The micro-insular distribution of the genus *Podarcis* within the Aeolian Archipelago: historical *vs*. palaeogeographical interpretation

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Several uninhabited islets of the Aeolian Archipelago harbour lacertid lizard populations, but only on three of these the autochtonous lizard Podarcis raffonei *occurs. A detailed analysis of the relative palaeogeographical and historical features suggests that human exploitation in particular, represents on of the main causes which have influenced their present-day micro-insular distribution.*

Keywords: *Podarcis raffonei*, *Podarcis sicula*, palaeogeography, history, Aeolian Islands.

Introduction

Two species of lizards of the genus *Podarcis* occur in the Aeolian Archipelago: the Italian Wall Lizard, *Podarcis sicula* (Rafinesque-Schmaltz 1810), and the threatened endemic Aeolian Wall Lizard, *P. raffonei* (Mertens 1952) (Fig. 1). A "micro-insular" pattern seems to characterise the present distribution of the latter species, which occurs on three islets (La Canna, Scoglio Faraglione, and Strombolicchio) and on some fragmented areas of Vulcano Island. According to Capula (1992) and Capula *et al.* (2002), the present-day absence of *P. raffonei* on the main islands is due to competitive exclusion and, extinction occurred as a consequence of the islands' colonisation by *P. sicula*. This hypothesis is strongly supported by the finding in the genome of *P. sicula* population of Lipari of some alleles typical of the *P. raