89, respectively. Diversity in Catania was meanly 1.5 in most stations, except for values 2.1 and 2.2 in

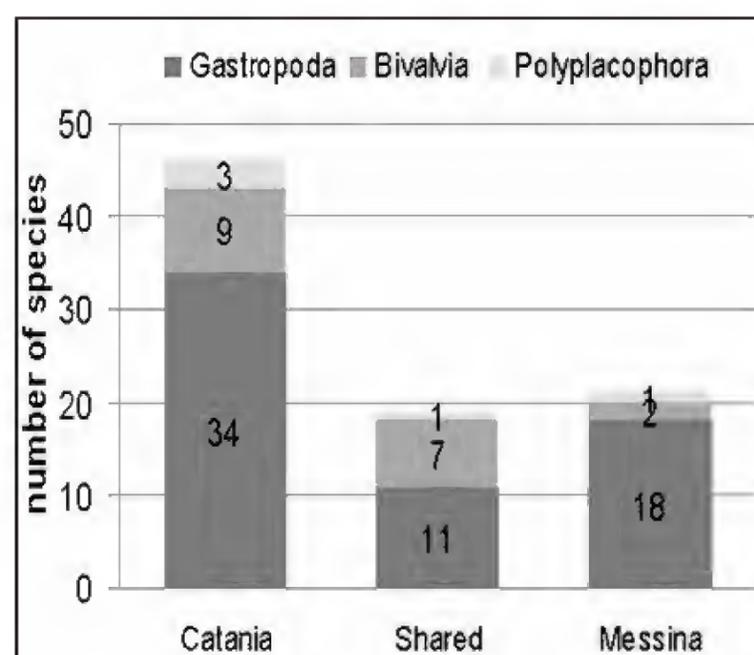


Figure 6. Numbers of Polyplacophora, Bivalvia and Gastropoda species exclusively recorded in Messina or Catania, and shared between the two areas.

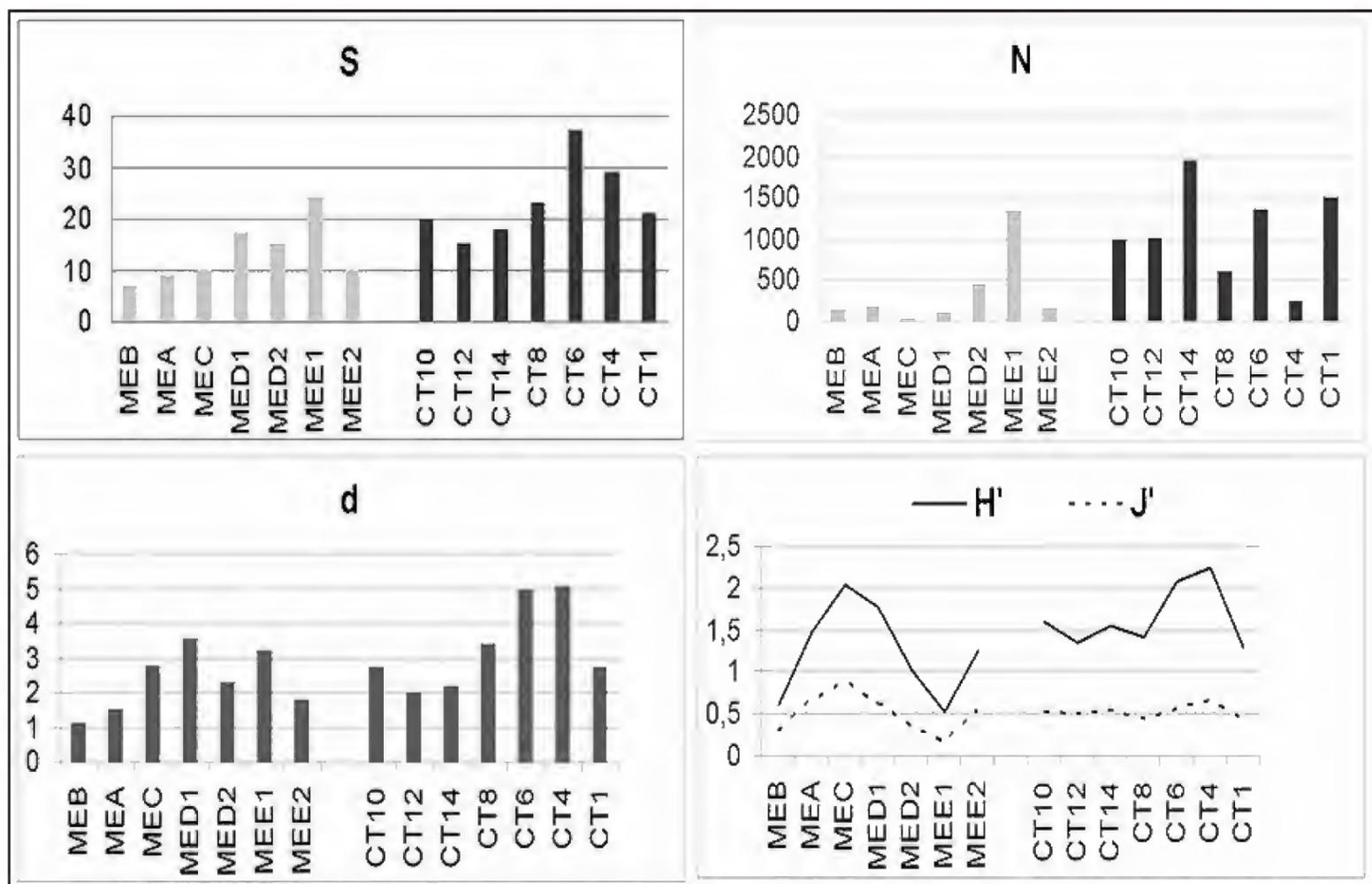


Figure 7. Trends of species number, abundance, Margalef richness, Shannon diversity, Pielou equitability observed in Catania and Messina. For each area, sampling stations are ordered from North (left) to South (right).

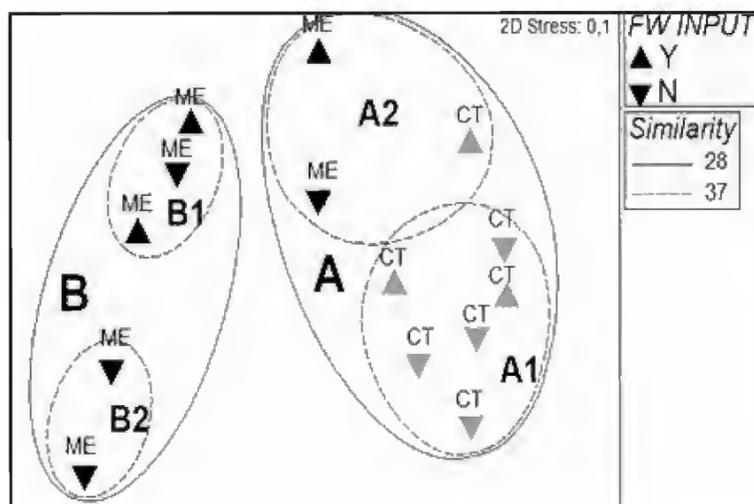


Figure 8. Nm-MDS ordination plot with superimposed cluster classification of Catania and Messina stations. Presence (Y) and absence (N) of freshwater inputs is also showed.

CT6 and CT4 respectively; equitability was meanly low, likewise in Messina, but with a more regular trend (Fig. 7).

The multivariate analysis highlighted further differences in the mollusc assemblages from the two areas. The Bray-Curtis similarity index and the

related cluster analysis (square root transformed data, average linkage) discriminated, at lower 28% level, a first group A of all Catania stations plus two Messina stations, from a second homogeneous group B of five stations of Messina (Fig. 8). At a higher level of 37%, the former group was constituted by a further sub-group A1 of six Catania stations, which were separated from a small sub-group A2 of stations from both areas. Such indication of a different composition/structure of the Messina and Catania mollusc assemblages was supported by the ANOSIM test, which indicated such area-related discrimination as a statistically significant factor (Global E 0.78, p-level 0.1%; number of permuted statistics greater than or equal to Global R: 0). Among the other factors that potentially affected the mollusc taxocenosis within each area group, the occurrence/absence of freshwater inputs (Fig. 8) and “exposure” (exposed/sheltered), were the most significant.

The ANOSIM test (two way crossed) for differences between areas across all stations with fresh water inputs, also resulted statistically significant,

with a Global R of 0.87 (p-level 0.4%; number of permuted statistics greater than or equal to Global R: 3). A 2D multi-dimensional scaling better clustered the stations submitted or not to such constraint inside the Messina area, with respect to a weaker separation inside the other clusters (Fig. 8).

Similarly, test for differences between the factor “area” across the factor “exposure” provided a Global R of 0.82, but with a lower significance level of 1.3% (number of permuted statistics greater than or equal to Global R: 1). The hypothesis of a possible interaction of the two local affecting factors was less strictly supported by test for differences between “freshwater inputs” across all “exposure”, which provided a Global R of 0.79, but with p-level 4% (number of permuted statistics greater than or equal to Global R: 1); in this respect, the general absence of freshwater inputs in the medium and high exposed stations should be noted. All the other abiotic and biotic factors, tested with ANOSIM, did not produce significant differences among the selected levels.

The Messina assemblage, with a lower average similarity of 32.9% (Table 1), was characterized by a small number of species, nine of which accounted

for 91.4% intra-group similarity. Most of similarity (49.1%) was due to two sole species, *Pisina glabrata* (Megerle von Mühlfeld, 1824) and *Setia amabilis* (Locard, 1886), with 33.7% and 15.4% respectively. The contribution of other species rapidly declined down to 3.1% for *Columbella rustica* (Linnaeus, 1758). A residual 8.6% cumulative similarity was due to 31 rare or occasional species. The Catania assemblage showed a higher 41.5% similarity and was due to a small group of frequent species, eleven of which accounted for 91.2 cumulative percentage. Most of such a cumulative contribution was due to the species *Cardita calyculata* (Linnaeus, 1758), *Pisina glabrata* and *Barleeia unifasciata* (Montagu, 1803), with an average contribution of 25.7%, 16.6% and 10.8%, respectively. Differently from Messina, the contribution of other species slowly declined, down to a minimum of 1.9% of *Crisilla galvagni* (Aradas et Maggiore, 1844). A consistent group of 54 less common species covered the residual 8.8%.

The same three species that were main responsible for the internal similarity of the Catania area, (*Cardita calyculata*, *Pisina glabrata*, *Barleeia unifasciata*) had a primary role to determine the

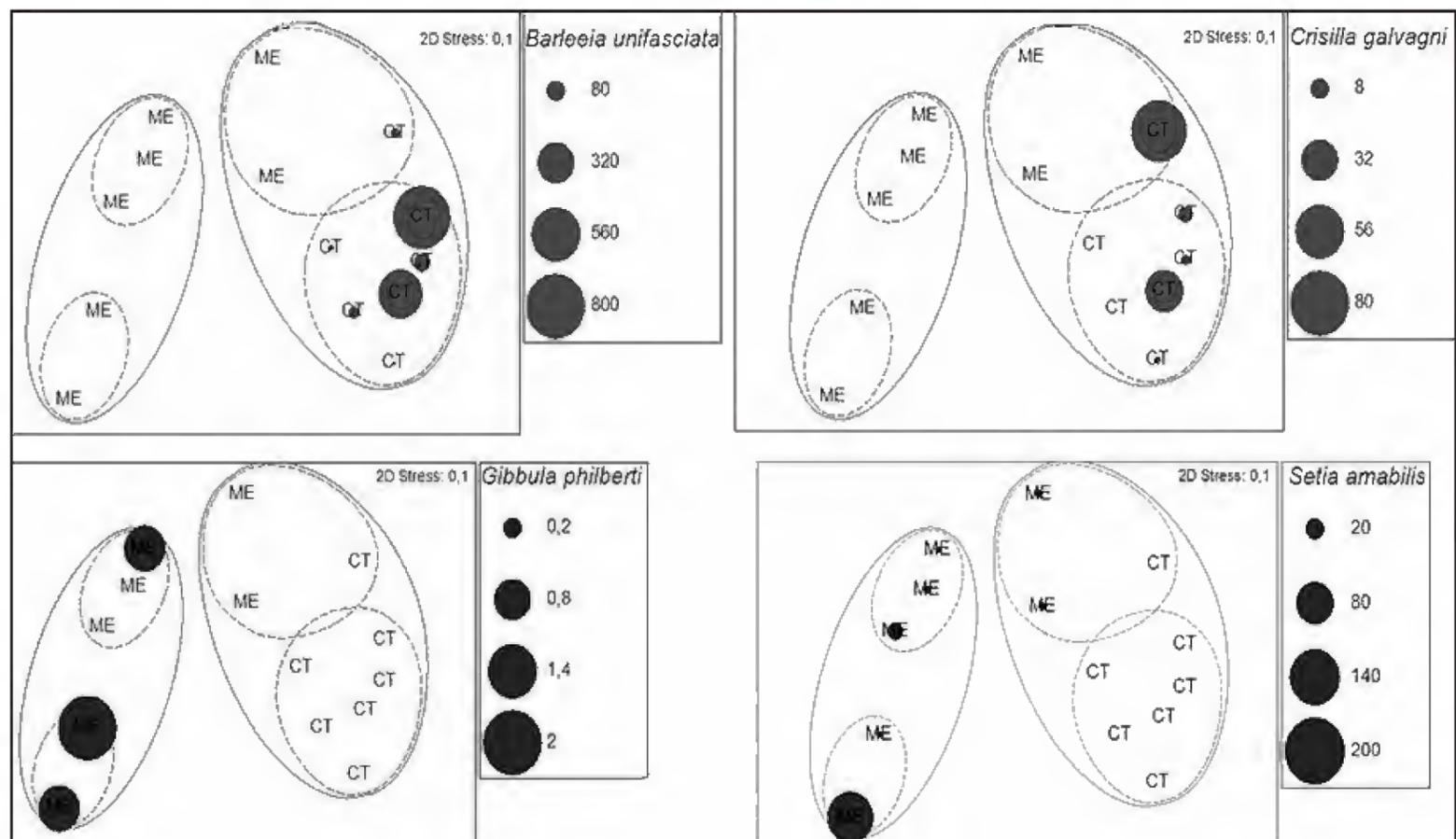


Figure 9. Nm-MDS ordination bubble-plots for some abundant and rare species which characterized the Messina and Catania mollusc taxocoenosis with superimposed cluster classification of the two areas.

inter-group dissimilarity, although at lower extent, accounting respectively for 13.5%, 8.9% and 9.5% of the 79.3% average dissimilarity. Over a total of 86 species, just 40 accounted for 90% cumulative dissimilarity. It is of interest to note that a small group of species, *Setia amabilis*, *Crisilla semistriata* (Montagu, 1808), *Lasaea adansonii* (Gmelin, 1791), that weakly contributed to the intra-group similarity, played a significant role in determining inter-group dissimilarity (Table 1). Such repartition of species per area is well represented in the bubble plots of figure 9, showing the abundances of *Setia amabilis* and *Barleeia unifasciata*, which are highly characterizing species for the Messina and Catania assemblages, respectively. Other two less abundant species, which might be linked to a particular area, were *Crisilla galvagni*, exclusively found in Catania, and *Gibbula philberti* (Récluz, 1843) which characterized the Messina area.

More in general, qualitative differences were recognized in some less frequent taxa that were exclusively or prevalently found in a single area (Table 2). Between the Rissoacea, for example, the genus *Alvania* Risso, 1826 and *Crisilla* Monterosato, 1917 best characterized the area of Catania (with eight and three species respectively) with respect to Messina (with two and none species respectively), whilst the genus *Rissoa* Desmarest, 1814 (two species) and *Setia* Adams H. & A., 1854 (two species) were exclusively found in Messina. Similarly, the genera *Granulina* Jousseau, 1888 (three exclusive species) and *Gibbula* Risso, 1826 (five exclusive species) best characterised Catania and Messina shorelines, respectively. A possible vicariant distribution between some congeneric species was also noted, such as for *Tricolia deshampsi* Gofas, 1993 and *T. miniata* (Monterosato, 1884) sampled only in Messina, with respect to *T. landinii* Bogi et Campani, 2007 collected exclusively in Catania.

## DISCUSSION

In this investigation, which provided the first quantitative data on mollusc assemblages from the Ionian subtidal fringe, a comparison between two areas, Messina and Catania, quite different in the typology of the natural substrata, has been carried out. Their spatial separation (almost 100 Km) and

station distribution (less than 1 km spaced), replicated similar investigations on intertidal communities which have put in evidence a highest grade of variability on a ten meter spatial scales (Kelaher et al., 2001) and even among replicates (Reichert et al., 2008). Such a local variability, in the present investigation has been considered in terms of stochastic patchiness and resolved by replicate pooling. Such procedure allowed a better discrimination of assemblages per stations and areas.

The fringe, as a peculiar aspect of photophilic habitat submitted to high levels of environmental stress (e.g. hydrodynamism, insulation, desiccation, freshwater inputs), was expected to be characterized by impoverished assemblages; in contrast, the total number of recorded species was high, in comparison with deeper subtidal assemblages both from western (Poulicek, 1985), central (Richards, 1983) and eastern Mediterranean (Antoniadou et al., 2005). Number of species and abundance were markedly higher in Catania with respect to Messina, probably due to the rough lavic substratum and a more irregular/uneven shoreline, which increases space availability, habitat complexity and shelter, with respect to the smooth conglomeratic beach-rock and connected concrete blocks.

Although richer in species number and individuals, the lava cliff did not substantially overlie the conglomeratic beach-rock in terms of mollusc diversity, that was moderately high in both substrata typologies. By contrast, equitability was low, thus testifying for a generalised de-structured condition of both the assemblages. In general, the studied mollusc assemblages showed a high grade of stochastic variability, especially in Messina, according to the wide fluctuation of univariate diversity indices and to the low internal similarity of each sample group. Nevertheless, statistically significant differences between the two areas, mainly due to a small number of dominant species (Kelaher et al., 2001) were found. Such differentiation of the two mollusc assemblages was moderately altered by the "intrusion" of two Messina stations in the Catania group, which might be viewed as an evidence of a cenotic affinity, rather than as an ecological transition. In this respect, we note that most of the recorded molluscs are known to be ecologically related to the Mediterranean photophilic algal assemblage complex, with diversified preference in terms of depth, light, exposure.

	ME	sh.	CA		ME	sh.	CA
Polyplacophora				Gastropoda			
<i>Callochiton calcatus</i> Dell'Angelo & Palazzi, 1994	•			<i>Haminoea hydatis</i> (Linnaeus, 1758)			•
<i>Acanthochitona crinita</i> (Pennant, 1777)		•		<i>Haminoea navicula</i> (da Costa, 1778)		•	
<i>Acanthochitona fascicularis</i> (Linnaeus, 1767)			•	<i>Odostomia improbabilis</i> Oberling, 1970			•
<i>Lepidochitona monterosatoi</i> Kaas & Van Belle, 1981			•	<i>Mitra cornicula</i> (Linnaeus, 1758)		•	
<i>Leptochiton cimicoides</i> (di Monterosato, 1879)			•	<i>Naticarius hebraeus</i> (Martyn, 1786)		•	
<u>Gastropoda</u>				<i>Ocinebrina hispidula</i> (Pallary, 1904)		•	
<i>Alvania cancellata</i> (da Costa, 1778)			•	<i>Odostomella doliolum</i> (Philippi, 1844)			•
<i>Alvania cimex</i> (Linnaeus, 1758)			•	<i>Omalogyra atomus</i> (Philippi, 1841)			•
<i>Alvania clathrella</i> (Seguenza L., 1903)			•	<i>Paradoris indecora</i> (Bergh, 1881)		•	
<i>Alvania lanciae</i> (Calcara, 1845)			•	<i>Parthenina clathrata</i> (Jeffreys, 1848)			•
<i>Alvania scabra</i> (Philippi, 1844)			•	<i>Pisinna glabrata</i> (Megerle von Mühlfeld, 1824)			•
<i>Alvania simulans</i> Locard, 1886			•	<i>Phorcus richardi</i> (Payraudeau, 1826)		•	
<i>Alvania subcrenulata</i> (B.D.D., 1884)			•	<i>Pusillina marginata</i> (Michaud, 1830)			•
<i>Alvania zetlandica</i> (Montagu, 1815)			•	<i>Rissoa similis</i> Scacchi, 1836		•	
<i>Ammonicera fischeriana</i> (Monterosato, 1869)			•	<i>Rissoa variabilis</i> (Von Mühlfeldt, 1824)		•	
<i>Aplysia parvula</i> Mörch, 1863		•		<i>Setia amabilis</i> (Locard, 1886)		•	
<i>Aplysia fasciata</i> Poiret, 1789			•	<i>Setia scillae</i> (Aradas & Benoit, 1876)		•	
<i>Barleeia unifasciata</i> (Montagu, 1803)			•	<i>Sinezona cingulata</i> (O. G. Costa, 1861)			•
<i>Bittium lacteum</i> (Philippi, 1836)			•	<i>Tricolia deschampsii</i> Gofas, 1993		•	
<i>Bittium reticulatum</i> (da Costa, 1778)			•	<i>Tricolia miniata</i> (Monterosato, 1884)		•	
<i>Bulla striata</i> Bruguière, 1792			•	<i>Tricolia landinii</i> Bogi & Campani, 2007			•
<i>Cerithiopsis nofronii</i> Amati, 1987			•	<i>Vexillum ebemus</i> (Lamarck, 1811)			•
<i>Cerithium vulgatum</i> Bruguière, 1792			•	<i>Vitreolina incurva</i> (B.D.D., 1883)			•
<i>Columbella rustica</i> (Linnaeus, 1758)			•	<i>Vitreolina philippi</i> (de Rayneval & Ponzi, 1854)			•
<i>Conus ventricosus</i> Gmelin, 1791			•	<i>Williamia gussoni</i> (Costa O. G., 1829)			•
<i>Crisilla beniamina</i> (Monterosato, 1884)			•	<u>Bivalvia</u>			
<i>Crisilla galvagni</i> (Aradas & Maggiore, 1844)			•	<i>Anomia ephippium</i> Linnaeus, 1758			•
<i>Crisilla semistriata</i> (Montagu, 1808)			•	<i>Arca noae</i> Linnaeus, 1758			•
<i>Eatonina pumila</i> (Monterosato, 1884)			•	<i>Barbatia barbata</i> (Linnaeus, 1758)			•
<i>Epitonium pulchellum</i> (Bivona, 1832)			•	<i>Brachidontes pharaonis</i> (P. Fischer, 1870)			•
<i>Fissurella nubecula</i> (Linnaeus, 1758)			•	<i>Cardita calyculata</i> (Linnaeus, 1758)			•
<i>Fossarus ambiguus</i> (Linnaeus, 1758)			•	<i>Chama gryphoides</i> Linnaeus, 1758			•
<i>Gibberula jausseni</i> van Aartsen et al., 1984			•	<i>Hiatella arctica</i> (Linnaeus, 1767)		•	
<i>Gibbula adansonii</i> (Payraudeau, 1826)			•	<i>Hiatella rugosa</i> (Linnaeus, 1767)			•
<i>Gibbula ardens</i> (Salis Marschlins, 1793)			•	<i>Irus irus</i> (Linnaeus, 1758)			•
<i>Gibbula philberti</i> (Récluz, 1843)			•	<i>Lasaea adansonii</i> (Gmelin, 1791)			•
<i>Gibbula racketti</i> (Payraudeau, 1826)			•	<i>Lima lima</i> (Linnaeus, 1758)			•
<i>Gibbula turbinoides</i> (Deshayes, 1835)			•	<i>Musculus costulatus</i> (Risso, 1826)			•
<i>Gibbula umbilicaris</i> (Linnaeus, 1758)			•	<i>Mytilaster minimus</i> (Poli, 1795)		•	
<i>Gibbula varia</i> (Linnaeus, 1758)			•	<i>Mytilaster solidus</i> Monterosato, 1883			•
<i>Granulina boucheti</i> Gofas, 1992			•	<i>Mytilus galloprovincialis</i> Lamarck, 1819			•
<i>Granulina marginata</i> (Bivona, 1832)			•	<i>Ostrea edulis</i> Linnaeus, 1758			•
<i>Granulina vanharenii</i> (van Aartsen et al., 1984)			•	<i>Ostrea stentina</i> Payraudeau, 1826			•
<i>Gyroscala lamellosa</i> (Lamarck, 1822)			•	<i>Striarca lactea</i> (Linnaeus, 1758)			•

Table 1. Similarity Percentage analysis for species contribution to Bray-Curtis similarity ( $S'$ ) and dissimilarity ( $\hat{C}$ ) within each area and between the two areas respectively. Av., average; SD, standard deviation; N, abundance of individuals.

SIMPER within/between Area-Groups	Group ME av. S'	Group ME S'	Group CT av. S'	Group CT S'	av. $\delta$	$\delta$ /SD	$\delta$ contr. %
	32.92		41.53				
	av. N		av. N				
<i>Cardita calyculata</i>	2.51	2.73*	15.64	10.68*	10.65	1.48	13.47
<i>Barleeia unifasciata</i>	0.00	–	9.96	4.48*	7.53	1.11	9.51
<i>Pisinna glabrata</i>	10.90	11.09*	11.12	6.89*	7.09	1.37	8.96
<i>Ammonicera fischeriana</i>	0.25	–	6.53	3.68*	5.22	0.94	6.59
<i>Acanthochitona crinita</i>	0.29	–	4.53	3.79*	3.29	2.57	4.16
<i>Mytilaster solidus</i>	1.69	0.14	5.24	2.4*	3.21	0.84	4.06
<i>Gibbula turbinoides</i>	3.54	0.15	0.47	–	2.73	0.87	3.45
<i>Setia amabilis</i>	3.23	5.07*	0.00	–	2.71	0.87	3.43
<i>Crisilla semistriata</i>	0.00	–	3.79	–	2.62	0.49	3.32
<i>Lasaea adansoni</i>	0.00	–	2.57	–	2.29	0.46	2.89
<i>Bittium reticulatum</i>	0.34	–	2.62	1.43*	1.93	1.11	2.44
<i>Eatonina pumila</i>	1.05	0.07	3.37	1.35*	1.90	1.07	2.40
<i>Crisilla galvagni</i>	0.00	–	2.71	0.06	1.81	0.97	2.29
<i>Crisilla beniamina</i>	0.00	–	2.30	–	1.80	0.83	2.27
<i>Columbella rustica</i>	1.69	0.04	2.58	1.3*	1.73	1.36	2.19
<i>Sinezona cingulata</i>	0.00	–	1.94	–	1.12	0.51	1.41
<i>Gibbula adansonii</i>	1.11	–	0.40	–	1.03	0.77	1.30
<i>Fissurella nubecula</i>	0.00	–	1.45	–	0.98	1.01	1.24
<i>Musculus costulatus</i>	1.06	0.07	1.68	1.06*	0.93	1.17	1.18
<i>Arca noae</i>	0.74	–	0.98	–	0.90	0.95	1.14
<i>Gibbula ardens</i>	1.10	–	0.00	–	0.81	0.75	1.02
<i>Brachidontes pharaonis</i>	0.14	–	1.10	–	0.77	1.05	0.98
<i>Mytilus galloprovincialis</i>	0.00	–	0.99	–	0.75	0.50	0.95
<i>Aplysia parvula</i>	0.90	0.05	0.00	–	0.68	1.08	0.86
<i>Alvania scabra</i>	0.00	–	1.01	–	0.65	0.68	0.83
<i>Chama gryphoides</i>	0.29	–	0.57	–	0.56	0.74	0.71
<i>Alvania lanciae</i>	0.29	–	0.64	–	0.54	0.70	0.68
<i>Gyroscala lamellosa</i>	0.29	–	0.52	–	0.46	0.84	0.58
<i>Acanthochitona fascicularis</i>	0.00	–	0.69	–	0.45	0.40	0.57
<i>Gibbula philberti</i>	0.49	–	0.00	–	0.44	0.79	0.56
<i>Omalogyra atomus</i>	0.00	–	0.78	–	0.42	0.40	0.53
<i>Aplysia fasciata</i>	0.00	–	0.53	–	0.42	0.40	0.53
<i>Tricolia landinii</i>	0.00	–	0.39	–	0.39	0.58	0.50
<i>Alvania simulans</i>	0.00	–	0.73	–	0.39	0.40	0.50
<i>Irus irus</i>	0.00	–	0.39	–	0.39	0.59	0.49
<i>Gibbula ricketti</i>	0.55	–	0.00	–	0.37	0.61	0.47
<i>Ostrea edulis</i>	0.00	–	0.40	–	0.36	0.60	0.45
<i>Tricolia miniata</i>	0.49	–	0.00	–	0.35	0.60	0.44
<i>Alvania cancellata</i>	0.00	–	0.49	–	0.35	0.81	0.44
<i>Granulina vanharenii</i>	0.00	–	0.52	–	0.34	0.60	0.43

Table 2. Distribution of mollusc species in the shallow sublittoral zones of Messina (ME), Catania (CA) and shared (sh.) between the two areas.

Such mélange of species tied to different environmental conditions is explicated in literature as a trapping effect exerted by the branching algae towards the settling larvae and early juveniles (Poulicek, 1985). This supposed “branching effect” did not significantly affect the composition and structure of the mollusc assemblages, which clustered independently from typology and extent of algal covering. Such evidences do not agree with literature data that indicate a significant effect of algal architecture on the mollusc assemblage discrimination (Chemello & Milazzo, 2002; Pitacco et al., 2014; Antoniadou et al., 2005). By contrast, the hypothesis that redundant algal-associated assemblages can play a key role for the maintenance of biodiversity of the broader geographical area (Antoniadou et al., 2005) is here supported. Moreover, contrasting effects of algal covering towards zoobenthic larvae should be considered, since the wave exposed fringe is submitted to a highest sediment/nutrient resuspension that is known to favour spores with respect to benthic larvae in space competition (Richmond & Seed, 1991; Oigman-Pszczol et al., 2004). Once developed, algae might favour larval recruitment and juvenile/adults surviving, providing food and protection from predators and desiccation (Poulicek, 1985; Antoniadou et al., 2005), but limitedly to a short time period, due to their ephemeral character.

Mollusc assemblages that were dominated by small sized species with a short life span reflected such an irregular and transient availability of resources in their high densities and low organization levels. The algal assemblage, in turn, is driven by the substratum type and its (micro)topographic complexity, both of which directly and indirectly affect the settlement and persistence of benthic organisms. In this respect, the geo-lithological structure of the natural substrata and the related texture might be explicative for the observed patterns of diversity among the two areas far apart. The conglomeratic rocks of the Messina Strait is more even and less porous with respect to the basaltic surface of Catania cliffs, which is more irregular and richer in hollows and crevices. The more uneven surface, promoting phyto-benthic colonization, in turn improves shelter and sediment trapping, that is in accordance with the higher richness of the bivalve species observed in the Catania area.

The less fluctuating Shannon  $H'$  and equitability of species/abundance of the Catania mollusc assemblage with respect to the Messina area, also support the hypothesis that substratum roughness acts as structuring factor. Other local factors, both related or not with the natural substratum typology, do not play a recognizable role, except for freshwater inputs combined with shelter exposure. The effects of geographical distance, that might be more important than substratum type or roughness in determining assemblage structure (Guarnieri et al., 2009), might be also considered, in reason of the latitudinal gradient between the two areas.

Such a gradient determines a southward temperature increase that near Catania marks the crucial 15°C seawater winter isotherm (Bianchi et al., 2012). In our opinion, the climatic gradient was not directly responsible for the quantitative differences between the two areas, but may partially explicate the different species composition. Some of the forty-six (Catania) and twenty-one (Messina) not shared species have a limited Mediterranean distribution, and some of these species are known from a restricted area, as the recently “rediscovered” *Crisilla galvagni* (Scuderi & Amati, 2012).

## CONCLUSIONS

The mollusc assemblages from two subtidal fringes of eastern Sicily configure as an impoverished aspect of the photophilic associated fauna, submitted to some strong environmental constraints that limit the number of characteristic species but allow the transient recruitment of opportunistic and occasional taxa.

The investigated areas, although submitted to similar climatic and edaphic conditions, have differently structured substrata which result more or less favourable to species settlement and survival in accordance with high (Catania) or low (Messina) cliff roughness. The respective assemblages, although characterized by a high local variability, show some common traits that allow to recognize a real taxocoenosis.

Some scarcely known species, mainly localized in the lava cliff, may be preferentially tied to such peculiar environment. The accessory taxa that are partially supplied by other nearby communities

testify for the role of shallow fringe assemblages to maintain the biodiversity at local and at broader geographical scale.

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## On the rediscovery of the vermetid “*Siphonium*” *gaederopi* Mörch, 1861 (Gastropoda Vermetidæ) with systematic and ecological observations on the early juveniles stages

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### ABSTRACT

Some specimens of a not identified *Dendropoma* Mörch, 1862 were collected in the Mediterranean. Further taxonomical studies allowed to identify this material as “*Siphonium*” *gaederopi* (Mörch, 1861), a species never recorded again after its first description. It is here redescribed and figured on the basis of the mentioned collected material and after the study of the type material of Mörch’s collection, among which the syntype is here selected. This species is assigned to *Dendropoma*, according to the morphological characters of the shell, radula, external soft parts and operculum. The shell, the soft parts and the juvenile stage of *D. gaederopi* are here figured for the first time and compared to congeners and to *Vermetus granulatus* (Gravenhorst, 1831), similar only in shell morphology. The new findings of this species represent the first certain record, after the doubtful locality of the original description.

### KEY WORDS

Mollusca; Vermetidae; *Siphonium*; rediscovery; *Dendropoma*; ecology; juveniles.

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### INTRODUCTION

The genus *Siphonium* Mörch, 1859 [not Link, 1807] was synonymised by Keen (1961), who restored *Dendropoma* Mörch 1861 as a good name for the genus, with *D. lituella* Mörch, 1861 as type species.

Scuderi (1995) had been recently reviewed the systematic position of the two known Mediterranean species of the genus *Dendropoma*: *D. petraeum* (Monterosato, 1878) is synonymised with *D. glomeratum* Bivona, 1832, while the studied type material of *D. anguliferum* (Monterosato, 1884) in the ZMR was not enough to establish whether this latter is a good species, so it still continues to have an uncertain systematic position

because of the lacking of recent material. Some specimens of a third species of *Dendropoma*, markedly different from the two congeneric, has been recently recorded in the Mediterranean sea. This species corresponded to the description of “*Siphonium*” *gaederopi* Mörch, 1861, which was described on material doubtfully reported from Spain and never cited in the recent time. The comparison of the specimens found with the type material of this latter species, housed in ZMUC, confirmed the previous diagnosis. A syntype is here selected among the material of the lot GAS-216.

The shell of adult specimens of *D. gaederopi* has a close morphological resemblance with that of another Mediterranean species, *Vermetus granulatus* (Gravenhorst, 1831).

In particular the former is very similar to a morphotype of the latter, called "form A" (Scuderi, 1999), but has different protoconch and operculum and the colour pattern of external soft parts is peculiar too. Differences on the shell sculpture of sub-adult shells of the two species (see remarks) are discriminating too.

## MATERIAL AND METHODS

Living samples of *D. gaederopi* were collected by undermining the shells from hard substrates at -4/18 m depth; empty shells and juveniles stages were collected among the shell grit drawn at -35 m depth collected handily with ARA. Pictures of the external soft parts were obtained by observing the living animals in aquarium.

Type material of "*Siphonium*" *gaederopi* were examined from the Mörch's collection stored in ZMUC.

ACRONYMS. AGC: Alfio Germanà collection, Catania, Italy; ARC: Agatino Reitano collection, Catania, Italy; DISTEBA: Department of Biological and Environmental Science and Technologies, University of Salento, Lecce, Italy; ISMAR-CNR: Istituto di Scienze Marine, Consiglio Nazionale delle Ricerche, Genoa, Italy; ZMR: Zoological Museum, Rome, Italy; ZMUC: Zoological Museum, University of Copenhagen, Denmark.

## SYSTEMATICS

### *Dendropoma gaederopi* (Mörch, 1861)

EXAMINED MATERIAL. Type material. Four lots in ZMUC labelled GAS 215/216/217/218, with two labels, probably in Mörch's handwriting (Figs. 13, 14) and the label of the Museum (Fig. 15), were constituted by several tens of specimens; one specimen on *Spondylus gaederopus* Linnaeus 1758 is here selected as syntype among the lot GAS 216 (Fig. 1).

Other examined material. Agrigento, SW-Sicily, Italy: Linosa Is., "Cala Pozzolana di Levante", -4/6 m, on ancient earthenwares; same locality, 7 living specimens, -18m, on the shell of a living *Charonia tritonis variegata* (Lamarck, 1816); "Faro", -35 m,

shell-grit, 2 shells; "Punta Arena Bianca", infralittoral shell-grit, 1 shell. Siracusa, SE-Sicily, Italy: Vendicari, beached shell-grit, 1 shell on the upper valve of *Spondylus gaederopus* Linnaeus, 1758; Marzamemi, 3 living specimens on calcareous stones, -5/6m (ARC and AGC). Lecce, S-Apulia, Italy: Otranto, 1 specimen with operculum and 4 protoconchs, on calcareous stones, -5/10m.

DESCRIPTION. Shell solid, generally funnel involved, with the last tele-whorl rounded and equal to the half of the entire shell (Figs. 2–5). Sculpture constituted by dorsal longitudinal keels, variable in number (often 2), which could produce striking spiny formations in large specimens. Between the keels, numerous and concentric lamellae cover the surface of the shell, particularly in young specimens (Figs. 3, 4). The mouth is rounded and has a diameter of 2–2.5 mm in adult specimens (Fig. 5): in the syntype here selected the external diameter of the aperture is 5.8 mm. Like in many species of *Dendropoma*, an eroded scar is often visible on the substratum around the apertural opening. The basal portion of the external side of the tube forms a second labial lip, that leans on the substratum. Dense mass of individuals were not observed, except one little cluster among type material (GAS 216) of about 20 shells of various size on a fragment of a large Bivalve, maybe a *Spondylus* Linnaeus, 1758.

The living animal (Fig. 8) is yellow-cream in colour, becoming red-orange on the anterior part of the cephalo-thorax, metapodium and foot, around the operculum; very small black spots are visible too. Black shade are present on the dorsal part and around the base of the cephalic tentacles and the mouth, which are both yellow in colour; the mantle edge is yellow with black alternate lines.

The operculum (Figs. 6, 7) is large as the aperture and is quite different from that of all the congeners, being reverse-cone shaped, with the concave part upward, relatively deep and brown in color, often occupied by encrusting calcareous algae. The convex downward part is glossy and red-chestnut in color and do not present, unlike the two congeners, any depression around the central large button, but only a thin, almost undetectable scar.

Protoconch (Figs. 9–11) 0.5 mm high and 0.6 mm wide, swollen, but compressed superiorly and inferiorly, constituted by 1 and ½ smooth whorls.

A first embrional shell, separated from the rest of the protoconch, is distinguishable (Fig. 10).

EARLY DEVELOPMENTAL STAGES. Usually *D. gaederopi* has a not polygirate protoconch: the presence of a first embryonic nucleus, separated from the rest of the protoconch shell, suggest that this species could have a planctonic stage, which allow the diffusion of the species. Few juveniles found among shell grit and undoubtedly belonging to *D. gaederopi*, however, show one or two additional protoconch whorls (Fig. 12), confirming the possibility of some vermetids to produce more than one type of larval stage depending on seasons (Scuderi & Cantone, 2007). Moreover the first protoconch whorl seem to have a different coiling axis, differing of about 45° from that of the rest of the protoconch. This character, observed on other species of the same genus, could have phylogenetic implications. This changing of axis coiling in the protoconch seem to anticipate the subsequent changing of 90° of the first telewhorl, which allow vermetids to settle on the substratum.

DISTRIBUTION. Except for the doubtful locality reported in the original description ("...probably from Spain"), this species is known only from the material here examined, from S-Italy to Pelagic Is., between Sicily and N-African coasts of Libya. Not full grown specimens are easily mistakable with other congeners or with *V. granulatus* and this could reduce the real geographical distribution of the species along the Mediterranean and the E-Atlantic.

REMARKS. *Dendropoma gaederopi* was collected from the very shallow to the deeper fringe of infralittoral, 4/35 m depth, often on big shells, like *Spondylus* or *Charonia* Gistel, 1847: this habit appear not similar to the Mediterranean congeneric species, which are present on rocks in intertidal and upper infralittoral zones. Further findings of this species in S-Apulian, cited as *Dendropoma* sp. (Terlizzi et al., 2003; Scuderi & Terlizzi, 2012), seem to suggest that it could be present in a wider geographical area, mainly in South Mediterranean, but it probably still remain unrecognized, due to taxonomical difficulty in its identification.

Mörch well described *D. gaederopi*, clearly distinguishing it from the other species of

"*Siphonium*" (= *Dendropoma*). The Mediterranean congeneric *D. cristatum* (Biondi, 1857) results quite different on the basis of teleoconch's shell sculpture mainly constituted by more dense and thin axial lamellae and only one spiral chord, the not smooth protoconch, the colour pattern of external soft parts (Fig. 20) and the feature of the operculum (Figs. 16, 17) (see Scuderi, 1995 for further details). The analysis of the type material of the second Mediterranean species of *Dendropoma*, *D. anguliferum* Monterosato, 1884, housed in ZMR (n. 21295), have stated the differences between this latter and *gaederopi*, even if the question of the validity of the Monterosato's species remain opened (Scuderi, 2002).

Moreover, *D. gaederopi* seem not to be a gregarious vermetid, like some congeneric species, which could produces wide "trottoir" in some localities (Hadfield et al., 1972; Safriel, 1975; Barash & Zenziber, 1985; Chemello et al., 1990; Scuderi et al., 1998), and seem to prefer deeper waters.

Another Mediterranean vermetid is close similar to this species: except for the protoconch and the external characters of the soft parts, *D. gaederopi* differs from *V. granulatus* "form A" (Scuderi, 1999) by having a shell ambrate in color, with spiral sculpture constituted by only two (rarely more) axial ribs, which, in adult shells, produce spiny excrescences. In *V. granulatus* the basal portion of the external side of the tube never forms a second lip and no lamellae between the keels, nor scar eroded into the substratum are present. Moreover, as could be argued by pictures here presented, the operculum (Figs. 18, 19) is smaller and thin, the protoconch (Fig. 22) and external soft parts (Fig. 21) are different.

## DISCUSSION

*Dendropoma gaederopi* is not reported in any recent checklist of the Mediterranean malacofauna (Bruschi et al., 1985; Sabelli et al., 1990–92; Bodon et al., 1995), even if it was cited as valid species by Monterosato (1892) fide Mörch (1861–1862).

The syntype here selected among the type series from ZMUC carries a black cross on the upper part of the shell, maybe to mark the semple from which



Fig. 1–14. *Dendropoma gaederopi*. Fig. 1. Syntype (ZMUC), on *Spondylus gaederopus*. Fig. 2. Shell, Linosa, aperture  $\text{\O} 1\text{ mm}$ . Fig. 3. Shell, Linosa, aperture  $\text{\O} 1.5\text{ mm}$ . Fig. 4. Shell, not full grown specimen, Linosa, aperture  $\text{\O} 0.5\text{ mm}$ . Fig. 5. Shell, Linosa, aperture  $\text{\O} 3\text{ mm}$ . Figs. 6, 7. Operculum in downward and lateral (a) view,  $\text{\O} 1.5\text{ mm}$ . Fig. 8. Drawing of the animal  $\text{\O} 1.5\text{ mm}$ . Fig. 9. Protoconch and first tele-whorl, upward view, Linosa,  $0.5\text{ mm} \times 0.6\text{ mm}$ . Fig. 10. Same, detail of the nucleus. Fig. 11. Protoconch and first tele-whorl, side view, Linosa,  $0.5\text{ mm} \times 0.6\text{ mm}$ . Fig. 12. Multispiral protoconch and first tele-whorl, side view, Linosa,  $1.5\text{ mm} \times 0.85\text{ mm}$ . Fig. 13, 14. Original labels in Mörch's handwriting (ZMUC). Fig. 15. Label of ZMUC. Fig. 16, 17. *D. cristatum*. Operculum in downward and lateral view  $\text{\O} 3.5\text{ mm}$ . Fig. 18, 19. *Vermetus granulatus*. Operculum in downward and lateral (a) view  $\text{\O} 0.25\text{ mm}$ . Fig. 20. Drawing of the animal  $\text{\O} 3.5\text{ mm}$ . Fig. 21. Drawing of the animal  $\text{\O} 1.5\text{ mm}$ . Fig. 22. Protoconch and first tele-whorl, lateral view, Vendicari,  $0.6\text{ mm} \times 0.5\text{ mm}$ .

the operculum, preserved in a separate glass-tube, was obtained (the shell is breacked probably to draw out the soft parts). All the material was accompanied by two series of labels: one original, probably in Mörch's hand-writing; the second label of the ZMUC. An additional label reports: "Following Bieler (1996) possible type(s) of *Siphonium gaederopi* Mörch, 1861".

With *D. gaederopi* the number of known Mediterranean species of this genus increase to three, but further and more exhaustive studies should regard *D. anguliferum* to ascertain if it is really a good species.

All vermetid species have normally gastropod-like coiled early developmental stages: some spown as free swimming larvae; others are crawling juveniles at hatching. Hadfield et al. (1972) stated that nurse yolk assumption by the embryos influences the larval mode of life and dimensions, but only in *Vermetus rugulosus* both type of larvae could be simultaneously produced (Scuderi & Cantone, 2007).

The finding of more than one type of juveniles suggest that this species could take advantage from the planktonic lifestyle to settle on islands rocky environments and from the direct development to ensure specimen's enlargement to the established population.

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## First assessment of the vermetid reefs along the coasts of Favignana Island (Southern Tyrrhenian Sea)

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### ABSTRACT

Intertidal vermetid reefs, particularly vulnerable to environmental changes and human activities, are now experiencing high mortality in several areas of the Mediterranean Sea. Since the increase of knowledge on this habitat is important for conservation purposes, we provide a first baseline assessment of the vermetid reefs along the coasts of the Favignana Island (Marine Protected Area “Egadi Islands”). Preliminary results showed the presence of a true reef, similar to a fringing reef, displaying at least three local patterns, distinguishable for width (from 2.3 to 15.5 m), height of the outer and of the inner margin (from 5.6 to 18 cm and from 8.3 to 26 cm, respectively) and number, width and depth of cuvettes. Moreover, significant differences in topographic complexity among the areas were evidenced whereas no correlation between coastal exposure and topographic complexity was found.

### KEY WORDS

Bioconstruction; Favignana Island; habitat and topographic complexity; vermetid reef.

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### INTRODUCTION

Vermetid reefs are bioconstructions built up by the gastropod mollusc *Dendropoma petraeum* (Monterosato, 1884) in association with some coralline algae such as *Neogoniolithon brassica-florida* (Harvey) Setchell & Mason. These bioconstructions are unique and highly diverse systems that play a fundamental structural role, as they protect coasts from erosion, regulate sediment transport and accumulation, serve as carbon sinks, make the habitat more complex and heterogeneous and provide numerous habitats for animal and vegetal species thus increasing intertidal biodiversity (Pandolfo et al., 1992; Pandolfo et al., 1996; Badalamenti et al.,

1998). In the Mediterranean Sea their distribution is restricted to the warmest part of the basin with the largest formations generally found off the coasts of Israel and Lebanon, but they have also been reported in Turkey, Crete, continental Spain and Baleari Islands, Algeria, Morocco, along Maltese and Italian shores (Pérès & Picard, 1952; Molinier & Picard, 1953; Molinier, 1955; Safriel, 1975; Boudouresque & Cinelli, 1976; Dalongeville, 1977; Kelletat, 1979; Richards, 1983; Laborel, 1987; Azzopardi, 1992; Garcia-Raso et al., 1992; Templado et al., 1992; Bitar & Bitar-Kouli, 1995a, 1995b; Azzopardi & Schembri, 1997).

In Sicily, large and more or less continuous vermetid reefs are present along the north/northwestern

coasts between Zafferano Cape and Trapani and within the Marine Protected Area (MPA) “Egadi Islands” (Chemello, 1989; Chemello et al., 1990a, 1990b; Badalamenti et al., 1992a, 1992b; Chemello et al., 2000; Dieli et al., 2001; Chemello, 2009). Isolated reefs are found at Milazzo Cape and only small reefs are found around Taormina and Syracuse, on the eastern coast of Sicily, and on the Islands of Lampedusa and Ustica, that represent the limit of distribution respectively on the south and on the north of the Sicilian coasts (Chemello et al., 1990a; Chemello et al., 2000; Dieli et al., 2001; Consoli et al., 2008; Chemello, 2009). These biogenic constructions, enclosed in the SPA/BIO Protocol (Barcelona Convention) are now threatened by environmental changes and human activities (e.g. pollution, climate change, ocean acidification) thus experiencing high mortality in several areas of the Mediterranean Sea (Di Franco et al., 2011; Galil, 2013; Milazzo et al., 2014).

Due to the high vulnerability of these habitats, action plans for their conservation should be a priority. We know that the increase of knowledge is essential for the conservation and protection of this highly valuable habitat. Since only a low percentage of Sicilian vermetid reefs are subjected to conservation and many of them are not yet investigated (Chemello, 2009; Chemello & Silenzi, 2011), with this study we provide a first baseline assessment of the vermetid reefs present along the coasts of Favignana Island (MPA “Egadi Islands”).

The aims of the present study were: i) to provide a first description of the reef typology and ii) to test the effect of the coastal exposure on the topographic complexity of the reefs.

## MATERIAL AND METHODS

### *Study area*

The study was carried out at Favignana Island (MPA “Egadi Islands”), located approximately five kilometers from the west coast of Sicily. The Island, part of the Aegadian Archipelago, represent an example of a lower Pleistocene bioclastic calcarenite, characterized by a typical association known as foramol (Kil, 2010). The west side is characterized by the presence of the calcareous Monte Santa Caterina (300 metres high), flanked by areas with lower relief. The mechanical and chemical erosion

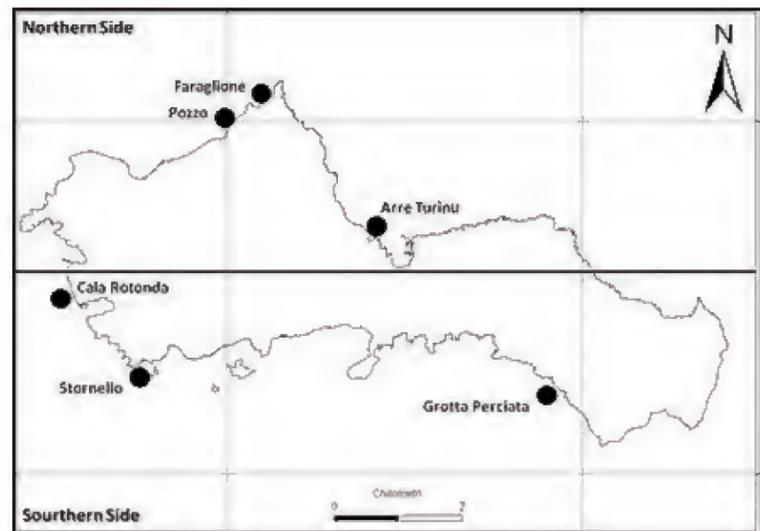


Figure 1. Location of the study areas: Favignana Island.

produced detritic deposits that partially mask the abrasion platform. The eastern side of the mountain shows a high cliff in the northern part, that gradually dips to the south. The coastline is highly rugged and not very high. The south dipping surface might be the result of either depositional or erosional processes. From a geological point of view, two main tectonic units can be recognized: the Monte Santa Caterina and the Punta Faraglione.

### *Vermetid reef analysis*

A preliminary survey allowed us to locate six study areas characterized by the presence of a vermetid reef: Faraglione, Pozzo, Arre Turinu, Grotta Perciata, Cala Rotonda and Stornello (Fig. 1).

The areas were chosen in such a way to also test the effects of the coastal exposure on the vermetid reef topographic complexity. Three along the northern side: Faraglione, Pozzo and Arre Turinu, and three along the southern side: Grotta Perciata, Cala Rotonda and Stornello. In each area the reef topographic complexity was measured using a 1m x 1m quadrat (three random replicates). The 4 sides and the 2 diagonals of the quadrat were measured using a meter with a resolution of 0.01m. Topographic complexity was calculated as the ratio between the registered measures (real measure,  $X_i$ ) and the known measures of the used quadrat ( $X_n$ ):  $X_i/X_n$  (Graziano et al., 2009).

The more the ratio is far from 1, the more complex is the substrate. To describe the reef typology the following variables were considered: the reef width from the inshore towards the open sea (measured using a meter with a resolution of 0.01m), the height of the inner and the outer margin and the slopes of the margins (measured using a goniometer).

### Data analysis

Differences in reef topographic complexity were analysed using permutational multivariate analysis of variance (PERMANOVA, Anderson, 2001). For the topographic complexity, the design consisted of three factors: Coastal exposure (Sd; two levels, fixed factor), Area (Ar; three levels, random, nested in Sd) and Site (St; three levels, random, nested in ArxSd). All multivariate analyses were based on Bray-Curtis dissimilarities of  $\log(x + 1)$  transformed data and each term in the analyses was tested using 9999 random permutations of the appropriate units. The analyses were performed using the software package PRIMER 6 (Clarke & Gorley, 2006).

## RESULTS

### Reef typology

All the vermetid reefs are consistent with a true reef (according to Antonioli et al., 1999), displaying at least three local patterns, distinguishable for width, height of the outer and of the inner margin and number, width and depth of cuvettes. A description of the different patterns are reported below.

Pattern 1: Pozzo and Faraglione (northern side, Figs. 2–5).

OUTER MARGIN: wide, flattened and irregular. In the inner side, crevices were also present. Sometimes at Faraglione are present two outer margins. INNER MARGIN: *Dendropoma petraeum* is absent. CUVETTES: not many, not deep and with a variable width. At Faraglione they are mainly present near the outer margin. At Pozzo some of them are fullfilled of sediment.

Study Areas	Width (m)	Height of the inner margin (cm)	Height of the outer margin (cm)	Slope of the inner margin (°)	Slope of the outer margin (°)
Faraglione	7.03 ± 0.23	8.66 ± 0.23	18 ± 0.23	38.3 ± 0.23	45 ± 0.23
Pozzo	15.46 ± 0.23	17.33 ± 0.23	15.33 ± 0.23	45 ± 0.23	45 ± 0.23

Pattern 2: Grotta Perciata and Stornello (southern side, Figs. 6–9).

OUTER MARGIN: thin and not continuously arranged. INNER MARGIN: *Dendropoma petraeum* is absent. CUVETTES: not many and not deep.

Study Areas	Width (m)	Height of the inner margin (cm)	Height of the outer margin (cm)	Slope of the inner margin (°)	Slope of the outer margin (°)
Grotta Perciata	7.31 ± 0.23	10.33 ± 0.23	15.66 ± 0.23	27.5 ± 0.23	42.5 ± 0.23
Stornello	5.10 ± 0.23	8.33 ± 0.23	8 ± 0.23	33.3 ± 0.23	29.16 ± 0.23

Pattern 3: Arre Turinu (northern side) and Cala Rotonda (southern side, Figs. 10–13).

The reef is damaged. OUTER MARGIN: it has a variable height and sometimes it is absent. Some crevices can also be present together with regrowth areas. INNER MARGIN: *Dendropoma petraeum* is absent. CUVETTES: many and sometimes very deep.

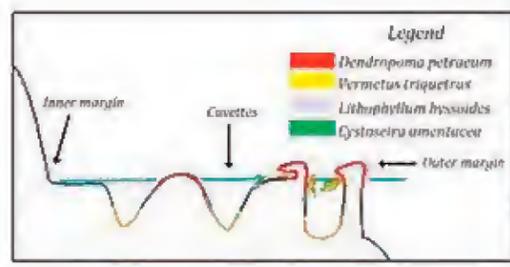
Study Areas	Width (m)	Height of the inner margin (cm)	Height of the outer margin (cm)	Slope of the inner margin (°)	Slope of the outer margin (°)
Arre Turinu	6.38 ± 0.23	26 ± 0.23	17 ± 0.23	26.6 ± 0.23	45 ± 0.23
Cala Rotonda	2.30 ± 0.23	12 ± 0.23	7.6 ± 0.23	41.6 ± 0.23	38.3 ± 0.23

### Reef topographic complexity

The PERMANOVA on the reef topographic complexity provided an evidence of significant differences in topographic complexity among the areas whereas no differences were recorded between the two coastal exposures (Fig. 14; Table 1).

Source	df	SS	MS	Pseudo-F	P(MC)
Sd	1	8627	8627	0.349	0.771
Ar(Sd)	4	98876	24719	9.1486	0.0001
St [Ar (Sd)]	12	32423	2701.9	1.8084	0.0098
Res	36	53789	1494.1		
Total	53	1.9372E5			

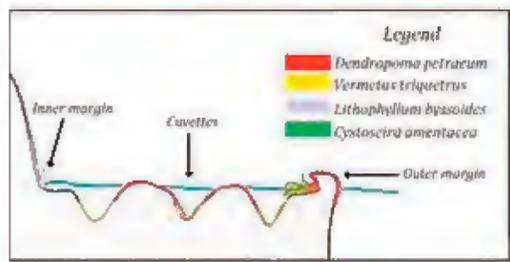
Table 1. PERMANOVA on the topographic complexity data.



2



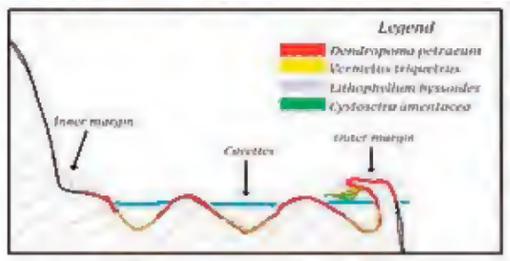
Figures 2–5. Scheme of the pattern 1 (Fig. 2), Faraglione (Fig. 3), Pozzo (Fig. 4), Pozzo: outer margin (Fig. 5).



6



Figures 6–9. Scheme of the pattern 2 (Fig. 6), Grotta Perciata (Fig. 7), Stornello (Fig. 8), Grotta Perciata: outer margin (Fig. 9).



10



Figures 10–13. Scheme of the pattern 3 (Fig. 10), Arre Turinu (Fig. 11), Cala Rotonda (Fig. 12), Arre Turinu: outer margin (Fig. 13).

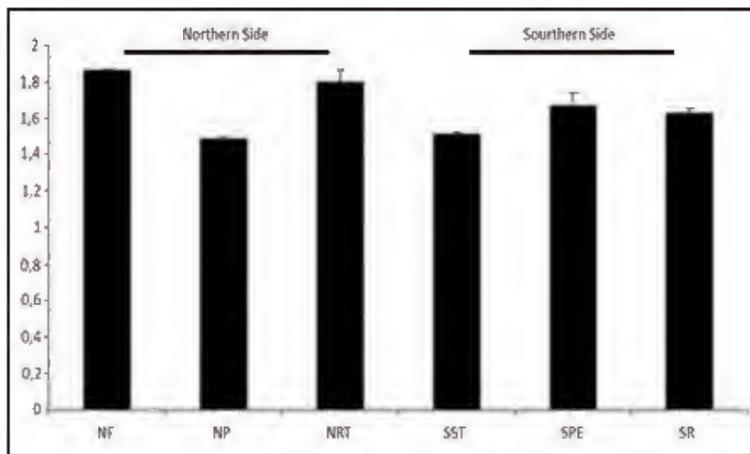


Figure 14. Topographic complexity in the studied areas.

## DISCUSSION AND CONCLUSION

The vermetid reefs along the coasts of Favignana are consistent with a true reef described along the north-western Sicilian coasts (Antonioli et al., 1999). The reef distribution around Favignana confirms the need of carbonatic substrates and of an abrasion platform for the formation of true reefs (Dieli et al., 2001). All the reefs are characterized, along a transect from the inshore towards the open sea, by the typical patches recognized for other Sicilian reefs (Chemello et al., 2000; Dieli et al., 2001). The reefs width were in agreement with the values reported for other Sicilian reefs whereas the height values were lower (Dieli et al., 2001). Some differences were highlighted locally in the considered variables, in particular in the margins, in the depth and in the number of cuvettes. Data on topographic complexity showed significant differences among the areas (small scale) but no relationship between the coastal exposure (large scale) and the reef topographic complexity was evidenced.

Vermetid reefs play an important role as modulators of morphological coastal processes and as ecological “engineers”, making the habitat more complex and tridimensional and promoting marine biodiversity (Pandolfo et al., 1996; Chemello et al., 2000; Bressan et al., 2009). Therefore, much more attention should be paid to the study of the reef morphology and distribution together with the associated communities and the trophic processes within associated species.

Moreover, since the easy accessibility of vermetid reef makes it highly vulnerable to coastal human activity (Franzitta et al., 2006; Graziano et al., 2007), a correct planning in the areas where

reefs are present, in order to minimize all potential environmental threats, should be a priority.

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## A preliminary checklist of the species of non-marine Molluscs from the Alburni Mountains, Campania, Southern Italy (Mollusca Gastropoda Bivalvia)

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### ABSTRACT

An annotated checklist of the species of non-marine molluscs from the Alburni Mountains (Salerno Province, Campania, Southern Italy) is reported. The research was carried out from 2010 to 2013 inside a Site of Community Importance (SCI) and a Special Protection Area (SPA), of the Cilento, Vallo di Diano and Alburni National Park. The non-marine molluscs sampled on the field were compared with data available from the literature and malacological collections. Up to now, only 12 non-marine Mollusc species were known from the Alburni Mountains through bibliographical data. In all, the malacofauna of Alburni Mountains is composed by 83 non-marine Mollusc species (73 species of land snails, and 10 species of freshwater molluscs). The presence of nine species (six species of land snails and three species of freshwater snails) was confirmed by our field investigation, four species (3 species of land snails and 1 species of allochthonous freshwater snails) were recorded only by bibliographical data and were not yet found. Our analysis identifies 70 species of non-marine Molluscs (64 species of land snails, 6 species of freshwater molluscs) recorded on the basis of field data which were not previously recorded from the study area. At least 11 species are new records for the Campania Region. Extremely interesting is the record of *Vertigo angustior* Jeffreys, 1830 a species protected in European Union by the Annex II of the “Habitats Directive” and listed as “Vulnerable” at the European level. A Red List of Threatened Species is proposed and the species were classified with the code of I.U.C.N. (Version 2014.3). Five allochthonous species were surveyed for the first time in the study area: 3 land snails: *Lucilla scintilla* (Lowe, 1852), *Lucilla singleyana* (Pilsbry, 1829) and *Paralaoma servilis* (Shuttleworth, 1852), and 2 freshwater snails: *Potamopyrgus anti-podarum* (J.E. Gray, 1843) and *Ferrissia fragilis* (Tryon, 1863). Four species are known exclusively from the literature: *Vertigo (Vertigo) moulinsiana* (Dupuy, 1849), *Macrogastrea (Pyrostoma) plicatula* (Draparnaud, 1801), *Ceriuella virgata* (Da Costa, 1778), and *Haitia acuta* (Draparnaud, 1805).

### KEY WORDS

Non-marine Molluscs; Alburni Mountains, Campania; faunistics; conservation.

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## INTRODUCTION

The knowledge of the malacofauna of Campania (about 150 species, personal data; 13,595 sq Km) is far below than that of other regions. This is even more evident when we consider the protect areas of this territory as those of the Alburni Mountains whose malacofauna is virtually unknown (Fig. 1).

In all Campania Region, only papers on checklist of Capri Island and Vesuvius National Park are known in the last 10 years (Petraccioli et al., 2005a, 2005b, 2006a, 2006b, 2007; Picariello et al., 2011); moreover there are only historical reports, nearly 100 years old, concerning the most common species and quoted with obsolete names. The purpose of this paper is, therefore, to help bridge this gap by increasing the malacofauna knowledge of this group in an important area of the Campania Region as the Alburni Mountains, with particular reference to the species listed in the Annex of the Habitats Directive, in the Index of the protected fauna of Italy and in the various red lists (Manganelli et al., 2000a; Cerfolli et al., 2002; I.U.C.N., 2014).

## MATERIAL AND METHODS

The Alburni Mountains are a calcareous massif in the Salerno Province (Campania Region) belonging to the Lucan Sub Apennines chain, located in the Eastern area of Cilento, near the borders between Campania and Basilicata. In North-East the range degrades into the plain of Vallo di Diano between the valleys of the Calore Lucano, Tanagro and Sele rivers. The massif extends for about 250 km<sup>2</sup>. The study area (SCI IT8050033 named: "Monti Alburni", and SPA IT8050055 named: "Alburni") is included in Cilento, Vallo di Diano and Alburni National Park and covers 14 administrative municipalities (Aquara, Auletta, Castelcivita, Controne, Corleto Monforte, Ottati, Petina, Polla, Postiglione, San Pietro al Tanagro, San Rufo, Sant'Angelo a Fasanella, Sant'Arzenio, and Sicignano degli Alburni) (see TEMI, 2010).

A detailed investigation on the historical and current literature and a comprehensive study of Neapolitan public and private molluscan collections were preliminarily performed. We also inspected the original sites reached by Costa (1874) 140 years ago.

From 2010 to 2013 the field surveys were conducted in 127 sampling points (stations or plots) between 100 and 1742 meters above sea level (sum-

mit of Monte Alburno/Panormo) in all suitable habitats present on the territory of the Alburni Mountains in accordance with the vegetation types reported in the land use map (1: 25.000) available by the "Ente Parco". Adult specimens and shells of non-marine molluscs were hand-collected through visual search, leaf litter and soil collecting and sorting. Samples were then air dried and sieved down to 0.5 mm mesh. Samples of sediment were screened with calibrated sieves. The cleaned up material was examined under lens and/or stereo microscope to sort the smallest fraction, namely. Fractions above 1 cm were searched by a Leica EZ4 stereo microscope (Leica Microsystems GmbH, Wetzlar, Germany), both incident and transmitted, and then photographed with a digital camera. The specimens for anatomical exams were drowned in water and fixed in 75% ethanol. The reproductive apparatus was extracted by means of scalpel, scissors and forceps. The illustrations of genitalia were sketched using a camera lucida mounted on the above stereomicroscope.

The sampled specimens were collected with permission of the "Ente Parco Nazionale del Cilento e Vallo di Diano" (Permit no. 16341/19.10.2010). Two sampled specimens for species were deposited in the Museo Naturalistico of Corleto Monforte (Salerno Province), a museum acknowledged as an "institution of regional interest" (Decreto dalla Giunta Regionale Campaniana n. 2010 del 29/12/2008). In addition, when other specimen/species were collected, we preserved them in the private collection of the authors. The species identification was based on qualified dichotomic keys (Giusti & Pezzoli, 1980; Girod et al., 1980; Bech, 1990; Giusti et al., 1995; Kerney & Cameron, 1999). The taxonomic order and nomenclatural arrangement of the list follow: Bodon et al. (1995), Manganelli et al. (1995, 1998, 2000b), Castagnolo (1995), Ponder & Lindberg (1996), Nordsieck (2002) and Bank (2011); the common names were based on Janus (1982) and on the web site: <http://media.eol.org>.

For each species a brief note on the abundance in the study area is reported according to the following classification: Very rare (sampled in 1–5 stations), Rare (sampled in 6–10 stations), Uncommon (sampled in 11–19 stations), Common (sampled in 20–35 stations), Widespread (sampled in over 35 stations). The bibliographical and museological data were then reported. If present in the I.U.C.N. Red List, each species is classified

with the code of Red List of Threatened Species (I.U.C.N., 2014) and Cuttelod et al. (2011).

data from 1986. Classified as “LC” by Cuttelod et al. (2011) and by I.U.C.N. (2014).

## RESULTS

### *Species surveyed on the field*

Phylum MOLLUSCA Cuvier, 1795  
 Classis GASTROPODA Cuvier, 1795  
 Subclassis ORTHOGASTROPODA Ponder et Lindberg, 1996

Ordo ARCHITAENIOGLOSSA Haller, 1890

Familia COCHLOSTOMATIDAE Kobelt, 1902

*Cochlostoma montanum* (Issel, 1866)  
*Cochlostoma montanum cassiniacum* (Saint-Simon, 1878)

Common, 34 plots, locally abundant. Museal

Familia ACICULIDAE J.E. Gray, 1850

*Platyla talentii* Bodon et Cianfanelli, 2008

Rare, 10 plots, locally abundant (Figs. 2, 3). Endemic of Southern Apennine. Bodon & Cianfanelli, 2008. Classified as “NT” by Cuttelod et al. (2011) and “NT” by I.U.C.N. (2014).

Ordo NEOTAENIOGLOSSA Haller, 1892

Familia POMATIIDAE Newton, 1891 (1828)

*Pomatias elegans* (O.F. Müller, 1774)  
 Round-mounted Snail

Common, 28 plots. Museal data from 1986.

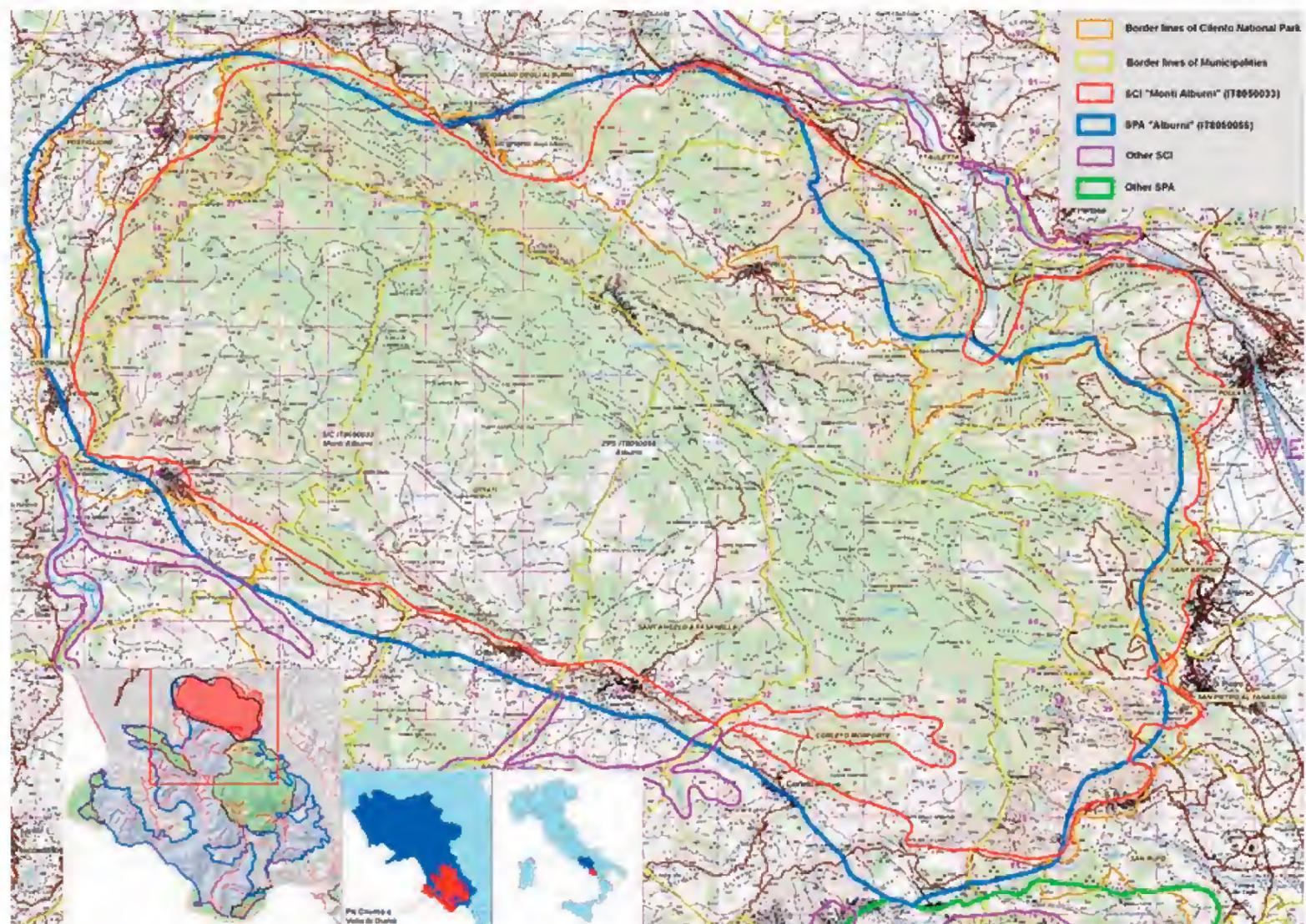


Figure 1. The study area: Alburni Mountains, S-Italy.

Familia HYDROBIIDAE Stimpson, 1865  
Mud snails

*Pseudamnicola (P.)* cfr. *moussonii* (Calcara, 1841)

Very rare, 1 plot. Classified as “LC” by Cuttelod et al. (2011) and by I.U.C.N. (2014). Endemic species in Europe (Cuttelod et al., 2011).

*Belgrandia minuscula* (Paulucci, 1881)

Very rare, 2 plots. Bodon et al. (2005). Classified as “DD” and Endemic species in Europe by Cuttelod et al. (2011) and “DD” by I.U.C.N. (2014).

*Potamopyrgus antipodarum* (J.E. Gray, 1843)  
New Zealand mud snail, Jenkins' Spire Snail

Very rare, 2 plots (Fig. 4). Allochthonous species, introduced from New Zealand (Lori et al., 2005; Lori & Cianfanelli, 2007; Cianfanelli, 2009; Cuttelod et al., 2011). Classified as “LC” by I.U.C.N. (2014).

*Bythinella opaca* (M. von Gallenstein, 1848)  
*Bythinella schmidtii* (Küster, 1852)

Very rare, 4 plots. Bodon et al. (1999) in an adjacent locality; Bodon et al., 2005. Classified as “LC” by Cuttelod et al. (2011) and by I.U.C.N. (2014). Endemic species in Europe (Cuttelod et al., 2011).

Familia ELLOBIIDAE Pfeiffer, 1854

*Carychium tridentatum* (Risso, 1826)  
Long-toothed Herald Snail

Uncommon, 14 plots, locally abundant.

Familia LYMNAEIDAE Rafinesque, 1815

*Galba truncatula* (O.F. Müller, 1774)  
Dwarf Pond Snail

Very rare, 2 plots. Museal data from 1986. Classified as “LC” by Cuttelod et al. (2011) and by I.U.C.N. (2014).

*Radix labiata* (Rossmässler, 1835)  
*Lymnaea (Radix) peregra* (O.F. Müller, 1774)  
*Radix peregra* (O. F. Müller, 1774)  
Wandering Snail

Very rare, 3 plots. Costa (1874): sub *Limnaeus Gibilmannicus* (see O. G. Costa, 1839). Museal data from 1986. *Radix peregra* is classified by I.U.C.N. (2014) as synonym of *Radix balthica* (Linnaeus, 1758). *Radix labiata* is classified as “LC” by Cuttelod et al. (2011).

Ordo PULMONATA Cuvier in Blainville, 1814  
Subordo BASOMMATOPHORA Keferstein, 1864  
Familia ANCYLIDAE

*Ancylus fluviatilis* O.F. Müller, 1774  
River Limpet

Rare, 7 plots. Classified as “LC” by Cuttelod et al. (2011) and by I.U.C.N. (2014).

*Ferrissia fragilis* (Tryon, 1863)  
*Ferrissia wautieri* (Mirolli, 1960)  
Fragile Ancyloid

Very rare, 1 plot (Fig. 5). Classified as “LC” by I.U.C.N. (2014). Cryptic invader of Italian freshwater ecosystems from North America (Cianfanelli et al., 2007; Lori & Cianfanelli, 2007).

Subordo STYLOMMATOPHORA A. Schmidt, 1855  
Familia PYRAMIDULIDAE Kennard et B.B. Woodward, 1914

*Pyramidula pusilla* (Vallot, 1801)  
Rock Snail

Common, 24 plots, locally abundant.

*Pyramidula rupestris* (Draparnaud, 1801)  
Rock Snail

Very rare, 1 plot. Costa (1874).

Familia VERTIGINIDAE Fitzinger, 1833

***Vertigo (Vertigo) pygmaea*** (Draparnaud, 1801)  
Common Whorl Snail, Crested vertigo

Very rare, 1 plot. Classified as “LC” by Cuttelod et al. (2011)

***Vertigo (Vertilla) angustior*** Jeffreys, 1830  
Vertigo sinistrorso minore, Narrow-mouthed Whorl Snail

Very rare, 1 plot (Fig. 6). Species protected in European Union by the Annex II of the “Habitats Directive”, and in Italy by the D.P.R. n. 357/1997 than modified by D.P.R. n. 120/2003. In Europe, this species is listed as Vulnerable (VU) (criteria: A2ac+3c) at the European level and at the level of the 27 member States of the European Union (Cuttelod et al., 2011). The species is regionally protected in Tuscany, Umbria and Emilia-Romagna. The species has been regarded in Italy as “NT” by Manganeli et al. (2000a). Classified as “LR” by Cerfolli et al. (2002), and “NT” by I.U.C.N. (2014).

***Columella edentula*** (Draparnaud, 1805)  
Toothless Chrysalis Snail

Very rare, 2 plots. Classified as “LC” by Cuttelod et al. (2011) and by I.U.C.N. (2014). Endemic species in Europe (Cuttelod et al., 2011).

***Truncatellina callicratis*** (Scacchi, 1833)

Rare, 10 plots. Endemic species in Europe classified as “LC” by Cuttelod et al. (2011).

Familia ORCULIDAE Pilsbry, 1918

***Sphyradium doliolum*** (Bruguière, 1792)

Uncommon, 12 plots. Classified as “LC” by Cuttelod et al. (2011).

***Pagodulina pagodula*** (des Moulins, 1830)

Very rare, 1 plot. Classified as “LC” by Cuttelod et al. (2011) and by I.U.C.N. (2014). Endemic species in Europe (Cuttelod et al., 2011).

Familia CHONDRINIDAE Steenberg, 1925

***Rupestrella philippii*** (Cantraine, 1840)

Very rare, 4 plots. Classified as “LC” by Cuttelod et al. (2011).

***Chondrina avenacea*** (Bruguière, 1792)

Widespread, 36 plots. Museal data from 1874. (Costa, 1874). Classified as “LC” by Cuttelod et al. (2011) and by I.U.C.N. (2014). Endemic species in Europe (Cuttelod et al., 2011).

Familia LAURIIDAE Steenberg, 1925

***Lauria sempronii*** (Charpentier, 1837)

Rare, 8 plots.

Familia ARGNIDAE Hudec, 1965

***Argna biplicata*** (Michaud, 1831)

Very rare, 4 plots. Classified as “LC” by Cuttelod et al. (2011) and by I.U.C.N. (2014). Endemic species in Europe (Cuttelod et al., 2011).

Familia VALLONIIDAE Morse, 1864

***Acanthinula aculeata*** (O.F. Müller, 1774)  
Pricly Snail

Common, 21 plots. Classified as “LC” by Cuttelod et al. (2011).

***Gittenbergia sororcula*** (Benoit, 1859)

Rare, 9 plots. Locally very abundant. Classified as “LC” by Cuttelod et al. (2011).

Familia ENIDAE B.B. Woodward, 1903 (1880)

***Chondrula tridens*** (O.F. Müller, 1774)

Very rare, 2 plots. Classified as “NT” by Cuttelod et al. (2011).

***Jaminia quadridens*** (O.F. Müller, 1774)

Uncommon, 17 plots. Locally very abundant. Museal data from 1986. Classified as “LC” by Cuttelod et al. (2011) and by I.U.C.N. (2014).

***Merdigera obscura*** (O.F. Müller, 1774)

*Ena obscura* (O.F. Müller, 1774)

Lesser Bulin

Uncommon, 11 plots. Classified as “LC” by Cuttelod et al. (2011) and by I.U.C.N. (2014). Endemic species in Europe (Cuttelod et al., 2011).

Familia PUNCTIDAE Morse, 1864

***Punctum pygmaeum*** (Draparnaud, 1801)

Dwarf Snail

Common, 33 plots.

***Paralaoma servilis*** (Shuttleworth, 1852)

*Paralaoma caputspinulae* (Reeve, 1852)

Pinhead Spot

Very rare, 2 plots. Allochthonous species, introduced from New Zealand (Lori et al., 2005; Lori & Cianfanelli, 2007; Cianfanelli, 2009; Christensen, 2012).

Familia DISCIDAE Thiele, 1931 (1866)

***Discus rotundatus*** (Müller, 1774)

Discus Snail, Rounded Snail

Rare, 7 plots.

Familia HELICODISCIDAE H.B. Baker, 1927

***Lucilla scintilla*** (Lowe, 1852)

Oldfield Coil

Very rare, 1 plot (Fig. 7). Allochthonous species. The indigenous distribution for this species includes North America (Lori et al., 2005; Lori & Cianfanelli, 2007; Cianfanelli, 2009).

***Lucilla singleyana*** (Pilsbry, 1889)

Smooth Coil

Very rare, 1 plot (Fig. 8). Allochthonous species. Originally probably from North America, introduced to Europe (Lori et al., 2005; Lori & Cianfanelli, 2007; Cianfanelli, 2009).

Familia VITRINIDAE Fitzinger, 1833

***Vitrina* cfr. *pellucida*** (O.F. Müller, 1774)

Pellucid Glass Snail

Uncommon, 11 plots. Classified as “LC” by Cuttelod et al. (2011).

Familia PRISTILOMATIDAE T. Cockerell, 1891

***Vitrea subrimata*** (Reinhardt, 1871)

Common, 26 plots.

***Vitrea etrusca*** (Paulucci, 1878)

Very rare, 4 plots.

***Vitrea contracta*** (Westerlund, 1871)

Milky Crystal Snail

Common, 26 plots.

Familia ZONITIDAE Mörch, 1864

***Aegopsis verticillus*** (Férussac, 1822)

Very rare, 1 plot (Fig. 9).

Familia OXYCHILIDAE P. Hesse, 1927 (1879)

***Retinella olivetorum*** (Gmelin, 1791)

*Retinella olivetorum olivetorum* (Gmelin, 1791)

Common, 33 plots. Museal data from 1986.

***Oxychilus* (*Oxychilus*) cfr. *draparnaudi*** (Beck, 1837)

Draparnaud's Glass Snail, Dark-bodied Glass snail

Uncommon, 16 plots. Museal data from 1986.

- Mediterranea hydatina* (Rossmässler, 1838)  
 Very rare, 1 plot.  
 Familia EUCONULIDAE Baker, 1928
- Daudebardia rufa* (Draparnaud, 1805)  
 Widespread, 42 plots. Locally very abundant (Figs. 10, 11, 12, 13).  
 Rare, 8 plots.  
 Familia FERUSSACIIDAE Bourguignat, 1883
- Familia MILACIDAE Ellis, 1926  
*Tandonia sowerbyi* (A. Férussac, 1823)  
 Keeled Slug, Sowerby's Slug  
 Uncommon, 11 plots.  
 Familia LIMACIDAE Lamarck, 1801
- Limax maximus* Linnaeus, 1758  
 Leopard Slug, Great Grey Slug, Giant Garde Slug  
 Rare, 6 plots.  
 Familia SUBULINIDAE P. Fischer et Crosse, 1877
- Lehmannia marginata* (O. F. Müller, 1774)  
 Tree slug  
 Very rare, 1 plot.  
*Rumina decollata* (Linnaeus, 1758)  
 Decollate Snail  
 Very rare, 4 plots.
- Limacus flavus* (Linnaeus, 1758)  
 Yellow Slug, Tawny Garden Slug  
 Very rare, 2 plots.  
 Familia OLEACINIDAE H. Adams et A. Adams, 1855
- Familia AGRIOLIMACIDAE H. Wagner, 1935  
*Deroceras reticulatum* (O.F. Müller, 1774)  
 Netted Slug, Gray Fieldslug  
 Rare, 6 plots.  
 Familia TESTACELLIDAE J.E. Gray, 1840
- Deroceras invadens* Reise, Hutchinson, Schun-  
 ach et Schlitt, 2011  
 Chestnut Slug, Brown Field Slug, Longneck  
 Fieldslug, Widespread Pest Slug  
 Very rare, 4 plots.  
*Testacella scutulum* G.B. Sowerby I, 1821  
 Shield Shelled Slug  
 Very rare, 4 plots.
- Familia CLAUSILIIDAE J.E. Gray, 1855  
 Door Snails  
*Medora* sp.  
 Very rare, 3 plots.

***Cochlodina (Cochlodina) laminata*** (Montagu, 1803)  
Plaited Door Snail

Rare, 6 plots. (Costa, 1874).

***Charpentieria (Stigmatica) paestana*** (Philippi, 1836)

*Siciliaria paestana* (Philippi, 1836)

Widespread, 42 plots. Locally abundant.

***Charpentieria (Stigmatica) cfr. ernae*** (Fauer, 1978)

Very rare, 2 plots. Museal data from 1970. Endemic of Southern Appennine. (Fauer, 1978; Welter-Schultes, 2012; Nordsieck, 2013).

***Macrogastra (Pyrostoma) attenuata*** (Rossmässler, 1835)

*Macrogastra (Pyrostoma) attenuata iriana* (Polonera, 1885)

Lined door snail

Very rare, 2 plots.

***Clausilia cruciata*** (S. Studer, 1820)

*Clausilia cruciata bonellii* E. Von Martens, 1873

Very rare, 3 plots. Museal data before 1950.

Familia HYGROMIIDAE Tryon, 1866

***Xerotricha conspurcata*** (Draparnaud, 1801)

Very rare, 2 plots. Museal data from 1986. Classified as “LC” by Cuttelod et al. (2011).

***Hygromia cinctella*** (Draparnaud, 1801)

Girdled Snail

Rare, 8 plots. Classified as “LC” by Cuttelod et al. (2011) and by I.U.C.N. (2014). Endemic species in Europe (Cuttelod et al., 2011).

***Cerņuella (Cerņuella) cisalpina*** (Rossmässler, 1837)

Common, 21 plots. Locally abundant. Museal data from 1986. Classified as “LC” by Cuttelod et al. (2011) and by I.U.C.N. (2014). Endemic species in Europe (Cuttelod et al., 2011).

***Cerņuella (Xerocincta) neglecta*** (Draparnaud, 1805)  
Luddesdown Snail, Neglected dune snail

Very rare, 3 plots. Museal data from 1986. Classified as “LC” by Cuttelod et al. (2011) and by I.U.C.N. (2014). Endemic species in Europe (Cuttelod et al., 2011).

***Cerņuellopsis ghisottii*** Manganelli et Giusti, 1988

Very rare, 3 plots. Hallgas, com. pers., 2013. This species is endemic to Italy. Classified as “VU” by Cuttelod et al. (2011) and by I.U.C.N. (2014) (IUCN Criteria (Europe) (version 3.1): B1ab(iii)+2ab(iii). Endemic species in Europe (Cuttelod et al., 2011).

***Trochoidea (Trochoidea) pyramidata*** (Draparnaud, 1805)

Very rare, 2 plots. Classified as “LC” by Cuttelod et al. (2011).

***Trochoidea (Trochoidea) trochoides*** (Poiret, 1789)

Very rare, 2 plots. Museal data from 1985. Classified as “LC” by Cuttelod et al. (2011).

***Monacha (Monacha) cfr. cartusiana*** (O.F. Müller, 1774)

Chartreuse Snail, Carthusian Snail

Common, 35 plots. Museal data from 1986. Classified as “LC” by Cuttelod et al. (2011) and by I.U.C.N. (2014). Endemic species in Europe (Cuttelod et al., 2011). Regarded as “Edible species” in Tuscany and Umbria Region.

***Monacha (Eutheba) cfr. parumcincta*** (Menke, 1828)

Common, 26 plots. Classified as “LC” by Cuttelod et al. (2011) and by I.U.C.N. (2014). Endemic species in Europe (Cuttelod et al., 2011).  
Familia HELICODONTIDAE Kobelt, 1904

***Helicodonta obvoluta*** (O.F. Müller, 1774)

*Helicodonta obvoluta obvoluta* (O.F. Müller, 1774)  
Cheese Snail



Figures 2-9. Non-marine Molluscs from the Alburni Mountains, Campania, Southern Italy. Figure 2. *Platyla talentii* alive (Photo by N. Maio). Figure 3. Shell of *Platyla talentii*: view. 3A. Particular of dorsal view. 3B. Particular of the mouth (Photos by N. Maio). Figure 4. *Potamopyrgus antipodarum* alive (Photo by N. Maio). Figure 5. Shell of *Ferrissia fragilis*: dorsal, lateral and ventral view (Photo by I. Niero). Figure 6. Shell of *Vertigo (Vertilla) angustior*: apertural view (Photo by I. Niero). Figure 7. Shell of *Lucilla scintilla*: umbilical, dorsal and apertural view (Photo by N. Maio). Figure 8. Shell of *Lucilla singlyana*: dorsal, apertural and umbilical view (Photo by N. Maio). Figure 9. Shell of *Aegopis verticillus* dorsal, umbilical and apertural view (Photo by N. Maio).

Rare, 7 plots. Classified as “LC” by Cuttelod et al. (2011) and by I.U.C.N. (2014). Endemic species in Europe (Cuttelod et al., 2011).

Familia HELICIDAE Rafinesque, 1815

*Chilostoma (Campylea) cfr. planospira* (Lamarck, 1822)

Uncommon, 18 plots. Museal data from 1986. Classified as “DD” by Cuttelod et al. (2011) and by I.U.C.N. (2014). Endemic species in Europe (Cuttelod et al., 2011).

*Marmorana (Ambigua) fuscolabiata fuscolabiata* (Rossmässler, 1842)

Widespread, 27 plots. Costa (1874), Degner (1927). Museal data from 1874. Classified as “DD” by Cuttelod et al. (2011) and by I.U.C.N. (2014). Endemic species in Europe (Cuttelod et al., 2011).

*Marmorana (Ambigua) cfr. fuscolabiata wullei* Kobelt, 1903

Common, 25 plots. Kobelt (1903a; 1903b), Degner (1927), Bacci (1951), Alzona (1971). Museal data from 1903.

*Eobania vermiculata* (O.F. Müller, 1774)  
Chocolate-band snail

Very rare, 3 plots. Museal data from 2006. Regarded as “Edible species” in Tuscany and Umbria Region.

*Cantareus apertus* (von Born, 1778)  
Green Garden Snail

Very rare, 2 plots. Museal data from 1986. Regarded as “Edible species” in Tuscany and Umbria Region.

*Cornu aspersum* (O.F. Müller, 1774)  
*Cantareus aspersus* (O.F. Müller, 1774)  
Garden Snail, Common Snail, Brown Garden Snail

Very rare, 4 plots. Museal data from 1986. Regarded as “Edible species” in Tuscany and Umbria Region.

*Helix (Helix) cfr. delpretiana* Paulucci, 1878

Rare, 9 plots. Museal data from 1986. This species is endemic to the Central Appenines in Italy. Classified as “DD” by Cuttelod et al. (2011) and by I.U.C.N. (2014). Endemic species in Europe (Cuttelod et al., 2011).

*Helix (Helix) cfr. ligata* O.F. Müller, 1774  
Ligate Snail

Uncommon, 11 plots. Museal data from 1986. Classified as “LC” by Cuttelod et al. (2011) and by I.U.C.N. (2014). Endemic species in Europe (Cuttelod et al., 2011).

Classis BIVALVIA Linnaeus, 1758

Ordo VENEROIDA H. et A. Adams, 1857  
Familia SPHAERIIDAE Deshayes, 1855 (1820)

*Pisidium casertanum* (Poli, 1791)  
Caserta Pea Mussel

Very rare, 5 plots. Classified as “LC” by Cuttelod et al. (2011) and by I.U.C.N. (2014).

#### *Species exclusively known from the literature*

Familia VERTIGINIDAE Fitzinger, 1833

*Vertigo (Vertigo) moulinsiana* (Dupuy, 1849)  
Vertigo of Demoulins, Demoulins’ Whorl Snail

Manganelli et al. (2001), Bodon et al. (2005). Find only in debris of Fiume Calore, near Grotta di Castelcivita, Salerno Province, by S. Cianfanelli and E. Talenti on 1994. Species protect in European Union by the Annex II of the “Habitats Directive” and in Italy by the D.P.R. n. 357/1997 than modified by D.P.R. n. 120/2003. The species is regionally protect in Tuscany, Umbria and Emilia-Romagna. The species has been initially classified as “LRcd”(= Lower risk, conservation dependant) by Bouchet et al. (1999), then the species has been regarded in Italy as “VU”(criteria: B2a, B2b) by Manganelli et al. (2000b, 2001). Classified as “LR” by Cerfolli et al. (2002), “VU” (criteria: A2ac) by Cuttelod et al. (2011) and by I.U.C.N. (2014).

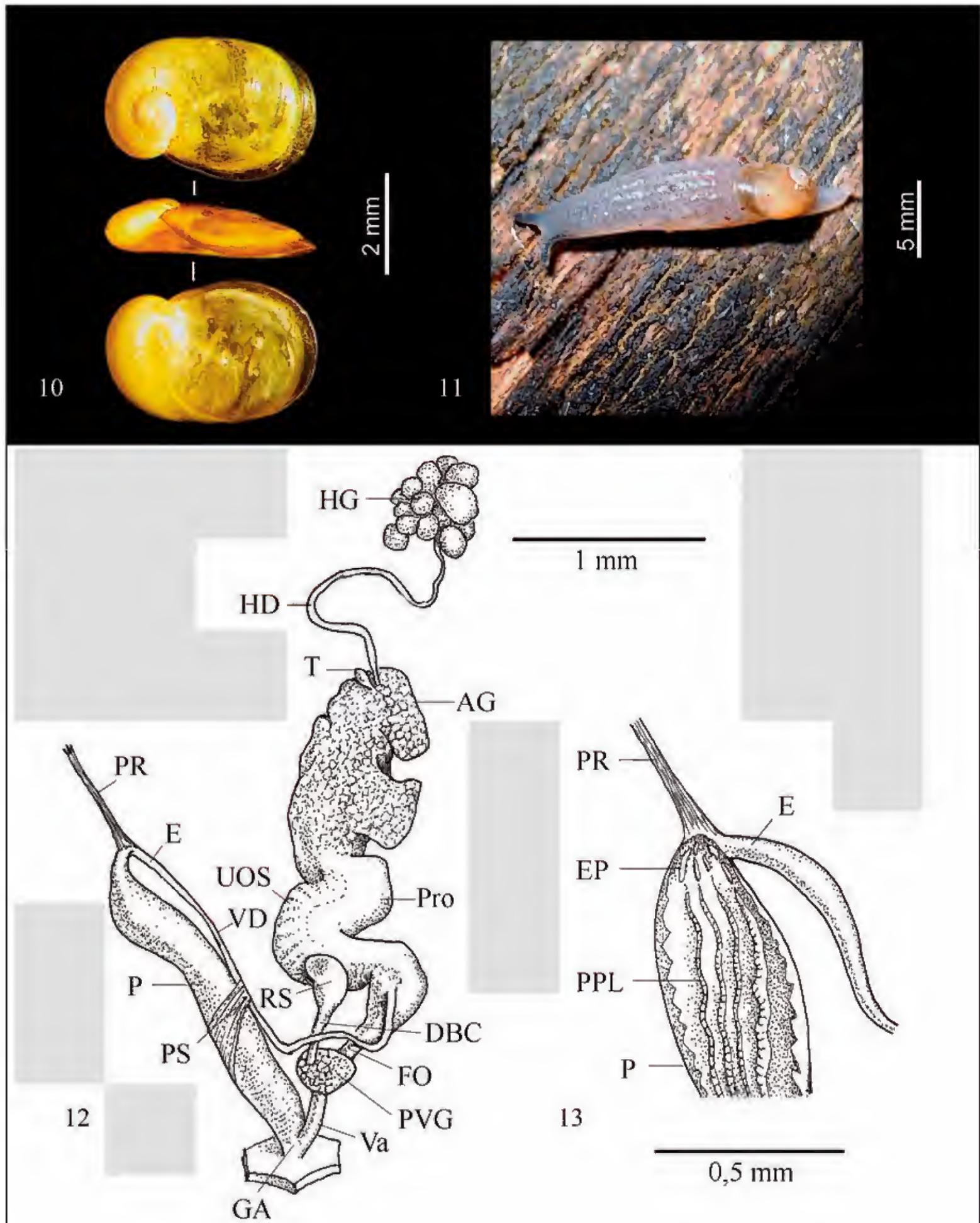


Figure 10. Shell of *Daudebardia rufa*: dorsal, apertural and umbilical view (Photo by I. Niero). Figure 11. *D. rufa* alive (Photo by N. Maio). Figure 12. Genitalia of *D. rufa* (Sant'Angelo a Fasanella (SA), 1160 m, 17.0V.2013, N. Maio, P. Crovato & I. Niero legit). Figure 13. Internal structure of the penis. Acronyms in figures: AG= albumen gland; DBC= duct of the bursa copulatrix; E= epiphallus; EP= epiphallic pore; FO= free oviduct; GA= genital atrium; HD= hermaphroditic duct; HG= hermaphroditic gland; P= penis; PPL= penis pleats; PR= penial retractor; Pro= prostate; PVG= perivaginal gland; PS = penis sheath; RS = reservoir of spermatheca; T= talon; UOS= uterine ovispermiduct; Va= vagina, VD= vas deferens. (Drawn by I. Niero).

Familia CLAUSILIIDAE J.E. Gray, 1855

*Macrogastra* cfr. *plicatula* (Draparnaud, 1801)

Costa (1874: sub *Clausilia plicatula* Drap.).  
Museum data before 1950.

From the South of Italy are cited 3 subspecies, in addition to *M. plicatula plicatula*: *M. p. amiaten-sis* Nordsieck, 2006; *M. p. apennina* Gentiluomo 1868, and *M. p. aprutica* Nordsieck, 2006 (Nordsieck, 2006).

Familia HYGROMIIDAE Tryon, 1866

*Cerneuella* cfr. *virgata* (Da Costa, 1778)  
Banded Snail

Kobelt (1907). Museum data from 1986. Regarded as “Edible species” in Tuscany and Umbria Region.

Familia OXYCHILIDAE P. Hesse, 1927 (1879)

*Oxychilus* sp.

Capasso (1958), Capolongo & Cantilena (1974).

Ordo HYGROPHILA A. Férussac 1822

Familia PHYSIDAE Fitzinger, 1833

*Haitia acuta* (Draparnaud, 1805)  
Acute Bladder Snail, European physa, Tadpole Snail, Bladder Snail, Pewter physa

Sacchi (1964): sub *Physa acuta*. Allochthonous species. The oldest alien species of Italy probably native to northeastern North America (Lori et al., 2005; Lori & Cianfanelli, 2007; Cianfanelli, 2009).

## DISCUSSION

Up to now, only 13 non-marine Mollusc species were known from the Alburni Mountains through bibliographical data (nine species of land snails and four species of freshwater snails), to which we add the new species listed in this paper for the study

area. The presence of nine species (six species of land snails and three species of freshwater molluscs) are confirmed by our field investigation. Only four species (the land snails *Macrogastra plicatula*, *Vertigo moulinsiana*, *Cerneuella virgata* and the allochthonous freshwater snails *Haitia acuta*) were documented exclusively by bibliographical data and have not been confirmed by the field surveys yet (Fiorentino et al., 2008; Reise et al., 2011). Our analysis identifies 79 species of non-marine molluscs (69 species of land snails, ten species of freshwater molluscs) recorded on the basis of field data. In total the occurrence of 83 species of non-marine molluscs (73 species of land snails, 10 species of freshwater molluscs) was herein attested in the survey area representing approximately the 56% of the estimated fauna of Campania Region (about 150 species, personal data).

At least 11 species are new records for the Campania Region (*Aegopis verticillus*, *Cerneuellopsis ghisottii*, *Lucilla scintilla*, *Argna biplicata*, *Cerneuella neglecta*, *Daudebardia rufa*, *Helix delpretiana*, *Pagodulina pagodula*, *Vitrina pellucida*, *Vitrea etrusca* and *Macrogastra attenuata*). *M. attenuata* (sub *M. lineolata*) and *D. rufa* were generically recorded from Matese Mountains (probably Molise) by Giusti et al. (1985). 70 species of non-marine molluscs (64 species of land snails, six species of freshwater molluscs), recorded on the basis of field data, have not been previously recorded from the study area.

Extremely interesting is the finding of samples of *Medora* sp.: it seems to be the second record of this genus for the region. The systematics of the genus *Medora* Adams, 1855 is in fact complex and, in many respects, still controversial. Regarding Italy, Nordsieck (1970) considered *M. italiana* (Küster, 1847) of the Central-Southern Apennines distinct from *M. albescens* (Menke, 1830) of the Balkan peninsula. In addition, he assigned to *M. italiana* various subspecies: only one from Campania: *M. i. italiana* (Küster, 1847) (locus typicus: Piedimonte d'Alife (= Piedimonte Matese, Caserta, Campania). Giusti et al. (1986) suggested that it was not possible to distinguish *M. italiana* from *M. albescens* with the subspecies *M. a. italiana* in the central part of Italy. The populations reported for Italy as *M. dalmatina* (Manganelli et al., 1995) were described by Nordsieck (2012) as a distinct sub-

species. Preliminary data by Colomba et al. (2012) suggest that the genus *Medora* shows a much more complex and articulate differentiation than hitherto hypothesized by morphological surveys so far. An attempt to clarify its organization and internal structure, at various taxonomic levels, a more detailed analysis including a higher number of molecular markers and additional *Medora* populations from Italy are required.

Other interesting records are: *Vertigo angustior*, a species protected in the European Union by the Annex II of the Council Directive 92/43/EEC of May 21st 1992 on the conservation of natural habitats and of wild fauna and flora known as “Habitats Directive”, that includes “animal and plant species of community interest whose conservation requires the designation of special areas of conservation (SPA)” and listed as “Vulnerable” at the European level and *Platyla talentii*, an endemic species of Southern Apennine, recently described by Bodon & Cianfanelli (2008), classified as “Near Threatened” by Cuttelod et al. (2011) and by I.U.C.N. (2014).

Five allochthonous species were surveyed for the first time in the study area: three land snails (*Lucilla scintilla*, *L. singleyana* and *Paralaoma servilis*) and two freshwater snails (*Potamopyrgus antipodarum* and *Ferrissia fragilis*). *L. scintilla* and *L. singleyana* are native in North America; they were probably introduced into Europe in the second half of the 20th century (Horsák et al., 2009). *L. singleyana*, *P. servilis* and *F. fragilis* are the second records for the Campania Region, the first is Bodon et al. (2004) sub *Helicodiscus singleyanus* (Pilsbry, 1890), Bodon et al. (2004) sub *P. caputspinulae* (Reeve, 1852) and D'Antonio & Bravi (1990) sub *F. wautieri* (Mirolli, 1960).

In the past, three endemic taxa had been described as new for the Alburni area: *Helix (Iberus) wullei* first described by Kobelt (1903a: 14-15, tavv. 1766-1768) from “Monte Alburno circa vicum Postiglione prov. Salernitanae” and later as *Iberus wullei* (Kobelt, 1903b: pag. 4-5, fig. without number); *Xerophila (Xerolauta) peninsularis* forma “*alburni*” described by Kobelt (1907: pp. 59-60, Tafel 357 Fig. 2221) from “Monte Postiglione, des alten Alburnus” and *Siciliaria ernae* described by Fauer (1978: 265, abb. 1) from “Passo Sentinella im SO der Monti Aburni” [municipality of Corleto Monforte], and “6 km West of San Rufo”. Today *X.*

*peninsularis* is considered a junior synonym of *Cerņuella virgata* (Da Costa, 1778) but the taxonomic status of *Iberus* (= *Marmorana*) *wullei* and of *S. ernae* need to be confirmed. The Demoulin's Whorl Snail, listed in the Standard Data Form of the SCI of “Monti Alburni” is not confirmed by our field surveys.

A Red List of Threatened Species is also proposed and the species were classified with the code of I.U.C.N. (Version 2014.3).

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## Distribution of two *Amphiope* L. Agassiz, 1840 (Echinoidea Clypeasteroidea) morphotypes in the Western-Proto-Mediterranean Sea

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### ABSTRACT

Several species belonging to the genus *Amphiope* L. Agassiz, 1840 (Echinoidea Astriclypeidae) from the Mediterranean Oligo-Miocene have been synonymised with *A. bioculata* (Des Moulins, 1835), the type-species of the genus, based on the interpretation given by Philippe (1998) as a taxon characterized by a large amount of morphological variability. A recent study introduced the characters of the internal test structure and the plating patterns as taxonomic tools in this genus. That paper indicated the occurrence of at least five different species in the examined sample from the Oligo-Miocene of Sardinia, thus pointing to a previous over-estimation of the variability-range of the type-species and to the need of a review of the largely unresolved taxonomy of *Amphiope*. According to a recent study, *Amphiope* is considered as a shallow-water echinoid, inhabiting sandy bottoms with high hydrodynamic energy; so it represents a coastline marker, useful for the study of the paleo-geographic changes occurred in the Proto-Western-Mediterranean during the Miocene. The diffusion and speciation of *Amphiope* were highly influenced by those changes. In particular, the speciation rate of this genus was likely favored by the occurrence of isolated populations created when islands (e.g.: Balears, Calabria, Corse, Kabylies, Sardinia) separate from the mainland, above all in the western part of that Basin, because of the opening of the Balearic Basin during the Late Oligocene-Early Miocene and of the Tyrrhenian Sea during the Burdigalian-Tortonian (references in this work). Two main morphotypes of *Amphiope* sensu Stara & Sanciù (2014), developed in the Western Mediterranean from the late Oligocene to the late Miocene. They are herein called the “*bioculata*” group, characterized by roundish to broad elliptical lunules with major diameter/minor diameter ratio (SI) < 1.59, and the “*nuragica*” group, with more or less narrow lunules and SI > 1.6. According to this authors, most Miocene forms with narrow elliptical lunules would derive from *A. nuragica* (Comaschi Caria, 1955), late Oligocene-early Miocene of Sardinia, the most archaic form so far known of this genus. The forms belonging to the “*bioculata*” group likely derived from a different common ancestor bearing round to broad ovoidal lunules. “*A. bioculata*” described by Cottreau (1914), from the Burdigalian (Philippe, 1998) of Saint Cristol (Nissan, Hérault, France), is so far the most ancient known form belonging to this group. This work proposes a possible speciation sequence of the “*nuragica*” group.

### KEY WORDS

*Amphiope*; Western-Proto-Mediterranean Sea; Paleogeography.

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## INTRODUCTION

### *Paleogeography and paleoecology*

*Amphiope* L. Agassiz, 1840 (Echinoidea Astri-  
clicypeidae) is considered as a shallow-water echin-  
oid, typical of sandy settings characterized by high  
hydrodynamic energy (Stara et al., 2012). According  
to Stara & Rizzo (2013, 2014) and Stara & Sanci-  
u (2014) it represents also a valid coastline marker.

On the basis of the fossil record and the avail-  
able paleoecological data it is herein hypothesized  
that the diffusion of *Amphiope* was highly influ-  
enced by the paleogeographic (Doglioni et al.,  
1998; Rosenbaum et al., 2002; Carminati et al.,  
2012, Stara & Rizzo, 2014) and paleoecological  
(Popescu, 2009) changes occurred in the Western  
Proto-Mediterranean during the Miocene. In partic-  
ular the opening of the Balearic and Ligurian Basins  
during the Late Oligocene-Early Miocene and  
of the Tyrrhenian Sea during the Burdigalian-  
Messinian (Doglioni et al., 1998; Rosenbaum et al.,  
2002; Carminati et al., 2012) originated islands  
(e.g.: Balears, Calabria, Corse, Kabylies, Sardinia)  
separated by deep water, thus leading to the occur-  
rence of isolated populations and favoring speci-  
ation within this Astri-*clicypeid* genus.

The orogenetic trend in the Mediterranean area  
mainly derived from the differential movement  
between the Adria microplate, belonging to the  
African plate, and the European one.

The geodynamic and paleogeographic evolution  
of the Western Mediterranean may be divided into  
two distinct phases: the first occurred during the  
Chattian-Burdigalian, the second started in the  
Burdigalian and it is still active today.

First phase - The migration of the Sardinia-  
Corsica microplate and the Calabrian block, with  
respect to the more stable European plate, likely  
began 25-23 My ago, with a general translation  
towards SE. This drift was accompanied by a 45°  
counterclockwise rotation of the Sardinia-Corsica  
microplate between 20.5 and 15 Ma, with a broad  
oceanic domain in the Liguro-Provençal basin (up  
to 400 km in the southern part) between 20.5 and 18  
Ma (Gattacceca et al., 2007). These evidences  
firstly improved the presence of a connection  
between the Liguro-Provençal Basin and the Valencia  
trough before 20.5 Ma, then the connection between  
the Alboran and the Algerian basins. Based on the

available paleontological data it is here hypothes-  
ized that the transcurrent belt located to the north  
of the Sardinia-Corsica microplate and the  
Calabrian block led to the formation of a neritic sea,  
occasionally connecting for short periods the  
Ligurian-Provençal Sea to the Po Basin.

Second phase - Further translation towards SE,  
with a rotation of about 15° of the Calabrian block  
(Gueguen, 1995), led to the opening of the Tyrrhe-  
nian Basin, in the Late Miocene. As a result of these  
changes the Mediterranean began to take on an  
appearance more similar to the current one.

Doglioni et al. (1998) has affirmed that the Apen-  
nine orogenetic front kept on migrating towards E  
leading to the emersion of the Apennine Chain, thus  
separating the Tyrrhenian Sea from the Adriatic after  
the Burdigalian. On the other hand, based on the  
opinion by Rosenbaum et al. (2002) and on the  
available macro-paleontological data (Stara &  
Rizzo, 2013; 2014), it seems likely that the connec-  
tion between the Tyrrhenian and the Adriatic basins  
had been realized in the Plio-Pleistocene when the  
Calabrian block reached the Apennine Arc, with the  
exception of the Ligurian Channel (the Val Bormida  
Channel of Stara & Rizzo, 2013). The crustal  
thinning of the back-arc areas located W to the  
Sardinia-Corsica microplate led to extensive flows  
of basaltic lava (indicated by magnetic field anom-  
alies) in the Balearic and the Tyrrhenian basins; both  
of them were deep water seas with a maximum  
depth of 3000 and 3700 m, respectively.

Kotsakis et al. (2004) prospected the occurrence  
of a Sardinia-Tuscany bio-paleoprovince during the  
Serravallian, on the basis of the close similarity of  
the vertebrate fauna present in these areas. This  
would imply the existence of landmass bridges or  
shallow water basins separating lands, important  
factors conditioning the diffusion of *Amphiope*  
between the two sides of the Tyrrhenian Basin.

## MATERIAL AND METHODS

The studied material consists of 78 *Amphiope*  
specimens, preserved as whole coronas deprived of  
the spines, from 5 Oligo-Miocene localities of  
Western-Mediterranean Basin. 44 *A. lovisatoi*  
Cotteau, 1895 (inventory code: (PL1301-03,  
PL1317, PL1413, PL1418-20, PL1422-24, PL1427,  
PL1429, PL1567-70, PL1572-80, PL1583, PL1585-

87, PL1692-99, PL1700-07, PL1709-14, PL1715-18, PL1720-23, PL1726) from Chiaramonti (Sassari province); 1 *Amphiope* sp. from Capo Frasca (Medio Campidano Province); 19 *A. nuragica* from Cuccuru Tuvullao (Cagliari Province) MAC (PL1590-91, PL1678-80, PL1684, PL1727, PL1820, PL1829; PL1835-44); 1 *A. montezemoloi* Lovisato 1901 from Bonnanaro, Sassari; 5 *Amphiope* sp. from Calabria (Vibo Valentia Province, Italy), no code; 2 from Alicante (unknown locality); 1 from Torrent, Valencia Province (Spain) are housed at the Museo di Storia Naturale “Aquilegia” (MAC code) of Cagliari; the Holotype of *A. nuragica*, at the University of Cagliari Sardinia (Italy), UNICA code, inventory 9CC.8-10504. 10 *Amphiope* specimens from Calabria (Vibo Valentia Province, Italy) number 104/E 101-110, are housed at the Civico Museo Paleontologico di Ricadi (Vibo Valentia province), Calabria, Italy. 3 specimens from Torrent, Valencia Province (Spain) were studied in private collections. One syntype of *A. bioculata* from Sure-Pres-Bollène today “Suze-la-Rousse” near “Bollène”, France, housed at the Muséum d’Histoire Naturelle of Bordeaux (code MHNB), France, inventory number MHNBx 2014.6.317.

The plate pattern of the syntype of *A. bioculata*, variety A of Des Moulins (1835), is not visible, but the two lunules are clearly rounded, as described by the author (“*foraminibus subrotundis*”).

Morphological abbreviations (Fig. 1) TL = test length; TW = test width; TH = test height; PL = petalodium length; L1 = lunule length; L2 = lunule width. The measure of TL is reported in mm; other data in % TL; SI = lunule shape index ( $L2/L1$ ); WI = lunule width index  $(L1+L2)/2$ .

Biometric analyses were carried out and data analyzed using the software PAST-version 3.2 (2014) (Hammer, 2014), to help the interpretation of the samples collected from Sardinia and Calabria. Systematic palaeontology follows Kroh & Smith (2010).

## TWO MAIN AMPHIOPE MORPHOTYPES

The genus *Amphiope* sensu Stara & Sancieru (2014) developed from the end of the Oligocene to the late Tortonian-early Messinian in the Proto-Western-Mediterranean Sea.

*A. nuragica* (Comaschi Caria, 1955), from the Oligo-Miocene of Sardinia, is the more ancient species so far known belonging to this genus (Stara & Borghi, 2014), though the genus *Amphiope* looked like already well differentiated in the Aquitanian.

Based on the phylogenetic hypothesis proposed by Stara & Borghi (2014) most forms with narrow transversely elongate lunules derived from *A. nuragica*, whereas those with sub-rounded to broad elliptical lunules as *A. bioculata* (including “*A.*

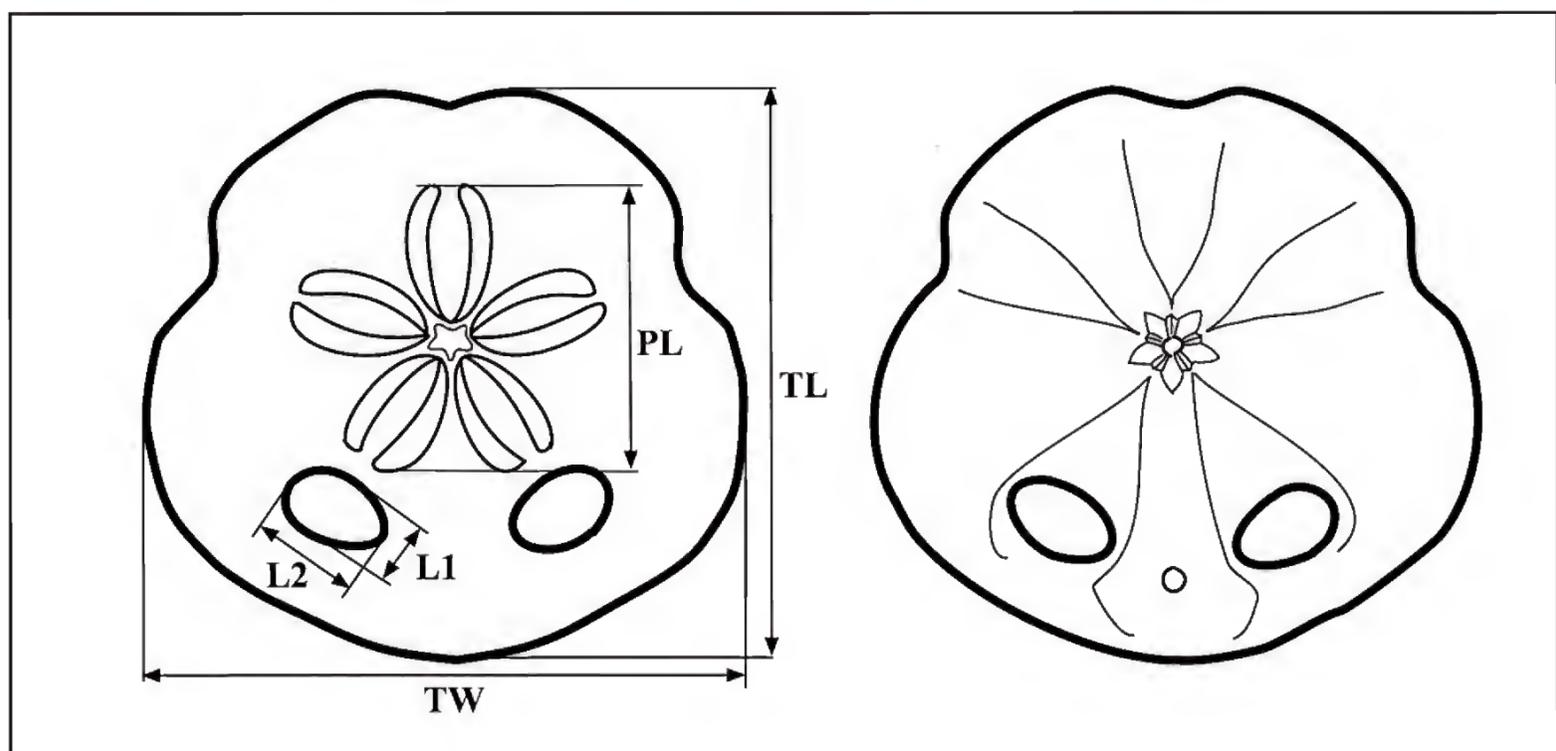


Figure 1. Set of morphometric measurements used in this work.

*bioculata*” from the Aquitanian of Carry, France, as interpreted by Cottreau, 1914 and Philippe, 1998) originated from a different common ancestor.

Two main morphotypes of the genus *Amphiope* are here proposed: the “*nuragica*” group (Pl. 1 Figs. 3-4), characterized by narrow transversely elongate lunules with  $SI > 1.6$ , and the “*bioculata*” group (Pl. 1 Figs. 1-2), with roundish to broad ovoid lunules and  $SI < 1.59$ . Both these groups are well represented in the study area, however in this paper we’ll go deep into the “*nuragica*” forms only, since clear structural data are so far available only for this group.

#### DISTRIBUTION OF THE TWO MAIN MORPHOTYPES IN THE WESTERN MEDITERRANEAN

*Amphiope* has been recorded from more than 30 localities both in Sardinia (Comaschi Caria, 1955, 1972; Stara et al, 2012) and in the Rhône Basin (France) (Cottreau, 1914; Philippe, 1998). This echinoid has been cited in Italy also in Tuscany (Gianini, 1957; present paper), Campania (Barbera & Tavernier, 1989), Calabria (Cottreau, 1914; Carone & Domning, 2007), Sicily (Garilli et al., 2010). In Spain *Amphiope* was recorded in Catalogna (Lambert, 1928), Mallorca (Llompart, 1983), Valencia (personal communication of Bajo Campos, July

2012) and Alicante (present paper). *Amphiope* has also been recorded from Algeria (Pomel, 1887-88 and Cotteau et al., 1891) and Corse (Cotteau, 1877).

The finding localities corresponding to these records are reported in Table 1 and figure 2, with the attribution to the “*nuragica*” or to the “*bioculata*” group. The asterisc marks the species not directly examined by the authors.

The syntype of *A. bioculata* from the Bollène area has the  $SI = 1$ ; the sample of *A. bioculata* described by Cottreau (1914) has a mean value of  $PL = 53$  and  $SI$  ranges from 0.95 to 1.47, with a mean of 1.22. The studied sample of *A. nuragica* from Sardinia has a similar mean value of  $PL (51)$ , however  $SI$  ranges from 2 to 3 with a much higher mean value (2.4) than that of *A. bioculata* sensu Cottreau (1914).

Based on its small sized petalodium ( $PL = 40-47$ , with a mean value of 43.3) the sample from the Tortonian of Calabria clearly differs from all the others belonging to the “*nuragica*” group (Fig. 3), with the exception of the few specimens from the Tortonian of Valencia (mean  $PL = 44$ ).

In the sample from Calabria  $SI$  ranges from 2.4 to 4.3, with a mean value of 3.

A specimen from Sicily shows the lowest value for the “*nuragica*” group ( $SI = 1.6$ ), whereas a specimen of *A. hollandei* Cotteau, 1877 (the holotype) from Corse has the highest value ( $SI = 6.5$ ).

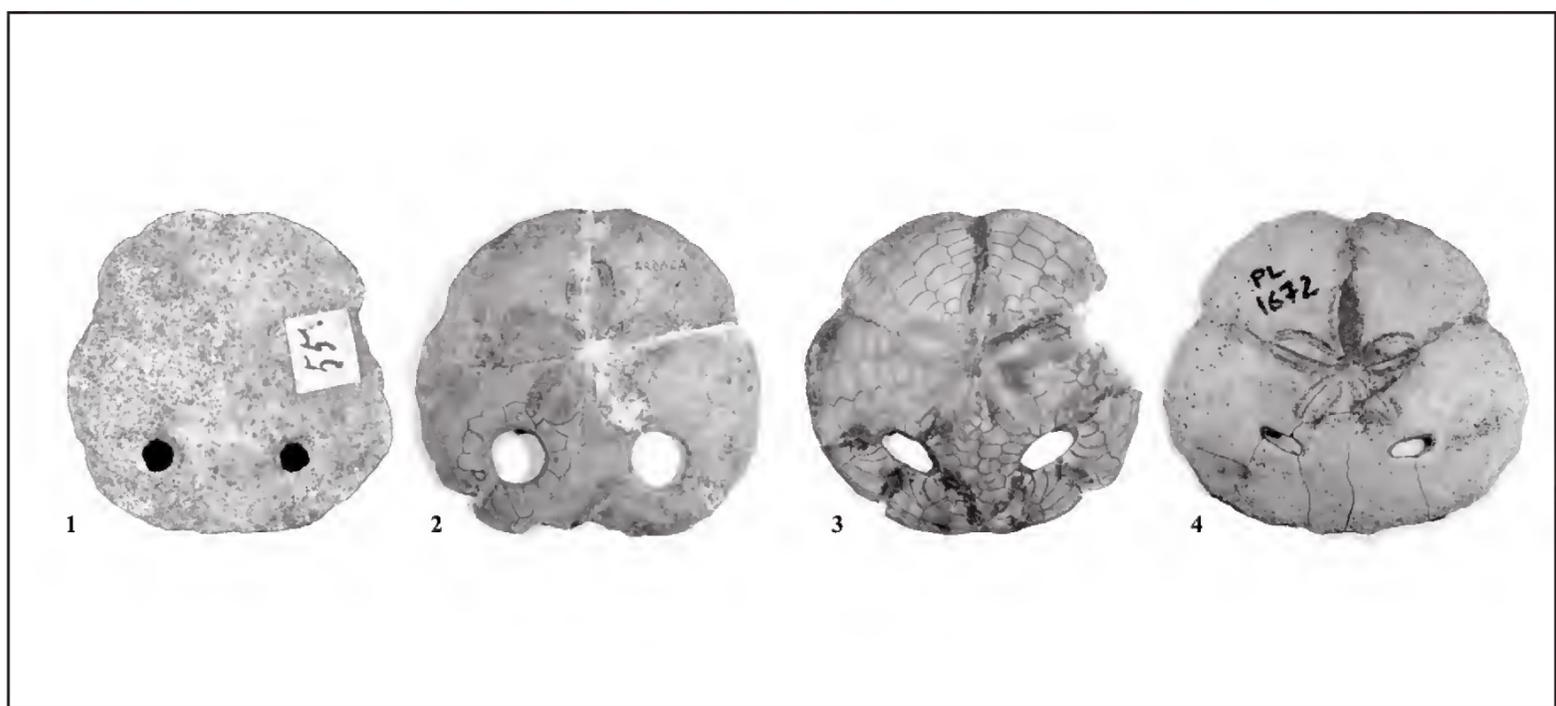


Plate 1. Main *Amphiope* morphotypes. Figure 1-2, “*bioculata*” group; Figure 1: *A. bioculata* syntype MHNbx 2014.6.317; Figure 2: *A. montezemoloi* MAC.PL1676. Figure 3-4, “*nuragica*” group; Figure 3: *A. nuragica* MAC.PL. 1680; Figure 4. *Amphiope* sp. from Calabria, MAC.PL1672.

TYPE	PL % TL	L1 % TL	L2 % TL	WI	SI
<i>Amphiope bioculata</i> , syntype MHN2014.6	—	10	10	10	1
<i>A. cf. bioculata</i> (in Cottreau, 1914)*	53			10.2 (9-12.6)	1.22 (0.95-1.47)
<i>A. montezemoloi</i> , San Giorgio	-	16.8	16	16.4	0.95
<i>A. nuragica</i> , holotype	51			13.5 (11.5-15)	2.4 (2-3)
<i>A. sp.</i> , Sicilia	56	9	15	12	1.6
<i>A. deyrieri</i> , France*	? 47	5.5	15.5	10.5	2.8
<i>A. sp. 1</i> , Calabria	44	5	13	9	2.6
	41	5.5	14	9.7	2.5
	45	5.5	18	11.7	3.3
	44	6	17	11.5	2.8
	47	5	16	11.5	3.2
<i>A. sp. 2</i> , Calabria	44	4	14.5	9.2	3.6
	43	4.5	14	9.2	3.1
	40	5	12	8.5	2.4
	42	3.5	15	9.2	4.3
<i>A. sp. 1</i> , Valencia	42	5	13	9	2.6
	44	4.5	11	7.7	2.4
<i>A. depressa</i> , Algeria*	44	5	10	7.5	2
<i>A. sp.</i> , Capo Frasca	54	7.5	16	11.7	2.1
<i>A. sp. 2</i> , Valencia	55	5	14	9.5	2.8
<i>A. sp.</i> , Alicante	52	4	17	10.5	4.5
<i>A. hollandei</i> , Corsica*	54	3	20	11.5	6.6
<i>A. sarasini</i> , France*	50	6	13	9.5	2.1
<i>A. palpebrata</i> , Algeria*	52	6.5	14	10.2	2.1

Table 1. Data PL, L1, L2, WI and SI of species included in the “*nuragica*” group, present in the area under study. For comparison, in the first three rows are reported the data of syntype of *A. bioculata* and two other forms of the group.

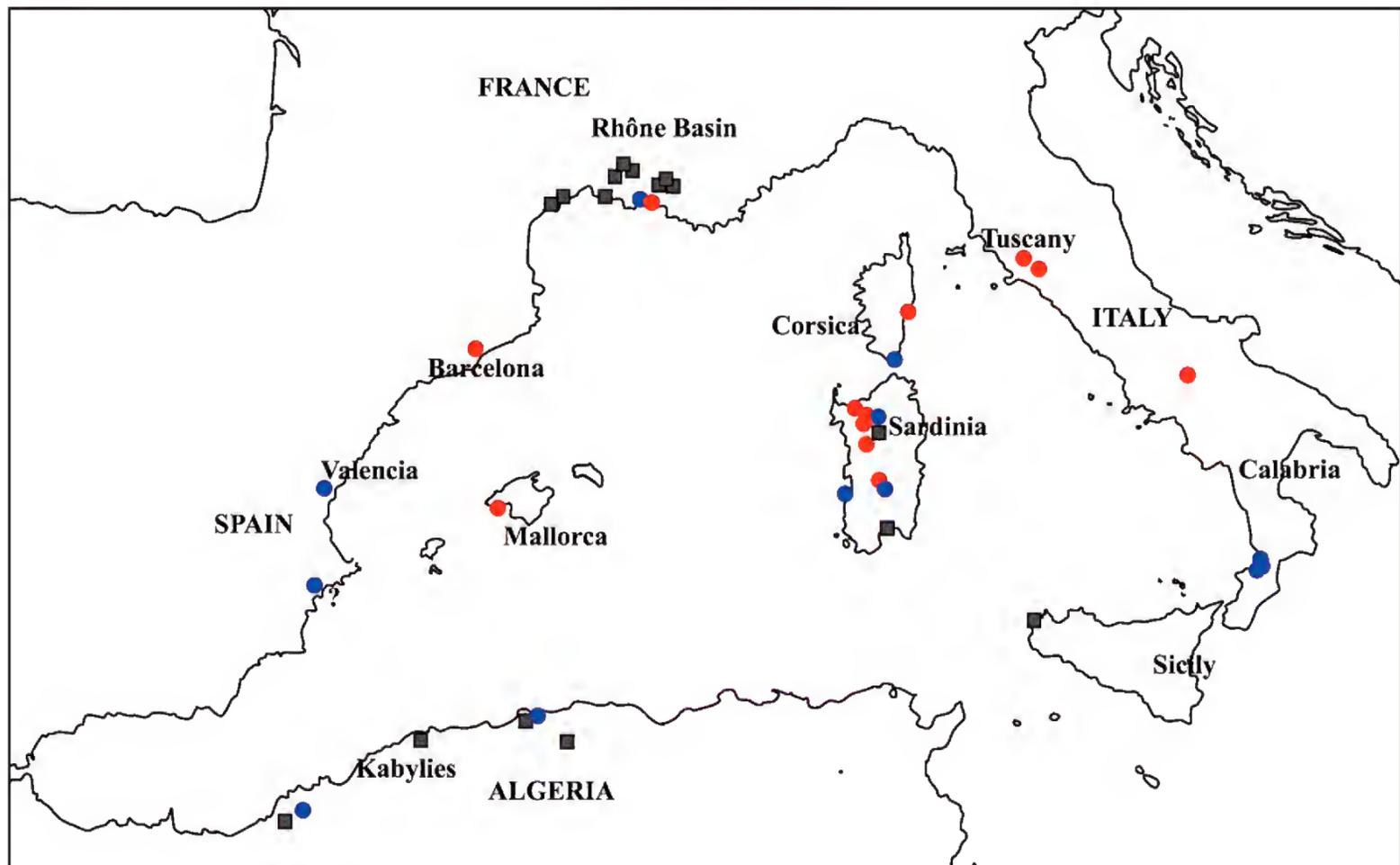


Figure 2. Distribution of two main morphotypes in the Western Mediterranean basin. Red dot = “*bioculata*” group; blue dot = “*nuragica*” group; square dot = insufficient data.

However the last two are border-line cases represented by single specimens; additionally the specimen from Corse is poorly preserved (*vide* Cottreau, 1914) and the drawing may be not reliable.

The shape index of lunules is not discriminant between the forms of the “*nuragica*” group, however comparison based on the values of L1 and L2 is more significant. In the large sample from Sardinia (Stara & Borghi, 2014) the range of L1 is 6-16.7 (6-11.2 in *A. nuragica*), that of L2 is 11-23.5 (14.1-23.5 in *A. nuragica*). The samples from Calabria and Valencia show much lower values of the lunule length (L1 ranges from 3.5 to a maximum of 6), L2 ranges from 11 to 18.

Based on these observations the sample from Calabria is characterized by:

1. the smallest petalodium so far known for the genus *Amphiope*; only some specimens from Valencia and *A. depressa* Pomel, 1887, from Algeria show similar values of PL (see Fig. 3)

2. lower values of L2, WI and above all L1 when compared to the species described from Sardinia by Stara & Borghi (2014): *Amphiope lovisatoi* and *A. nuragica* (Fig. 4). A larger sample

is needed to confirm the same results also for the examined specimens from Valencia.

## CONCLUSIONS

This preliminary study indicates clear morphological differences within the “*nuragica*” group, with respect to the size of the petalodium (PL) and of the lunules. In particular the samples from the late Miocene of Calabria (Southern Italy) and Valencia (Spain) show much smaller petalodium and smaller lunules when compared to the other known species belonging to this group.

It is presumable that in some nearshore areas of the Mediterranean (e.g. along the coasts of Calabria, Balearic, Kabilyes, Sardinia, Corsica), separated by deep water, different species of *Amphiope* developed independently, adapting to the environmental changes occurred through the Miocene, mainly climate, due also to the latitudinal migration of lands, and ecology.

On the other hand, during the Miocene *Amphiope* showed also structural modifications

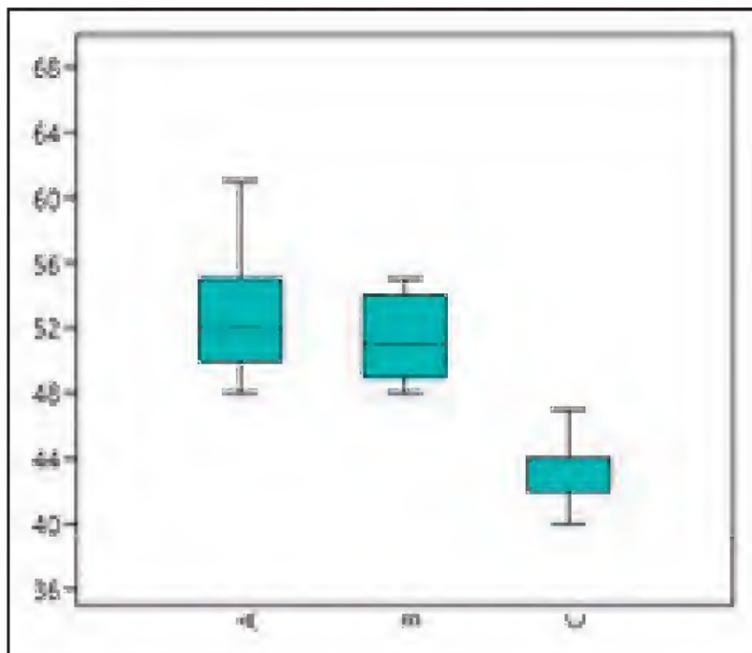


Figure 3. Petalodium comparison data on some species belonging to the “*nuragica*” group (PL in% TL). A = *A. lovisatoi*; B = *A. nuragica*; C = *Amphiope* sp. Calabria.

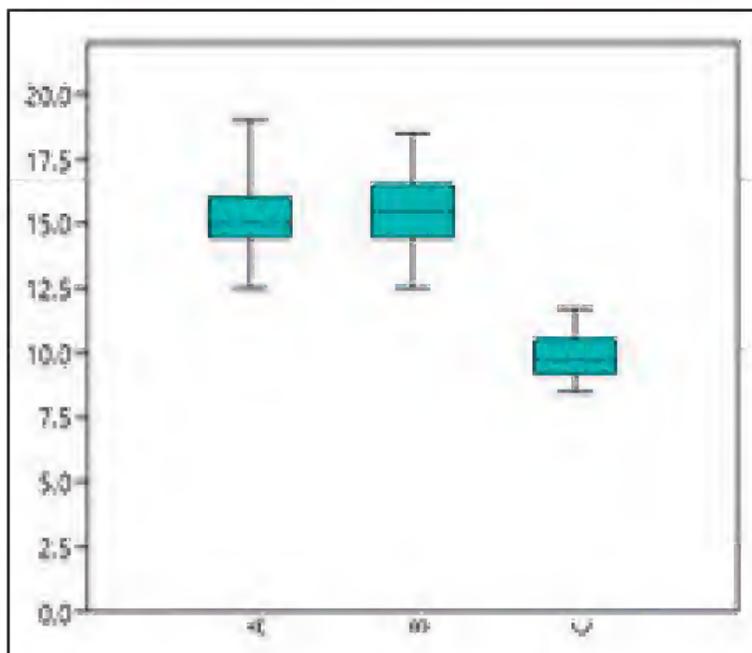


Figure 4. Size of lunules (WI) comparison on some species belonging to the “*nuragica*” group. A = *A. lovisatoi*; B = *A. nuragica*; C = *Amphiope* sp. Calabria.

common to almost all of the Mediterranean forms, such as the decreasing number of plates and a progressive lightening of the test-structure (Stara & Borghi, 2014; Stara & Sanciu, 2014).

Future studies focusing on paleoecology will be probably able to explain these dynamics and in particular why some populations underwent significant morphological modifications (e.g. the decreasing in the petalodium size seen in the samples from Calabria and Valencia).

The results of this study indicate the occurrence of different species in the “*nuragica*” group, that is *Amphiope* characterized by narrow and transversely elongate lunules. All these forms likely derived from a common ancestor living in the Archipelago formed during the Oligocene-Miocene boundary between the Provençal and the Sardinian-Corsica coasts.

A similar differentiation is expected to be also in the “*bioculata*” group and also this argument will be the object of future studies.

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## The genus *Ercella* Monterosato, 1894: new molecular evidence (Pulmonata Stylommatophora Helicidae)

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### ABSTRACT

In this paper we report on new molecular data (COI sequences) of different and representative populations of *Ercella mazzullii* (De Cristofori et Jan, 1832), *E. cephaloeditana* Giannuzzi-Savelli, Oliva et Sparacio, 2012 and *E. insolida* (Monterosato, 1892) (Pulmonata, Stylommatophora, Helicidae). Present results are compared with those from recent literature and the current knowledge on phylogenetic relationships among Helicidae pulmonate gastropods is reviewed. Obtained results suggest that: i) *Cornu* Born, 1778 and *Cantareus* Risso, 1826 are separate and well distinct from *Helix* Linnaeus, 1758; ii) *Ercella* Monterosato, 1894 is a valid and independent genus rather than a subgenus of *Cornu*; iii) *Cornu aspersum* (O.F. Müller, 1774) is a group of species (i.e. "aspersum" group) whose taxonomic status needs to be defined further studies; iv) *Cornu*, *Cantareus* and *Ercella* might belong to the same tribe that, still, remains to be defined.

### KEY WORDS

*Ercella*; Helicidae; mitochondrial markers; phylogenetic reconstruction.

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### INTRODUCTION

Colomba et al. (2011) reported on a multidisciplinary study based on genital morphology, DNA analysis, distribution, ecology and fossil records of *Cornu mazzullii* (De Cristofori et Jan, 1832), a species endemic to North-Western Sicily. Obtained results supported the hypothesis that *C. mazzullii* should be attributed to the genus *Ercella* Monterosato, 1894 and that this genus was probably structured in three discrete clades (i.e., the *mazzullii* group) recognized as species including: (i) the populations living in Monte Pellegrino (Palermo)

and nearby mountains, *E. mazzullii* s. str., (ii) the endemic population of Cefalù, La Rocca, *E. cephaloeditana* Giannuzzi-Savelli, Oliva et Sparacio, 2012, and (iii) the populations living in the mountains of Trapani surroundings, *E. insolida* (Monterosato, 1892).

Based on the phylogenetic reconstruction obtained by the multigenic analysis of nuclear (ITS2) and mitochondrial (16S rDNA, 12S rDNA) molecular markers, Colomba et al. (2011) strongly suggested that the genus *Ercella* should be kept distinct from the closely related genera *Cornu* Born, 1778 and *Cantareus* Risso, 1826. In the

same paper, this hypothesis was also corroborated by the analysis of several 16S rDNA partial sequences downloaded from GenBank for other genera representatives of Western Palaearctic Helicidae taxa; noteworthy, the phylogenetic tree topology clearly showed *Cornu* and *Cantareus* distinct from *Helix* Linnaeus, 1758 (see Colomba et al., 2011, fig. 42).

*Cornu* Born, 1778 (type species: *Cornu copiae* Born, 1778) was reintroduced as distinct genus by Waldén (1976) with *Cryptomphalus* De Charpentier, 1837 (type species: *Cryptomphalus aspersum* O.F. Müller, 1774) as junior synonym; it was sometimes considered as subgenus of *Helix* Linnaeus, 1758 (type species: *Helix pomatia* Linnaeus, 1758) and sometimes as a distinct genus. The description of *Cornu copiae* was based on a teratological specimen of "*Helix*" *aspersa*; due to different interpretations of the Article 1.3.2 of the Code, a request for conservation of the name *Cornu* is still pending a ruling of the International Commission on Zoological Nomenclature.

*Cantareus* Risso, 1826 (type species: *Cantareus apertus* Born, 1778) was sometimes considered as subgenus of *Helix* and sometimes as a distinct genus.

Schileyko (1978) was the first one who described the internal structure of male sexual organs of "*Helix*" *aspersa* characterized by a penial papilla and a prominent semicircular fold in the distal part of the penis (see also Nordsieck, 2013). Because of these anatomical differences, the Author attributed this species to the genus *Cryptomphalus*.

Giusti et al. (1995) showed a close similarity between genitalia of "*Helix*" *aperta* and "*Helix*" *aspersa* and, therefore, attributed these two species to the same genus, *Cantareus*, morphologically well distinct from *Helix*. Moreover, they reported that *Helix* has a real penial papilla inside the penis and, distally, an accessory penial papilla, whereas *Cantareus* shows a system of a real penial papilla, a false penial papilla and, distally, an "annular pad".

Neubert & Bank (2006) mainly confirmed these morphological differences and concluded in considering *Cornu* and *Cantareus* as related but distinct genera. One year later, similar observations were reported by Alonso & Ibáñez (2007).

At the same time, findings of scientific studies based on molecular data were in line with the taxo-

nomic frame showing *Helix* distinct from *Cantareus* and *Cornu*, the latter two considered the same genus (Manganelli et al., 2005; Koene & Schulenburg, 2005; Wade et al., 2006, 2007).

Nevertheless, despite all these anatomical and molecular evidence, recently Welter-Schultes et al. (2011) and Welter-Schultes & Audibert (2012) considered *Cornu* and *Cantareus* to belong to the genus *Helix*. Bank (2012) argued that such a systematic position is wrong, and, above all, it does not take into account a number of studies (cited above) suggesting a taxonomic choice closer to the real affinities among these taxa. Welter-Schultes et al. (2012), however, reaffirmed their beliefs and, besides, Welter-Schultes (2012) reported *Ercella* as synonym of *Helix*.

Nordsieck (2013), reviewing the papers, published in the last decades, dealing with anatomical and molecular data, concluded, in summary, that: "According to genital morphology and DNA analysis, "*Helix*" *aspersa* and relatives are not more related to *Helix* than *Eobania* and other genera of the *Helicinae* [...] These species must therefore be generically separated from *Helix*. The shell and the genital differences, especially those of the penis (Giusti et al. 1995, Neubert & Bank 2006, Colomba et al. 2011), are sufficient for the generic separation of *Cantareus* and *Cornu* (or *Cryptomphalus*, if the name *Cornu* is not valid because of Art. 1.3.2 ICZN, cf. Giusti et al. 1995: 491). *Ercella* is regarded as a subgenus of *Cornu* instead of a genus, because it is more closely related to *Cornu* than to *Cantareus*".

More recently, detailed molecular genetics studies (Korábek et al., 2014; 2015; Razkin et al., 2015) confirmed *Cornu* and *Cantareus* as two distinct genera forming a group with no sign of a close relationship with *Helix*. In addition, *Ercella* DNA sequences, when included in such analysis (see Korábek et al., 2015), confirmed this item, in line with Colomba et al. (2011).

At present there seems to be broad agreement in considering *Cornu* and *Cantareus* distinct genera, while on the position of *Ercella* opinions are still diverging. In order to be able to further test the "genus hypothesis" (*Ercella* as a distinct genus, Colomba et al., 2011) versus the "subgenus hypothesis" (*Ercella* as a *Cornu* subgenus, Nordsieck, 2013), we performed an additional molecular analysis to characterize and define even better, from a

molecular standpoint, the identity and reliability of *Erctella*.

In particular, phylogenetic relationships among taxa under study were analysed by comparing partial sequences of the gene encoding for the cytochrome oxidase subunit I (COI) - which is one of the most commonly used mitochondrial markers in molecular evolution and molecular phylogeny. Besides, to provide a little contribute in shedding some more light on Helicidae systematics, the analysis was extended to hundreds of specimens of the family Helicidae whose COI sequences were downloaded from GenBank database. A similar analysis was carried out including 16S rDNA partial sequences of the same taxa. Molecular analyses have been performed either with single (16S or COI) or combined (16S+COI) molecular datasets.

## MATERIAL AND METHODS

### *Specimens and Collection sites*

For each population, 2-5 sicilian *Erctella* specimens were analysed. Please note that each locality and/or collection site is named in the original language (Italian). Collected samples were identified and [labelled] as follows: *Erctella insolida* (from Trapani province: Custonaci, Trapani [CU], M.te Cofano, Trapani [COF]; San Vito lo Capo: cala Mancina, Trapani [SV]); *Erctella mazzullii* (from W-Palermo surroundings: M.te Pellegrino [MP]; Sferracavallo, Palermo [CMS]; Carini: M.te Columbrina, Palermo [COL]; Cinisi: M.te Pecoraro, Palermo [PEC]); *Erctella cephaloeditana* from Cefalù: la Rocca, Palermo [CM]; *Cornu aspersum* (= *H. aspersa*) [CA] from Cefalù, Palermo, Sicily; and *Cantareus apertus* [CAP] from Cefalù, Palermo, Sicily and Assoro, Enna, Sicily.

### *DNA extraction, amplification and sequencing*

Samples were stored separately at -20 °C in test tubes. Of each individual, a piece of foot tissue was used for total DNA extraction (by Wizard Genomic DNA Purification Kit, Promega). COI fragments (581-663 bp) were amplified using LCO\_1490 (5'-GGTCAACAAATCATAAAGATATTGG-3') and HCO\_2198 (5'-TAAACTTCAGGGTGACCAAATCA-3')

(Folmer et al., 1994). PCR cycles were as follows: 95°C for 5 min; 95°C for 1 min, 42°C for 1 min, 72°C for 1 min (35 cycles); 72°C for 5 min. To remove primers and unincorporated nucleotides, amplified products were purified with the Wizard SV gel and PCR Clean-up kit (Promega). Sequencing of purified PCR products was carried out using automated DNA sequencers at Eurofins MWG Operon (Germany). All COI sequences generated in this study were uploaded in GenBank (accession numbers: KR921883-KR921914).

### *Phylogenetic analyses*

The analysis was conducted on two partial gene sequences: COI and 16S rDNA, integrating our data with those obtained from GenBank database. In particular, in addition to the sequences obtained from specimens tested directly in this study (KR921883-KR921914), to further expand the analysis and refine its resolving power, we included 16S rDNA sequences of *Erctella mazzullii*, *E. insolida*, *E. cephaloeditana*, *Cornu aspersum* and *Cantareus apertus* previously generated by our research group (GQ402393-GQ402396, GQ402398-GQ402402, GQ402403-GQ402405, GQ402407-GQ402409, GQ402410-GQ402411, GQ402412-GQ402414, GQ402417-GQ402419, GQ402420-GQ402422, GQ402387-GQ402389, GQ402390-GQ402392, see Colomba et al., 2011), joined to both COI and 16S rDNA sequences downloaded from GenBank of the following taxa: *Eobania vermiculata* (O.F. Müller, 1774) (KJ458509, KJ458510, KJ458511, JF277395, JF277393, JF277391), *Theba geminata* Mousson, 1857 (KJ458559, HM034468), *T. subdentata* (Férussac, 1821) (KJ458562, HM034496), *T. pisana* (O.F. Müller, 1774) (KJ458561, JX911311), *T. andalusica* Gittenberger et Ripken, 1987 (KJ458558, KF582631), *Murella muralis* (O.F. Müller, 1774) (GU391399, JX827154), *Helix lucorum* Linnaeus, 1758 (AF126144, GU784803), *Helix pomatia* Linnaeus, 1758 (AF208297, JX911304), *Helix secernenda* Rossmässler 1847 (KP072386, KP072387, KP072388, KP072086, KP072087, KP072088), *Helix vladika* Kobelt, 1898 (KP072303, KF823104), *Helix melanostoma* Draparnaud 1801 (KJ458524, KP072107), *Iberus gualtierianus* (Linnaeus, 1758) (AY928605, AY928606, DQ822123, DQ822165, DQ822166, AY546285), *Hemicycla*

*bidentalis* (Lamarck, 1822) (KJ458528, HM147180), *Pseudotachea splendida* (Draparnaud, 1801) (KJ458552, AY546292), *Levantina caesareana* (Mousson, 1854) (KP072332, KP072181) *Otala lactea* (O.F. Müller, 1774) (AY937264, AY937263), *O. punctata* (O.F. Müller, 1774) (JF717823, JF717824, KJ458545, JF717805, JF717806, JF717807), *Helix aspersa* (AF126139, AF126135, AF126134, AF126140, AF126136, JN701926, JN701927, GU598217, AY546283, HQ203051, HQ203052, JX911287), *Cantareus apertus* (KJ458491, JX911286). Finally, *Limax maximus* Linnaeus, 1758 (Family Limacidae) (KF894386), *L. cinereoniger* Wolf, 1803 (KF894380), *Limacus flavus* (Linnaeus, 1758) (FJ896815), *Muticaria syracusana* (Philippi, 1836) (Family Clausiliidae) (HQ696868, AY425597) and *M. neuteboomi* Beckmann, 1990 (HQ696866, HQ696867) were employed as outgroups.

All sequences were visualized with BioEdit Sequence Alignment Editor 7 (Hall, 1999), aligned with the ClustalW option included in this software and refined by eye. As far as concerns single (COI or 16S rDNA) molecular data sets, phylogenetic analyses were conducted in MEGA 5 (Tamura et al., 2011) by Maximum Likelihood algorithm. Substitution models, selected according to the "Find Best DNA model" option included in the software, were: HKY+G (COI) and GTR+G (16S rDNA); support for the internodes was assessed by bootstrap percentages (BP) (1000 replicates). For the combined (COI+16S rDNA) datasets, phylogenetic analyses were conducted in BEAST 1.6.1 (Drummond & Rambaut, 2007) using the \*BEAST implementation (Heled & Drummond, 2010). A series of initial runs were performed to optimize priors and runtime parameter choice to obtain effective sampling sizes (ESS) above 500 for all estimated parameters. The best-fit evolution models of nucleotide substitution were: HKY+G (COI) and GTR+G (16S rDNA) with empirical base composition; the Yule Process tree prior for mitochondrial data with piecewise linear population size model was applied with a UPGMA-generated tree as starting point. Trees from all runs were combined to produce an ultrametric consensus tree using TreeAnnotator 1.6.1. The first  $10^3$  trees were discarded as burnin. Support for nodes was expressed as posterior probabilities.

## RESULTS AND DISCUSSION

COI and 16S rDNA consensus trees and the multi-genic (COI+16S rDNA) tree included 69 molecular sequences, each. Obtained results allowed to make a few observations of some interest. In particular, COI consensus tree (Fig. 1), showed three separate clusters for (A) *Erctella* (discussed in detail below), (B) *Cantareus apertus* and (C) *Cornu aspersum* clearly distinct. Similarly, (D) *Eobania vermiculata*, (E) *Levantina caesareana*, (F) *Helix* spp. (including several species), (G) *Otala* spp. (*O. punctata* and *O. lactea*), (H) *Murella muralis*, (I) *Hemicycla bidentalis*, *Pseudotachea splendida*, *Iberus gualtierianus* and (L) *Theba* spp. (*T. geminata*, *T. subdentata*, *T. pisana*, *T. andalusica*) are separated. With regard to *Erctella*, the three taxa are clearly distinct and separated as *E. insolida* (SV1-SV3, CU4-CU5, COF2-COF4, from Trapani province), *E. mazzullii* (CMS1-CMS5, COL1-COL3, PEC1-PEC3, MP1-MP3, comprising specimens sampled on M.te Pellegrino and the nearby mountains of surroundings of Palermo), and *E. cephalaeditanana* (CM1-CM4, from Cefalù, La Rocca).

The 16S rDNA consensus tree topology (Fig. 2) is similar to that shown in figure 1. In fact, also in this case, *Erctella* is clearly distinct and well structured in three taxa, *Erctella insolida*, *E. cephalaeditanana* and *E. mazzullii*. Once again, it is confirmed a distinction between the (closely related) genera *Erctella*, *Cornu* and *Cantareus*; based on 16S rDNA sequences analysis, *Erctella* appears closer to *Cornu*, while in the COI tree *Cornu* is closer to *Cantareus*.

Mean molecular distances among the three taxa of *Erctella* (assessed by the maximum composite likelihood method), range from nearly 6 to 10% (16S rDNA) and about 4 to 7.5% (COI). These values, despite the issues of using mean molecular distances (see Meier et al., 2008), nevertheless, compared with those reported for other species, including Pulmonata (e.g. Hebert et al., 2003a, 2003b; Steinke et al., 2005; Nekola et al., 2009) can, in our opinion, justify the separation of *Erctella* populations into three species.

Genetic distances between different species within various animal groups, especially invertebrates, are variable (see for example Meier et al., 2008 and references therein). This is because they



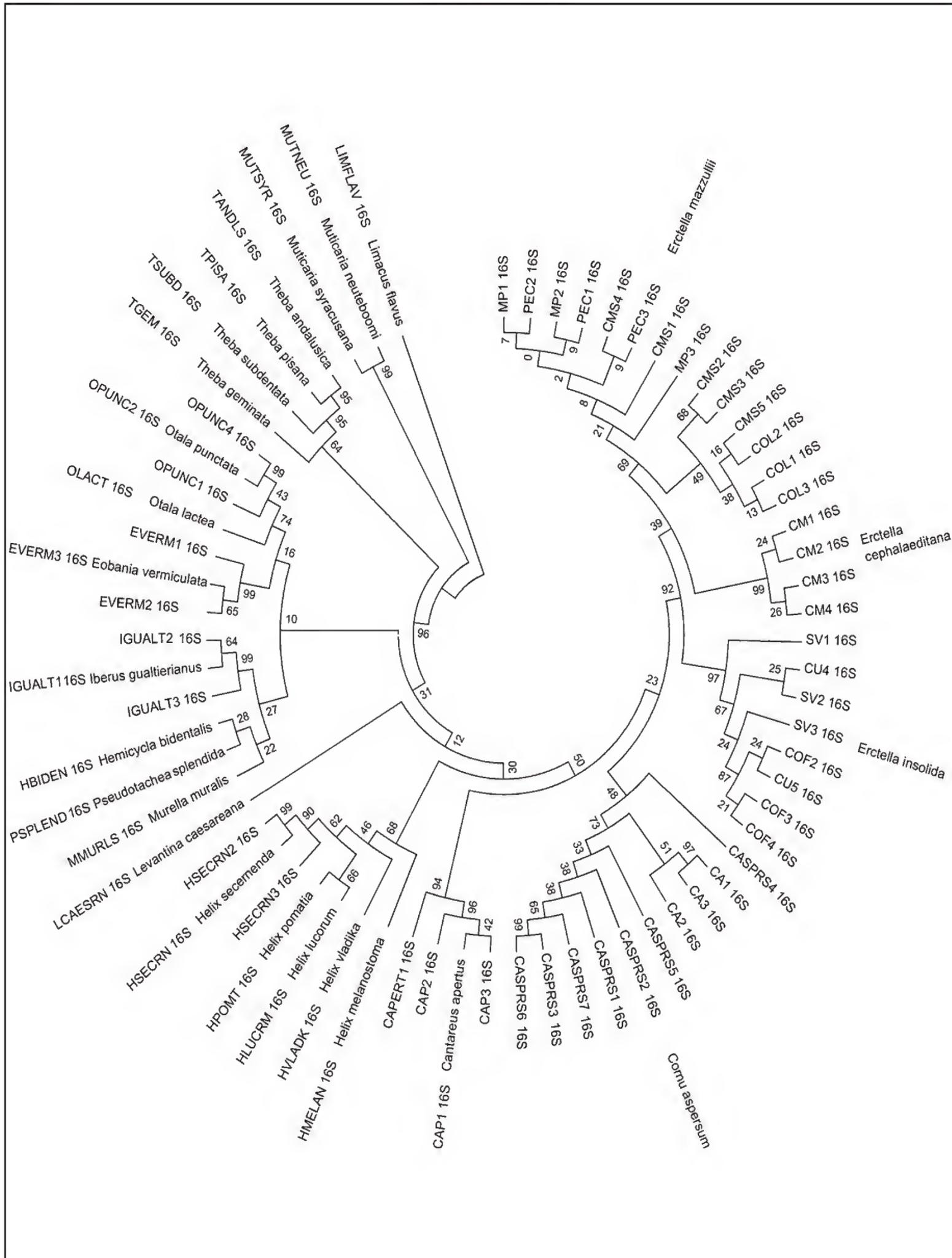


Figure 2. 16S rDNA consensus tree. The evolutionary history was inferred by using the Maximum Likelihood method based on GTR model. The percentage of replicate trees in which the associated taxa clustered together in the bootstrap test (1000 replicates) are shown next to the branches. A discrete Gamma distribution was used to model evolutionary rate differences among sites [5 categories (+G, parameter = 0.7920)].



Regarding relationships within the group *Cantareus-Ercella-Cornu* our data differ from Razkin et al. (2015). In fact, while for *Ercella* it is not possible to make a comparison because the Authors did not include this taxon in their analysis, on the other hand, in our tree, neither *Cornu* nor *Cantareus* can be considered Otalini, rather belonging to a distinct cluster (attributable to the "tribe" level) including *Ercella*.

Therefore, although *Cornu* and *Cantareus* show a certain degree of affinity particularly with *Eobania* for genitalia architecture (see Giusti et al., 1995) and share with Otalini similar biogeographic, ecological and evolutionary items typical of Western Mediterranean areas where these terrestrial molluscs differentiated (see Colomba et al., 2011), nevertheless, the consideration of *Cornu*, *Cantareus* and *Ercella* as a separate tribe, which still remains to be defined, is suggested. Furthermore, *Cornu*, *Cantareus* and *Ercella* share the same chromosome number ( $n = 27$ ) (Vitturi et al., 1982; Vitturi et al., 2005) (see Fig. 3), while *Eobania* and other Otalini examined up to now have  $n = 26$  (Burch, 1965; Thiriou-Quévieux, 2003). Finally, Otalini show in genital organs a relatively little dart sac and well-developed digit-like appendages, *Cornu-Cantareus-Ercella*, instead, show a massive dart sac and two groups of digitiform glands with short base and numerous and short digit-like appendages.

On the other hand, the separation between *Cornu-Cantareus-Ercella* and *Helix* is supported by: (i) the different geographical distribution of the genera: *Cornu* and *Cantareus* are widespread in North Africa and Southern Europe, with *Ercella* endemic to Northwestern Sicily, while *Helix* is mainly distributed in Central and Eastern Europe and, to a lesser extent, North Africa; (ii) the different morphology of genital organs (Schileyko, 1978; Giusti et al., 1995; Neubert & Bank, 2006; Alonso & Ibáñez, 2007) showing in *Cornu-Cantareus-Ercella* a different form of dart sac and of digitiform glands (see above); and (iii) molecular data (see Korábek et al., 2015 and quotes therein).

Comparing the three phylogenetic trees an interesting consideration about *Cornu aspersum* can be made. In fact, in line with other studies (Guiller et al., 2001; Guiller & Madec, 2010), in our study as well, this taxon seems to be not a single species but rather a species group (ie "*aspersum*" group)

showing a taxonomic situation more complex and heterogeneous than previously hypothesized within its area of origin and diversification (Southern Italy, Sicily and NW Africa). This result is further confirmed by personal unpublished morphological and molecular data of numerous Italian, Maltese and North African *C. aspersum* populations.

Finally, the position of *Murella muralis* remains to be clarified. In fact, it is not only different in all phylogenetic trees but, above all, discordant with what reported in other papers. This issue, which is beyond the aim of the present paper, requires further study and investigation, possibly increasing the number of specimens (joining to sequences downloaded from the database also sequences obtained from new samples collected directly in the field), increasing the number of genes analyzed and, above all, including in the analysis other taxa representatives of subfamilies more closely related to Murellinae, such as Ariantinae.

Overall, present results correspond well to several previous molecular studies carried out by nuclear and mitochondrial markers (Koene & Schulenburg, 2005; Colomba et al., 2011; Korábek et al., 2014; Razkin et al., 2015) and confirm that *Ercella* species lie always outside the clusters of *Cornu* and *Cantareus*.

## CONCLUSIONS

New molecular evidence provided in this study suggested also several comments on *Ercella* closely related genera. Hence, on this basis, despite the difficulties that the argument implies, some conclusions can be drawn.

The groups comprising *Cornu-Cantareus-Ercella* on one hand, and *Helix* on the other hand, appear separate and distinct from each other. In line with most of the papers reporting on anatomical and molecular characteristics observed in these animals, there seems to be no evidence that "*aperta*", "*aspersa*" and / or "*mazzullii*" may belong to the genus *Helix*.

Considering *Cornu* and *Cantareus* as Otalini, as assumed by Razkin et al. (2015) is not confirmed in our analysis. However, as mentioned above, the issue certainly needs further study in view of their aforementioned anatomical and biogeographical affinities.

We suggest considering *Cornu*, *Cantareus* and *Ercella* as related but distinct genera belonging to independent lineages; as hypothesized, they might be included into a new tribe (between Otalini and Helicini).

*Cornu aspersum* complex is in need of a thorough taxonomic revision in its area of origin.

Finally, it is appropriate to reiterate that our decision to consider *Ercella* a distinct genus including three different species (Colomba et al., 2011) was not only made on the basis of some, although important, molecular evidence, but also by the analysis of many other data that allowed us to assign to the various *Ercella* populations morphological, biological, paleontological and biogeographical peculiar characters, amplified by the particular distribution of the taxon, endemic to Northwestern Sicily. In this regard it is worth remembering that in the characterization of a taxon, at different levels, while gathering as many informations as possible (including morphological, ecological, molecular data, etc ...) is necessary, taxonomic reconstructions obtained with a methodology not always correspond to the ones obtained with another method (see Schileyko, 2013); for *Ercella*, instead, all (numerous) data are consistent with the hypothesis of differentiating it from other (similar, closely related) genera.

So that it seems appropriate to conclude with the words reported by A. Schmidt (1868) who claimed that, in taxonomy : “*Künstliche Systeme entstehen durch consequentes Geltendmachen eines einzelnen Principis*” [“the application of a single criterion produces artificial classifications”].

In more contemporary terms, we could say with Poins et al. (2014): “*Molecular phylogenetics is an irreplaceable tool for taxonomists, but interpretation of the results must be based on clear taxonomic concepts corroborated by all available resources - that is, the primary reference, the subsequent taxonomic literature and the type specimens of the organisms of interest. Otherwise, molecular phylogenetics can cause confusion with detrimental consequences to follow-up studies (e.g. ecological and evolutionary)*”.

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## Coen's Pyramidellidae (Gastropoda Heterobranchia): a revision of types

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### ABSTRACT

Coen introduced several new nominal taxa in the Pyramidellidae and in most Mollusca families. The Coen types, now at the Hebrew University of Jerusalem, have been examined; most of them are holotypes or lectotypes. Some lectotypes were already selected by van Aartsen, as stated in the label, therefore we have not done any further selection of types. The new pyramidellid species have been practically identified and named by Monterosato, and were all found in shell grit collected on the beach of Lido (a small island in front of Venice). None of the Coen's new species seems to be valid.

### KEY WORDS

Coen collection; Pyramidellidae; Adriatic Sea; Mediterranean Sea.

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### INTRODUCTION

Giorgio Silvio Coen (1873-1951) was born in Venice, graduated as a civil engineer in the prestigious University of Padua and spent his life in Venice. The malacology was for him a hobby, because his main work was as civil engineer. Anyway he had contacts with most of the eminent malacologists of the period, wrote several works and arranged a rich collection of molluscs. He was a victim of the anti-Semitic laws during fascist age and being banned from publishing in Italian magazines, during the years 1939–1944 he published on the *Acta Pontificia Academia Scientiarum*, Civitate Vaticana. After the II World War he returned in Venice, where he died. More informations on Coen's life are in Piani et al. (1990).

The first Coen's work is dated 1914, when he was about 40 years old, but his name was already present in the malacological world, because there was a *Turbonilla coeni* Preston, 1905 possibly (because the Author did not indicate the origin of the name) dedicated to him. When Coen was initiating his malacological activity, Tommaso di Maria (1841-1927), universally known as Monterosato, was one of the best known Italian malacologists and Coen used to send material to him for determination. Since the first publication, Coen uses names with indication "Monterosato ms", to indicate the name, normally specific, was assigned by Monterosato.

Really the aged Monterosato was quite a "splitter", with an attitude to create new species and varieties, at the same time it is surprising that all the

new Pyramidellidae names, based on Monterosato's determination are synonyms of well known species. We may suppose that the bad quality of Coen's specimens examined by Monterosato, as well as possible age-related problems of the Author are cause of this. The names dictated by the aged Monterosato, together with Coen's attitude, sometime referred as Bourguignat's "Nouvelle École", resulted in the creation of hundreds specific and varieties names. Possibly Coen, interested to civil architecture, was attracted by the details and loved to collect, and name, the various forms of shells.

In some cases Coen understands that even if Monterosato considered that shell as a variety, and assigned a variety name, the differences are so small that should not be the case. This is the case of *Pyrgulina brevicula* var. *rejecta* Monterosato ms. for which the Author states "*Forma poco diversa dalla tipica, così nominata perché trovata nel detrito* [Form slightly different from the typical, so named because found in shell grit]". In the case of *Turbonilla (Tragula) fenestrata* var. *turbifacta* Monterosato ms. the Author states "*Questa forma, dal Monterosato considerata come specie, turbifacta, mi par piuttosto varietà della fenestrata* [This form, considered by Monterosato a valid species, *turbifacta*, looks to me a variety of *fenestrata*]", practically he considers as a variety what Monterosato considered a separate species. A final consideration on the pyramidellid species: it is strange that notwithstanding the Coen's research in the northern Adriatic, and the obvious contacts with local fishermen, all the described species have been found in the shell grit from Venice-Lido. Possibly he was not much interested in micro molluscs and all the species have been found in a sample of shell grit given by to Monterosato.

Coen published more than sixty malacological works (Piani et al., 1990), the most extensive and interesting is the "Saggio di una Sylloge Molluscorum Adriaticorum" published on 1933, a commented list of north Adriatic molluscs, with description of several species and varieties. The work was enriched and published again on 1937, always as a "Memoria" of the "Real Comitato Talassografico Italiano" with the title "Nuovo Saggio di una Sylloge Molluscorum Adriaticorum".

The names created for varieties are to be considered subspecific, according to art. 45.6.4 of ICZN (4th. Edition).

Coen's collection was very rich, with material obtained by various malacologists (Mienis, 2012), because he established a Museum in Venice, which attracted the donations. Possibly due to the memory of the anti-Semitic persecution in Italy, Coen decided that after his death the collection had to be donated to the Hebrew University of Jerusalem, where it was shipped on 1953. Piani's opinion (Piani, 1983) about the presence of many Monterosato's types in Coen collection is disputed by Mienis (2012).

## MATERIAL AND METHODS

The Coen's collection is preserved at the Hebrew University of Jerusalem and has been loaned thanks to the courtesy of Dr. Henk K. Mienis, Hebrew University of Jerusalem. Most of the type specimens are worn and difficult to determine without a previous knowledge of the local forms and variability. Photos has been taken using a Digital SLR Canon EOS 400D.

Sometimes in the labels the term "co-typus" is abbreviated in "c-t". The term "co-typus" is used by Monterosato and Coen to indicate even the types, anyway it is no more accepted by ICZN.

## RESULTS

The species are listed in the same order of description, to be clear, in case of synonymy, which name has precedence. Plate IV, showing the pyramidellid is the same in both works (Coen, 1933, 1937), therefore the comments are the same. The locality "Lido" is the name of the long and narrow island in front of Venice, that is exposed to open sea and where is possible to collect fresh shell grit. For each bibliographic reference it is indicated the used name, because this is sometime different.

Quality of Coen's drawing is very bad, much worse than drawing of shells having some dimension, done a century before by other Authors (Philippi, Hoernes, Wood, Deahayes, etc.). All the drawings show a pointed apex, while some of the described species have a blunt apex!

In addition to the species dealt with in the present work, there is a *Pyrgulina praecisa* Coen, 1914 ex Monterosato ms, of which the Author gives

only a very bad photo at pl. IV, fig. 19. This name is not mentioned in the following works. According to art. 12.2.7 of ICZN, a species name based on an illustration of the taxon being named to be treated as not having been published, therefore this is a nomen nudum.

***Tiberia (Tiberiella) pretiosa* Coen, 1933**

ex Monterosato ms.

*Tiberia (Monterosato) pretiosa* Monterosato (sic) - Coen, 1933: 51 (n° 336), 164 (note 97), pl. IV, fig. 32

*Tiberia (Tiberiella) pretiosa* Monterosato - Coen, 1937: 38 (n° 261), 148 (note 92 bis), pl. IV, fig. 32

LABELS. • Coen's label with number 7301.

• Monterosato's handwritten label "*Tiberiella*, Mont. ms. *T. pretiosa*, Mont. Lido!!! ombelicata!"

• Monterosato's handwritten label "*Tiberia* Mont. Sezione di *Pyramidella*, pubblicata" [*Tiberia* Mont. Section of *Pyramidella*, published]

• Museum's label with register numbers "H U J 53798" and "Coen 7301".

REMARKS. Coen (1933, 164) describes the new species as: "*Vale la pena di richiamare l'attenzione su questa rarissima, minuta specie, di cui il mio esemplare fu determinato dall'Autore medesimo. La specie tipo di un sottogenere Tiberiella, non pubblicato, del Monterosato stesso, è ombelicata (fig. 32)*". [It is worthwhile to call the attention on this very rare, minute species, of which, my only specimen was determined by the Author himself. It is the type species of the subgenus *Tiberiella*, not published, of Monterosato's himself, and is umbilicated].

Really the species is listed as *Tiberia pretiosa* and the new genus *Tiberiella* is mentioned only in the note 97. This overlook will be rectified later on (Coen, 1937) and the species listed as *Tiberia (Tiberiella) pretiosa*. Author draws one specimen whose height, derived by the indicated scale factor is 2.5 mm. Note is unchanged in the second work (Coen, 1937). Therefore both the species and the genus were named by Monterosato, but published by Coen. The holotype is a worn specimen, 2.4 mm high (Fig. 1). The Coen's label indicates as locality

"Lido". The conical shape, and weak axial sculpture of the holotype suggest that could be *Parthenina monterosatii* (Clessin, 1900), that is not rare in the area. This specimen is the same mentioned by Aartsen et al. (1998: 7), who refers it to *Parthenina obtusa* (Brown, 1827).

Genus *Tiberiella* Coen, 1933 is considered by Aartsen et al. (1998: 7) and Schander et al. (1999: 151) a junior synonym of *Parthenina* Bucquoy, Dautzenberg et Dollfus, 1883, because both have as type species *Parthenina obtusa*. Based on our determination of holotype, the two genera do not have the same type species, but we agree that shall be considered synonyms.

The specific name *Tiberia (Tiberiella) pretiosa* Coen, 1933 ex Monterosato ms. shall be considered junior synonym of *Parthenina monterosatii* (Clessin, 1900).

***Odostomia litoris* Coen, 1933**

*Odostomia litoris* Coen - Coen, 1933: 52 (n° 345), 164 (note 98), pl. IV, fig. 33

*Odostomia litoris* Coen - Coen, 1937: 40 (n° 293), 149 (note 103), pl. IV, fig. 33

LABELS. • Coen's label "N° 7311 *Odostomia acuta veneta* typus (ms). Lido!"

• Monterosato's handwritten label "*Odostomia* gruppo dell'*acuta*"

• Museum's label with register numbers "H U J 20846" for lectotype and 53797 for paralectotype, both with "Coen 7311".

• A label stating that "lectotype chosen AARTSEN, 1982 - middle one with embryonic whorls preserved"

REMARKS. Coen (1933) describes the new species as: "*La nuova specie, da me trovata nel detrito di Lido, e sottoposta al Monterosato, fu da Lui riconosciuta come una nuova "Odostomia del gruppo dell'acuta (sic). Analoga a questa, ne differisce però per i giri piatti anziché convessi; per la sutura lineare fortemente impressa; infine per una carena, ottusa ma ben pronunziata, che appare sull'ultimo anfratto (fig. 33). Venezia-Lido*". [The new species, found by me in the shell grit from Lido, and submitted to Monterosato, was considered by him as a new "*Odostomia* of the *acuta*

group". It is similar to this, but differs for the flat instead of convex whorls; for the lineas suture strongly impressed; at last for a keel, obtuse but well pronounced, present on the last whorl (fig. 33). Venice-Lido].

Note is unchanged in the second work (Coen, 1937). Author draws one specimen whose height, derived by the indicated scale factor is about 2.9 mm. In this case the specific name was not assigned by Monterosato.

The lectotype is a worn specimen, 2.3 mm high (Fig. 6), fixed with the paralectotype on a black paper strip. The Coen's label indicates as locality "Lido". The specimen is *Odostomia unidentata* (Montagu, 1803), a species not rare in the area. *Odostomia acuta* Jeffreys, 1848 is normally umbellicated, has rounded, instead of angulated periphery, oblique instead of angulated columella, lower first teleoconch whorl and slightly rounded whorls.

### *Pyrgulina denticulus* Coen, 1933

ex Monterosato ms.

*Pyrgulina denticulus* Monts. - Coen, 1914: 12, pl. IV, fig. 17 nomen nudum

*Pyrgulina denticulus* Monterosato mss. - Coen, 1933: 52 (n° 355), 164 (note 99), pl. IV, fig. 34

*Chrysallida (Babella) denticulus* Monterosato-Coen, 1937: 38 (n° 274), 149 (note 99), pl. IV, fig. 34

LABELS. • Coen's label "N° 7318 *Chrysallida* (*Pyrgulina*) *denticulus* Monts. c. t. Venezia-Lido".

• Monterosato's handwritten label "*Pyrgulina denticulus* Mont. Lido!"

• Monterosato's handwritten label "La più comune tra le *Pyrgulina* del Lido" [The most common *Pyrgulina* at Lido].

• Museum's label with register numbers "H U J 53792" for lectotype and 53793 for paralectotype, both with "Coen 7318".

• A label stating that "lectotype selected by van Aartsen in glass vid"

REMARKS. Coen (1933, 164) describes the new species as: "*Assai simile ad una Turbonilla, è molto vicina alla P. interstincta Montagu per la forma*

*nettamente turriculato-conica, a profilo quasi rettilineo. Le pieghe oblique degli anfratti sono molto accentuate; ognuna di esse porta un tubercolo sotto la sutura ed è solcata alla base, onde la conchiglia ne appare clatrata, in senso inverso, subsuturalmente ed al posto della carena (fig. 34). Venezia-Lido". [Very similar to a *Turbonilla*, it is very close to *P. interstincta* Montagu for the turriculate-conical shape, with an almost straight profile. The oblique costae are very strong; each one has a tubercle below the suture and is sulcate at the base, **giving to the shell a clathrate appearance in reverse way, subsuturally and at the place of the keel (fig. 34). Venice-Lido**]. The bolded part of translation is doubtful because meaning of the sentence in original description is not clear.*

Note is unchanged in the second work (Coen, 1937). Author draws one specimen, whose height, derived by the indicated scale factor is about 3 mm.

The lectotype is a 3 mm high (Fig. 11), a little worn and is *Parthenina terebellum* (Philippi, 1844), a species very common in the shell grit of Venice area.

### *Pyrgulina alabastrum* Coen, 1933

ex Monterosato ms.

*Pyrgulina alabastrum* Monts. - Coen, 1914: 12, pl. IV, fig. 18 nomen nudum

*Pyrgulina alabastrum* Monterosato mss. - Coen, 1933: 52 (n° 358), 164 (note 99), pl. IV, fig. 36

*Chrysallida (Parthenina) alabastrum* Monterosato mss. - Coen, 1937: 38 (n° 275), 149 (note 96), pl. IV, fig. 36

LABELS. • Coen's label "N° 7320 *Chrysallida* (*Pyrgulina*) *alabastrum* Monts. c-t Venezia Lido".

• Monterosato's handwritten label "*Pyrgulina alabastrum* Monts. Lido!"

• Museum's label with register numbers "H U J 53786" for holotype, with "Coen 7320".

REMARKS. Coen (1933, 164) describes the new species as: "*Unico esemplare di una forma veramente turbonilloide. Conchiglia esilissima, turriculata, ottusa all'apice, composta di 6-7 giri pianeggianti, un poco allargata verso la base, ornata di pieghe longitudinali non oblique, solcate spiralmemente sotto la sutura, che è fortemente*

*impressa* (fig. 36). *Detrito di Lido*". [A single specimen of a maredly turbonilloid shape. Shell very thin, turriculate, blunt at the apex, consisting of 6-7 flat whorls, a little enlarged toward the base, sculptured by longitudinal ribs, not oblique, spirally furrowed below the suture, that is strongly impressed (fig. 36). Shell grit from Lido].

Note is unchanged in the second work (Coen, 1937). Author draws one specimen, whose height, derived by the indicated scale factor is about 2.8 mm.

The lectotype is a fresh specimen, 2.7 mm high (Fig. 17); the presence of two spiral cords on upper whorls and the lack of columellar plica, indicates that the specimen is a *Parthenina indistincta* (Montagu, 1808), a species quite frequent in the area, even at low depth.

***Pyrgulina ordita*** Coen, 1933 ex Monterosato ms.

*Pyrgulina ordita* Monterosato - Coen, 1933: 52 (n° 360), 165 (note 100), pl. IV, fig. 41

*Chrysallida (Trabecula) ordita* Monterosato - Coen, 1937: 38 (n° 280), 149 (note 102), pl. IV, fig. 41

LABELS. • Coen's label "N° 7321 *Chrysallida (Pyrgulina) ordita* Mont. Co-types Venezia Lido".

• Monterosato's handwritten label "*Pyrgulina ordita* Monts. Lido!!" and "una delle più meravigliose per la scultura"

• Museum's label with register numbers "H U J 53783" for holotype, with "Coen 7321" number.

REMARKS. Coen (1933: 165) describes the new species as: "*Conchiglia rissoiforme, tenuissima, jalina; ultimo giro grande; scultura consistente in strie longitudinali sottili, estese a tutta la superficie, anche basale; peristoma normale; fessura ombelicale apparente (fig. 41). Detrito di Lido*". [Shell rissoid-like, very thin, translucent; last whorl large; sculpture consisting of thin spiral striae, covering the whole surface, including the base; peristoma normal; false umbilical slit (fig. 41). Shell grit from Lido].

Note is unchanged in the second work (Coen, 1937). Author draws one specimen, whose height, derived by the indicated scale factor is about 1.6 mm.

The holotype is a broken specimen having the last three whorls, 1.6 mm high (Fig. 21). The flexuous and crowded axial ribs and the numerous spiral cords clearly indicates that the holotype is a *Parthenina juliae* (de Folin, 1872), a species common in the area at low depth.

***Pyrgulina coeni*** Coen, 1933 ex Monterosato ms.

*Pyrgulina coëni* Monts. - Coen, 1914: 12, pl. IV, fig. 21 nomen nudum

*Pyrgulina coëni* Monterosato mss. - Coen, 1933: 52 (n° 361), 164 (note 99), pl. IV, fig. 37

*Chrysallida (Partulida) coëni* Monterosato - Coen, 1937: 38 (n° 278), 149 (note 98), pl. IV, fig. 37

LABELS. • Coen's label "N° 7322 *Chrysallida (Pyrgulina) Coëni* Monts. types Venezia-Lido".

• Monterosato's handwritten label "*Pyrgulina Coeni*, Monts. ms. Lido!! Non esti (unclear) *P. turbonilloides*, Brusin, apice etc.!"

• Museum's label with register numbers "H U J 53787" for lectotype and 53788 for paralectotype, both with "Coen 7322".

• A label stating that "two species! Left one was selected by van Aartsen as the lectotype of *P. coeni*, right one is too badly preserved to allow identification"

REMARKS. In the first mention of the name (Coen, 1914: 12) add the note: "non = *turbonilloides* Brus.", meaning that it is similar, but different from *turbonilloides* (Brusina, 1869).

Coen (1933: 164) describes the new species as: "*Essa si differenzia dalle precedenti per essere ovoide, di habitus veramente rissoiforme, conservando però tutti i caratteri del gruppo. Le pieghe longitudinali, non oblique, né tubercolate, né solcate, cessano bruscamente nella regione caronale, così che la base dell'ultimo giro è perfettamente liscia e lucente. Bianco-lattea (fig. 37). Detrito di Lido*". [This species differs from the formers for the ovoid shape, of really rissoid-like habitus, maintaining anyway all the characters of the group. The longitudinal ribs, not oblique, neither tuberculate nor sulcate, abruptly ending at the periphery of last whorl, so the base of the last whorl is perfectly smooth and bright. Milky-white (fig. 37). Shell grit from Lido].



Figure 1. *Tiberia (Tiberiella) pretiosa* Coen's collection, holotype HUI 53798, H: 2.4 mm, Venice-Lido. Figs. 2-4. Original labels. Fig. 5. Museum's label. Fig. 6. *Parthenina monterosatii* (Clessin, 1900). Figs. 7, 8. *Odosstomia litoris* Coen's collection, lectotype and paralectotype, HUI 20846, H: 2.3 mm, Venice-Lido. Figs. 9-10. Original labels. Fig. 11. Museum's label. Fig. 12. *Odosstomia unidentata* (Montagu, 1803). Fig. 13. *Pyrgulina denticulus* Coen's collection, lectotype HUI 53792, H: 3 mm, Venice-Lido. Figs. 14, 15. Original labels. Fig. 16. Museum's label. Fig. 17. *Parthenina terebellum* (Philippi, 1844).



Figure 18. *Pyrgulina alabastrum* Coen's collection, lectotype, HUJ 53786, H: 2.7 mm, Venice-Lido. Figs. 19, 20. Original labels. Fig. 21. Museum's label. Fig. 22. *Parthenina indistincta* (Montagu, 1808). Fig. 23. *Pyrgulina ordita* Coen's collection, holotype, HUJ 53783, H: 1.6 mm, Venice-Lido. Figs. 24, 25. Original labels. Fig. 26. Museum's label. Fig. 27. *Parthenina juliae* (de Folin, 1872). Fig. 28. *Pyrgulina coeni* Coen's collection, lectotype, HUJ 53787, H: 1.9 mm, Venice-Lido. Figs. 29, 30. Original labels. Fig. 31. Museum's label. Fig. 32. *Partulida incerta* (Milaschewitsch, 1916)

Note is unchanged in the second work (Coen, 1937). Author draws one specimen, whose height, derived by the indicated scale factor is about 2 mm.

The lectotype is a worn specimen, 1.9 mm high (Fig. 25). Its shape leaves no doubt that it is a *Partulida incerta* (Milaschewitsch, 1916) of which are synonyms *P. turbonilloides* (Brusina, 1869) and *P. brusinai* (Cossmann, 1921). This species is frequent in the area, at low depth.

***Pyrgulina pyrgulella* Coen, 1933**

ex Monterosato ms.

*Pyrgulina pyrgulella* Monterosato - Coen, 1933: 52 (n° 363), 165 (note 101), pl. IV, fig. 42

*Chrysallida (Odostomella) pyrgulella* Monterosato mss. - Coen, 1937: 38 (n° 269), 148 (note 94), pl. IV, fig. 42

LABELS

• Coen's label "N° 7323 *Chrysallida (Pyrgulina) pyrgulella* Monts. (unclear) Venezia Lido".

• Monterosato's handwritten label "*Pyrgulina pyrgulella* Monts. Lido!!"

• Museum's label with register numbers "H U J 53791" for holotype with "Coen 7323".

REMARKS. Coen (1933: 164) describes the new species as: "*Conchiglia turricolata, ottusa alla sommità, composta di 6-7 giri, lisci gli apicali, gli altri solcati longitudinalmente, salvo una zona subsuturale di ogni giro e la base dell'ultimo, che rimangono lisce; columella obliquamente e fortemente ritorta; peristoma sinuoso alla base. Bianca (fig. 42). Detrito di Lido*". [Shell turriculate, blunt at the apex, consisting of 6-7 whorls, the apicals are smooth, the others longitudinally costate, except one subsutural zone of each whorl and the base of the last whorl, that are smooth; columella markedly and obliquely folded; peristome sinuose at the base. White (fig. 42). Shell grit from Lido].

Note is unchanged in the second work (Coen, 1937). Author draws one specimen, whose height, derived by the indicated scale factor is about 2 mm.

The holotype is 2.1 mm high (Fig. 30), worn and partially broken. The first teleoconch whorl appears smooth and this character suggests that specimen could be *Parthenina terebellum* (Philippi, 1844) (Clessin, 1900), a species quite frequent in the area, even at low depth.

***Pyrgulina vixstriata* Coen, 1933**

ex Monterosato ms.

*Pyrgulina vixstriata* Monterosato mss. - Coen, 1933: 52 (n° 364), 165 (note 99), tav. IV, fig. 38

*Chrysallida (Odostomella) vixstriata* Monterosato mss. - Coen, 1937: 38 (n° 267), 148 (note 93), tav. IV, fig. 38

LABELS

• Coen's label "N° 7324 *Chrysallida (Pyrgulina) vix striata* Monts. c-t Venezia Lido".

• Monterosato's handwritten label "*Pyrgulina vix-striata, Mont. buon tipo Lido!! N. B. la gomma non fa apparire le strie*" [*Pyrgulina vix-striata*, Mont. valid type Lido!! N. B. the glue prevents the observation of the striae].

• Museum's label with Lectotype register numbers "H U J 53781" and Paralectotype "H U J 53782", both with "Coen 7324".

• A label stating that: "*the single shell was selected as lectotype by van Aartsen, 25.8.1987*".

REMARKS. Coen (1933: 148) describes the new species as: "*Ha un habitus ovoide-rissoiforme; molto ottusa all'apice, consta di 4-5 giri convessi, ornati di pieghe longitudinali ondulate, che sono solcate trasversalmente sopra la sutura, ed evanescenti (non troncate) sulla base dell'ultimo giro. Bianca (fig. 38). Detrito di Lido*". [It has an ovoid, rissoid-like profile; very blunt at the apex, with 4-5 convex whorls, sculptured by longitudinal undulated ribs, that are transversally sulcate above the suture and evanescent (not truncated) at the base of the last whorl. White (fig. 38). Shell grit from Lido]

Note is unchanged in the second work (Coen, 1937). Author draws one specimen from Venice, whose height, derived by the indicated scale factor is 1.5 mm."

The lectotype is a specimen 1.3 mm high (Fig. 35). The flexuous and crowded axial ribs and the numerous spiral cords clearly indicates that both the specimens are *Parthenina juliae* (de Folin, 1872), a species common in the area at low depth.

It is interesting to note that the subgenus has been corrected in Coen's label to *Pyrgulina*, that is not the one used in the second publication. Unfortunately it is not possible to identify the erased word.

***Pyrgulina brevicula* var. *rejecta*** Coen, 1933  
ex Monterosato ms.

*Pyrgulina brevicula* var. *rejecta* Monterosato -  
Coen, 1933: 54 (n° 367), 165 (note 99), pl. IV,  
fig. 39

*Chrysallida (Partulida) brevicula rejecta* Monterosato  
mss. - Coen, 1937: 38 (n° 279), 149 (note 98),  
pl. IV, fig. 39

LABELS. • Coen's label "N° 7326 *Chrysallida*  
(*Pyrgulina*) *turbonilloides rejecta* Monterosato c-t  
Venezia Lido!".

• Monterosato's handwritten label "Pyrgulina  
*rejecta*, Monts. Lido!! Gruppo della turbonilloides"

• Museum's label with register numbers "H U J  
53779" for lectotype and 53780 for paralectotype,  
both with "Coen 7326".

• A label stating that "Specimen to the extreme  
right was selected as the lectotype by van Aartsen  
25.8.1987".

REMARKS. Coen (1933: 164) describes the new  
species as: "*Forma poco diversa dalla tipica, così*  
*nominata perchè trovata nel detrito: carattere, il*  
*solco spirale alla base delle pieghe longitudinali,*  
*molto profondamente impresso. Bianca (fig. 39).*  
*Detrito di Lido*". [Shape a little different from the  
typical, so called because found in the shell grit:  
characterised by very deeply impressed spiral  
groove at the base of longitudinal ribs. White (fig.  
39). Shell grit from Lido].

Note is unchanged in the second work (Coen,  
1937). Author draws one specimen, whose height,  
derived by the indicated scale factor is about 1.6 mm.

The lectotype is a worn specimen, 1.8 mm high  
(Fig. 41). Its shape leaves no doubt that it is a  
*Partulida incerta* (Milaschewitsch, 1916) of which  
are synonyms *turbonilloides* (Brusina, 1869) and  
*brusinae* (Cossmann, 1921). This species is frequent  
in the area, at low depth.

The lectotype has been selected by Aartsen (see  
above its label) from a set of four specimens fixed  
on a black paper strip (Fig. 42). The specimen at  
extreme left of the strip seems to be a *Parthenina*  
*indistincta* (Montagu, 1808).

It is surprising to note that both Monterosato's  
and Coen's label correctly refer the variety  
"*rejecta*" to *turbonilloides*, while in both publica-  
tions Coen uses a different specific name.

The real identity of *Chrysallida brevicula*  
(Jeffreys, 1883), originally described as *Odostomia*  
*brevicula*, has been clarified by Giannuzzi Savelli  
et al. (2011), who studied the type material with the  
result that the species was based on an immature  
specimen of *Turbonilla amoena* (Monterosato,  
1878).

***Pyrgulina cylindracea*** Coen, 1933  
ex Monterosato ms.

*Pyrgulina cylindracea* Monterosato mss. - Coen,  
1933: 54 (n° 368), 165 (note 102), pl. IV, fig. 43

*Chrysallida (Odostomella) cylindracea* Monterosato  
mss. - Coen, 1937: 38 (n° 271), 149 (note 101),  
pl. IV, fig. 43

LABELS. • Coen's label "N° 7327 *Chrysallida*  
(*Pyrgulina*) *cylindracea* Monts. c-t Venezia-Lido!".

• Monterosato's handwritten label "*Pyrgulina*  
*cylindracea* Monts. Lido!!"

• Museum's label with register numbers "H U J  
53784" for lectotype and 53785 for paralectotype,  
both with "Coen 7327".

REMARKS. Coen (1933: 165) describes the new  
species as: "*Conchiglia turricolata, melaniiforme,*  
*vitrea, con 5-6 giri poco, ma regolarmente,*  
*convessi, dei quali i primi sono globulosi e lisci, gli*  
*altri debolmente solcati. Base liscia. Apertura alla*  
*base acutamente svasata, come in una Melania (fig.*  
*43). Detrito di Lido*". [Shell turriculate, melania-  
like, vitreous, with 5-6 whorls, slightly and regu-  
larly convex, the formers are globose and smooth,  
the latter weakly sulcate. Base smooth. Aperture  
acutely expanded at the base, like in a *Melania* (fig.  
43). Shell grit from Lido].

Note is unchanged in the second work (Coen,  
1937). Author draws one specimen, whose height,  
derived by the indicated scale factor is about 1.8 mm.

The lectotype is a worn and partially broken  
specimen, 1.9 mm high (Fig. 48) and seems to be  
*Parthenina terebellum* (Philippi, 1844), a species  
very common in the shell grit of Venice area. The  
figured specimen is fixed to a black paper strip (Fig.  
49) with the final portion (about 2.5 whorls) of a  
much larger specimen that seems to belong to same  
species.



Figure 33. *Pyrgulina pyrgulella* Coen's collection, holotype, HUI 53791, H: 2.1 mm, Venice-Lido. Figures 34, 35. Original labels. Fig. 36. Museum's label. Fig. 37. *Parthenina terebellum* (Philippi, 1844). Fig. 38. *Pyrgulina vixstriata* Coen's collection, lectotype, HUI 53781, H: 1.3 mm, Venice-Lido. Fig. 39. *P. vixstriata*, paralectotype HUI 53782, H: 1.5 mm, Venice-Lido. Figures 40, 41. Original labels. Fig. 42. Museum's label. Fig. 43. *Parthenina juliae* (de Folin, 1872).



Figures 44, 45. *Pyrgulina brevicula* var. *rejecta* Coen's collection, lectotype, HUI 53779, H: 1.8 mm, Venice-Lido and paralectotypes HUI 53780, the specimen applied on paper strip at extreme left is a *Parthenina indistincta* (Montagu, 1808). Figs. 46, 47. Original labels. Fig. 48. Museum's label. Fig. 49. *Partulida incerta* (Milaschewitsch, 1916). Figs. 50, 51. *Pyrgulina cylindracea* Coen's collection, lectotype, HUI 53784, H: 1.9 mm, Venice-Lido and paralectotype HUI 53785. Figs. 52, 53. Original labels. Fig. 54. Museum's labels. Fig. 55. *Parthenina terebellum* (Philippi, 1844).

***Pyrgulina canaliculata*** Coen, 1933 ex Monterosato ms.

*Pyrgulina canaliculata* Monterosato ms. - Coen, 1933: 54 (n° 369), 165 (note 99), pl. IV, fig. 40  
*Chrysallida (Parthenina) canaliculata* Monterosato mss. - Coen, 1937: 38 (n° 276), 149 (note 97), pl. IV, fig. 40

LABELS. • Coen's label "N° 7328 *Chrysallida (Pyrgulina) canaliculata* co-types. Venezia Lido".

• Monterosato's handwritten label "*Pyrgulina canaliculata* Monts. Lido!!"

• Museum's label with register numbers "H U J 53794" for holotype, with "Coen 7328".

REMARKS. Coen (1933: 165) describes the new species as: "*Conchiglia turriculato-metaforme, con giri piani, di cui i primi lisci, gli altri con pieghe longitudinali profonde, tagliate sopra la sutura da un solco trasversale, e sull'ultimo giro clatrate fino alla metà; base liscia, apertura normale. Il nome viene dalla sutura, profondamente impressa. Bianca (fig. 40). Detrito di Lido*". [Shell turriculate, whorls flat, the former smooth, the following with deep longitudinal ribs, crossed above the suture by a spiral groove and, on the last whorl, clathrate up to the middle; base smooth, aperture normal. The name derives from the deeply impressed suture. White (fig. 40). Shell grit from Lido].

Note is unchanged in the second work (Coen, 1937). Author draws one specimen, whose height, derived by the indicated scale factor is about 1.9 mm.

The holotype is a worn specimen, 1.8 mm high (Fig. 51). The presence of two spiral cords on upper whorls and the lack of columellar plica, indicates that the specimen is a *Parthenina indistincta* (Montagu, 1808), a species quite frequent in the area, even at low depth.

***Pyrgulina mitis*** Coen, 1933 ex Monterosato ms.

*Pyrgulina mitis* Monterosato ms. - Coen, 1933: 54 (n° 370), 165 (note 103), pl. IV, fig. 44

*Chrysallida (Odostomella) mitis* Monterosato mss. - Coen, 1937: 38 (n° 270), 149 (note 100), pl. IV, fig. 44

LABELS. • Coen's label "N° 7329 *Chrysallida (Pyrgulina) mitis* Mont. c-t Venezia-Lido".

• Monterosato's handwritten label "*Pyrgulina mitis* Monts. Lido!!"

• Museum's label with register numbers "H U J 53789" for lectotype and 53790 for paralectotype, both with "Coen 7329".

• A label stating that "*most right hand specimen selected as lectotype by van Aartsen 25.08.1989*"

REMARKS. Coen (1933: 165) describes the new species as: "*Conchiglia turriculata, ad apice ottuso, giri piani, lisci i primi, gli altri con forti solchi per lungo, cessanti alla metà dell'ultimo giro ed ivi clatrate; sutura profondissima; apertura allungata, svasata acutamente alla base; la columella porta una piega dentiforme mediana molto pronunziata ed una profonda fessura ombilicale lungo la callosità columellare. Bianca (fig. 44)*". [Shell turriculate, apex blunt, whorls flat, the initials are smooth, the following with strong ribs, ending at the middle of the last whorl, where are clathrate; Suture very deep; aperture elongate, acutely expanded at the base; on the central part of the columella there is a strong tooth-like fold and a deep umbilical chink along the columellar callus. White (fig. 44).].

Note is unchanged in the second work (Coen, 1937). Author draws one specimen, whose height, derived by the indicated scale factor is about 1.8 mm.

The lectotype is 1.8 mm high (Fig. 57); it is *Parthenina terebellum* (Philippi, 1844), a species very common in the shell grit of Venice area. The figured lectotype (the one selected by van Aartsen) is fixed to a black paper strip (Fig. 58) with other three specimens.

***Eulimella curtata*** Coen, 1933 ex Monterosato ms.

*Eulimella curtata* Monterosato ms. - Coen, 1933: 54 (n° 375), 165 (note 104), pl. IV, fig. 45

*Eulimella curtata* Monterosato mss. - Coen, 1937: 40 (n° 300), 149 (note 104), pl. IV, fig. 45

LABELS. • Coen's label "N° 7331 *Eulimella curtata* Monts. c-t Venezia Lido".

• Monterosato's handwritten labels "*Eulimella commutata = acicula* Lido!!" and "*non è commutata ma curtata a Lido anche la non commutata*".



Figure 56. *Pyrgulina canaliculata* Coen's collection, holotype, HUI 52794, H: 1.8 mm, Venice-Lido. Figures 57, 58. Original labels. Fig. 59. Museum's label. Fig. 60. *Parthenina indistincta* (Montagu, 1808). Figs. 61, 62. *Pyrgulina mitis* Coen's collection, lectotype, HUI 53789, H: 1.8 mm, Venice-Lido and paralectotypes HUI 53790. Figs. 63, 64. Original labels. Fig. 65. Museum's label. Fig. 66. *Parthenina terebellum* (Philippi, 1844).



Figure 67. *Eulimella curtata* Coen's collection, holotype, HUI 20847, H: 2.7 mm, Venice-Lido. Figs. 68, 69. Original labels. Fig. 70. Museum's label. Fig. 71. *Eulimella flagellum* Coen's collection, holotype, HUI 20848, H: 2.7 mm, Venice-Lido Figs. 72, 73. Original labels. Fig. 74. Museum's label. Fig. 75. *Eulimella acicula* (Philippi, 1836).

Meaning of the second label not clear, therefore not translated.

• Museum's label with register numbers "HUI 20847" for holotype, with "Coen 7331".

REMARKS. Coen (1933: 165) describes the new species as: "Poco lontana dalla *E. acicula* Philippi, se ne distingue per l'habitus più metaforme ed ottuso all'apice, per i giri più convessi, e soprattutto

per l'apertura che, anziché allungata e regolarmente curva alla base, vi è abbreviata e di forma trapezoidale. Jalina (fig. 45). Detrito di Lido". [Not far from *E. acicula* Philippi, may be separated for the profile more regular and blunt at the apex, the more convex whorls, and mainly for the aperture, which instead of elongate and regularly curved at the base, is abbreviated and trapezoidal. Jaline (fig. 45). Shell grit of Lido].

Note is unchanged in the second work (Coen, 1937). Author draws one specimen, whose height, derived by the indicated scale factor is about 2.3 mm.

The holotype is a little worn specimen, 2.7 mm high (Fig. 63), the protoconch is coiled at right angle with respect to teleoconch axis, the profile is slightly cyrtocoid, whorls are flat, suture inclined and columellar plica is very weak or absent. The holotype seems to be *Eulimella acicula* (Philippi, 1836).

***Eulimella flagellum*** Coen, 1933  
ex Monterosato ms.

*Eulimella flagellum* Monterosato ms. - Coen, 1933:  
54 (n° 377), 165 (note 105), pl. IV, fig. 46

*Eulimella flagellum* Monterosato ms. - Coen, 1937:  
40 (n° 301), 149 (note 105), pl. IV, fig. 46

LABELS. • Coen's label "N° 7333 *Eulimella flagellum* Monts. co-typus (ms). Venezia Lido!".

• Monterosato's handwritten label "*Eulimella flagellum* Monts. oppure: ... .. (Unclear)! Lido "

• Museum's label with register numbers "H U J 20848" for holotype, with "Coen 7333".

REMARKS. Coen (1933: 165) describes the new species as: "*Forma stretta, allungatissima, con 10 giri piatti lisci lucenti, sutura profonda, apertura piriforme stretta ed allungata (fig. 46). Detrito di Lido*". [Shell narrow, very elongate, with 10 flat, smooth and bright whorls, deep suture, aperture pyriform, narrow and elongate (fig. 46). Shell grit from Lido].

Note is unchanged in the second work (Coen, 1937). Author draw one specimen, whose height, derived by the indicated scale factor is about 2.4 mm.

The holotype is 2.7 mm high (Fig. 67), the protoconch is coiled at right angle with respect to teleoconch axis, the profile is slightly cyrtocoid, whorls are flat, suture inclined and columellar plica is very weak or absent. The holotype could be a freak of *Eulimella acicula* (Philippi, 1836), or an *Eulimella clavatula* Sacco, 1892, a pliocenic species (see Chirli & Micali, 2011). The presence of a fossil specimen in the shell grit collected on the beach of the Lido is however unlikely.

## ACKNOWLEDGEMENTS

We thank Dr. Henk K. Mienis, Tel Aviv University, Department of Zoology, Israel, manager of mollusk collection for the loan of Coen's material.

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## Additional notes on the systematics and new records of East Atlantic species of the genus *Sorgenfreispira* Moroni, 1979 (Gastropoda Mangeliidae)

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### ABSTRACT

The Recent species currently ascribed to the *Bela brachystoma*-complex, Gastropoda Mangeliidae, (i.e.: *Bela brachystoma* (Philippi, 1844); *Bela africana* Ardovini, 2004; *Bela ardovinii* Mariottini et Oliverio, 2008; *Bela exilis* (Ardovini, 2004) should better be allocated in the genus *Sorgenfreispira* Moroni, 1979. Based on numerous samples, the distribution of the Recent species is summarised. *Sorgenfreispira brachystoma* (Philippi, 1844) comb. nov. ranges from Scandinavia to southern Morocco. *Sorgenfreispira africana* (Ardovini, 2004) comb. nov. is first recorded from Western Sahara, Ivory Coast, Angola and Ghana; *Sorgenfreispira ardovinii* (Mariottini et Oliverio, 2008) comb. nov. is first recorded from Ivory Coast; *S. exilis* (Ardovini, 2004) comb. nov. is first recorded from Mauritania, Western Sahara, Ivory Coast, Angola. Based on the study of the type material, *Bela brachystoma apicalis* Nordsieck, 1977, was actually based on specimens of *B. taprurensis* Pallary, 1904. *Bela taprurensis* is here first recorded from Libya.

### KEY WORDS

Gastropoda; Mangeliidae; *Bela*; *Sorgenfreispira*; Recent; first records; new combinations.

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### INTRODUCTION

After the revision by Mariottini et al. (2008, 2009), four morphologically similar Recent species are included in the *Bela brachystoma*-complex: *Bela brachystoma* (Philippi, 1844), originally described from the Mediterranean Sea, and three eastern Atlantic species, namely *B. africana* Ardovini, 2004, *B. ardovinii* Mariottini et Oliverio, 2008 and *B. exilis* Ardovini, 2004, all described, and so far known only from the type locality in Senegal. The species of this complex have been so far conservatively included in the genus *Bela* Gray, 1847, despite their very

peculiar sculpture of both protoconch and teleoconch as compared to the other species traditionally ascribed to *Bela* [e.g. *Bela zonata* (Locard, 1892) or *B. menkhorsti* van Aartsen, 1988; see Scarponi et al., 2014]. However, they certainly belong to a morphologically very homogeneous group, to which also several fossil species belong. Among them the Miocene *Cythara (Mangelia) moronii* Venzo et Pelosio, 1964, is the type species of the genus *Sorgenfreispira* Moroni, 1979, which was proposed to allocate those fossils, and is very similar to *B. exilis*. Therefore, we propose hereby to include *Pleurotoma brachystomum* Philippi, 1844 and the three eastern

Atlantic species of the complex in *Sorgenfreispira*. We have examined numerous samples of this complex from the East Atlantic, mostly at the Muséum National d'Histoire Naturelle (Paris, France), and summarized the known geographic ranges of each species, with new records for most species. For detailed morphological comparisons among the species see Mariottini et al. (2008).

ABBREVIATIONS AND ACRONYMS. CS-PM: Carlo Smriglio and Paolo Mariottini collection (Rome, Italy); lv: live collected specimen(s); MCZR: Museo Civico di Zoologia di Roma (Rome, Italy); MMP: Museo Malacologico Piceno (Cupra Marittima, Italy); MNHN: Muséum National d'Histoire Naturelle (Paris, France); MO: Marco Oliverio collection (Rome, Italy); RA: Roberto Ardovini collection (Rome, Italy); SEM: Scanning Electron Microscopy (SEM); sh: empty shell(s); SMF: Senckenberg Museum (Frankfurt, Germany); sta: station.

## SYSTEMATICS

### *Sorgenfreispira* Moroni, 1979: 2

Type species: *Cythara (Mangelia) moronii* Venzo et Pelosio, 1964, by original designation

DESCRIPTION. Shell very small for the genus, height 3.4–3.8 mm, width 1.5–1.6 mm, biconical, turriculate elongate, solid. Protoconch multispiral, dome shaped, of 2.6–2.7 convex whorls. Protoconch-I (embryonic shell) of 0.4 whorls, separated by a demarcation from protoconch-II (larval shell). First 1.7–1.8 apical whorls apparently smooth, the nucleus with very fine striae, the remaining with reticulated sculpture of 5–6 granulose spirals (3 major, 1–2 smaller subsutural, 1 smaller suprasutural), crossed by oblique axial riblets. Maximum diameter of protoconch 760–780  $\mu\text{m}$ . Protoconch-teleoconch transition not well marked. Teleoconch of 2.5–3 whorls, rounded, sutural ramp convex, whorl sides gently convex. Last whorl about 3/5 of shell length. Axial sculpture of 8–9 prominent, narrowly rounded axial ribs fading out at the base, regularly spaced, with equally sized interspaces. Spiral sculpture of 17–18 granulose cords, regularly spaces, with larger interspaces. Smaller granulose cordlets in most interspaces. Entire surface covered by microgranules. Aperture narrow, ovate, about 2/5 of the shell height.

Siphonal canal short, broad and open, very slightly deviating on the left. Inner lip with a weak parietal callus. Outer lip not varicose. Anal sinus marked, arcuate on shoulder slope. Colour yellowish with white axial ribs, darker brown band in the middle of teleoconch whorl, base milk white, parietal callus brown.

REMARKS. Moroni (1979) introduced this genus level taxon for a species of the Italian Miocene, comprising also a group of species of the Jutland Miocene, that Sorgenfrei (1958) had ascribed to the genus *Neoguraleus* Powell, 1939 (type species *Drillia sinclairi* Gillies, 882, Recent, New Zealand): *Pleurotoma tenella* Mayer, 1858, *Daphnella calais* Kautsky, 1925, and *Mangelia gürichi* Kautsky, 1925. Although the actual systematics of the three latter species may be debated, *Sorgenfreispira moronii* is undoubtedly related to *B. exilis*. Therefore, we propose hereby the transfer of *B. brachystoma*, *B. africana*, *B. ardovinii* and *B. exilis* to the genus *Sorgenfreispira* (for the distribution of this species see Fig. 1).

*Sorgenfreispira africana* (Ardovini, 2004) comb. nov. (Figs. 1, 2–5)

*Bela brachystoma africana* Ardovini, 2004: 7, Fig. unnumbered.

Type locality. South of Dakar, Senegal. Type Material. Holotype (MMP) and 1 paratype (RA).

EXAMINED MATERIAL. Western Sahara: sta. 12385-3, 22°33.9'N 16°54'E, 54-58 m 8 sh (MNHN); sta. 12[3]88-3, 22°30.5'N 16°53.8'E, 56-57 m 3 sh (MNHN); sta. 12381-1, 22°32.2'N 17°04'E, 58 m 42 sh (MNHN).

Mauritania. R/V N'Diogo sta. 204, 17°30'N 16°24'W, 88 m 1 sh (MNHN); sta. 218, 17°36'N 16°26'W, 99 m 2 sh (MNHN); sta. 244, 17°54'N 16°32'W, 200 m 1 sh (MNHN); sta. 245, 17°54'N 16°29'W, 145 m 1 sh (MNHN); sta. 289, 18°54'N 16°32'W, 60 m 1 sh (MNHN); 365, 19°30'N 16°55'W, 78 m 1 sh (MNHN); Miss. P. Etienne 1965 sta. 19, 20°20'N 16°22'W, 10 m 5 sh (MNHN).

Senegal. Region of Dakar: Gorée, 95 m 4 sh (MNHN), 95-110 m 1 sh (MNHN), 100 m 9 sh (MNHN); 14°51'N 17°30'W, 180–165 m 2 sh (MNHN); 14°32'N 17°25'W, 50 m 11 sh (MNHN); off Saloum, 50 m 9 sh (MNHN); 30 miles South of Dakar, Senegal, 45 m, 12 lv in the gut content of *Astropecten* cfr. *auranciacus* (CS-PM coll).

Ivory Coast. unknown locality, plateau continental [no further data], 107 sh (MNHN).

Ghana. R/V Calypso1953 sta. 25, 4°36.5'N 1°31'W, 4 sh (MNHN).

Angola. Corimba, Luanda, 10-20 m, 3 sh (MNHN).

DISTRIBUTION. Western Sahara, Mauritania, Senegal, Ivory Coast, Ghana, Angola (Fig. 1).

REMARKS. The valid introduction of this taxon is by Ardovini (2004), although subsequently (Ardovini, 2008) its author redescribed it as a new species, having realised that it was worth of species rank. *Sorgenfreispira africana* is not uncommon in East Africa, and it is here first recorded from Western Sahara, Mauritania, Ivory Coast, Ghana and Angola.

*Sorgenfreispira ardovinii* (Mariottini et Oliverio, 2008) comb. nov. (Figs. 1, 6–9)

*Bela ardovinii* Mariottini et Oliverio, 2008: 8, Figs. 97–99, 102, 119–126, 149–150, 166

Type locality. South of Dakar, Senegal. Type material.

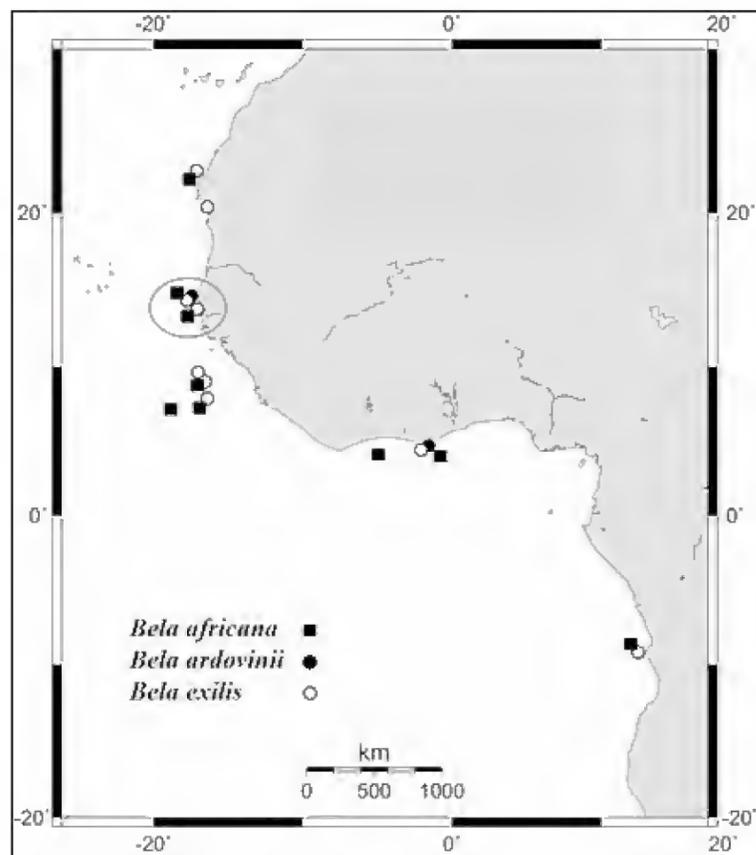


Figure 1. Map of the records of *Sorgenfreispira africana*, *S. ardovinii* and *S. exilis*. The area of their type locality and of records in Mariottini et al. (2008), off Senegal, is enclosed in the grey circle.

Holotype (MNHN 21321) and paratype K (MNHN 21322); paratypes A–F (RA); paratypes G–J, L (CS–PM); paratypes M–N (MO).

EXAMINED MATERIAL. The type material, all from 30 miles South of Dakar, -45 m: Ivory Coast: unknown locality, plateau continental [no further data], 8 sh (MNHN).

DESCRIPTION. Shell very small for the genus, height 3.7 mm, width 1.4 mm, biconical, turriculate elongate, solid. Protoconch multispiral, dome shaped, of 3.2–3.3 convex whorls. Protoconch-I (embryonic shell) of 0.8 whorls, separated by a demarcation from protoconch-II (larval shell). First 1.0–1.1 apical whorls densely covered by microgranules, next 0.7–0.8 whorl apparently smooth, the remaining with reticulated sculpture of 5 spiral series of tubercles (3 major, 1 smaller subsutural, 1 smaller suprasutural), crossed by weak opisthocline axial riblets, more evident subsuturally. Spiral cords corresponding to each spiral series of tubercles gradually appearing on the last protoconch whorl. Maximum diameter of protoconch 690–710  $\mu$ m. Protoconch-teleoconch transition not well marked. Teleoconch of 2.5–2.7 whorls, rounded, sutural ramp convex, whorl sides very gently convex. Last whorl about 3/5 of shell length. Axial sculpture of 8–10 rounded axial ribs fading at base, regularly spaced, with narrower interspaces. Spiral sculpture of one major granulose cord, and 20–28 granulose cordlets, irregularly spaced. Smaller granulose threads in most interspaces. Entire surface covered by microgranules. Aperture narrow, ovate, about 2/5 of shell height. Siphonal canal short, broad and open, slightly deviating to the left. Inner lip with a weak parietal callus. Outer lip not varicose. Anal sinus marked, arcuate on shoulder slope. Colour uniformly reddish-brown.

DISTRIBUTION. Senegal, Ivory Coast (Fig. 1).

REMARKS. *Sorgenfreispira ardovinii* remains the least common among the species of this complex. The 8 shells from Ivory Coast represent a remarkable range extension for the species, which was found there syntopic with *S. exilis* and *S. africana*.

*Sorgenfreispira exilis* (Ardovini, 2004) comb. nov. (Figs. 1, 10–13)

*Bela exilis* Ardovini, 2004: 8, Figs. unnumbered

Type locality. South of Dakar, Senegal. Type material. Holotype (MMP); paratypes 1–3 (RA).

EXAMINED MATERIAL. Western Sahara: sta. 12[3]88-3, 22°30.5'N 16°53.8'E, 56–57 m 1 sh (MNHN); sta. 12381-1, 22°32.2'N 17°04'E, 58 m 2 sh (MNHN).

Mauritania. R/V N'Diago sta. 229, 17°42'N 16°131'W, 40 m 1 sh (MNHN); sta. 309, 19°06'N 16°31'W, 24 m 1 sh (MNHN).

Senegal. Region of Dakar: 30 miles South of Dakar, 45 m, (in the gut content of *Astropecten* cfr. *auranciacus*) 18 lv; Goreé, 95 m 9 sh (MNHN); off Saloum, 50 m 5 sh (MNHN).

Ivory Coast. Unknown locality, plateau continental [no further data], 38 sh (MNHN).

Angola. Corimba, Luanda, 10–20 m 15 sh (MNHN).

DESCRIPTION. Shell very small for the genus, height 3.4–3.6 mm, width 1.3–1.5 mm, biconical, turriculate elongate, solid. Protoconch multispiral, dome shaped, of 2.8–2.9 convex whorls. Protoconch-I (embryonic shell) of 0.7–0.8 whorls, separated by a demarcation from protoconch-II (larval shell). First 1.6–1.7 apical whorls apparently smooth, covered with microgranules, the remaining with reticulated sculpture of 4 granulose spirals (3 major, 1 smaller subsutural), crossed by oblique axial riblets. Maximum diameter of protoconch 710–720  $\mu$ m. Protoconch-teleoconch transition not well marked. Teleoconch of 2.5–3 whorls, rounded, sutural ramp convex, whorl sides gently convex. Last whorl about 3/5 of shell length. Axial sculpture of 10–11 prominent, flexuous and narrowly rounded axial ribs, regularly spaced, with broader interspaces. Spiral sculpture of 2 major granulose cords, with 25–36 irregularly alternating smaller granulose cordlets and interspaces of variable size. Each cordlet actually consisting of a rows of densely packed rounded granules. Aperture narrow, ovate, about 2/5 of the shell height. Siphonal canal moderately long, broad and open, deviating on the left. Inner lip with a moderately developed parietal callus. Outer lip not varicose. Anal sinus marked, arcuate on shoulder slope. Colour yellowish-brownish with two dark brown bands, one subsutural and the second on the middle of the last whorl; parietal callus brownish with siphonal canal white.

DISTRIBUTION. Western Sahara, Mauritania, Senegal, Ivory Coast, Angola (Fig. 1).

REMARKS. Present records represent a remarkable range extension for the species, which was so far known only from the type locality (Senegal). It is here first recorded for Western Sahara, Mauritania, Ivory Coast and Angola.

*Sorgenfreispira brachystoma* (Philippi, 1844) comb. nov. (Figs. 14–17)

*Pleurotoma brachystomum* Philippi, 1844: 169, 176, pl. XXVI, Fig. 10

Type locality. *P. brachystomum*, Naples, Central Tyrrhenian Sea, Italy. Type material. Type material of *Pleurotoma brachystomum* is probably housed in the National Museum of Natural History (Santiago del Chile).

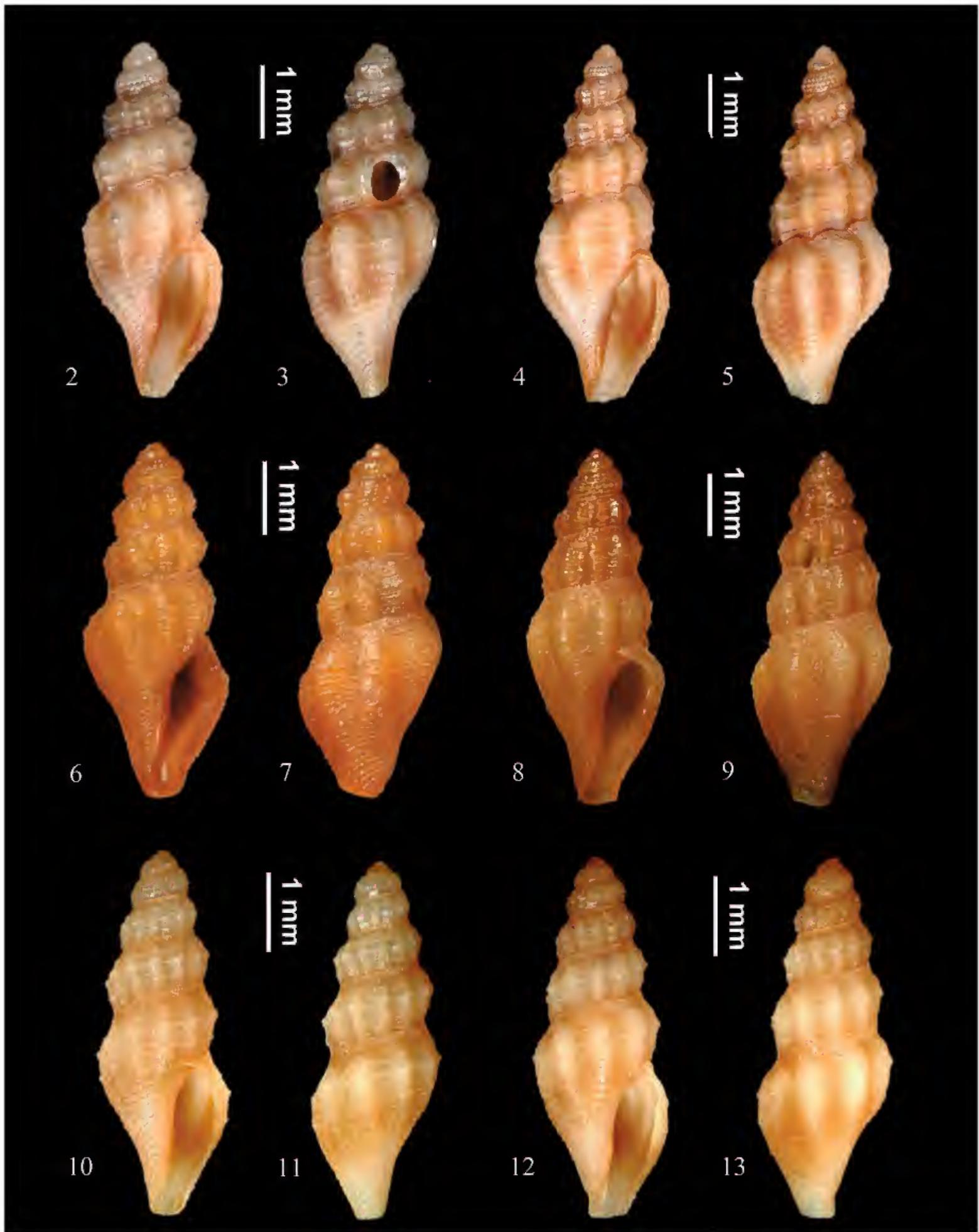
EXAMINED MATERIAL. Recent. [Atlantic] France: Gulf of Gascogne, CAPBRETON 88 sta. DE-01, 43°39.99'N 1°48.11'W, -134 m, 25 sh (MNHN); idem, sta. DR-29, 43°46.51'N 2°00.58'W, -165 m, 3 sh (MNHN); idem, DR-11, 43°22.77'N 1°59.18'W, -94 m, 16 sh (MNHN); idem, sta. DE-05, 43°57.42'N 2°05.16'W, -164 m, 8 sh (MNHN); Arcachon, [no further data], 3 sh (MNHN), 9 sh (Locard coll., MNHN); Brest, [no further data] 5 sh (Locard coll., MNHN); Capbreton, [no further data], 3 sh (Locard coll., MNHN).

Morocco. Agadir, R/V Vanneau 1923–1929 sta. 10, 29°54'N 9°58'W, -110 m, 16 sh (MNHN); idem, sta. 32, 34°01'N 7°32'W, -145 m, 3 sh (MNHN); idem, sta. 101, 30°39'N 10°03'W, 129 m, 3 sh (MNHN); sta. 39, 33°44'N 7°45'W, -85 m 1 sh (MNHN); idem, sta. 9, 30°05'N 09°50'W, -110 m 2 sh (MNHN); idem, sta. 30, 33°55'N 7°34'W, -75 m 17 sh (MNHN); Tangier, 5–10 m, 1 sh (MNHN). Mauritanie - R/V N.Diago sta. 239, 17°48'N 16°21'W, -79 m, 1 lv (MNHN); Mission Gruvel 25.03.08 sac 406, 13 sh (MNHN).

Sweden. [no further data], 1 sh (coll. Jousseume, MNHN).

England. [no further data], 3 sh (coll. Jousseume, MNHN).

[Mediterranean] France. Gulf of Lion, IFREMER/DEPRO 96 (R/V Europe) sta. chalut-10, 42°24.6'N 3°16.2'E, -100/151 m, 40 sh (MNHN); idem, sta. chalut-11, 42°09.4'N 3°22.5'E, -350 m, 5 sh (MNHN). Cap Béar, ECOMARGE 1984 sta. A61, 42°29.30'N 3°10.30'E, -42 m, 5 sh (MNHN); off Rhône delta, -50/100 m, 2 sh (MNHN). St Raphael,



Figures 2, 3. *Sorgenfreispira africana*. 6 x 1.7 mm, Corimba, Luanda, Angola, West Africa, 10-20 m (MNHN). Figures 4, 5. *S. africana*. 5.7 x 1.9 mm, Corimba, Luanda, Angola, West Africa, 10-20 m (MNHN). Figures 6, 7. *S. ardovinii*. 4.6 x 1.7 mm, Corimba, Luanda, Angola, West Africa, 20 m (MNHN). Figures 8, 9. *S. ardovinii*. 5.5 x 1.6 mm, Corimba, Luanda, Angola, West Africa, 20 m (MNHN). Figures 10, 11. *S. exilis*. 4.4 x 1.3 mm, Corimba, Luanda, Angola, West Africa, 10-20 m (MNHN). Figures 12, 13. *S. exilis*. 4.5 x 1.4 mm, Corimba, Luanda, Angola, West Africa, 10-20 m (MNHN).

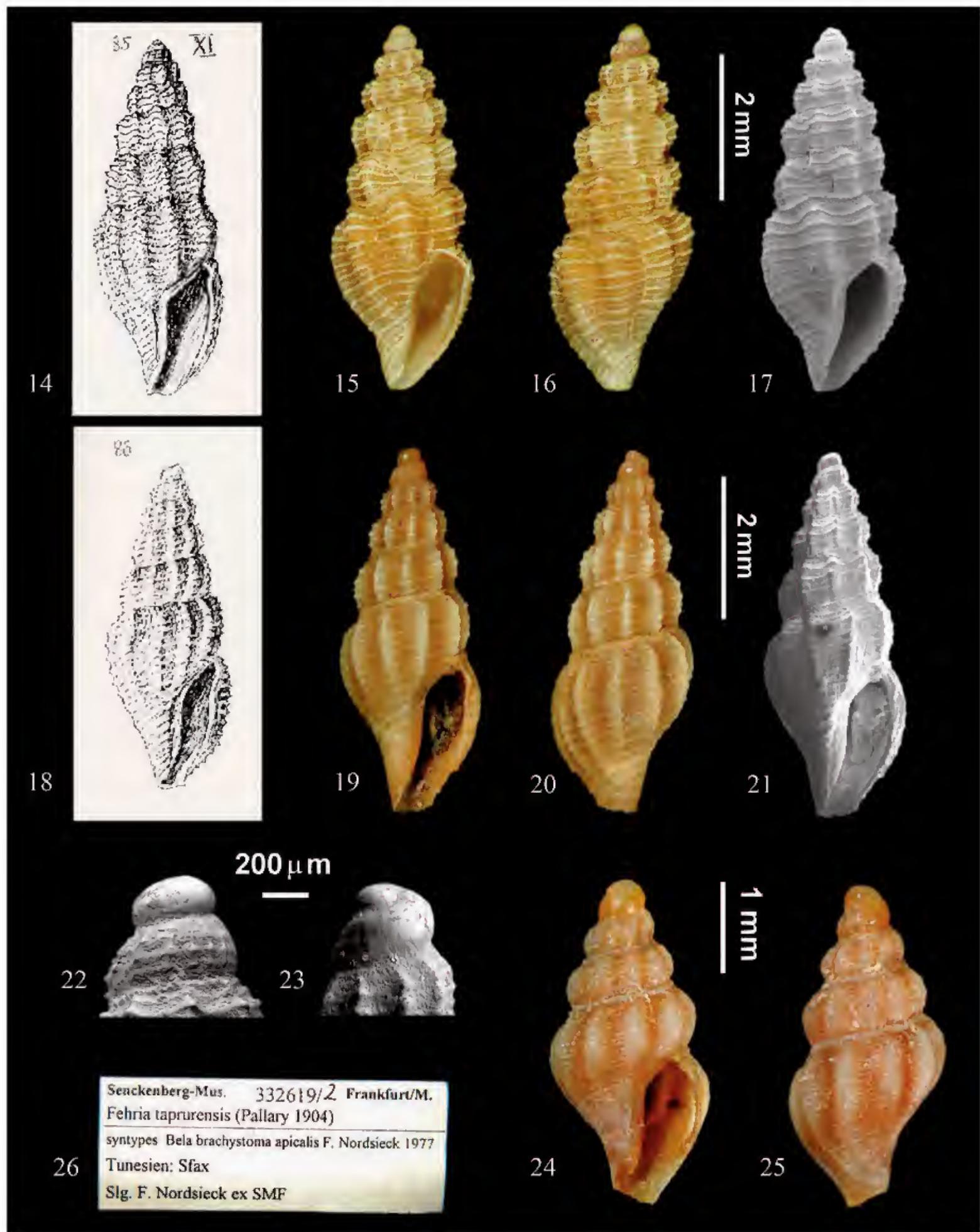


Figure 14. Drawing of “*Bela brachystoma brachystoma*” by Nordsieck (1977: pl. XI, fig. 85). Figs. 15–17. *Sorgenfreispira brachystoma*. 5.2 x 1.8 mm, San Vincenzo, Leghorn, Italy, 43°05'N 10°24'E, 34 m (CS-PM) (Fig. 17 SEM photograph). Fig. 18. Drawing of *B. brachystoma apicalis* by Nordsieck (1977: pl. XI, fig. 86). Figs. 19–21. *B. brachystoma apicalis*. Syntype A, SMF33269/2. 5.2 x 1.9 mm, Sfax, Tunisia, 34°47'N 10°53'E, 15 m (SMF) (Fig. 21 SEM photograph). Figs. 22, 23. Details of the protoconch of Syntype A, SMF33269/2, SEM photographs. Figs. 24, 25. *B. brachystoma apicalis*. Syntype B, SMF33269/2. 5.2 x 1.9 mm, Sfax, Tunisia, 34°47'N 10°53'E, 15 m (SMF). Fig. 26. SMF label of *B. brachystoma apicalis* syntypes.



Figures 27, 28. *Ginannia taprurensis*. Lectotype (MNHN-IM-2000-32699), 7.3 mm, Sfax, Tunisia (MNHN). Figures 29, 30. *G. taprurensis*. 6.6 x 2.2 mm, Sfax, Tunisia (MCZR). Figures 31, 32. *G. taprurensis*. 6.6 x 2.3 mm, Sfax, Tunisia (MCZR). Figures 33, 34. *G. taprurensis*. 6.1 x 2.3 mm, Al Khums, Libya, 15 m (CS-PM).

[no further data], 3 sh (Couturier coll., MNHN), 4 sh (Locard coll., MNHN). Marseille, [no further data], 5 sh (Locard coll., MNHN).

Spain. Estepona, 36°25'N 5°09'W, -150 m, 2 sh (SR); Baleares, [no further data], 1 sh (MNHN); Alboran, BALGIM sta. 143, 35°57'N 3°07'W, -252 m 1 sh (MNHN); Malaga, beach nourishment [from -20/40 m] 1 sh (MNHN).

Italy. Off San Vincenzo, 43°05'N 10°24'E, -34 m, 78 sh (CS-PM); off S. Marinella, -150/200 m, sediment in an old Roman dolium, 41°54.00'N, 011°47.66'E, 1 sh (MO); off Fiumicino, 41°43'N 12°06'W, -80 m, 38 sh (CS-PM); off Fiumicino, 41°38'N 12°11'W, -140 m, 27 sh (CS-PM); off Fiumicino, [no further data] (in the gut content of *Astropecten irregularis*), 16 juveniles (MO); 5 nm South of Fiumicino, -25 m (in mud), 2 lv (MO); Tor Paterno shoal, -150 m, 5 lv, 1sh (MO); Ponza Is., 40°51'N 12°55'W, -40 m, 24 sh (CS-PM); off Civitanova Marche, 43°18'N 13°46'E, -45 m, 11 sh (CS-PM); off Pescara, 42°31'N 14°12'E, -50 m, 24

sh (CS-PM); Sicily, [no further data], 2 sh (coll. Letellier, MNHN).

Croatia. Brac Island, 43°24'N 16°30'E, -50 m, 5 sh (CS-PM).

Libya. Unknown locality, -110/150 m, 19 sh (CS-PM).

Fossil. Italy: Guidonia, 42°00'N 12°43'E (Pliocene), 2 sh (CS-PM); Gallina, 38°05'N 15°41'E (Pliocene), 3 sh (CS-PM); Ficarazzi, 38°04'N 13°29'E (Upper Pliocene-Lower Pleistocene), 125 sh labelled "*P. granuliferum* var. *parva*" (coll. Monterosato, ex coll. Brugnone, MCZR); Monte Pellegrino, 38°04'N 13°29'E (Upper Pliocene-Lower Pleistocene), 48 sh labelled "*var. striiselevatoribus*" (coll. Monterosato, ex coll. Brugnone, MCZR).

DESCRIPTION. Shell small for the genus, height 4.5–7 mm, width 1.7–2.5 mm, biconical, turreted elongate, solid. Protoconch multispiral, dome shaped, of 2.3–2.4 convex whorls. First 1.6–1.9 apical whorls smooth, the remaining with reticu-

lated sculpture of 4-5 granulose spirals (3 major spirals in the middle of whorl, 1 smaller subsutural and 1 smaller above the teleoconch suture) crossed by oblique axial riblets. Maximum diameter of protoconch 510-650  $\mu\text{m}$ . Protoconch-teleoconch transition not well marked. Teleoconch of 5-6 whorls, rounded, sutural ramp straight or very slightly convex, whorl sides gently convex. Last whorl about 2/5 of shell length. Axial sculpture of 8-9 prominent, slightly opisthocline, flexuous and narrowly rounded axial ribs, regularly spaced, with broader interspaces. Spiral sculpture of 9-15 major cordlets, with irregularly alternating smaller cordlets and interspaces of variable size. Each cordlet consists of a rows of densely packed rounded granules. Aperture narrow, ovate, about 1/3 of the shell height. Siphonal canal short, narrow and open, deviating on the left. Inner lip with a moderately developed parietal callus. Outer lip varicose. Anal sinus marked, arcuate on shoulder slope. Animal with short head and two short tentacles. Black eyes on the external, thickened basal part of the tentacles, located on the distal third of their total height. Foot broad and long, slightly lobate anteriorly, tapering posteriorly. Background colour of the head-foot pinkish, semi-transparent, with light yellow spots, and light yellow speckles on the proximal part of the tentacles. Siphon pinkish, semi-transparent, with light yellow spots bordered by orange.

**DISTRIBUTION.** *Sorgenfreispira brachystoma* is known from the northeastern Atlantic and from the entire Mediterranean Sea. Based on literature data and on the material we have examined, it ranges from Norway (Høisæter, 2009), Sweden (Dyntaxa, 2013), United Kingdom and British Isles (Hayward & Ryland, 1990), to southern Morocco (Lat 34° N), and the entire Mediterranean Sea. Fossil shells are known from several Plio-Pleistocene European outcrops (England, France, Spain, Italy: see Chirli & Richard, 2008).

**REMARKS.** *Sorgenfreispira brachystoma* is a continental shelf species, easily distinguishable from all other members of the group by its very distinct shell sculpture (Mariottini et al., 2008). It has a multispiral protoconch with characteristic densely granulated spiral ribs. *Bela brachystoma apicalis* Nordsieck, 1977 is a synonym of *B. taprurensis* (Pallary, 1904) (see below).

***Bela* Gray, 1847: 270**

Type species: *Murex nebula* Montagu, 1803, by subsequent designation (Gray, 1847).

=*Fehria* van Aartsen, 1988 (type species: *Ginnania taprurensis* Pallary, 1904, by original designation)

***Bela taprurensis* (Pallary, 1904) (Figs. 18-46)**

*Ginnania taprurensis* Pallary, 1904: 218, pl. VII, Fig. 1

*Bela brachystoma apicalis* Nordsieck, 1977: 44, pl. 11, Fig. 86

Type locality. *Ginnania taprurensis* Pallary: Sfax, Tunisia, Mediterranean Sea. *Bela brachystoma apicalis* Nordsieck: Sfax, Tunisia, Mediterranean Sea. Type material. *Ginnania taprurensis* Pallary: Lectotype (MNHN-IM-2000-3269).

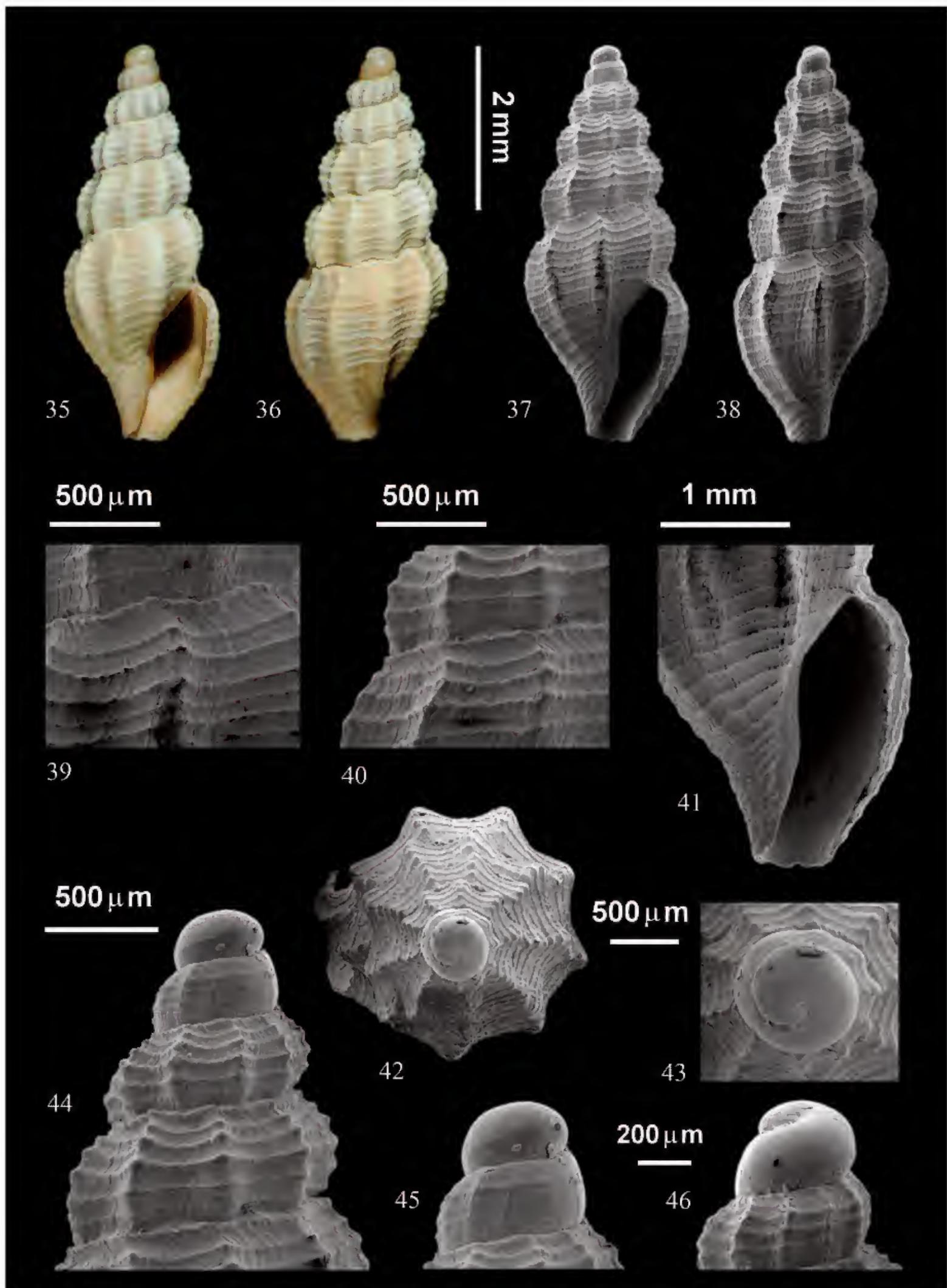
*Bela brachystoma apicalis* Nordsieck: 2 syntypes (SMF33269/2)

**EXAMINED MATERIAL.** The type material and: Tunisia: Sfax, 34°47'N 10°53'E, 15 m, 25 sh (CS-PM), 2 sh (coll. Monterosato, MCZR).

Libya: Al Khums, 32°43'N 14°18'E, 15 m, 4 sh (CS-PM).

**DISTRIBUTION.** Southern Mediterranean Sea, Gulf of Gabès (Pallary, 1904) and Libya; Aegean Sea (Manousis, 2012: 169) and Levant Sea (Bogi et al., 1989).

**REMARKS.** Nordsieck (1977: 45, pl. XII, fig. 90) redescribed *Ginnania taprurensis* Pallary and depicted a shell from Karpathos (Greece). Protoconch (2 convex whorls, rather blunt) and teleoconch description match the species as represented by the lectotype (Figs. 27, 28) and the two specimens in coll. Monterosato, presumably ex Pallary (Figs. 29-32). Nordsieck (1977) also described *B. brachystoma apicalis*, differing from the nominal species mainly for its paucispiral "protoconch [of] 11/2 very inflated whorls, which leads to the conclusion of a quite other life of larvae" (Nordsieck, 1977: 44, pl. 11, Fig. 86). The examination of two syntypes (Figs. 19-23) of *B. brachystoma apicalis* revealed that this taxon was actually based on shells of *B. taprurensis* (Pallary, 1904) (Figs. 27-46). Present sample from Libya (Figs. 33, 34) is the first record for the waters of that country.



Figures 35–38. *Bela taprurensis*. 4.8 x 1.8 mm, Sfax, Tunisia, 34°47'N 10°53'E, 15 m (CS-PM) (Figs. 37, 38 SEM photographs). Figures 39–46. Details of the shell of figs. 35–38 (SEM photographs).

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We would like to express our gratitude to Virginie Héros and Philippe Maestrati (MNHN), Ronald Janssen (SMF) and Massimo Appolloni (MCZR) for the help in the study of the materials under their care, and Cesare Tabanelli with Cesare Bogi for the bibliographic assistance.

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## Description of a new species of the genus *Trophonopsis* Bucquoy et Dautzenberg, 1882 (Gastropoda Muricidae Pagodulinae) from the Mediterranean Sea

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### ABSTRACT

Based on shell characters, a new species of the gastropod family Muricidae, *Trophonopsis sparacioi* n. sp., from Mediterranean Sea is described. Shells of the new taxon were collected from bathyal bottoms, in the Tyrrhenian Sea. The new taxon is compared with others species of the genus *Trophonopsis* Bucquoy et Dautzenberg, 1882, occurring in northeastern Atlantic and Mediterranean Sea.

### KEY WORDS

*Trophonopsis sparacioi* n. sp.; Muricidae; Pagodulinae; Mediterranean Sea.

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### INTRODUCTION

The genus *Trophonopsis* Bucquoy et Dautzenberg, 1882 has been traditionally included in the subfamily Trophoninae (Muricidae), while recently Barco et al. (2012) have included this genus in their newly erected subfamily Pagodulinae, based on clear evidence from the radular morphology.

Five Recent species of the genus *Trophonopsis* were so far recognised in northeastern Atlantic and Mediterranean Sea according to Houart (2001) and CLEMAM (Gofas & Le Renard, 2014): *T. alboranensis* (Smriglio et al., 1997) (Figs. 1–5, 39, 40), *T. barvicensis* (Johnston, 1825) (Figs. 6–10, 41, 42), *T. breviatus* (Jeffreys, 1882) (Figs. 11–15, 43, 44), *T. droueti* (Dautzenberg, 1889) and *T. muricatus* (Montagu, 1803) (Figs. 16–20, 45, 46). These taxa have been reviewed by Houart (2001), who considered *T. alboranensis* in the original genus *Houartiella* Smriglio, Mariottini et Bonfitto, 1997,

later synonymized with *Trophonopsis* by Peñas et al. (2006). In particular, two *Trophonopsis* species have an Atlantic distribution, being *T. droueti* endemic to the bathyal bottoms of the Azores (Bouchet & Warén, 1985; Houart, 2001), while *T. barvicensis*, which occurs at 50–1.000 m depth, is distributed from Morocco and the Azores, to the British Isles and West Scandinavia (Houart, 2001; Segers et al., 2009). *Trophonopsis barvicensis* was recently reported in the Mediterranean Sea from El Garraf (Spain), as a Würmian fossil, by Giribet & Penas (1997) and from the Djibuti bank (Spain), which could represent the extreme limit of its distribution into the Mediterranean, by Gofas et al. (2011). Furthermore, *T. alboranensis* and *T. breviatus* are endemic to Alboran and Black Sea, respectively (Smriglio et al., 1997; Houart, 2001; Gofas et al., 2011). *Trophonopsis breviatus* has been also recorded from Çanakkale and Bozcaada Isle, Turkey (Panayotis Ovalis, pers. comm.). Only *T. muricatus*

displays both a wide distribution, occurring in the Mediterranean and in the northeastern Atlantic up to the northern Great Britain, and a wide bathymetric range (0.5-300 m) (Rolán, 1983; Houart, 2001; Gofas et al., 2011).

Recently, we had the chance to examine shells of *Trophonopsis* from a spot located in the Tyrrhenian Sea, inhabited by rich bathyal benthic invertebrate communities (molluscan assemblages have been partially characterized in the past by Smriglio et al., 1989; Smriglio & Mariottini, 1996, 2000, 2001; Smriglio et al., 1999). After morphological comparison with the species of *Trophonopsis* occurring in northeastern Atlantic and Mediterranean, the studied shells have been regarded as belonging to a distinct, unnamed species, which is here described as new to science: *Trophonopsis sparacioi* n. sp.

**ABBREVIATIONS AND ACRONYMS.** The materials used for this study are deposited in the following private and Museum collections, BA: Bruno Amati collection, Rome, Italy; CS-PM: Carlo Smriglio-Paolo Mariottini collection, Rome, Italy; H: height; MO: Marco Oliverio collection, Rome, Italy; MTC: Monterosato collection; MCZR: Museum of Zoology of Rome (section collections of Malacology); MNHN: Muséum National d'Histoire Naturelle, Paris, France; MZB: Museum of Zoology Bologna (collection of the Laboratory of Malacology, University of Bologna, Italy); sh: empty shell(s); W: width.

## MATERIAL AND METHODS

Samples consisted mainly of empty shells, in a few cases with dried soft parts, from CS-PM private collection and material stored in the MTC at the MCZR.

Sediment sampling was collected by fishermen trawlers from muddy-bathyal bottoms located off the coasts of Latium (Central Tyrrhenian Sea). Sediment samples were sieved through a 1 mm mesh and sorted under a stereomicroscope. Scanning Electron Microscopy (SEM) observations were carried out by a Philips XL30 at the Interdepartmental Laboratory of Electron Microscopy (LIME, University of "Roma Tre", Rome, Italy). Current systematics is based on WoRMS (2013), that for *Trophonopsis* species treated in this work is in

accordance with CLEMAM (Gofas & Le Renard, 2014). Sculpture of the teleoconch was described according to the notation of Merle (2001, 2005).

## SYSTEMATICS

Family MURICIDEA Rafinesque, 1815

Subfamily Pagodulinae Barco, Schiaparelli, Houart et Oliverio, 2012

type genus *Pagodula* Monterosato, 1884 (by original designation)

Genus *Trophonopsis* Bucquoy, Dautzenberg et Dollfus, 1882

type species *Murex muricatus* Montagu, 1803 (by original designation)

### *Trophonopsis sparacioi* n. sp.

**EXAMINED MATERIAL.** The type material (Figs. 21–33, 47, 48) consists of 100 shells, 27 of them with dry soft parts, from the Central Tyrrhenian Sea, off coasts of Latium, 500/600 m (41°51'N 11°28'E). Holotype, MNHN IM-2000-27897; paratype 1, MNHN IM-2000-27898; paratypes 2, MZB60093 and 3, MZB60094; paratypes 4, MCZR00222a and 5, MCZR00222b; paratypes 6 and 7, MO; paratypes 8 and 9, BA; paratypes 10-99, CS-PM.

Other examined material. *Trophonopsis alboranensis*: from CS-PM collection (Rome): paratypes "A-B-D" and 13 sh, Alboran Sea (type locality), 80-150 m; 1 sh, Alboran Island, 180 m.

*Trophonopsis barvicensis*: from MTC collection: 2 sh, Bergen, Norway; 2 sh, Oban, Scotland, 25 fathoms; 4 sh, Shetland, England; 3 sh, England; 42 sh, North Atlantic Ocean, 226 m; 60 sh, Palermo, Italy. From CS-PM collection (Rome): 4 sh, Aberdeen Bank (57°13'N 01°05'W), Scotland, 59-68 m.

*Trophonopsis breviatus*: from CS-PM collection (Rome): 2 sh Bozcaada Island, Turkey 85 m; 4 sh from Marmara Island, Marmara Sea.

*Trophonopsis muricatus*: from MTC collection: 2 sh, Northumberland coast, Scotland; 5 sh, England; 10 sh, Le Croisic (Saint-Nazaire), France; 4 sh, Villefranche sur Mer (Nice), France; 2 sh, Minorca, Balears, Spain; 3 sh, Corsica; 4 sh, Sardinia, Italy; 4 sh, Positano (Naples), Italy; 3 sh, Golfo di Napoli, Italy; 1 sh, Naples, Italy; 192 sh, Palermo, Italy 1 sh, Algeria; 15 sh, Ficarazzi

(Palermo), Italy, fossil; 3 sh, Ficarazzi (Palermo), Italy, fossil; 3 sh, Giannettilla (Caltanissetta), Italy; 3 sh, Babbaurra (Caltanissetta), Italy; 1 sh, Magnisi (Siracusa), Italy; 3 sh, Sciacca (Agrigento), Italy; 1 sh, Morocco. From CS-PM collection (Rome): 3 sh, Algeciras, Spain, 20-35 m; 4 sh, Capo Corso, Corsica, France, 70 m; 8 sh, Capraia Island (Leghorn), Italy, 80-200 m; 1 sh, Capraia Island (Leghorn), Italy, 400 m; 14 sh, Elba Island, Tuscany, Italy, 300 m; 3 sh, Elba Island (Leghorn), Italy, 50 m; 2 sh, Civitavecchia (Rome), Italy, 40 m; 3 sh, Fiumicino (Rome), Italy, 160 m; 8 sh, Circeo (Latina), Italy, 90 m; 108 sh, Ponza Island (Latina), Italy, 125-165 m; 1 sh, Capo Portiere (Latina), Italy, unspecified depth; 3 sh, Golf of Carini (Palermo), Italy, 120 m; 48 sh, 60 miles offshore Sfax, Tunisia, 100 m; 11 sh, Libyan coasts, 110-150 m.

*Pagodula echinata* (Kiener, 1840): from CS-PM collection (Rome): about 600 sh, offshore Fiumicino (Rome), Central Tyrrhenian Sea (41°51'N 11°28'E), Italy, 500-600 m.

**DESCRIPTION OF THE HOLOTYPE.** Shell of small size for the genus, H = 5.6, W = 2.9 mm, fusiform, elongate, with high spire and siphonal canal open and moderately long, last whorl about three quarter of entire shell length. Protoconch paucispiral, with a diameter of 580 µm and 1.5 rounded whorls, ornamented with narrow, irregular spiral threads. Teleoconch with 3.5 whorls, axial sculpture consisting of 11 lamellate ribs, slightly spiny at the shoulder. Infrastutural ramp without cords (cords 1 and 2 absent), convex part of the last whorl with 6 primary cords (cords 3-8). Aperture small, ovate with a thin, knife-edge outer lip, to some extent undulate. Columellar lip narrow, smooth and adherent. Siphonal canal narrow, with evident growth ridges. Shell uniformly white or greyish-white, vitreous. Operculum corneous, ovoid, planispiral with lateral nucleus.

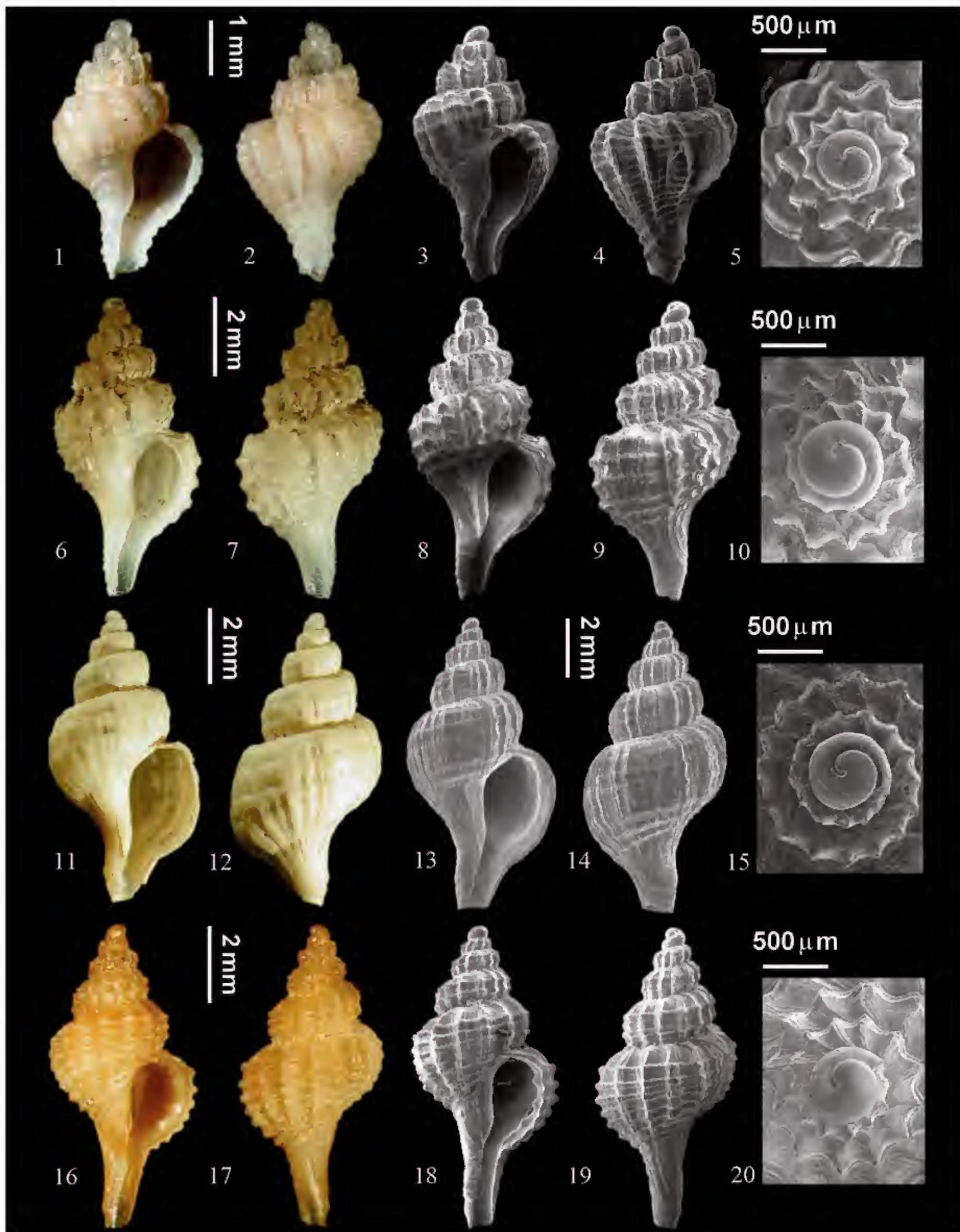
**VARIABILITY.** Shell height ranging from 5.8 to 6.3 mm with an average of 6.10 mm (50 sh measured), while the width is ranging from 2.9 to 3.1 mm (50 sh measured), with an average of 2.95 mm. Protoconch diameter from 550 to 650 µm, with an average of 589 mm (11 sh measured by SEM analyses). Teleoconch always comprising 3.5 whorls, which can be considered as a diagnostic character, and 6 (rarely 7) primary cords in the

convex part of the last whorl. Number of lamellate ribs of the axial sculpture ranging from 11 to 14, with an average of 12.24.

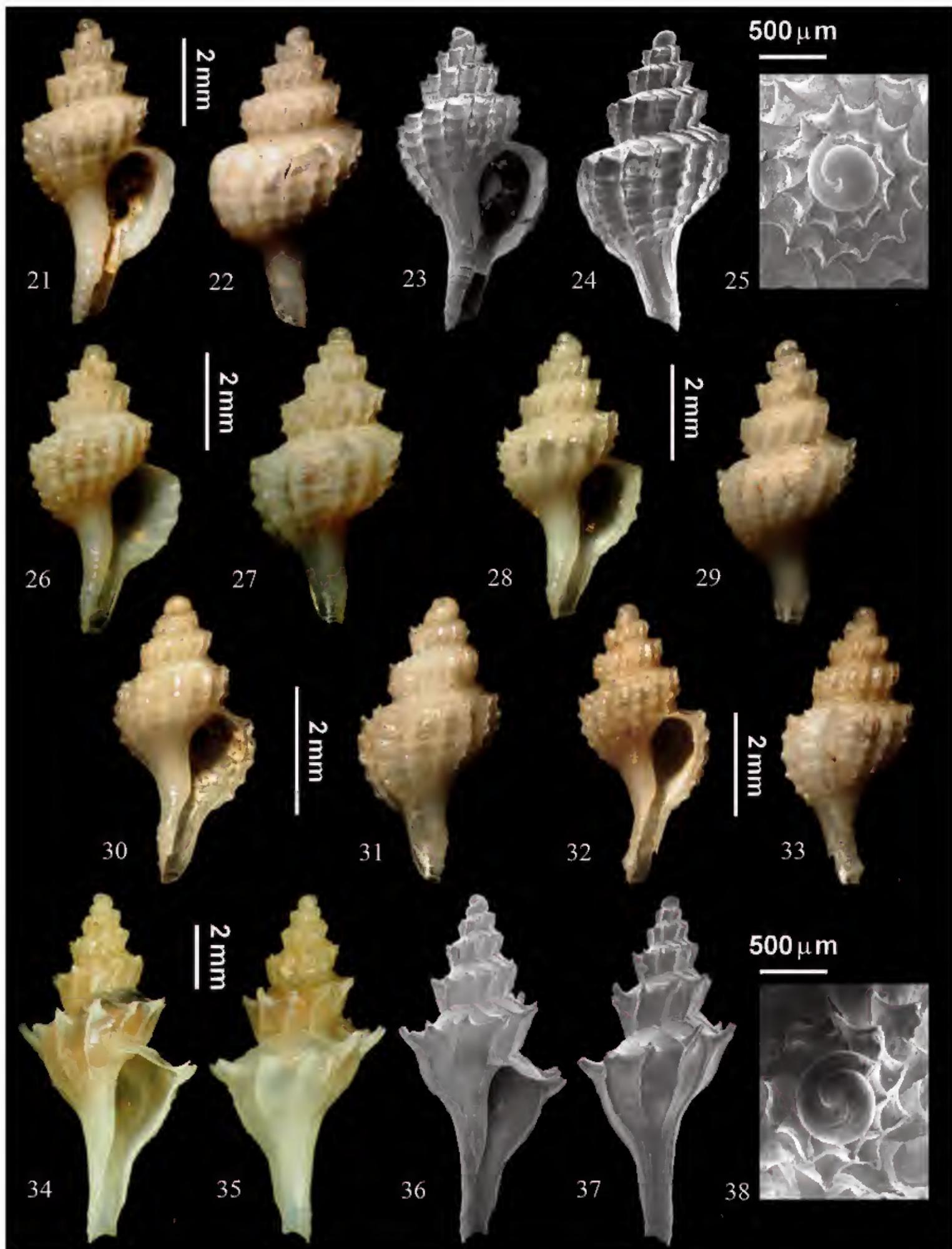
**ETIMOLOGY.** This species is dedicated to Ignazio Sparacio (Palermo, Italy), for his great contribution to scientific research and his editorial work for the biodiversity of the Mediterranean region.

**DISTRIBUTION AND BIOLOGY.** Locus typicus: Central Tyrrhenian Sea off the coasts of Latium (41°51'N 11°28'E). Habitat: Biocoenosis CB (sensu Pérès & Picard, 1964), 360-600 m depth.

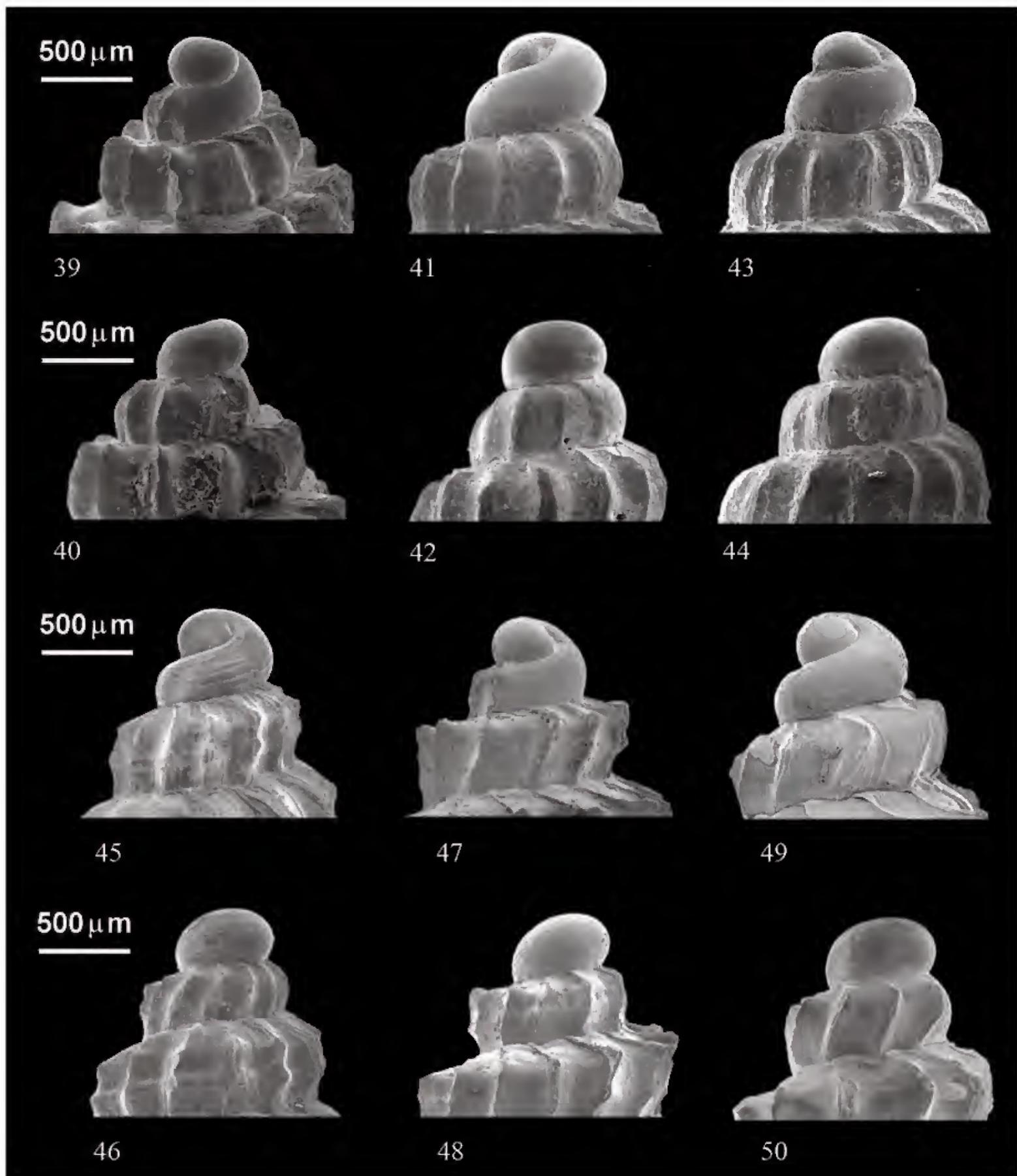
**REMARKS.** All shells of *T. sparacioi* n. sp. (Figs. 21-33, 47, 48), some of them with soft parts, were sorted out from sediment samples collected at bathyal depths. In particular, empty shells from muddy bottoms (biocoenosis VB, sensu Pérès & Picard, 1964), while shells with soft parts from deep-sea coral banks (biocoenosis CB, sensu Pérès & Picard, 1964). The benthic communities of this Tyrrhenian Sea area have been investigated since the late eighties, and have been partly characterized (Smriglio et al., 1989; Smriglio & Mariottini, 1996, 2000, 2001; Smriglio et al., 1999). The analysis of the accompanying dredged organogenic sediment revealed many fragments of alive azooxantellate corals like *Desmophyllum cristagalli* Milne Edwards et Haime, 1848 and *Madrepora oculata* (Linné, 1758), indicating that this species belongs to the biocoenosis CB. Furthermore, together with the empty shells of the new taxon, we collected another abundant pagoduline, *Pagodula echinata* (Kiener, 1840) (Figs. 34-38, 49, 50), which typically inhabits circalittoral/bathyal muddy bottoms (Smriglio et al., 1989; Houart, 2001; Gofas et al., 2011). For *P. echinata*, it is interesting to recall that the fossil *P. vaginata* (De Cristofori et Jan, 1832) differs by presenting "a distinct difference in the larval shell, which in the recent form consist of about 1.5 whorls while the Pliocene form has more than 2.5 whorls, and possibly planktotrophic larval development" (Bouchet & Waren, 1985 p. 138). Moreover, La Perna (1996) remarked "at that time, the two species lived in ecologically segregated populations, *P. vaginata* being linked to deep-shelf and upper-slope bottoms, and *P. echinata* to deeper bathyal bottoms". Possibly, this difference in habitat has enabled *P. echinata* to be protected during the Quaternary climatic cooling, which instead caused



Figures 1–5. *Trophonopsis alboranensis*. Paratype D, H 4.7 x W 2.8 mm. Alboran Sea, 80–150 m depth. CS-PM. Figures 6–10. *T. barvicensis*. H 7.4 x W 3.7 mm. Aberdeen Bank, E. Scotland, 59–68 m depth, 57°13'N–01°05'W. CS-PM. Figures 11, 12. *T. breviatus*. H 7.6 x W 4.2 mm. Marmara Island, Marmara Sea. CS-PM. Figures 13–15. *T. breviatus*. H 9.5 x W 5.2 mm. Bozcaada Island, Turkey, 85 m depth. CS-PM. Figures 16–20. *T. muricatus*. H 7.6 x W 3.7 mm. Circeo, Italy, 90 m depth. CS-PM.



Figures 21–25. *Trophonopsis sparacioi* n. sp. Paratype 10, H 6.2 x W 3.3 mm. Central Tyrrhenian Sea. CS-PM. Figures 26, 27. *T. sparacioi* n. sp. Paratype 2, H 5.8 x W 2.9 mm. Central Tyrrhenian Sea. MZB60093. Figures 28, 29. *T. sparacioi* n. sp. Holotype, H 5.6 x W 2.9 mm. Central Tyrrhenian Sea. MNHN IM-2000-27897. Figures 30, 31. *T. sparacioi* n. sp. Paratype 4, H 4.5 x W 2.9 mm. Central Tyrrhenian Sea. MCZR00222a. Figures 32, 33. *T. sparacioi* n. sp. Paratype 11, H 6.1 x W 2.8 mm. Central Tyrrhenian Sea. CS-PM. Figures 34–38. *Pagodula echinata*. H 10.7 x W 5.4 mm; Central Tyrrhenian Sea. CS-PM.



Figures 39, 40. *T. alboranensis*. Same as Fig. 1. Figures 41, 42. *T. barvicensis*. Same as Fig. 6. Figures 43, 44. *T. breviatus*. Same as Fig. 11. Figures 45, 46. *T. muricatus*. Same as Fig. 16. Figures 47, 48. *T. sparacioi* n. sp. Same as Fig. 34. Figures 49, 50. *Pagodula echinata*. Same as Fig. 11.

the extinction of *P. vaginata*. We think that *P. vaginata* represents the sister species of *P. echinata* that has lost the planktotrophic larval stage showing a different successful adaptive strategy, as described for other Recent couples of sibling species (Pusateri

et al., 2012; Pusateri et al., 2013). *Trophonopsis sparacioi* n. sp. clearly differs from all other *Trophonopsis* occurring in Northeastern Atlantic and Mediterranean Sea mainly for its small size and shell sculpture. Only *T. alboranensis* has similar

dimensions, but this species shows a totally different shell sculpture consisting of nodulose axial ribs with a higher number of spiral cords (compare Figs. 1–5 and 39, 40 to Figs. 21–25 and 47, 48) (Smriglio et al., 1997; Houart, 2001; Gofas et al., 2011). *Trophonopsis barvicensis* possesses both protoconch and teleoconch of bigger size and its shell sculpture shows less axial ribs and spiral cords, also less spiny at intersections (compare Figs. 6–10 and 41, 42 to Figs. 21–25 and 47, 48). *Trophonopsis sparacoi* n. sp. clearly differs from *T. breviatus* in many respects, the latter having a more convex shell outline, being less sculptured, and having a bigger protoconch (compare Figs. 11–15 and 43, 44 to Figs. 21–25 and 47, 48). *Trophonopsis muricatus* is bigger in size, shows a more convex shell outline, a more reticulated sculpture, less spiny at the intersections, and a longer siphonal canal. The protoconch of this species is similar in size, but shows less spiral threads, coarser in the last part of the whorl (compare Figs. 16–20 and 45, 46 to Figs. 21–25 and 47, 48).

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# The family Cypraeidae (Gastropoda Cypraeoidea) an unexpected case of neglected animals

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## ABSTRACT

The family Cypraeidae Rafinesque, 1815 (Gastropoda Cypraeoidea), commonly called Cowries, are particularly well-known among shell collectors, because of their beauty and relative availability. While most species are common in shallow reef environments, some other are quite hard to find, because they may come from remote or hardly accessible habitats, or they are in fact just rarely found. Because of this rarity and beauty, several cowries get high market values among collectable shells. This relevant economic interest produced two kind of outcomes: a proliferation of taxonomic complexity, and a very detailed knowledge of every variation of a given species, making cowries collection one of the most specialized ones. Notwithstanding this, it is quite remarkable that cowries had attracted very little interest by biologists and professional malacologists. Few scientific studies are available to date. This review attempts to overview some of the major biological highlights of the Family, to promote future researches in this diverse group of gastropods.

## KEY WORDS

Cypraeidae; Evolution; Biogeography; Speciation.

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## INTRODUCTION

The family Cypraeidae Rafinesque, 1815, cowries (Gastropoda Cypraeoidea) comprises about 220 species of marine gastropods (but this figure may vary with different taxonomies, see f.i. Moretzsohn, 2014), widespread along the tropical and subtropical seas. Many species are commonly found in tropical shallow water reefs, although others are adapted to temperate waters and/or deep water environments. Most species are herbivorous grazers, but some are carnivorous, being more commonly sponge eaters.

The main characteristic of cowries (which is however shared by some other gastropods) is the

presence of a retractable mantle that covers the entire shell, when in full extension (Figs. 1–6). This makes the cowrie shell particularly shiny, because, at variance to most gastropods, shell layers are continuously deposited outside the shell itself, rather than in the aperture and inside. The mantle is seldom richly branched, with protrusions known as papillae (Figs. 1, 2, 4–6), that may have both respiratory and mimetic functions. When disturbed, the animal can quickly retract the mantle showing off the brilliant shell.

The amazing richness of shell and mollusk colors in cowries (as in many other mollusks as well) has been always an evolutionary puzzle.

Cowries are not toxic animals, as far as we know, so the brilliant colors of shells and mantles could not be considered as warning signals for predators (aposematism). Sometimes, the mantle, when fully expanded, may camouflage the shell itself (see f.i. the genus *Naria* Broderip, 1837, with fully branched mantle that may resemble algae tufts or coelenterate colonies) (Fig. 7).

In some other cases, the mantle is quite thin and almost transparent, so the shell is easily visible below (see f.i. the genus *Zoila* Jousseau, 1884). Cowries are commonly cryptic (i.e. they hide) and nocturnal, and this is of course a clear adaptation to reduce predation. Nevertheless, some species, in their adulthood, graze freely in the open during the day (see f.i. the genera *Zoila*, *Barycypraea* Schilder, 1927; and *Cypraea tigris* Linnaeus, 1758). Such cowries tend to have heavy big shells, which is a clear adaptation to avoid predation by fishes and/or crustaceans. Some may also have deltoid shells, with a flat base, another clear adaptation to stick to rocky surfaces (thanks to a foot acting as a sucker) and prevent easy predation [see f.i. *Mauritia mauritiana* (Linnaeus, 1758), *Monetaria caput-serpentis* (Linnaeus, 1758), etc.].

Another environmental factor affecting shell structure is sea current and/or waves action. Generally cowries with thick and heavy shells are typical of turbulent waters. This feature is also variable among individuals of the same species, since lightweight shells tend to be more common in calm lagoons or in deeper waters, while heavy calloused shells are more easily found in the open ocean or in high surf waters.

## THE UNUSUAL DEVELOPMENT OF A COWRIE SHELL

The cowrie shell follows a developmental pattern that is quite different from most mollusks. The first shell to be produced is the larval shell of the veliger (Fig. 8). While most species spend their larval time in the plankton, others have a direct intracapsular development (direct developers). Once metamorphosed, the shell keeps growing by adding whorls around its columella (Fig. 9). Eventually, during this growth, the shell may first resemble an *Oliva* shell (Fig. 10; i.e. 'oliva stage'), or a *Bulla* (i.e. 'bulla stage').

In both such stages, the spire is well visible and the shell is very different from the adult one, both for its structure and color. The shell is very thin and all cowries are cryptic at this stage. This is easily interpreted as an adaptation to prevent predation. Although no secure data are available, many personal observations and info obtained from shell divers may point to the fact that cowries get to adulthood very fast, perhaps within few months from birth.

At the end of the juvenile stage, cowries undergo a deep change in their shells: the last whorl usually covers the entire shell, so the spire gets included in it, and it eventually bends over the columellar side to tighten the shell aperture (Fig. 1). This tightening is even more pronounced by the deposition of shell teeth, one of the most typical features of cowries (Fig. 12).

Cowries have no operculum, so teeth are an alternative strategy to make the aperture as narrow as possible, to prevent access to soft parts when the mollusk is retracted. Soon after teeth formation, the shell stops growing, and it starts thickening by deposition of shell and glaze layers, ending up into the typical thick and glossy shell (Fig. 12). The fact that cowries stop growing at adulthood is quite unusual among gastropods, which rather tend to have an undetermined growing pattern. Moreover, the growing rate and/or time to adulthood seem to be quite variable, even among the same species, ending up with a remarkable variability in adult shell sizes (see f.i. Okon, 2013a, b; 2014).

The shell of a cowrie mollusk is therefore quite different from most gastropod shells, as it evolved several unusual characteristics, including a relevant thickness, a very glossy surface, and a very narrow aperture. Moreover, many cowrie shells are brightly colored, making them quite visible to predators. Notwithstanding this, cowries are among the most successful gastropods in coral reefs, and they perform quite well in many other marine environments. As mentioned, some do not even hide at adulthood (see f.i. Fig. 13).

In the attempt to understand the peculiar adaptations of cowries, we first have to consider that the shell of Cypraeidae is generally thick and very compact, hard to brake, with a very narrow aperture, and the mollusk is usually very mucous, which makes the cowrie quite slimy. These joined characteristics are likely a good adaptation against predation,

because the thickness of the shell, the absence of possible holds, the slimy surface, and the relative unreachability of soft parts, may discourage most predators. In fact, such characteristics make predation by small fishes and crabs very difficult.

Actually, cowries are often wholly swallowed by big fishes, since they cannot easily crack them, although it sometimes happens with strongly beaked fishes. Another important source of predation are octopuses, that drill the cowrie shell and



Figures 1–6. Examples of mantles and papillae in Cypraeidae (all from Hawaii). Fig. 1. *Lyncina carneola propinqua* (Garrett, 1879); Fig. 2. *Talparia talpa* (Linnaeus, 1758); Fig. 3. *Luria tessellata* (Swainson, 1822); Fig. 4. *Lyncina lynx* (Linnaeus, 1758); Fig. 5. *Naria poraria* (Linnaeus, 1758); Fig. 6. *Ovatipsa chinensi amiges* (Melvill et Standen, 1915). Photos courtesy David Lum.



Figure 7. *Naria erosa* (Linnaeus, 1758) showing its extended mantle resembling an algae tuft (Zanzibar, Tanzania). The shell is barely visible in the middle of the dorsum, since the mantle is not fully extended.



Figures 8–12. Developmental stages of *Naria spurca* (Mediterranean Sea). Fig. 8. Veliger shell; Fig. 9. Young shell (just metamorphosed); Fig. 10. 'Oliva' stage; Fig. 11. Subadult; Fig. 12. Adult. Photos courtesy Andrea Nappo and Dario Marcello Soldan.

digest the mollusk, and eventually use cowrie shells (and others) to adorn their dens. Predations by shell drilling gastropods (e.g. Naticidae or Muricidae) seem to be much more rare.

## COWRIES' REPRODUCTION

Cowries reproduction is quite remarkable too. Females lay eggs in clusters of capsules on hard surfaces and, at variance to many other gastropods, they hatch eggs by covering them with the foot (Fig. 14). Abandoned eggs may dye quite soon. This commitment in parental cares is unusual in marine gastropods, and it may be another reason for the success of this Family. When intracapsular development ends, planktotrophic larvae hatch and swim in the water column until they metamorphose. The length of larval stages may be different, and could be somehow related to the capacity of a given species to undergo local genetic diversification (i.e. subspecies and/or geographic races). Some species seem to have quite few divergent races, while others have a much higher geographically structured pattern.

On the other hand, direct developers seem to show different morphologies in different areas. In direct developers, young mollusks undergo intracapsular development and, since they feed at the expenses of accessory eggs in the capsule, they keep growing until they hatch as crawling snails. This development, evolved many times in cowries, especially in some temperate water genera (*Zoila*, *Cypraeovula* Gray, 1824, *Notocypraea* Schilder, 1927), has been often considered as an adaptation to improve the chances of larvae to find specific foods, like sponges they feed on. In fact, most direct developers are fully depending over limited food supplies, and they need to hatch as close as possible to their food, to increase chances of reaching adulthood.

## DISTRIBUTION AND BIOGEOGRAPHY

Cowries are subtropical marine animals (Fig. 15), so most of them live in the oceans between the two tropics. The highest number of species is found in the Indo-Pacific Ocean, and far less species live in the Atlantic (and the Mediterranean). Paulay and



Figure 13. Two *Zoila friendii jeaniana* (Cate, 1968) (f. *sherylae* L. Raybaudi Massilia, 1990) grazing their host sponge in the open (Point Qobba, W-Australia). Photo courtesy Daniel Edinger.



Figure 14. *Erronea caurica* cfr. *quinquefasciata* (P.F. Röding, 1798) on eggs (Oman, Marisah Island). Photo courtesy Massimo Scali & Beautifulcowries Magazine.

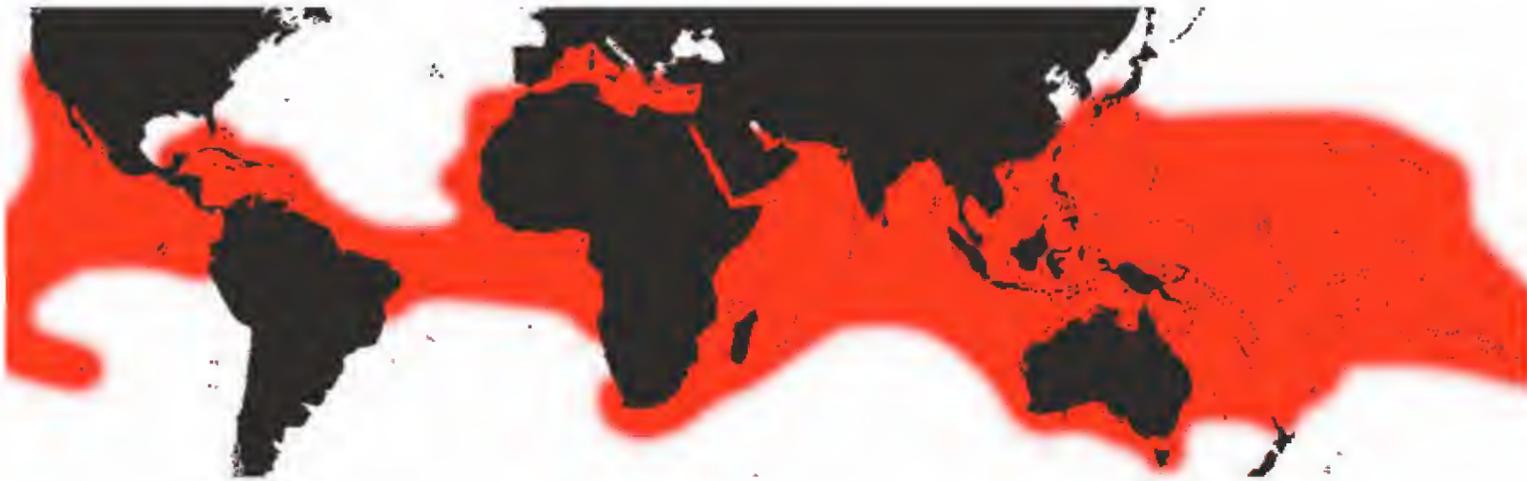


Figure 15. Distribution map of the living species of cowries. Photo courtesy Mirco Bergonzoni.

Meyer (2006) proposed a species richness map of the Indo-Pacific cowries. The highest species richness is in the region going from the Philippines to Melanesia, especially along the boundary between East Indian Ocean and West Pacific. Species richness significantly decreases going west towards Africa (although it locally increases again there), or east along the Pacific Ocean towards Polynesia and West America. Quite significantly, similar species-richness patterns have been found in reef-building corals, as in other reef-related organisms (see f.i. Malay & Paulay, 2010). In fact, the region comprising the ocean territories of Indonesia, the Philippines, Malaysia (Sabah), East Timor, Papua New

Guinea and the Solomon Islands, is known as ‘the coral triangle’, hosting more than 500 species of reef-building corals (Veron, 1995). The reasons for these similar species distribution patterns could be both environmental and historical. Apparently the thousand of islands and reefs in South East Asia, as well as their highly diverse habitats, were central to a rich species radiation in cowries and other reef-related animals. So that, probably, most of the widespread Indo-Pacific cowries have once originated in this area, and migrated (with different success) outwards by larval dispersion.

As mentioned, the duration of veliger stages has been again related to dispersion and speciation rates

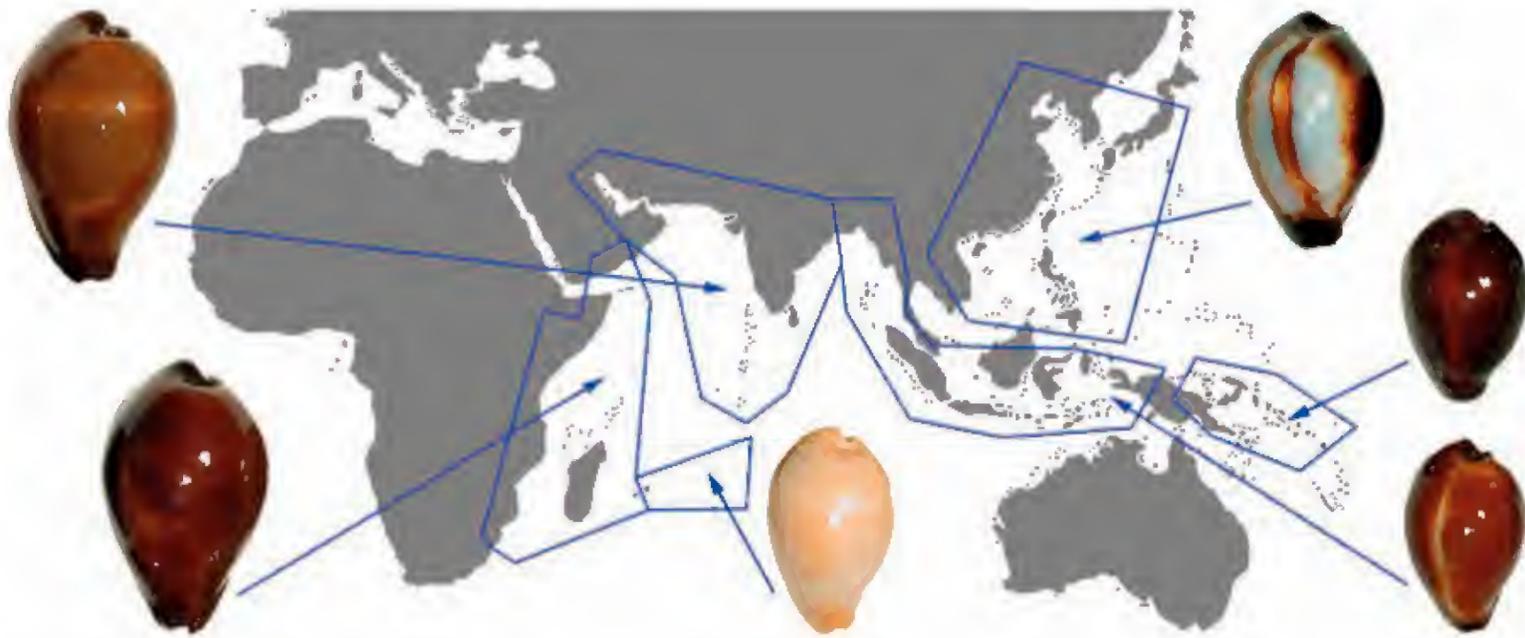
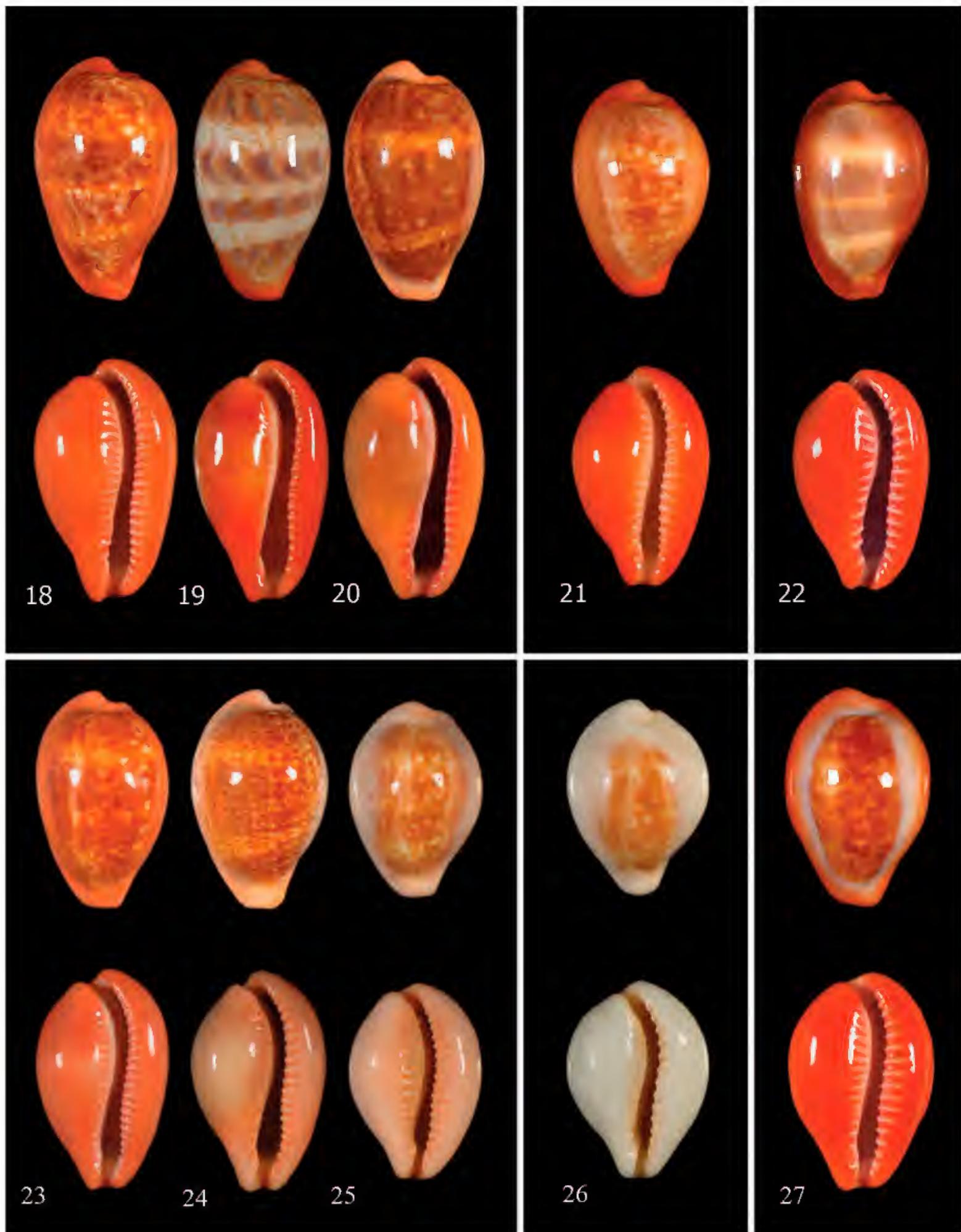


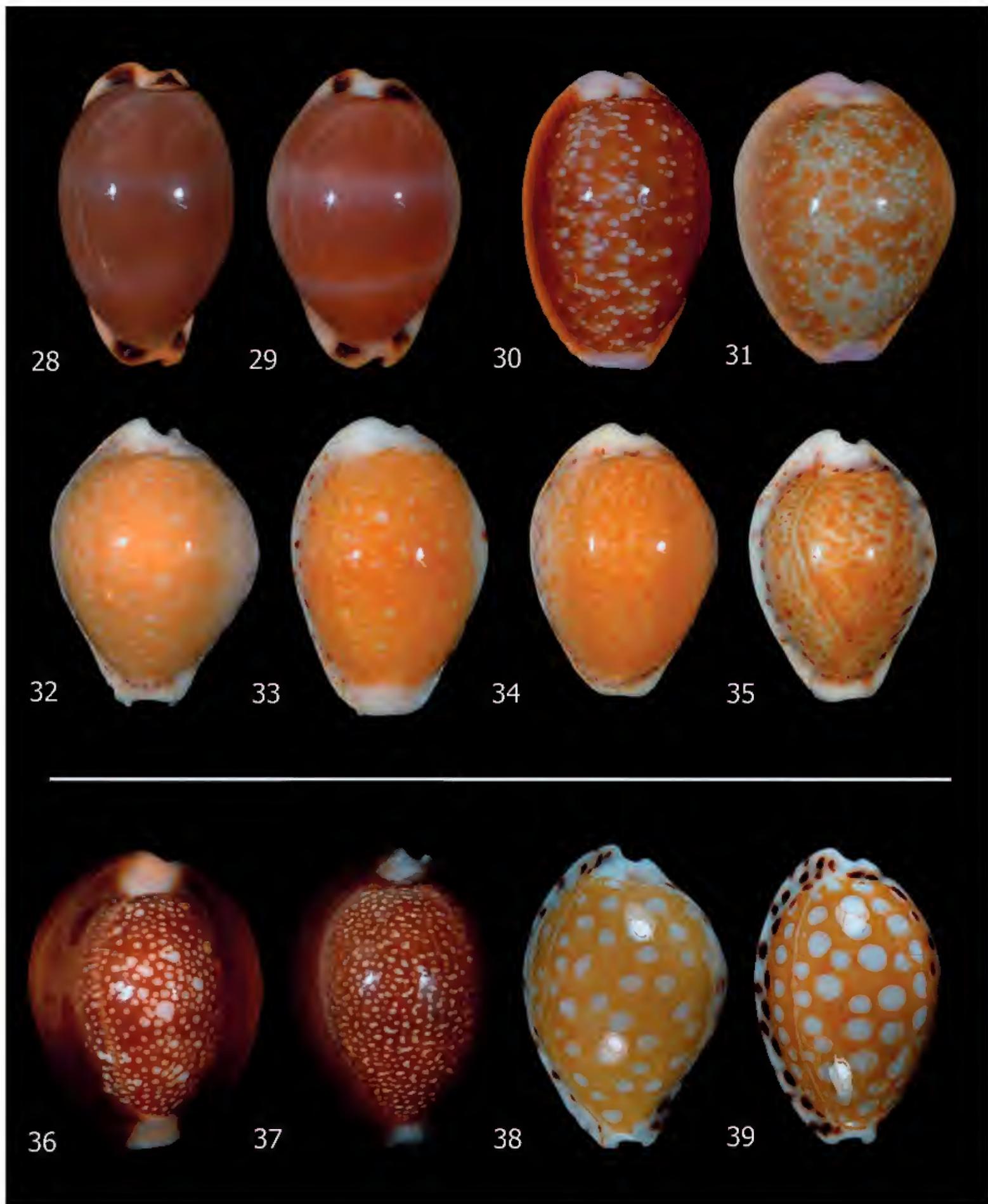
Figure 16. Geographic diversification of the *Erronea onyx* species group. From left to right: *Erronea adusta adusta* (East Africa); *Erronea adusta nymphae* (Mauritius; Chagos); *Erronea adusta persica* (India, Oman, Persian Gulf); *Erronea adusta andamanensis* (East Indian Ocean); *Erronea adusta melanesiae* (South West Pacific); *Erronea onyx* (North West Pacific). Photo courtesy Mirco Bergonzoni.



Figure 17. Examples of the variability of the *Leporicypraea mappa* species complex from different basins. Photo courtesy Mirco Bergonzoni & Cypraea.net.



Figures 18–27. Examples of the variability of the *Zonaria pyrum* species complex. Figs. 18–21. *Z. pyrum pyrum* (Gmelin, 1791): Mediterranean Sea to Mauritania-Senegal (North of Dakar); Fig. 22. *Z. pyrum insularum* Schilder, 1928: Algarve (Portugal), Cadiz (Spain), Morocco, Canary Is.; Figs. 23–25. *Z. pyrum petitiana* (Crosse, 1872): South of Dakar (Senegal), Ivory Coast, Gabon, C. Verde; Fig. 26. *Z. pyrum angelicae* (Clover, 1974): North Gabon, Guinea Gulf (?); Fig. 27. *Z. angolensis* (Odhner, 1923): South Gabon, Luanda area (Angola). Photos courtesy Mirco Bergonzoni & Beautifulcowries Magazine.



Figures 28–39. Examples of close relative couples of taxa of Cypraeidae. The one on the left is always the one with a wide distribution range, the right one is the endemic relative with its range limited to peripheral locations. Above the line, the couples considered as subspecies; below the line, the couples considered as different species, from left to right. Figs. 28, 29: *Luria lurida* (Mediterranean Sea) and *L. lurida oceanica* (Ascension Is.); Figs. 30, 31: *Naria helvola* and *N. helvola hawaiiensis* (Hawaii); Figs. 32, 33: *Naria cernica* and *N. cernica leforti* (Easter Island); Figs. 34, 35: *Naria acicularis* and *N. acicularis sanctahelenae* (Ascension and Saint Helena); Figs. 36, 37: *Monetaria caputserpentis* and *M. caputdraconis* (Easter Island and Sala Y Gomez); Figs. 38, 39: *Cribrarula astaryi* (f. *lefaiti*) and *C. garciai* (Easter Island). Photos courtesy Beautifulcowries Magazine.

by Paulay and Meyer (2006). Although duration of veliger stages is only weakly correlated to species range, it is significantly related to the diversification of cowries along the Indo-Pacific basin: i.e. the lower the veliger time is, the most is the geographic/taxonomic diversification. In fact, it is quite evident that some Indo-Pacific cowrie species show very little geographic variation, see f.i. *Monetaria caputserpentis*, *Monetaria annulus* (Linnaeus, 1758), while others are much more prone to produce local races/subspecies. Only because they have been recently analyzed in detail, I can mention here the *Erronea onyx* (Linnaeus, 1758) species complex (Bergonzoni, 2013a), which appeared to differentiate in allopatric races (Fig. 16), and the *Leporicypraea mappa* (Linnaeus, 1758) species group (Fig. 17), one of the most biogeographically and evolutionary complex cases among cowries (Bergonzoni & Passamonti, 2014). By analyzing such complexes in detail, very interesting cases on evolutionary history of marine organisms became

evident, including allopatric speciation events, incipient speciation, relevance of genetic flow for morphological diversification, etc. More case studies are really interesting, but they still have to be analyzed in detail, as f.i. the genera *Cribrarula* Strand, 1929 and *Talostolida* Iredale, 1931, and the *Bistolida stolidia* (Linnaeus, 1758) and *Erronea caurica* (Linnaeus, 1758) species complexes, just to name some.

As mentioned, cowries also colonized the Atlantic, although their species richness is much lower in this Ocean. Most likely, this colonization was rather old, since at present the cold currents of South West America (Humboldt Current) and South West Africa (Benguela Current) are evidently a strong barrier for larval dispersion and cowries settling. At present, no species seems to be able to spread from the Indo-Pacific to the Atlantic Ocean north of Namibia, or in South America. Of course no one lives in the Arctic Ocean as well. Nevertheless, Atlantic cowries have evident affinities with Indo-Pacific ones. For instance, the genus *Macrocyprea* Schilder, 1930 is present at both sides of



Figure 40. Representatives of the South African genus *Cypraeovula*. Photo courtesy Goncalo Rosa and Mirco Bergonzoni.

the Isthmus of Panama, as it likely originated locally before the Isthmus was closed. On the other side of the Atlantic, we have examples of couples of allied species found in the Mediterranean and the Red Sea/North West Indian Ocean [*Luria lurida* (Linnaeus 1758)/*Luria pulchra* (Gray, 1824)], maybe a Thetyan residue. Some other genera are endemic to this region (*Zonaria* Jousseaume, 1884; *Schilderia* Tomlin, 1930). Finally, a peculiar distri-

bution is given by the *Naria spurca* complex of species: this comprises three species, *Naria spurca* (Linnaeus 1758), *Naria acicularis* (Gmelin, 1791), and *Naria cernica* (Sowerby, 1870). The first is distributed in the Mediterranean/West Atlantic, the second along the East American coastlines, the latter is one of the most widely dispersed indopacific cowries. Although the exact colonization tempos and modes of Atlantic cowries are hard to speculate,



Figures 41–45. Extreme variability in *Zoila* from Western and South Australia. Figs. 41–43: *Zoila friendii* subspecies/forms. Fig. 44: *Z. ketyana* subspecies/forms. Fig. 45: *Z. venusta* subspecies/forms. Photos courtesy Mirco Bergonzoni & Cypraea.net.

their phylogenetic relatedness to Indo-Pacific ones is evident. Detailed phylogeographic analyses are potentially of great interest to reconstruct the geological history of the Atlantic basin, its past connections and/or geological changes.

Again, as for Indo-Pacific cowries, in the Atlantic as well the duration of cowries larval stages has been correlated by the rate of morphological diversification. One paradigmatic example comes from

the *Zonaria pyrum* (Gmelin, 1791) species complex (Figs. 18–27), spreads in the Mediterranean and West Africa region. Again, a short larval stage has been related to the extreme capacity to differentiate geographically, with different taxa spreading along the African coast (Bergonzoni, 2013b).

Another interesting case of evolution comes from cases of species/subspecies couples in which one has a wide range, and the allied one has a



Figures 46–47. The genus *Umbilia* (South and East Australia). Fig. 46: *Umbilia hesitata* species complex. Fig. 46: *U. armeniaca*. Photos courtesy Mirco Bergonzoni & Cypraea.net.



Figure 48. *Barycypraea teulerei* (Oman). Two males approaching a female hatching eggs into a empty bivalve shell.



Figure 49. *Barycypraea fultoni fultoni* (Natal, S. Africa). Photo courtesy Felix Lorenz & Beautifulcowries Magazine.

peripheral endemic distribution. Figures 28–39 show some cases. Most of them are isolated endemics, likely arisen paraphyletically. Quite remarkably, they are treated much differently in established taxonomy: some are actually considered as full species, some other as subspecies, although no evident reason (besides Authors' opinion) has been produced so far.

As mentioned, cowries were able to colonize temperate waters as well. This is particularly evident for South Africa and West/South Australia, in which endemic genera evolved. In South Africa, the most striking evolutionary radiation is the genus *Cypraeovula* (Fig. 40), including different closely related species that sometimes hybridize too. On the other side of the Indian Ocean, in Western Australia, another striking example of colonization of temperate waters is the genus *Zoila* (Lorenz, 2001; Wilson and Clarkson, 2004) (Figs. 41–45). The *Zoila* cowries are sponge eaters and direct developers, and this caused a flourishing of local races, making them one of the most taxonomically complex groups of marine organisms. Along with *Zoila*, another similar case is the genus *Notocypraea*, which is however much less known in detail. Finally the genus *Umbilia* Jousseaume, 1884 (Wilson and Clarkson, 2004) is another striking Australian endemism of temperate waters, as it is distributed along the East and South coast (Figs. 46, 47).

Other cases of direct developers are found as well, such as the genera *Barycypraea* and *Muracyprea* Woodring, 1957, and few others. In all

cases, these species have a very limited range. F.i. *Barycypraea teulerei* (Cazenavette, 1846) (Fig. 48), a shallow water direct developer (Scali, 2013; 2014), seems to be found in a limited area of Oman only, while the deep water relative *Barycypraea fultoni* (Sowerby III, 1903) is found between Mozambique and South Africa (Bergonzoni, 2012) (Fig. 49). Another case of direct developer with little dispersal capacity is *Muracyprea mus* (Linnaeus, 1758), limited to the Gulf of Venezuela coasts and Guajira Peninsula in Colombia.

## THE MOLECULAR PHYLOGENETICS OF COWRIES AND THEIR TAXONOMY

This is probably the field of cowries biology that has been more thoughtfully investigated. In fact, a huge phylogenetic reconstruction, based on DNA, have been proposed by Meyer (2003; 2004). The primary outcome of this pivotal work is an ultimate tuning of the sovraspecific taxonomy of the family. Quite remarkably, most of the subfamilies and genera proposed by older Authors on morphology (see f.i. Schilder & Schilder, 1938; Schilder, 1939; 1966;) have been confirmed by DNA.

The family Cypraeidae is now subdivided into 7 subfamilies (Archicypraeinae, Erosariinae, Umbiliinae, Cypraeinae, Bernayinae, Luriinae and Cypraeovulinae) and 48 genera (Moretzsohn, 2014), and this arrangement has gained a very good agreement among cowrie experts.

Even if a relatively stable sovraspecific taxonomy has been reached in the Family, this is certainly untrue for species level and, even more, below it. Most of the proposed taxonomies are based on morphological analyses, as well as on Authors' opinions. Only few DNA data and/or detailed evolutionary studies are available to date. Moreover, a certain degree of taxonomic proliferation has been certainly triggered by economic factors: in fact, many cowrie collectors want new names, so that a new named cowrie gets a much higher value in the market. This cause what I'd call 'economic speciation', with some humor, of course! This approach should be strongly stigmatized for two reasons: 1st, it produces an unnecessary proliferation of taxonomic names; 2nd, it has no biological bases in most cases.

Another problem comes from the rules of taxonomy, and this is particularly evident for species and subspecies names, which are under the provisions of the International Code of Zoological Nomenclature. In my opinion, new species and subspecies names should not be introduced in taxonomy if not based on rigorous biological and evolutionary analyses. Nevertheless, specialized

collectors need to have names to refer to morphologies that are just not so important for evolutionary biologists, like local variants, unstable morphs, aberrations, etc. The use of 'forma' names should be a good compromise, because they, one side, meet collectors' needs for names, and, the other do not increase taxonomic complexity (i.e., infrasub-specific names are not under the provisions of the Code). This approach is not without problems, of course, but it seems to me the only possible compromise between two different, and sometimes contrasting, needs.

## MUTATIONS AND ABERRATIONS

### *Albinism and rufinism*

As it happens in all living beings, cowries may show some interesting mutations and aberrations. Some of them, being rare, may produce some of the most sought-after and priced cowries, so all collectors know them very well. On the other hand, their biological causes are quite unknown or neglected. I try to highlight some of them here.



Figure 50. *Zoila decipiens* from Broome area, W-Australia. From left to right: black (normal), albino and rufinistic shells. Photo courtesy Drew Strickland.

The first example comes from rare recessive mutations, such as cowries' albinism (producing white shells) or rufinism (producing orange shells) (Fig. 50). These phenotypes are evidently due to rare mutations affecting the genes for shell color. It is quite remarkable that white or orange shells are not necessarily associated to white and orange animals, respectively. This clearly points out to the observation that genes for shell color are different from the ones of the soft parts. For this reason, it would be inaccurate to call such specimens 'albino' or 'rufinistic', but I use these terms here for simplicity. Both rufinistic and albino cowries have been proposed to be the result of mutations over the same metabolic pathways producing brown/black pigments (melanin?). For a detailed discussion see Passamonti and Hiscock (2013).

Besides their high collecting value, the appearance of rare mutants within a population represents an interesting case to study the dynamics of allele frequencies, and the effects that collecting pressure may have on the variability of natural populations. A paradigmatic example is that of *Zoila rosselli satiata* Lorenz, 2002, from Fitzroy Reef, Quobba Point, North West Australia. This once quite large population was an important source of rosselli specimens, and many hundreds have been collected over the years. Among normal shells, around 40 rufinistic specimens were found (f. *edingeri* Raybaudi Massilia, 1990) (Beals, 2013) (Fig. 51). These shells were collected over a limited time-lapse, as the first ones were collected in 1988, and they disappeared soon after 1997. Why the mutant disappeared so fast? One may think that this is because all orange shells were collected, so they



Figure 51. *Zoila rosselli satiata* and *Z. rosselli satiata* f. *edingeri* (rufinistic). Both found at Point Quobba, W-Australia. Photo courtesy Daniel Edinger and Beautiful-cowries Magazine.

could not produce orange progeny anymore. However, this is not fully the case: since rufinistic mutations are likely recessive (i.e. they may 'hide' in heterozygous individuals), two heterozygous black mates may well produce  $\frac{1}{4}$  of orange shells, according to Mendelian proportions. So, the overall collecting pressure (on both black and orange specimens) is rather the reason of this disappearance: by reducing dramatically the number of individuals, the population underwent a strong 'bottleneck', which is well known in evolutionary biology to reduce genetic variability. Because chances for rare alleles to pass throughout a population bottleneck are very scarce, the rufinistic allele was soon lost from the population, and no *edingeri* was found since then. This also means that the chances that this allele will appear again in Quobba are quite low, and the *edingeri* rufinistic mutation is simply no longer existing. However, rufinistic shells are found within many other *Zoila* species, as well as in some other cowries. So rufinism is likely a case of recurrent mutation. F.i. an independent rufinistic morph has been recently evidenced in another *Zoila rosselli* population (see Lorenz, 2011; 2014).

Albinos are much more rare among cowries. Although many cowries may be white or whitish, the rare albino mutants are only known for very few cowries [f.i. in *Cypraea tigris* (Fig. 52), and *Zoila decipiens* Smith, 1880 (Fig. 50)]. What is quite interesting is that albino morphs may become fixed in some populations (i.e. all the shells are albinos), hence they are not rare mutants anymore: two paradigmatic examples are *Naria eburnea* Barnes, 1824 (Fig. 53) and *Erronea nymphae* Jay, 1850 (see Fig. 16). Both are clearly related to non-albino relatives, *Naria miliaris* (Gmelin, 1791) and *Erronea adusta* (Lamarck, 1810), respectively. These are likely cases in which the 'albino' allele was fixed into a new population because of a 'founder effect', i.e. when a new population had established in a new area the albino allele became by chance the unique one (i.e. it was fixed).

### *Niger and rostrated cowries*

This is another interesting feature, which appears to be unique to some cowries and only one ovulid species, *Calpurnus verrucosus* (Linnaeus, 1758). It is evident that these two characteristics are the outcome of the unusual developmental scheme



Figure 52. Two normal *Cypraea tigris* along with an albino one (Madagascar and Philippines). Photo courtesy Mirco Bergonzoni & Cypraea.net.

of cowries' shells. As mentioned, adult cowries stop growing, since the deposition of shell layers and pigments stops or strongly reduces. However, in some specimens, the signal to stop seems not to work properly, and the shell keeps growing by adding layers of shell and/or pigment. Hence such cowries quickly get a 'gondola shape' (rostrated), as well as a deep black color (melanic or 'niger' cowries). Both phenomena may appear together, or not, depending on species. Some species become melanistic and rostrated altogether, others may only be rostrated (these are the ones that do not have brown/black colors in normal adults). Also, the degree of rostration and melanism may vary among individuals (Figs. 54, 55).

Even if such phenotypes are occasionally found over the entire range of some cowrie species, it is quite remarkable that they get much more common in two specific areas: the southern reefs of New Caledonia, and the Keppel Bay area in Queensland. The biological causes of such aberrations are still unknown, and some have linked these phenomena to the presence on heavy metals (nickel?) in the water (see, f.i., Pierson and Pierson, 1975). What I think it is interesting is the presumable genetic base of melanism and rostration: as mentioned, both could easily be interpreted as a malfunctioning of genetic regulation of shell development. The pattern of expression of



Figure 53. Two species of the genus *Naria*. *Naria miliaris* from China (left) and *N. eburnea* from New Caledonia (right).

developmental genes is somehow affected (by metals? by other environmental factors? by mutations?), and the genes for deposition of shell color and layers just fail to stop at adulthood, as it happens in normal cowries. Needless to say that we have no clue on which genes are involved in such processes, and this would certainly be a nice case study for developmental biologists.

## CONCLUSIONS

In this paper I tried to highlight some biological peculiarities of cowries, making them interesting case studies to many aspects of evolutionary biology, not only for taxonomy. Cowries are very interesting marine organisms, and, even if they have been studied by very few professional biologists, they are well known by amateurs, and a huge amount of 'first-hand' data are available. This manuscript is far to be complete, and many other interesting cases could be highlighted; nevertheless I hope that this short review has attracted your interest to this amazing group of animals, that certainly deserves more studies. The collection of cowries, which is unfortunately so deeply money-driven, is certainly a restraint to biological studies, since some species are hardly accessible and collecting data are often vague (to preserve a relevant



Figures 54, 55. Examples of different degrees of melanism and rostration in New Caledonian cowries.  
Fig. 54: *Mauritia (Arabica) eglantina*; Fig. 55: *Bistolida stolidi*.

source of income for divers/dealers). On the other hand, an important collecting effort is a precious help for biologists, since maybe for no other group of gastropods we have such a huge amount of knowledge 'in the field'. We should therefore try to build a 'bridge' between the two worlds (cowries amateurs and biologists) that both may benefit: collectors will start to consider cowries not as just precious and beautiful objects, and evolutionary biologists/professional malacologists as interesting animals to study. Only this way, the preconception that cowries are just pretty but uninteresting animals will be definitively overcome.

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# The Recent Rissoidae of the Mediterranean Sea. Notes on the genus *Onoba* s.s. H. Adams et A. Adams, 1852 (Gastropoda Prosobranchia)

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## ABSTRACT

The Mediterranean species belonging to the genus *Onoba* H. Adams et A. Adams, 1852 as currently conceived, are reviewed. With the exception of *O. semicostata* (Montagu, 1803) and *O. aculeus* (Gould, 1841) that range mostly in the European North-Eastern Atlantic and are rarely found in the Western Mediterranean, this genus is represented by six species with rather limited ranges: *O. dimassai* Amati et Nofroni, 1991; *O. josae* Moolenbeek et Hoenselaar, 1987; *O. guzmani* Hoenselaar et Moolenbeek, 1987; *O. tarifensis* Hoenselaar et Moolenbeek, 1987; *O. gianninii* (Nordsieck, 1974) and *O. oliverioi* Smriglio et Mariottini, 2000. A further possibly undescribed species is figured. For all species comparative morphometrics are provided. *Onoba josae* Moolenbeek et Hoenselaar, 1987 is here recorded for the first time in Italy, with the easternmost locality in this range.

## KEY WORDS

taxonomy; Rissoidae; *Onoba*; Recent; Mediterranean Sea; first record.

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## INTRODUCTION

The genus *Onoba* H. Adams et A. Adams, 1852 has been frequently discussed in the malacological literature (e.g. H. & A. Adams, 1852: 358; Jeffreys, 1867: 37; Watson, 1873: 387; Verril, 1884: 182; Friele, 1886: 28; Dautzenberg, 1889: 52; Warén, 1973: 4; Warén, 1974: 130; Rolán, 1983: 139; Ponder, 1985: 54; Templado & Rolán, 1986: 117; Bouchet & Warén, 1993: 659; Ponder & Worsfold, 1994: 26; Rolán, 2008: 233; Nekhaev et al., 2014: 269) and has a global distribution, ranging in both hemispheres from the poles to at least the subtropics (Ponder, 1985: 55; Rolán, 2008: 233; Avila et al., 2012: 4).

It is currently subdivided into some few subgenera: *Onoba* (type species *Turbo striatus* J. Adams, 1797), *Ovirissoa* Hedley, 1916 (type species *Rissoa adarensis* Smith, 1902), *Subestea* Cotton, 1944 (type species *Alvania seminodosa* May, 1915) and *Manawatawhia* Powell, 1937 (type species *M. analoga* Powell, 1937).

Seven central-western Mediterranean species, most of which have been described during the last forty years, are currently ascribed to the nominal subgenus (Rolán, 1983: 139; Aartsen et al., 1984: 20; Templado & Rolán, 1986: 117; Oliverio et al., 1986: 35; Moolenbeek & Hoenselaar, 1987: 153; Hoenselaar & Moolenbeek, 1987: 17; Amati & Nofroni, 1991: 30; Smriglio & Mariottini, 2000: 15;

Giannuzzi-Savelli et al., 2002: 80; Rolán, 2008: 233; Gofas et al., 2011: 193; Avila et al., 2012: 5; Bouchet, 2014); these species are: *Onoba semicostata* (Montagu, 1803), *O. gianninii* (Nordsieck, 1974), *O. tarifensis* Hoenselaar et Moolenbeek, 1987, *O. guzmani* Hoenselaar et Moolenbeek, 1987, *O. josae* Moolenbeek et Hoenselaar, 1987, *O. dimassai* Amati et Nofroni, 1991 and *O. oliverioi* Smriglio et Mariottini, 2000. Another species, *O. aculeus* (Gould, 1841), geographically ranging typically on both sides of northern Atlantic including Greenland, has been reported only once from the Mediterranean Sea (Giannuzzi-Savelli et al., 2002: 80).

The missing of new further records convinced some Authors to exclude this species from the main Mediterranean check-lists (Rolán, 2008: 241; Nekhaev et al., 2014: 272). A further possibly undescribed species has been recorded (*Onoba* sp.: Amati & Nofroni, 1991: 34), but never formally named. The anatomy of the genus *Onoba* has been studied by Ponder (1985: 56). Here we utilize the only shell morphology for the description and comparisons of the Mediterranean species. The most important iconographic references are reported for each species.

ABBREVIATIONS AND ACRONYMS. BA: Bruno Amati collection, Rome, Italy. CS: Carlo Smriglio collection, Rome, Italy. IN: Italo Nofroni collection, Rome, Italy. lv: live collected specimen. MCZR: Museo Civico di Zoologia, Rome, Italy. MNHN: Muséum National d'Histoire Naturelle, Paris, France. MO: Marco Oliverio collection, Rome, Italy. MZB: 'Museo di Zoologia' of the University of Bologna, Italy. PM: Paolo Mariottini collection, Rome, Italy. RAMM: Exeter's Royal Albert Memorial Museum & Art Gallery, Exeter, Devon, UK. SB-MS: Stefano Bartolini-Maria Scaperotta collection, Florence, Italy. SEM: Scanning Electron Microscope. sh: empty shell. v.: versus. ZMA: Zoological Museum, Amsterdam, The Netherlands.

## SYSTEMATICS

Family Rissoidae Gray, 1847: 152 (as *Rissoaina*)  
Genus *Onoba* H. Adams et A. Adams, 1852: 358  
Type-species: *Turbo striatus* J. Adams, 1797 non Da Costa, 1778 = *Onoba semicostata* (Montagu, 1803: 326 (by monotypy))

MORPHOLOGY. Diagnosis shell of genus *Onoba* (from Ponder, 1985: 54): “Shell: minute to small,

ovate-conic to elongate-ovate, non-umbilicate to narrowly umbilicate, smooth or with weak to strong spiral sculpture, with a few spiral keels. Axial sculpture usually rather weak to very weak; sometimes axial ribs present but do not extend over base; sculpture rarely clathrate. Aperture with simple peristome, oval, weakly angled and channelled posteriorly, simple and rounded anteriorly; outer lip opisthocline, varix weak to heavy. Protoconch dome-shaped, sometimes with 1 or more spiral keels; smooth (*Ovirissoa*) or with microsculpture of granules, anastomosing or spirally aligned raised threads or, sometimes, wavy, spirally arranged rows of granules. Periostracum very thin to well developed”.

Diagnosis shell of subgenus *Onoba*: (from Ponder, 1985: 56): “Shell: broadly ovate-conic to elongate ovate, rather solid, non-umbilicate, usually with many well developed spiral cords and, sometimes, weak axial ribs; microsculpture of fine spiral lirae usually present. Strong spiral cords in a few species and, in some species, surface smooth. Aperture subcircular, subangled and weakly channelled posteriorly, varix on outer lip strong to moderate. Protoconch domeshaped of about 1 1/2 whorls in nearly all species, rarely up to 2 2/4 whorls (as in *O. 'semicostata'*); sculptured variously, for example, with exceedingly weak to moderately strong spiral lines with either parallel to oblique wrinkles or granules between, as in *O. aculea* (Gould) and *O. moreleti* Dautzenberg and in Fretter & Graham's (1978) figure of *O. 'semicostata'*; with irregular, raised, wavy threads, as in *O. foveauxiana* (Suter); with scattered granules, as in *O. fumata*, *O. kermadecensis* (Powell) and several other southern species, as well as *O. n. sp.* from the Eocene of France; (see also Thiriot Quievreux & Babio, 1975; Fretter & Graham, 1978).”

### *Onoba semicostata* (Montagu, 1803) (Figs. 1–6)

*Turbo striatus* J. Adams, 1797: 66 non da Costa, 1778: 86

*Turbo semicostatus* Montagu, 1803: 326, pl. XXI, fig. 5

*Rissoa ecostata* Michaud, 1830 (WoRMS: Bouchet, 2014)

*Rissoa minutissima* Michaud, 1830 (WoRMS: Bouchet, 2014)

*Rissoa peticularis* Menke, 1830 (WoRMS: Bouchet, 2014)

*Onoba candida* (Brown, 1827) (Giannuzzi-Savelli, 2002: 80)

ICONOGRAPHIC REFERENCES. Montagu (1803: 326, pl. XXI, fig. 5); Reeve (1878: pl. V fig. 40 as *Rissoa striata*); Rolán (1983: 139, 140, 3 unnumbered figures as *Onoba aculeus* and 5 unnumbered figures as *Onoba striata*); Rolán (2008: 234, figs. 1-12); Giannuzzi-Savelli et al. (2002: 80, fig. 255 as *Onoba candida* (Brown, 1827)); Nekhaev et al. (2014: 269, figs. 1 A–B, 4 A, D).

TYPE LOCALITY. Atlantic Ocean, south coast of Devonshire, United Kingdom.

TYPE MATERIAL. Not seen. Probable syntypes in Montagu collection (RAMM)

EXAMINED MATERIAL. Norway: Grande, Viken, -100/200 m, 07.1974, 1 sh (BA); Spain: Vigo-Baiona, North-West Atlantic, beached, 08.1982, 1 sh (IN); Vigo Bay (Atlantic) -15 m (legit Palazzi, 1982), 11 juv. sh (IN); Fuengirola, (Malaga) beached (ex coll. Bogi), 1 sh (IN); France: Carteret, Normandy, (Atlantic, 1976), beached, 1 sh (IN); Binard (Atlantic, 1975) among littoral seaweeds, 2 lv (IN); no locality, 1 sh (IN).

ORIGINAL DESCRIPTION. Montagu, 1803: “*T. with a short, conic, white shell, obtusely pointed: volutions four or five, rounded, well defined by the separating line, and wrought with faint ribs, and fine obsolete transverse striae on the body whorl, both of which are inconspicuous on the superior spires: the ribs do not extend to the lower part even of the body, where the spiral transverse striae become most conspicuous: aperture suborbicular; pillar lip a little reflexed, Columella smooth. Length half a line; breadth one half its length. Found in sand on the south coast of Devonshire, but very rare. This at first sight might be confounded with Turbo Spiralis, but differs in the volutions being more rounded, in the ribs being coarser, and in being destitute of the tooth-like plication of the columella.*”

DISTRIBUTION AND HABITAT. Eastern Atlantic, Madera (Ávila et al., 2012), Spain (Rolán, 2008), British Isles (Jeffreys, 1867: 37; Fretter & Graham, 1978), Faroe Islands (Warén, 1996; Sneli et al., 2005), Iceland (Warén, 1996), Norway (Høisæter, 2009). Barents Sea, Kola Peninsula (Golikov & Kussakin, 1978; Nekhaev et al., 2014: 271). Mediterranean Sea (Ávila et al., 2012), Alboran

Sea, Fuengirola (Giannuzzi-Savelli et al., 2002: 80). Common and abundant under rocks and among algae, from the intertidal to -1000 m depth (Templado & Rolán, 1986: 120); common on rocks in -8 m, less common in -80 m, rare under -200 m in the Zelenetskaya Bay, Barents Sea (Nekhaev et al., 2014: 272).

REMARKS. *Onoba semicostata* is the only Mediterranean *Onoba* with a planktotrophic larval development, and is therefore easy to identify (Rolán, 2008: 35, figs. 3–6; Nekhaev et al., 2014: 276, figs. 4 A, D). Shells tend to be curved (var. *distorta* Marshall fide Jeffreys, 1887: 35) and occasionally may have an additional labial varix. Shells collected in the central Mediterranean are probably fossils (Würm). *Onoba aculeus* differs from *O. semicostata* in having a paucispiral protoconch (indicating a non planktotrophic development), a slightly scalariform suture with more convex whorls without subsutural axial ribs. *Onoba breogani* Rolán, 2008, known, at moment, for Galicia (Spain, Atlantic), is very similar to *O. semicostata* in shell morphology, having also subsutural axial ribs, but differs in its paucispiral protoconch.

***Onoba aculeus*** (Gould, 1841) (Figs. 7, 8)

*Cingula aculeus* Gould, 1841: 266, fig. 172

*Rissoa saxatilis* Möller, 1842: 9

*Rissoa artica* Lovén, 1846: 156

*Rissoa multilineata* Stimpson, 1851: 14

*Onoba aculeus* (Gould, 1841) (Giannuzzi-Savelli et al., 2002: 80)

ICONOGRAPHIC REFERENCES. Gould, (1841: 172, fig. 172) (not a good picture); Bouchet & Warén (1993: 660, fig. 1507); Delongueville & Scaillet (2001: 12, fig. 10); Giannuzzi-Savelli et al. (2002: 80, fig. 254); Nekhaev et al. (2014: 272, figs. 2 C–D, 4 B, E).

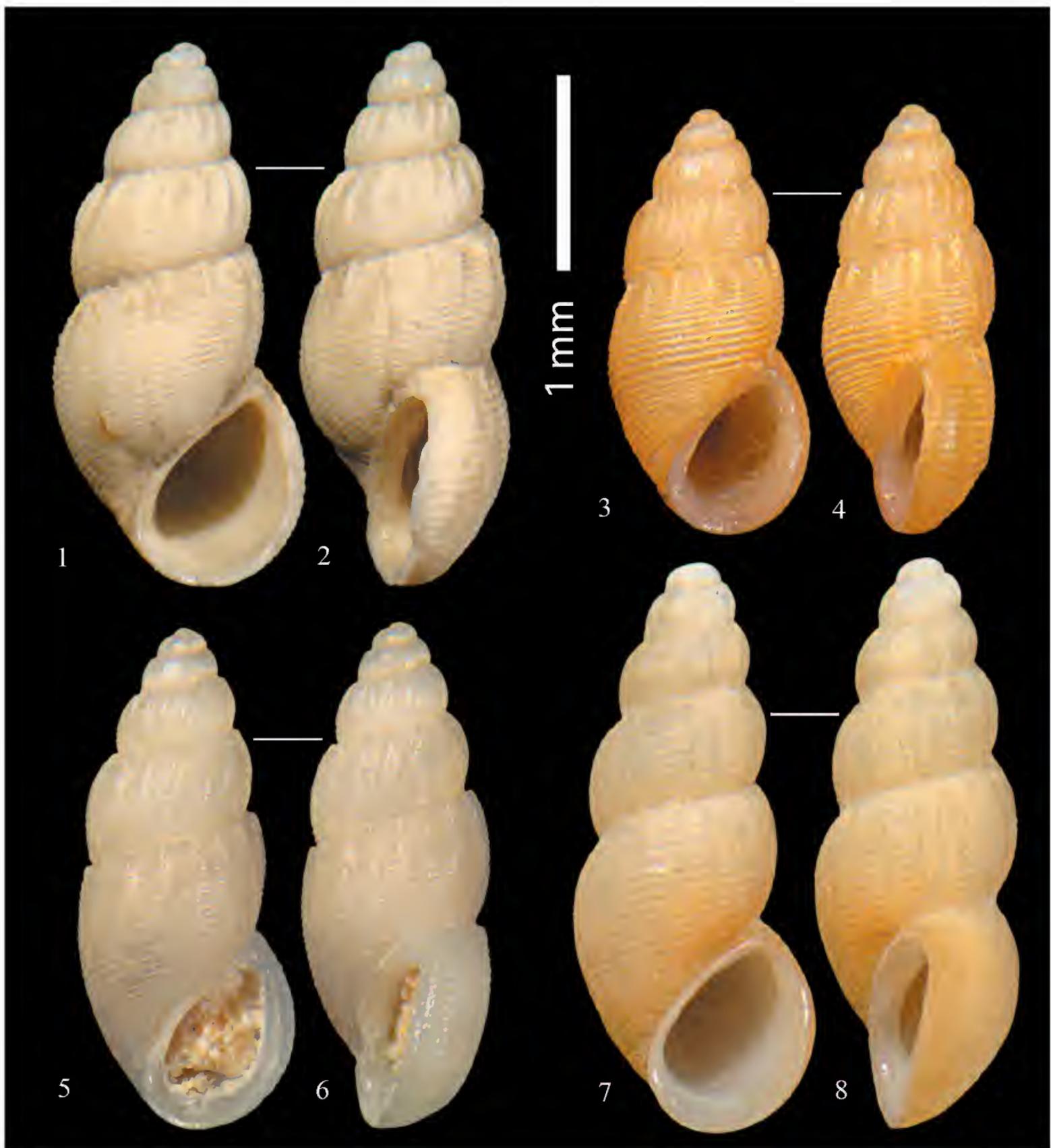
TYPE LOCALITY. East Boston, Massachusetts (USA).

TYPE MATERIAL. Not seen. Originally deposited at the Boston Society of Natural History (BSNH: State Coll., No. 32. Soc. Cab., No. 2359. Gould, 1841: vi, 266).

EXAMINED MATERIAL. Bergen (Norway, Atlantic), -1 m, 2 lv (IN).

ORIGINAL DESCRIPTION. Gould, 1841: “Shell minute, sub-cylindrical; whorls convex, covered with regular, microscopic revolving lines; aperture ovate; umbilicus partial. Shell minute, ovate-cylindrical, elongated, light yellowish horn-color; whorls six, convex, and separated by a deep sutural region; the two upper ones forming a blunt apex,

the lowest rather more than half the length of the shell; the whole covered with regular, crowded, microscopic revolving lines; aperture one third the length of the shell, oval, oblique, angular behind, the margin simple and entire, barely touching the preceding whorl, somewhat expanded, and on the left side elevated, and slightly turned over an



Figures 1–6. *Onoba semicostata* (Montagu, 1803): Figures 1, 2. Grande, Viken (Norway, Atlantic), height 2.9 mm (BA). Figures 3, 4. Binard (France, Atlantic), height 2.3 mm (IN). Figures 5, 6. Fuengirola, (Spain, Mediterranean Sea), height 2.7 mm (IN). Figures 7, 8. *Onoba aculeus* (Gould, 1841), Bergen (Norway, Atlantic), height 3.05 mm (IN).

*umbilical depression or chink; operculum horny. Length 3/20 inch, breadth 1/15 inch, divergence 23°. Found sparingly on the partially decayed timbers of an old wharf, and plentifully on stones, about low-water mark, at East Boston.*"

DISTRIBUTION AND HABITAT. Western Atlantic (Gould, 1841), Greenland (Møller, 1842; Schiøtte & Waren, 1992), Eastern Atlantic, Faroe Islands (Snelli et al., 2005), Iceland (Ingólfsson, 1996; Waren, 1996), British Isles (Fretter & Graham, 1978), Northern Norway (Høisæter, 2009). Barents Sea, Kola Peninsula and White Sea (Golikov, 1987), Galicia (Templado & Rolán, 1986: 121). Mediterranean Sea, Alboran Sea (Giannuzzi-Savelli et al., 2002: 80). Very common in the Barents Sea in 0/-3 m on sandy bottoms (Nekhaev et al., 2014: 272). The species seems to prefer shallow waters with algae, and can tolerate brackish waters (Templado & Rolán, 1986: 121).

REMARKS. The record from Ria de Vigo (Galicia: Templado & Rolán, 1986: 121) is the southernmost occurrence in the Atlantic Ocean, whilst the Alboran Sea record (Giannuzzi-Savelli et al., 2002: 80) should represent the southern limit overall. Shells tend to be curved. *O. aculeus* is very similar to *O. galaica* Rolán, 2008, from Galicia (Spain). Whilst some measurements of teleoconchs (e.g. number of spirals cords on the penultimate and the body whorl) and protoconchs (maximum diameter) are similar in the two species (Rolán, 2008), the different protoconch sculpture (with fine spiral cords in *O. aculeus* and almost smooth in *O. galaica*) (Fretter & Graham, 1978; Warén, 1996; Rolán, 2008) and the less marked teleconch microsculpture, along with other minor differences (e.g. deeper suture, larger size according to Warén, 1996) allow an easy separation of *O. aculeus* and *O. galaica*. See below under *Onoba semicostata* for the differences from *Onoba aculeus*.

***Onoba dimassai*** Amati et Nofroni, 1991 (Figs. 9–12)

*Onoba dimassai* Amati & Nofroni, 1991: 30, figs. 1–4

ICONOGRAPHIC REFERENCES. Amati & Nofroni (1991: 30, figs. 1–4); Giannuzzi-Savelli et al. (2002: 82, 83, fig. 256)

TYPE LOCALITY. San Felice Circeo, Central Tyrrhenian Sea, Italy -30/50 m.

TYPE MATERIAL. Holotype (MCZR), 9 paratypes (loc. type) (BA), 2 paratypes (type loc.) (IN), 1 paratype (type loc.) (coll. Di Massa, Trieste), 2 paratypes Ventotene Is., Central Tyrrhenian Sea -25 m (MCZR ex coll. Pizzini), 7 paratypes Ventotene Is., Le Sconcioglie Shoal, Central Tyrrhenian Sea, -41 m (MO), 3 paratypes Ponza Is., Central Tyrrhenian Sea, bioclastic sand sample *Posidonia oceanica* -15 m, 04.1979 (coll. A. Lugli, MO), 1 paratype Ponza Is., Central Tyrrhenian Sea, -35 m, 05.1983 (coll. Di Massa TS), 1 paratype S. Stefano Is., Central Tyrrhenian Sea, -40 m (MZCR ex coll. Pizzini), 1 paratype Giannutri Is., Central Tyrrhenian Sea, -27 m (MZCR ex coll. Pizzini), 1 paratype Giglio Is., Central Tyrrhenian Sea, -30 m, 06.1983 (coll. Di Massa, Trieste).

EXAMINED MATERIAL. Type material; Italy: Ponza Is., Central Tyrrhenian Sea, -35 m, 1982-83, 3 sh (BA); Giglio Is., Central Tyrrhenian Sea, -30 m, 05.1983, 1 sh (BA); Ventotene Is., Central Tyrrhenian Sea, -40 m, Summer 2000, 9 sh (BA); 3 sh (topotypes) (BA); Zannone Is., Central Tyrrhenian Sea, -36.5 m, about 60 sh (IN). Egypt: Port Said, 1 sh (IN).

ORIGINAL DESCRIPTION. Amati & Nofroni 1991: "Conchiglia di piccole dimensioni, ovato-conica, elongata, fragile, semitrasparente, non ombelicata. Protoconca ottusa di 1,20-1,25 giri convessi, lisci; dimensioni: diametro del nucleo mm 0,13-0,18, diametro del primo mezzo giro mm 0,25-0,28; diametro massimo mm 0,30-0,38. Teleoconca di 2-3 giri convessi, separati da una linea di sutura evidente e leggermente canalicolata. Ultimo giro abbastanza ampio, pari a circa i 2/3 dell'altezza totale. Apertura ovale, angolata posteriormente, arrotondata e leggermente svasata anteriormente; labbro ortocline semplice, tagliente, liscio, leggermente inspessito esternamente. Scultura costituita da numerosi cordoncini spirali (24-30 sull'ultimo giro); a forte ingrandimento tutta la superficie, sia i cordoncini che lo spazio tra gli stessi, appare percorsa da strie spirali filiformi. Sono presenti deboli strie di accrescimento ortocline. Colore biancastro, ma gli esemplari più freschi appaiono leggermente giallastri. Opercolo e parti molli sconosciuti: Dimensioni: h. mm 1,40-2,10; d. mm 0,90-1,15; Rapporto d/2h 0,273-0,343."

DISTRIBUTION AND HABITAT. Central Mediterranean Sea in the infralittoral zone in algal facies -15/50 m, also reported for Port Said (Egypt).

REMARKS. *Onoba dimassai* may have occasionally an additional labial varix on teleoconch. Compared to that of *O. dimassai*, the shell of *O. josae* is larger and stronger (H 2.2–3.2 mm v. H 1.4–2.2 mm in *O. dimassai*), deeper suture v. canaliculate in *O. dimassai*; stronger and more spaced spiral sculpture than in *O. dimassai*; outer lip slightly opisthocline v. orthocline in *O. dimassai*; protoconch sculptured with 8 thin and irregular spiral cordlets v. an apparently smooth protoconch (also at SEM) in *O. dimassai*. *Onoba tarifensis* has a more slender shell with a more cylindrical outline and a finer, less incised sculpture, consisting in a higher number of spiral cordlets both on the penultimate and on the body whorl (18–24 and 31–38, respectively v. 8–15 and 18–30 in *O. dimassai*); a protoconch sculptured with 7 thin and irregular spiral cordlets v. an apparently smooth protoconch (also at SEM) in *O. dimassai*. *Onoba gianninii* has a larger shell (H 2.2–2.6 mm v. H 1.4–2.2 mm in *O. dimassai*), is usually collected at greater depths (-93/500 m v. -15/50 m for *O. dimassai*), has a finer teleoconch sculpture, with a higher number of spiral cordlets on the body whorl (30–40 v. 18–30 in *O. dimassai*), and finally differs in having a clear umbilical chink, absent in *O. dimassai*.

***Onoba josae*** Moolenbeek et Hoenselaar, 1987 (Figs. 13-15, 27)

*Onoba moreleti* sensu van Aartsen et al. (1984: 20 fig. 81), not Dautzenberg, 1889

*Onoba josae* Moolenbeek & Hoenselaar (1987: 153 figs. 6-8)

ICONOGRAPHIC REFERENCES. van Aartsen et al., 1984: 20, fig. 81; Moolenbeek & Hoenselaar, 1987: 153, figs. 6–8; Giannuzzi-Savelli et al., 2002: 82, 83, figs. 260–261; Gofas et al., 2011: 193, two unnumbered figures; Scaperrotta et al., 2013: 62, five unnumbered figures.

TYPE LOCALITY. Getares, Bay of Algeciras, Spain.

TYPE MATERIAL. Not seen. Holotype (ZMA Moll. no. 3.87.034), 40 paratypes (ZMA Moll. no. 3.87.035), 40 paratypes (coll. H.J. Hoenselaar), 1 paratype (MNHN of Parigi), 1 paratype (IRScNB),

4 juv. paratypes Spain, Getares, 3 paratypes Getares, 28 paratypes Getares (coll. H.J. Hoenselaar), 19 paratypes Getares (ZMA no. 3.87.036 and coll. H.P.M.G. Menkhorst).

EXAMINED MATERIAL. Italy: S. Felice Circeo, Central Tyrrhenian Sea, -30/50 m, 07/1982, 1 sh (BA); Spain: North of Getares (Cadiz - Mediterraneo), legit Gubbioli, 09/1987, 3 sh and 9 fragments, beached (IN); Tarifa -30 m, 1 sh (SB-MS).

ORIGINAL DESCRIPTION. Moolenbeek & Hoenselaar, 1987: “Description of the holotype. – Length 2.5 mm, width 1.3 mm (fig. 6). Shell oval-conical, semitransparent with some gloss on the surface, umbilicum closed. Protoconch dome-shaped, with about 1 ¼ whorls and with 8 weak and irregular spirals, protruding very little. Teleoconch about 3 ¼ whorls with smooth spiral cords. The interstices are broader than the spiral cords (ratio 1:2) and are covered with 7-8 very fine, somewhat undulating spiral striae. Penultimate whorl with about 9 spiral cords. The upper half of the penultimate whorl with very weak costae. Body whorl somewhat convex, with about 22-24 spiral cords. Aperture subcircular below and rather angular above (angle about 90°), weakly channeled posteriorly. Peristome simple, sharp and continuous. Outer lip clearly opisthocline. Colour white. Operculum, periostracum and soft parts unknown.”

DISTRIBUTION AND HABITAT. Strait of Gibraltar, -30 m. One specimen without soft parts from Latal coast (Italy), in bioclastic sediment, -30/50 m.

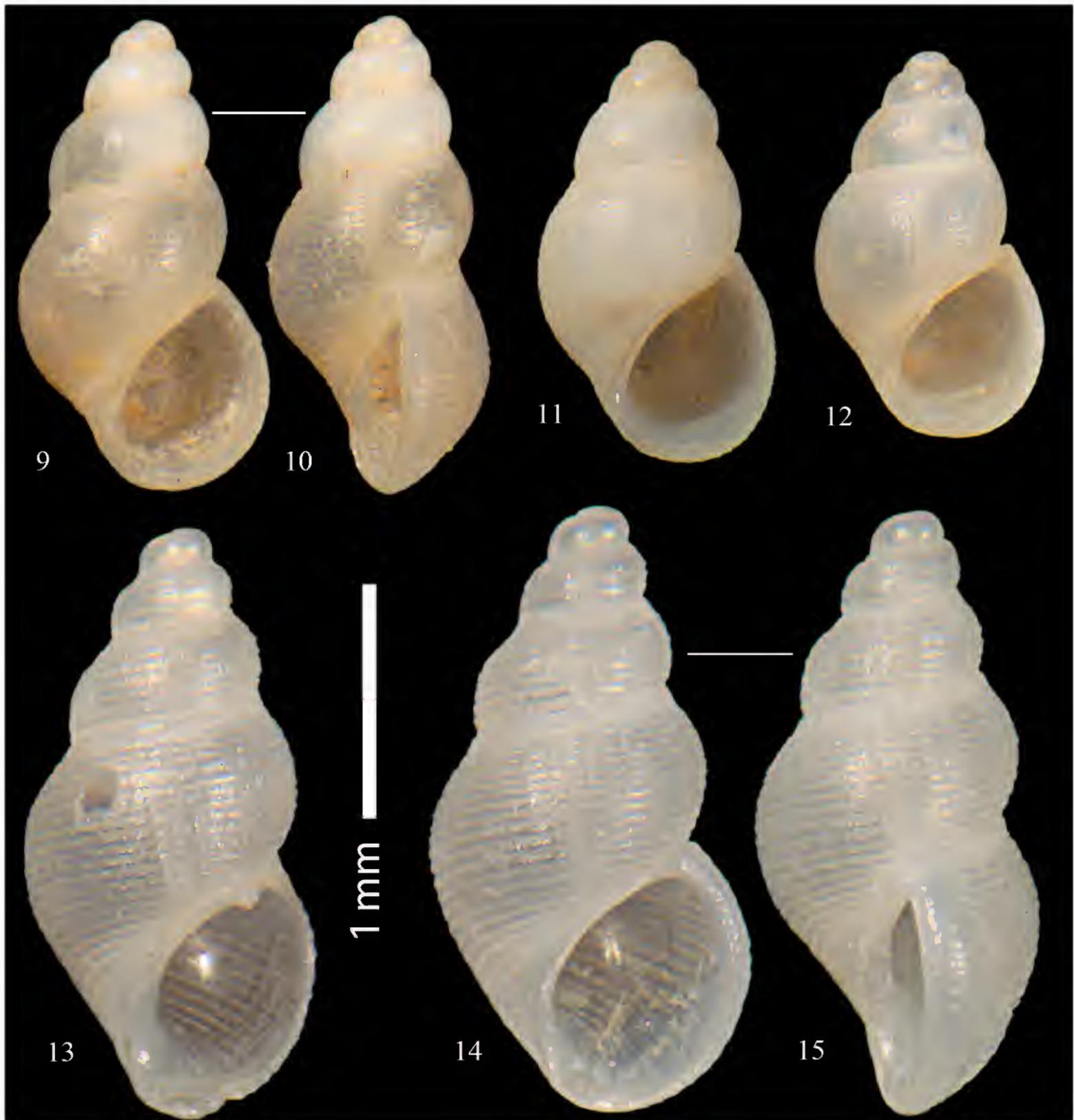
REMARKS. van Aartsen et al. (1984) erroneously identified specimens from Getares (Spain) with *O. moreleti* Dautzenberg, 1889 (Ponder, 1985: 162, figs. 113c, d; Moolenbeek & Hoenselaar, 1987: 155, figs. 1–5), currently considered endemic to the Azores (originally reported as living at great depths, but later collected also in shallower waters: Gofas, 1990: 125). So far, *O. josae* was never reported from outside the area of Gibraltar Strait. The specimen collected in the Central Tyrrhenian and herein reported is the first record from outside that area. The record is based on a single, partly broken and empty adult shell (Fig. 13) so it does not provide information on the local population viability. The shell was sorted out from a sample collected by fishing nets residuals from -30/50 m depth, along with many specimens of *O. dimassai*. *Onoba moreleti* differs from *O. josae* in having a more slender and smaller shell, (1.7–1.9 mm v. 2.2–3.2 in *O. josae*),

less convex spire, smaller aperture, more or less dark yellowish colour v. white colour in *O. josae*, and a lower number of spiral cordlets both on the penultimate whorl and on the body whorl (respectively 8–9 and 16–17 v. 9–14 and 22–26 in *O. josae*). *Onoba josae* may have thin subsutural axial ribs and, very rarely, an additional labial varix.

***Onoba guzmani*** Hoenselaar et Moolenbeek, 1987 (Figs. 21, 22)

*Onoba guzmani* Hoenselaar & Moolenbeek 1987: 19, figs. 7–12

ICONOGRAPHIC REFERENCES. Hoenselaar & Moolenbeek (1987: 19, figs. 7–12); Giannuzzi-



Figures 9–12. *Onoba dimassai* Amati et Nofroni, 1991: Figures 9, 10. San Felice Circeo, Central Tyrrhenian Sea (Italy) paratype, height 2.05 mm (BA). Figure. 11. San Felice Circeo, Central Tyrrhenian Sea (Italy) paratype, height 1.85 mm (BA). Figure. 12. Port Said (Egypt), height 1.7 mm (IN). Figures 13–15. *O. josae* Moolenbeek et Hoenselaar, 1987: Figure. 13. San Felice Circeo, Central Tyrrhenian Sea (Italy), height 2.57 mm (BA). Figures 14, 15. Getares Nord, Cadiz (Spain, Mediterranean Sea), height 2.6 mm (IN).

Savelli et al. (2002: 82, 83, fig. 258); Gofas et al. (2011: 193, 1 unnumbered figure).

TYPE LOCALITY: Tarifa, Spain.

TYPE MATERIAL. Not seen. Holotype (ZMA Moll. no. 3.87.003), 10 paratypes (ZMA Moll. no. 3.87.004), 25 paratypes (coll. Hoenselaar), 3 paratypes, Spain, Tarifa, IV.1985 (ZMA Moll. no. 3.87.005).

EXAMINED MATERIAL. Spain: Getares North, Cadiz (Mediterranean) legit Nofroni, 08/1985, 1 sh, beach (IN); Tarifa -30 m, 1 sh (SB-MS).

ORIGINAL DESCRIPTION. Hoenselaar & Moolenbeek, 1987: "Description of the holotype. - Length 1.8 mm, width 0.80 mm (fig. 7). Shell minute, elongate-conic, non-umbilicate, fragile, semitransparent with some gloss on its surface. Protoconch dome-shaped, 1 ¼ whorls, smooth. Teleoconch with 2 ¾ whorls with microscopical pit-marks more or less forming spirals (fig. 9). Suture deep; whorls concave. On the base 4 shallow spirals (fig. 10). Aperture ovate or drop-shaped, with an opisthoclinal outer lip, varix small or lacking, peristome simple (figs. 10, 12). Operculum, periostracum and soft parts of the animal unknown."

DISTRIBUTION AND HABITAT. Reported for the Strait of Gibraltar and Tangier (Atlantic Morocco) and Tarifa (Spain) -30 m.

REMARKS. *Onoba guzmani* is very similar to *O. lincta* (Watson, 1873), endemic to Madeira (Atlantic) (Watson, 1873: 387), which has a different teleoconch sculpture of fine spiral threads and some strong cords on the base (v. numerous series of microtubercles spirally arranged, and 4 spiral cordlets on the base) and the suture more incised, canaliculated. The protoconch of *O. tarifensis* it is sculpted by 7 weak spiral cordlets (v. smooth in *O. guzmani*), a different teleoconch sculpture of 31–38 fine spiral cordlets on the last whorl (v. numerous series of microtubercles spirally arranged, and 4 spiral cordlets on the base) (Hoenselaar & Moolenbeek, 1987, figs 3 and 9) and a stronger labial varix.

***Onoba tarifensis*** Hoenselaar et Moolenbeek, 1987 (Figs. 23, 24)

*Onoba tarifensis* Hoenselaar & Moolenbeek, 1987: 17, figs. 1–6

ICONOGRAPHIC REFERENCES. Hoenselaar & Moolenbeek (1987: 17, figs. 1–6); Giannuzzi-Savelli et al. (2002: 82, 83, fig. 259); Gofas et al. (2011: 193, 1 unnumbered figure).

TYPE LOCALITY. Tarifa, Spain.

TYPE MATERIAL. Not seen. Holotype (ZMA Moll. no. 3.87.001), 8 paratypes (ZMA Moll. no. 3.87.002), 15 paratypes (coll. Hoenselaar), 1 paratype, Tarifa, IV.1985 (coll. Hoenselaar).

EXAMINED MATERIAL. Spain: Tarifa, Cadiz, legit Gubbioli, 1988, beach, 1 sh (IN); Tarifa -30 m, 1 sh (SB-MS); Punta Carnero, Getares, 1 sh (CS); Cala Cica, Getares, 1 sh (CS).

ORIGINAL DESCRIPTION. Hoenselaar & Moolenbeek, 1987: "Description of the holotype. - Length 1.55 mm, width 0.76 mm (figs. 1–4, 6). Shell minute, elongate-conic, non-umbilicate, fragile and semitransparent, some gloss on its surface. Protoconch dome-shaped, a little less than 1 ½ whorls with about 7 smooth spiral cords (fig. 6). Between these cords there is a microsculpture of rows of exceedingly minute irregular pits, except for the first ½ whorl which looks smooth. Teleoconch with 2 ½ whorls, with a very fine spiral sculpture of more or less smooth spiral cords/ribs; in between these cords a spongy sculpture of irregular pits (fig. 3). Penultimate whorl with about 20 spiral cords, body whorl with about 38 spiral cords. Suture deep, whorls concave. On the base a strong spiral columellar twist (fig. 4). Aperture ovate with an opisthoclinal outer lip and a strong varix (fig. 5), peristome simple, weakly angled and channeled posteriorly, simple and rounded anteriorly. Operculum, periostracum and soft parts of the animal unknown."

DISTRIBUTION AND HABITAT. Reported for the Strait of Gibraltar (Spain) 0/-30 m.

REMARKS. *Onoba josae* compared to *O. tarifensis*, has a stronger and larger shell with fewer spiral cordlets both on the penultimate whorl and on the body whorl (9–14 and 22–26 respectively v. 18–24 and 31–38 respectively in *O. tarifensis*). See under *O. guzmani* for distinction from *O. tarifensis*.

***Onoba gianninii*** (Nordsieck, 1974) (Figs. 18–20)

*Setia (Crisillosetia) gianninii* Nordsieck, 1974: 11, fig. 4

*Cingula gianninii* (Nordsieck, 1974) (See Verduin, 1984: 61, fig. 25)

*Setia gianninii* Nordsieck, 1974 (See Amati & Nofroni, 1991: 32)

ICONOGRAPHIC REFERENCES. Nordsieck (1974: 11, fig. 4); Verduin (1984: 61, fig. 25); Oliverio (1988: 113, fig. 1 (operculum and radula)); Amati & Nofroni (1991: 32, figs. 6–10); Bouchet & Warén (1993: 662, figs. 1518, 1519); Ardochini & Cossignani (1999: 38, fig. 035); Smriglio & Mariottini (2000: 17, figs. 7, 8); Giannuzzi-Savelli et al. (2002: 82, 83, fig. 257); Scaperrotta et al. (2012: 63, 5 unnumbered figures).

TYPE LOCALITY. Strait of Bonifacio, Corsica, 'station K1', -200/220 m.

TYPE MATERIAL. Lectotype (designated by Amati & Nofroni, 1991) MCZR, 1 paralectotype (coll. Giannini, Empoli). Bouchet & Warén (1993: 662) reported some "paratypes" in coll. Carrozza, coll. van Aartsen and coll. SMNH (not listed in the original work), which should be more correctly defined as "paralectotypes".

EXAMINED MATERIAL. Lectotype (MCZR); France: Bastia, Corsica, depth (unprecised) bioclastic sands sample, 1 sh (BA); Italy: Capraia Is., Northern Tyrrhenian Sea, -400 m, 1 sh (BA); off Fiumicino, Central Tyrrhenian Sea, -300 m, 4 sh (BA); Capraia Is., Northern Tyrrhenian Sea, -350 m, 3 sh (IN); Capraia Is., Northern Tyrrhenian Sea, 1 sh (Bogi collection, Livorno).

ORIGINAL DESCRIPTION. Nordsieck, 1974: "Setia (Crisillosetia) gianninii n. sp. 3/1,7 mm. Olotipo nella collezione Giannini. Pallida, semitrasparente; 5 giri molto convessi, il primo (protoconca) attenuato. Sutura profonda. Circa 30/40 striae spirali sull'ultimo giro, 15 sul penultimo. Sottile plica ombelicale. Comparando questa indubbiamente nuova specie con tutte le altre del sottogenere (v. tavola R IV del Vol. III) ci si avvede che non esiste alcuna altra specie ad essa avvicinata sia per la convessità dei giri, il numero delle spirali e le misure della conchiglia."

DISTRIBUTION AND HABITAT. Central Mediterranean Sea: Corsica (France), Sardinia, Tuscany and Latium (Italy), Algeria -93 m. (Bouchet & Warén, 1993: 663). In bioclastic sediments from -93/500 m depth.

REMARKS. *O. gianninii* may sometimes have an additional labial varix. *O. oliverioi* and *O. gianninii* have been found sympatric in the Central Tyrrhenian Sea, in the deepest bathymetric range of *O. gianninii* (-200/600 m *O. oliverioi* v. -93/500 m of *O. gianninii*). The shells of these two species are very similar; *O. oliverioi* differs mainly for the smaller size (H 1.6–2.3 mm at 2.5–3 whorls v. H 2.5–2.6 mm at 2.5–3.25 whorls in *O. gianninii*), the flatter more sculpted and slightly smaller protoconch, (maximum diameter 0.40–0.44 mm v. 0.46 mm (fide Bouchet & Warén, 1993: 663 in *O. gianninii*), the less slender outline (H/W = 1.44/1.65 v. H/W = 1.66–1.80 in *O. gianninii*), and the larger aperture (H/Ha = 1.84–2.16 v. H/Ha = 2.18–2.22 in *O. gianninii*). See under *O. dimassai* for distinction from *O. gianninii*.

***Onoba oliverioi*** Smriglio et Mariottini, 2000 (Figs 16, 17)

*Onoba oliverioi* Smriglio & Mariottini, 2000: 16, figs. 1–6

ICONOGRAPHIC REFERENCES. Bouchet & Warén (1993: 663, figs. 1520, 1521) (sub nomine *Onoba gianninii*); Smriglio & Mariottini (2000: 16, figs. 1–6).

TYPE LOCALITY. Central Tyrrhenian Sea (41° 51' N, 11° 28' E) off coast of Latium -350/600 m.

TYPE MATERIAL. Holotype (MZB 14000); 1 paratype, type locality (MCZR); 9 paratypes, type locality (CS); 1 paratype, type locality (MO); 1 paratype, type locality (PM).

EXAMINED MATERIAL. Type material partly examined: type locality, 9 paratypes (CS), type locality, 1 paratype (MCZR).

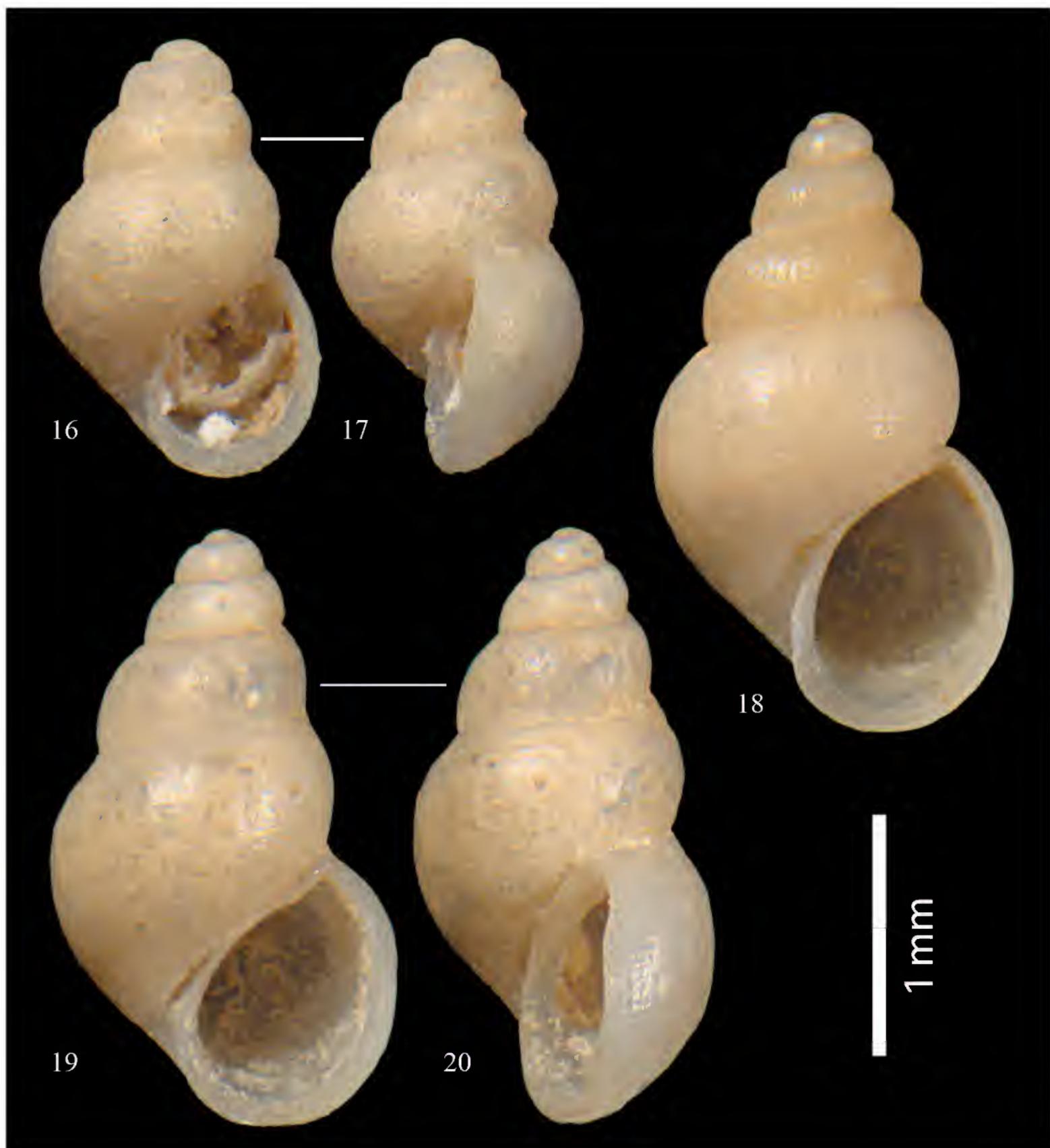
ORIGINAL DESCRIPTION. Smriglio & Mariottini, 2000: "Shell small (from 1.61 to 2.32 mm in height), conical-ovate, with a large aperture, blunt apex. Protoconch dome-shaped consisting of about 1.5 whorls, with a diameter of 400–440 µm, sculptured with 6–8 fine and irregular spiral cordlets. Among them, several other interrupted fine furrows create a sort of micro-tuberculated sculpture. Teleoconch of about 3.0 rounded convex whorls, the last one is about 2/3 of the entire length, average ratio H/W = 1.55, average ratio H/Ha = 1.99. Suture pronounced and shallowly channeled, axial growing lines evid-

ent, spiral sculpture consisting of about 27 evenly spaced ribs, with about 2-3 much smaller furrows in the inter-spaces. Aperture ovoid, umbilical crevice slightly visible. Colour milky-white or yellowish translucent. Operculum and animal unknown.”

DISTRIBUTION AND HABITAT. Italy: Central Tyrrhenian Sea: Latium and Sardinia. France: Corsica. On

muddy bottom in a deep-sea coral biocoenosis (biocoenosis VB and CB sensu Pérès & Picard, 1964) at a depth of -200/600 m (Bouchet & Warén, 1993: 663; Smriglio & Mariottini, 2000: 16).

REMARKS. *Onoba oliverioi* is characterized by having a shell with a low H/W ratio and to live at a maximum depth of -600 m. *O. oliverioi* differs



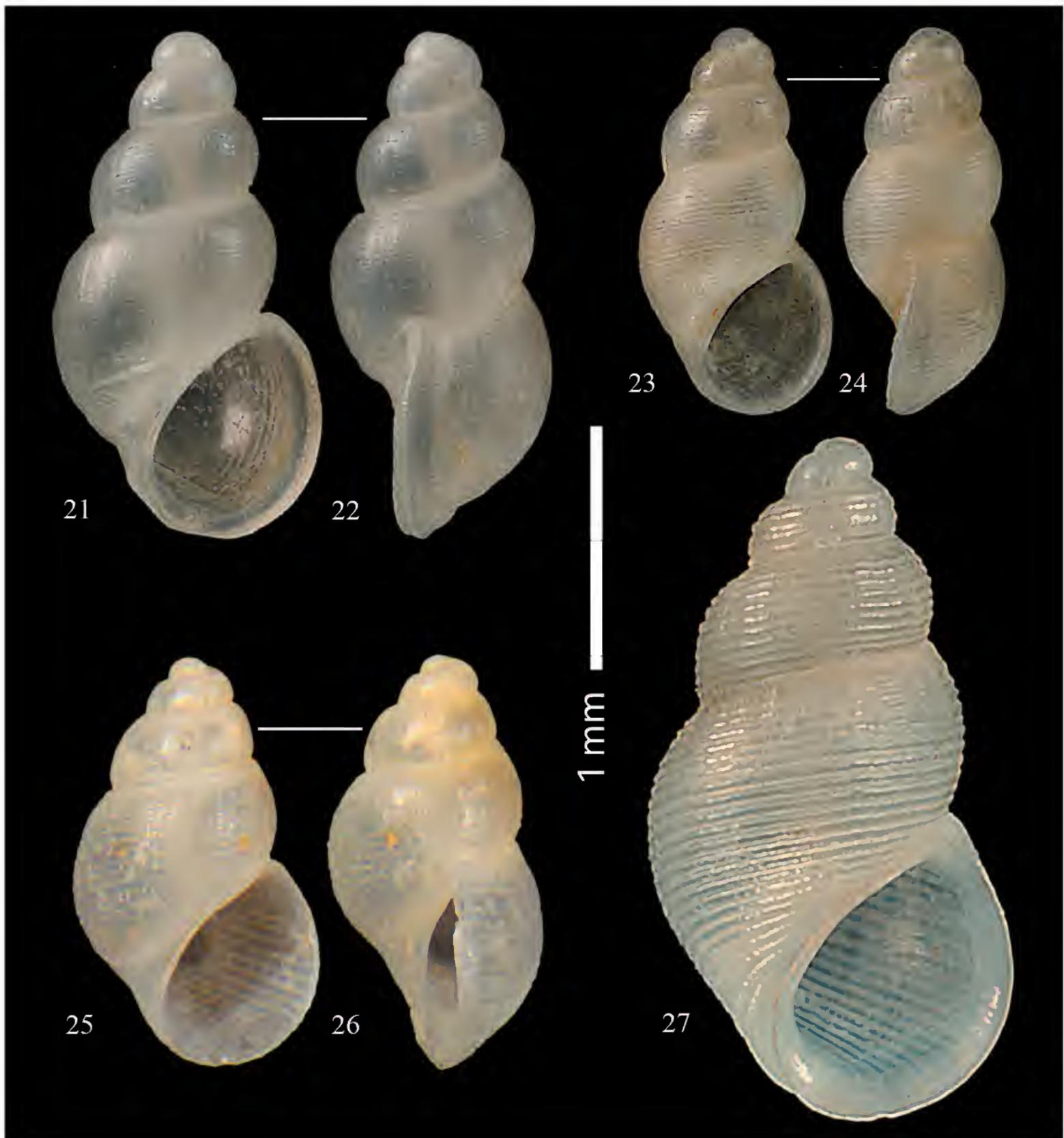
Figures 16–17. *Onoba oliverioi* Smriglio et Mariottini, 2000, Central Tyrrhenian Sea, Latium (Italy) paratype H, height 1.8 mm (CS). Figure 18. *O. gianninii* (Nordsieck, 1974): Fiumicino, Central Tyrrhenian Sea (Italy), height 2.6 mm (BA). Figures 19, 20. *O. gianninii*: Bastia, Corsica (France), height 2.5 mm (BA).

from *O. dimassai* for the deeper habitat (-200/600 m v. -15/50 m in *O. dimassai*), by its higher number of protoconch whorls (about 1.5 v. 1.2–1.25 in *O. dimassai*), the protoconch sculptured with 6–8 fine irregular spiral cordlets v. an apparently smooth protoconch (also at SEM) in *O. dimassai* and a larger maximum diameter of the protoconch (0.40–0.44

mm v. 0.30–0.38 mm in *O. dimassai*). The number of the spiral cordlets on the teleoconch is broadly similar in the two species (about 25–30). See under *O. gianninii* for distinction from *O. oliverioi*.

*Onoba* sp. (Figs. 25, 26)

*Onoba* sp. A. Amati & Nofroni, 1991: 34, fig. 5



Figures 21, 22. *Onoba guzmani* Hoenselaar et Moolenbeek, 1987, Tarifa (Spain), height 2.1 mm (SB-MS). Figures 23, 24. *O. tarifensis* Hoenselaar et Moolenbeek, 1987, Tarifa (Spain), height 1.6 mm (SB-MS). Figures 25, 26. *Onoba* sp. San Felice Circeo, Central Tyrrhenian Sea (Italy), height 1.7 mm (BA). Figure 27. *O. josae* Moolenbeek et Hoenselaar, 1987, Tarifa (Spain), height 2.8 mm (SB-MS).

Character	<i>Onoba semicostata</i>	<i>Onoba aculeus</i>	<i>Onoba dimassai</i>	<i>Onoba josae</i>	<i>Onoba guzmani</i>	<i>Onoba tarifensis</i>	<i>Onoba gianninii</i>	<i>Onoba oliverioi</i>
H	1.8-3.5	2.0-4.5	1.4-2.2	2.2-3.2	1.4-2.1	1.45-1.75	2.5-2.6	1.61-2.32
W	1.15-1.35	1.35-2.0	0.9-1.15	1.3-1.5	0.7-1.1	0.75-0.82	1.5-1.55	1.08-1.4
Ha	1.0-1.15	1.08-1.1	0.75-0.95	1.1-1.2	0.59-0.95	0.72-0.75	1.2-1.3	0.85-1.11
R.H/W	2.0-2.59	2.25-2.36	1.56-1.82	1.63-1.81	1.9-1.98	2.0-2.06	1.66-1.8	1.44-1.65
R.H/Ha	2.30-3.04	2.77-2.96	1.88-2.21	2.0-2.22	2.21-2.37	2.22-2.39	2.18-2.22	1.84-2.16
Tcs	yes	yes	no	no	no	no	no	no
St	deep, and channeled	deep, slightly to scalariform	slightly channeled	deep	deep	deep	deep	pronounced and shallow channeled
Nw	2.8-3.8 (5/5.5)*	3.8 (4.5/5.6)*	2-3	3.25-3.5	2.75-3	2.5-2.75	2.5-3.25	2.5-3
Nspw	12-15	10-14	8-15	9-14	microscopical pit-marks more or less forming spirals	18-24	15-17	11-12
Nslw	25-29	22-24	18-30	22-26	4 shallow spirals on the base	31-38	30-40	23-31
Asc	yes	occasionally, pronounced striae of growth	no	occasionally	no	no	no	no

Table I. Ranges of morphometric characters of the teleoconch in Mediterranean species of the genus *Onoba*. Measurements in mm. H: height; W: width; Ha: height aperture; R.H/W: ratio height/width; R.H/Ha: ratio height/height aperture; Tcs: Tendency to curved shells; St: Suture; Nw: number of teleoconch whorls; Nspw: Spiral cords on the penultimate whorl; Nslw: number of spirals cords on the last whorl; Asc: Axial subsutural cords. \*( ) Da Nekhaev et al., 2014. Probably also include the whorls of the protoconch.

ICONOGRAPHY REFERENCES. Amati & Nofroni (1991: 34, fig. 5)

EXAMINED MATERIAL. Italy: San Felice Circeo, Central Tyrrhenian Sea, -30/50 m, VIII.1982, legit Angelo Amati, 1 sh (BA).

DESCRIPTION. Shell small, fragile, ovate-conical shape, semi-transparent, non umbilicated. Protoconch dome-shaped, paucispiral, with slightly twisted nucleus, consisting of just over one whorl (estimate uncertain, protoconch-teleoconch boundary not clearly visible), 0.25 mm high, with a nucleus diameter of 0.13 mm and a maximum diameter of 0.32 mm without microsculpture as seen at a magnification of 90x. Teleoconch of 2.8 convex whorls with deep suture. Outer lip not tickened (probably the specimen was not fully adult) orthocone. Sculpture of 24 fine and flat spiral cordlets on the body whorl, 12 of which above the aperture. Finer threads covering the entire surface, visible at a magnification of 90x. Color white. Operculum and soft parts unknown.

Dimensions: H = 1.7 mm, W = 1.05 mm, Ha = 0.84 mm, H/W ratio = 1.619; H/Ha ratio = 2.023.

DISTRIBUTION AND HABITAT. San Felice Circeo, Central Tyrrhenian Sea, Italy, a single shell in organogenic detritus in the infralittoral at -30/50m. Found sympatric with *O. dimassai* and *O. josae*.

REMARKS. The single shell, so far known, is peculiar among the European *Onoba*, in its particular apex, with a paucispiral protoconch and a twisted nucleus. It is easily recognizable from all other species. *Onoba dimassai* is similar in the fragile shell, the white colour, the orthocone outer lip and the teleoconch spiral sculpture. It differs, however, in the different (not twisted) apex and the wider and more spaced teleoconch spiral cordlets. *O. nunezi* Rolán et Hernandez, 2004, endemic to the Canary Islands, is slightly smaller (about H 1.3 mm v. H 1.7 mm in *Onoba* sp.), is more slender, has a teleoconch spiral sculpture of about 10 weak well-spaced cordlets and the whole teleoconch surface is covered with finer and more numerous threads (Rolán & Hernandez, 2004: 174). *Manzonina vigoensis* (Rolán, 1983) was described as belonging to the genus *Onoba* but later Moolenbeek & Faber (1987)

and Moolenbeek & Hoenselaar (1992) assigned it to the genus *Manzonina* Brusina, 1870; it resembles *Onoba* sp. for the general shape of the shell and the paucispiral protoconch with a twisted nucleus; but differs for the different sculpture of the teleoconch, with aligned micro-perforations a thickened outer lip both typical of the genus *Manzonina*.

## ACKNOWLEDGMENTS

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# The endemic door snail of Marettimo (Egadi Islands, Sicily, Italy): *Siciliaria (Siciliaria) scarificata* (L. Pfeiffer, 1856) (Pulmonata Clausiliidae)

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## ABSTRACT

The door snail *Siciliaria (Siciliaria) scarificata* (L. Pfeiffer, 1856) (Pulmonata Clausiliidae) is redescribed. The species is endemic to Marettimo (Egadi Islands, Sicily, Italy) and it is the only one of the genus *Siciliaria* Vest, 1867 living in this island. *Siciliaria scarificata* can be morphologically identified by the presence of a high columellar lamella, ascending in a double “S” curve, a wide anterior upper palatal plica, long basal plica, sulcalis present; clausilium plate distally less narrowed; genitalia are characterized by very short bursa copulatrix duct; short diverticulum of bursa copulatrix; penial papilla conic and short. Notes about its taxonomy, biology and conservation status are also provided.

## KEY WORDS

Door snail; *Siciliaria*; island endemism; taxonomy; conservation status.

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## INTRODUCTION

Vest (1867) described the genus *Siciliaria* for a group of door snail species from Sicily with *S. grohmanniana* Rossmässler, 1836 type species.

Adolf Schmidt (1868) classified the seven sicilian species known so far, into two groups which mainly differ by the formation of the clausilium plate and by sculpture, development of lamellae (inserta, inferior lamella) and palatal plicae. The first group is reported as: “Formenkreis of *semplicata*” which includes *Clausilia grohmanniana*, *C. septemplicata* Philippi, 1836, *C. calcarae* Philippi, 1844, *C. confinata* Benoit, 1859 (= *scarificata* L. Pfeiffer, 1856), and *C. tiberii* A. Schmidt, 1868; the second group as “Formenkreis of *crassicostata*” with *C. crassicostata* L. Pfeiffer, 1856 and *C. nobilis* L. Pfeiffer, 1848.

O. Boettger (1877) named as *Siciliaria* Vest, 1867 sensu stricto the “Formenkreise of *semplicata*”, and as *Trinacria* O. Boettger, 1877 the “Formenkreise of *crassicostata*”. Nordsieck (1979) listed the same species as O. Boettger (1877) and reunited the species groups (*Siciliaria* s. str., *Trinacria* (preoccupied) = *Sicania* Tomlin) because *S. calcarae* has an intermediate morphological position. Nordsieck (2002) listed 12 species of *Siciliaria* s.str., sub *Charpentieria (Siciliaria)*, and classified them in two species groups, based on some shell characters.

Nordsieck (2007), in his catalog on world Clausiliidae, listed 12 species with 7 subspecies of *Siciliaria* s.str., even as *Charpentieria (Siciliaria)*: *Siciliaria (Siciliaria) calcarae calcarae*, *S. calcarae belliemii* (Brandt, 1961), *S. crassicostata*, *S. eminens* (A. Schmidt, 1868), *S. ferrox* (Brandt,

1961), *S. grohmanniana*, *S. leucophryna* (L. Pfeiffer, 1862), *S. nobilis*, *S. riberothi* (Brandt, 1961), *S. scarificata* (L. Pfeiffer, 1856), *S. septem-  
plicata septemplicata*, *S. septemplicata alcamoensis* (Brandt, 1961), *S. septemplicata hemmeni* Beckmann, 2004, *S. spezialensis* (H. Nordsieck, 1984), *S. tiberii tiberii*, *S. tiberii scalettensis* Beckmann, 2004.

This checklist is confirmed by Bank (2011) and by Nordsieck (2013).

The genus *Siciliaria* s. str. is endemic to Western Sicily, from Caccamo in the East to the island of Marettimo in the West, and from San Vito lo Capo in the North, to Castelvetro and Ribera in the South. The hot spot of biodiversity are the mountains in the northern part, whereas in the central and southern area (Sicani Mountains) the presence of *Siciliaria* is discontinuous. The genus *Siciliaria* s. str. is reported in Quaternary deposits of Palermo (De Gregorio, 1886: Monte Pellegrino; 1927: Pietrazzi, Bellolampo; our personal data: Mount Catalfano) and in the Quaternary deposit of Wied tal-Bahrija in the Island of Malta (Giusti et al., 1995).

*Siciliaria scarificata* was discovered by the sicilian naturalist Luigi Benoit (1804–1890) who distributed shells of this door snail to his malacologists colleagues under the name of *Clausilia confinata*. Luis Pfeiffer (1856) published the first valid description with the name *C. scarificata* (Fig. 1) reporting its distribution as “Habitat in Sicilia”. Subsequently, L. Pfeiffer (1859) specified the distribution as “*in insula Maretima Siciliae*”. However in the course of 1800s and up to about the 1970s most authors used the name *C. confinata* Benoit or the incorrect spelling *C. sacrificata* Benoit, 1875 (see below). The original description and all subsequent descriptions were based on shell features; while genitalia were never described and illustrated.

This paper is intended to redescribe this species in detail (shell and genitalia) and also provided notes about its taxonomy, biology and conservation status.

## MATERIAL AND METHODS

All living specimens were relaxed in water and then preserved in 80% ethanol. Five specimens were anatomically investigated under a Leica MZ12.5 stereomicroscope using scalpel, scissors and needles. Empty shells were kept dry, and have been measured with a digital gauge. The plicae and

lamellae were studied breaking the shells with a scalpel. The method of calculating the number of whorls by Kerney & Cameron (1979) was used. Shell measures were based on the study of 20 specimens. Photos were carried out with a Panasonic Lumix DMC-FZ20 digital camera. Anatomical details were drawn using a Wild camera lucida. The collection data are listed as follows: State, region, municipality, locality, altitude, dates, collection and number of specimens in parentheses. Toponyms (place-names) are reported following Map “IGM 1: 25000, Isola di Marettimo, sheet 256 IV - N.O.”. Each locality and/or collection site is named in the original language (italian).

Voucher specimens were stored in the following Museums and private collections: F. Liberto, Cefalù, Italy (LC); Museo Naturalistico F. Minà Palumbo, Castelbuono, Italy (MNMP); A. Reitano, Tremestieri Etneo, Italy (RC); I. Sparacio, Palermo, Italy (SC).

CONCHOLOGICAL ACRONYMS. AUPP: Anterior upper palatal plica; CL: columellar lamella; D: shell width; H: shell height; L: lunella; LPP: lower palatal plica (basal plica); PL: parietal lamella; PLL: parallel lamella; PP: principal plica; PUPP: posterior upper palatal plica; SCL: sub-columellar lamella; SL: spiral lamella; SUL: sulcalis; SP: sutural plica. ANATOMICAL ACRONYMS. BC: bursa copulatrix; BCD: diverticulum of bursa copulatrix; DBC: duct of the bursa copulatrix; E: epiphallus; FO: free oviduct; G: penial papilla; GA: genital atrium; P: penis; PR: penial retractor muscle; V: vagina; VD: vas deferens.

## SYSTEMATICS

Family CLAUSILIIDAE J.E. Gray, 1855

Genus *Siciliaria* Vest, 1867

Type species: *Clausilia grohmanniana* Rossmässler, 1836

*Siciliaria (Siciliaria) scarificata* (L. Pfeiffer, 1856)

*Clausilia scarificata*, L. Pfeiffer, 1856: 185, Pl. 2, figs. 20–22 - Habitat in Sicilia

*Clausilia scarificata*, L. Pfeiffer, 1859: 765–766 - Habitat in insula Maretima Siciliae

*Clausilia confinata*, Benoit, 1859: Pl. 6, fig. 6

*Clausilia scarificata*, Küster, 1860–1861: 298, Pl. 34, figs. 1–3 - Insel Maretima



Figure 1. Reproduction of original drawing of *Siciliaria (Siciliaria) scarificata* (L. Pfeiffer, 1856). Figure 2. Map of Western Sicily, the arrow shows the position of Marettimo. Figures 3, 4. *Siciliaria scarificata* in natural habitat. Figures 5, 6. Landscape of Marettimo, slope with Mediterranean maquis.

*Clausilia confinata*, Vest, 1867: 167

*Clausilia confinata*, A. Schmidt, 1868: 40–42

*Clausilia confinata*, Appellius, 1869: 173

*Medora scarificata*, Kobelt, 1871: 39

*Clausilia sacrificata*, Benoit, 1875: 152 - isola di Marettimo

*Siciliaria confinata*, Möllendorff, 1875: 17

*Clausilia confinata*, L. Pfeiffer, 1877: 523 - Ins. Marettimo Siciliae

*Clausilia (Siciliaria) confinata*, O. Boettger, 1877:

33, "gruppe *Siciliaria*" - Sicilien

*Clausilia confinata*, Westerlund, 1878: 20 - Sicilia

*Clausilia sacrificata*, O. Boettger, 1879: 89, Pl. 172, fig. 1731 - Insel Marettimo im Westen von Sicilien

*Clausilia (Siciliaria) sacrificata*, Kobelt, 1881: 78 - Marettimo

*Clausilia confinata*, Benoit, 1882: 105 - isola di Marettimo

- Clausilia confinata*, Westerlund, 1884: 46 - Mare-  
tino bei Sicilien
- Clausilia (Siciliaria) confinata*, Monterosato, 1892:  
28 - Isola di Maretimo
- Clausilia (Siciliaria) confinata*, Westerlund, 1892: 48
- Clausilia (Siciliaria) confinata*, Westerlund, 1901:  
39-40, 180 - I. Maretimo
- Delima (Siciliaria) scarificata*, Wagner, 1924: 124  
- Insel Maretimo im w. Von Sizilien
- Clausilia (Siciliaria) confinata*, Sacchi, 1955: 23
- Siciliaria confinata*, Sacchi, 1956: 8-9
- Siciliaria confinata*, Sacchi, 1957: 673
- Delima (Siciliaria) confinata*, Alzona, 1971: 91,  
sectio *Siciliaria* - Is. Marettimo
- Siciliaria (Siciliaria) scarificata*, Nordsieck, 1979:  
259
- Siciliaria (Siciliaria) scarificata*, Manganelli et al.,  
1995: 24, 47 - Isola di Marettimo (Egadi)
- Charpentieria (Siciliaria) scarificata*, Nordsieck,  
2002: 33-34
- Charpentieria (Siciliaria) scarificata*, Beckmann,  
2004: 186, 188 - Insel Marettimo
- Siciliaria scarificata*, Fiorentino et al., 2004 -  
Marettimo
- Charpentieria (Siciliaria) scarificata*, Nordsieck,  
2007: 54
- Charpentieria (Siciliaria) scarificata*, Bank, 2011:  
23 - Sicily
- Siciliaria scarificata*, Welter-Shultes, 2012: 342 -  
S. Italy, Marettimo island
- Siciliaria (Siciliaria) scarificata*, Nordsieck, 2013:  
1-14

TYPE LOCALITY. Marettimo (Egadi Islands, Sicily, Italy). This species was communicated by the naturalist Luigi Benoit to L. Pfeiffer who published the first valid description reporting its distribution as "Habitat in Sicilia" (L. Pfeiffer, 1856).

EXAMINED MATERIAL. Italy, Sicily, Favignana, Island of Marettimo (Egadi Islands), Punta Troia, 50 m, VIII.1997, 3 shells (RC); idem, Case Romane, 200 m, VI.2005, 23 shells (RC); idem, VI.2005, 4 shells (RC); idem, from Case Romane to Monte Falcone 300-680 m, 30.V.2010, 11 specimens, 60 shells, (LC 8021-8096); idem, VI.2005, 3 shells (MNMP); idem, contrada Pelosa, 60 m, 30.V.2010, 16 specimens and 42 shells (SC); idem, Case Romane, 200 m, 30.V.2010, 18 shells (SC).

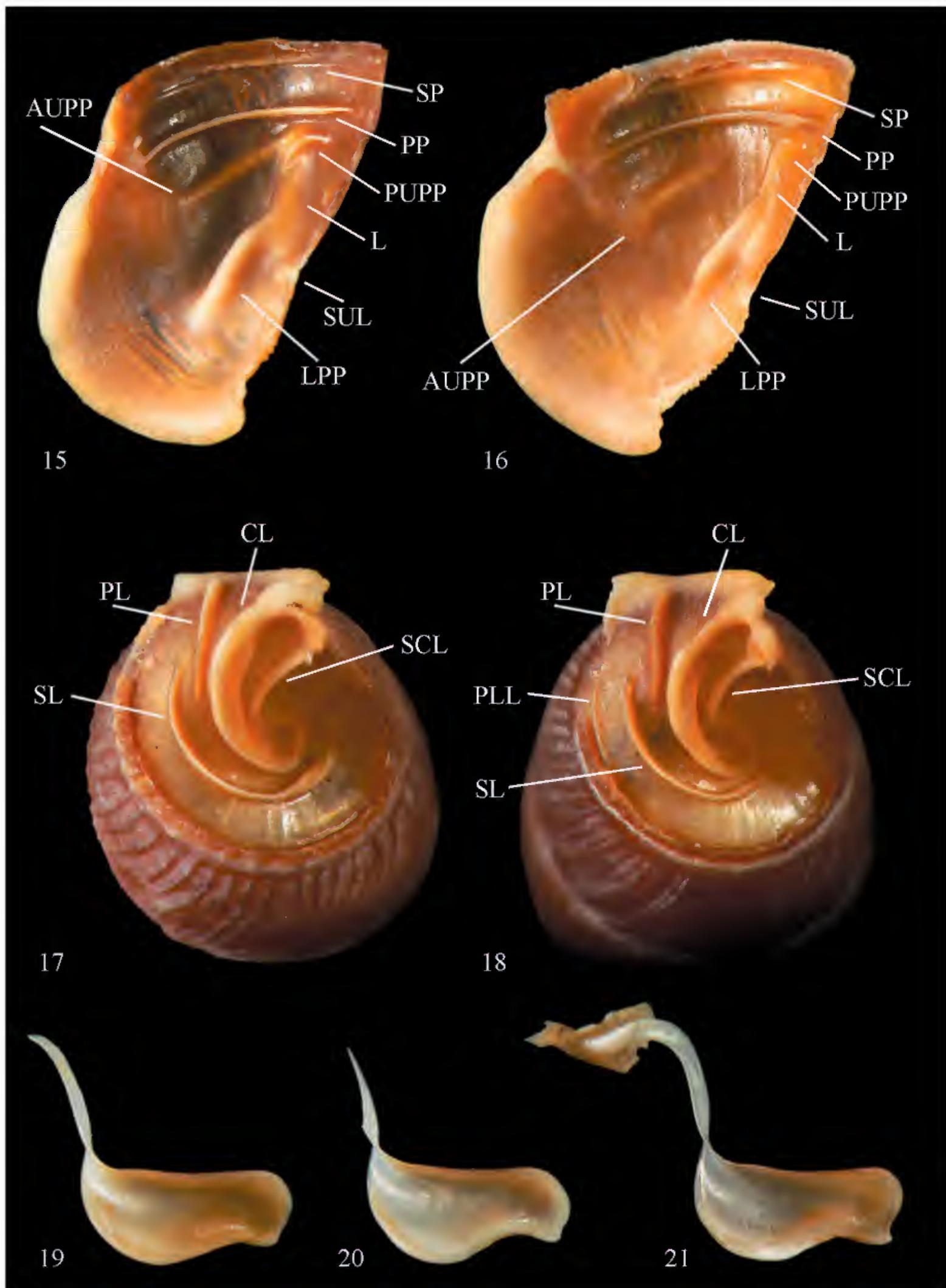
ORIGINAL DESCRIPTION. L. Pfeiffer (1856): "*T. rimata, fusiformis, truncata, solida, confertim plicato-costulata, purpurascens-fusca; spira ventrosa, sublate decollata; sutura albo-papillata; anfr. superst. 7 1/2 convexiusculi, ultimus basi breviter cristatus; apertura piriformis; lamella supera exigua, marginem non attingens, infera valida, arcuatim ascendens; lunella distincta, angusta, flexuosa; plicae palatales 3, suprema elongata, secunda brevior, antice callosa, tertia infera, sub-columellari parallela; perist. hepaticum, continuum, breviter solutum, undique expansum et reflexiusculum. - Long, (trunc.) 17, diam. 5 mill. Ap. 5 mill. longa, 4 lata*".

DIAGNOSIS. Terrestrial pulmonate snail with shell sinistral, fusiform, brown-purplish in color; aperture with five lamellae (on parietum and columellar side) and lunella and five plicae (on palatum); in particular high columellar (lower parietal) lamella, ascending in a double "S" curve; a wide anterior upper palatal plica; long basal plica; short sulcalis; genitalia are characterized by very short bursa copulatrix duct, short diverticulum of bursa copulatrix; penial papilla conic and short.

DESCRIPTION (Figs. 7-14). Shell sinistral, fusiform, elongated, generally decollated, rather thick and robust, brown-purplish in color, with apertural margin light brownish; obtuse apex; external surface with transverse ribs, 8.5 ribs per 2 mm of the penultimate whorl (10 specimens); spire with 9-10 slightly convex whorls (7 in decollate shells), slowly and regularly growing; sutures shallow, with slightly evident papillae (papillae more numerous along sutures from level with first 3-7 whorls); basal keel little distinct; umbilicus closed; aperture oval, with five lamellae (on parietum and columellar side) and lunella and five plicae (on palatum). On palatum there is a short lunella and starting from suture: a thin sutural plica very close to suture; a well raised principal plica; a wide anterior upper palatal plica, separated from or connected with upper palatal plica; long basal plica, internal beginning of which is joined to the base of lunella; a short sulcalis (Figs. 15, 16). A relatively conspicuous callosity on the upper external border of palatum embedding external apexes of upper palatal plica and principal plica. On parietum, starting from suture; there are: parallel lamella very thin or absent; non emergent spiral lamella in the centre of pari-



Figures 7–10. Shells of *Siciliaria (Siciliaria) scarificata* (L. Pfeiffer, 1856), Island of Marettimo, Sicily, Italy (CL 8032), H: 17.8 mm, D: 5 mm. Figures 11–14. *idem*, (CL 8033), H: 18.1 mm, D: 4.6 mm.



Figures 15–21. *Siciliaria (Siciliaria) scarificata* (L. Pfeiffer, 1856), Island of Marettimo, Sicily, Italy. Figures 15, 16: palatum (CL 8083, 8084). Figures 17, 18: parietum (CL 8085, 8088), Figures 19–21: clausilium (CL 8094–8096).

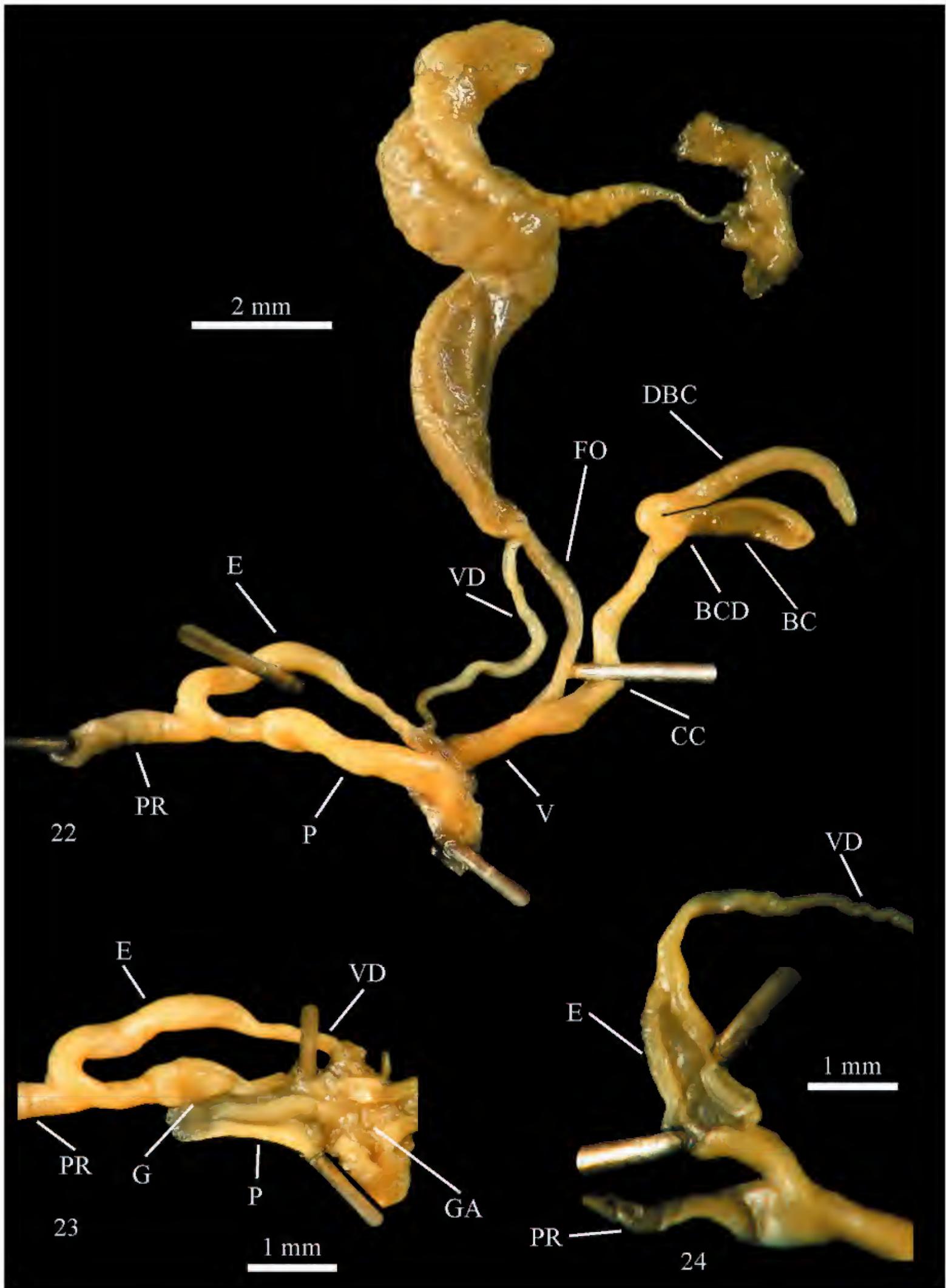


Figure 22. Genitalia of *Siciliaria (Siciliaria) scarificata* (L. Pfeiffer, 1856), Island of Marettimo, Sicily, Italy. Figure 23. Internal ornamentation of penis, with penial papilla (same specimen of Fig. 22). Figure 24. Internal ornamentation of epiphallus (CL 8022).

etum; tooth-like (upper) parietal lamella; high columellar (lower parietal) lamella, ascending in a double "S" curve; scarcely emergent subcolumellar lamella (Figs. 17, 18). Peristome continuous, thickened, reflected, fused above to last whorl wall. Normal type clausilial apparatus, with palatal edge of clausilium plate somewhat bent up, outer corner more or less pointed, sutural angle bent up (Figs. 19–21). The outer edge of the clausilium plate rests against the lunella and the sulcalis in the closed position.

Body. Animal narrow, posteriorly pointed, skin yellowish in color with brown-greyish tubercles; foot narrow with sole paler than body, bipartite by an indistinct longitudinal central groove and with margins divided by small parallel radial groove (5 specim. in alcohol preserved).

Genitalia (Figs. 22–24). General scheme of semidiaulic monotrematic type. Genitalia consisting of large ovotestis with many close acini; long thin, convoluted hermaphrodite duct; very large, albumen gland; well developed ovispermiduct, formed by female portion externally regularly subdivided and spaced by annular constrictions, large prostatic portion and seminal groove externally not visible; slender free oviduct (2.6 mm); bursa copulatrix complex consist of slender copulatory duct (2.9 mm) which branches in very short bursa copulatrix duct with leaf-like bursa copulatrix (2 mm), and slight longer diverticulum of bursa copulatrix (3.6 mm in length); vagina (1.8 mm in length) uniform in diameter for almost its entire length; vas deferens long and slender, entering epiphallus; epiphallus (3.9 mm) divided by point of insertion of robust penial retractor muscle into conical proximal portion and shorter cylindrical distal portion; a swelling is present at the transition penis-epiphallus; cylindrical penis (2.4 mm in length) slightly wider than vagina. Internal walls of penis with two furrows; relatively short, conic penial papilla with rounded apex (Fig. 23). Internal walls of epiphallus covered with small papille and crossed by two low pleats (Fig. 24).

DISTRIBUTION AND BIOLOGY. *Siciliaria scarificata* is endemic of the Island of Marettimo, the westernmost of the Egadi Islands, in Western Sicily (Fig. 2). It lives in limestone habitat with Mediterranean maquis, on walls and in the crevices of calcareous rocks, under stones, in conoids of debris and at the base of cliffs (Figs. 3–6).

REMARKS. Nordsieck (2002) classified the 12 species of *Siciliaria* s. str. in two groups, based on some shell characters. The first group is named "*nobilis-calcarae*" and is characterized by: columellar lamella (inferior lamella) low to moderately high, mostly only one anterior upper palatal plica present, clausilium plate distally not markedly narrowed, outer corner blunt to pointed. This group is further divided into two subgroups: "*nobilis*" subgroup (*S. nobilis*, *S. spezialensis*, *S. crassicostata*, and *S. eminens*) has palatal edge of clausilium plate not upbent; "*calcarae*" subgroup (*S. calcarae*, *S. tiberii*, and *S. leucophryna*) has palatal edge of clausilium plate more or less upbent. The second principal group is named "*grohmanniana*" (*S. grohmanniana*, *S. septemplicata*, and *S. scarificata*), it is characterized by columellar lamella high, two anterior upper palatal plicae present, clausilium plate distally narrowed with outer corner more or less pointed. *Siciliaria ferrox* and *S. riberothi* were not included in none of these groups because of ambiguous character combinations.

*Siciliaria scarificata* is considered transitional to the two principal groups, because it has inferior lamella less high, second anterior upper palatal plica missing, clausilium plate distally less narrowed. Nordsieck (2013) reaffirms *S. scarificata* is closely related to the other species of the "*grohmanniana*" group.

At present it is difficult to establish the real affinity between these species using only morphological observations. Consequently, discussion of the relationships of *S. scarificata* is postponed to when more data (molecular data in particular) will be available.

Here we add some morphological data for the "*grohmanniana*" group not considered by Nordsieck (2002; 2013). *Siciliaria grohmanniana* has a small "inserta lamella" (0.7 mm) placed between the columellar lamella and the spiral lamella, running from the point of arrest of clausilium outward. This lamella, reported by A. Schmidt (1868) for *S. grohmanniana* and also for *S. septemplicata*, is absent in *S. scarificata*. *Siciliaria grohmanniana* and *S. septemplicata* have a shorter sulcalis compared with *S. scarificata*. Welter-Shultes (2012) reports on a subclausalis, which we don't recognize.

The genitalia of *S. scarificata* are similar to those of other species of *Siciliaria* s. str. known: *S.*

*septemplicata* (Wagner, 1913, pl. 572, fig. 14), *S. grohmanniana* (Wagner, 1925, pl. 1, fig. 8) *S. calcarae* (Wagner, 1925, pl. 3, fig. 25), *S. ferrox* (Brandt, 1961, p. 7, 13, fig. 1). The duct of the bursa copulatrix is very short, and the diverticulum is slightly longer of the duct of the bursa copulatrix + bursa copulatrix; cylindrical penis; slight swelling at the conjunction penis-epiphallus.

Westerlund (1892) described two varieties of *S. scarificata* (sub *confinata*): *C. confinata merens* Westerlund, 1892, locus typicus "Sicilien, in der Provinz Palermo", which is a synonym of *S. leucophryna* (see Nordsieck, 2013), syntype in Göteborg Natural History Museum n° 2638, and *C. confinata commeata* Westerlund, 1892, locus typicus "Sicilien, bei Trabia" which is a probable older synonym of *S. ferrox* Brandt, 1961 (Reitano et al., 2007, Nordsieck, 2013).

CONSERVATION STATUS. Although *S. scarificata* has a scattered distribution over the whole island, its limited distribution to Marettimo justified an assessment as Lower Risk (Near Threatened) [NT, nt]. The Island of Marettimo is included in the SICp "Isola di Marettimo" (ITA 010002) and in the ZPS "Arcipelago delle Egadi - area marina e terrestre" (ITA 010027), however *S. scarificata* is not protected by any specific regulation or law, although it should be strongly recommended. Suggested measures include sympathetic habitat management and population monitoring.

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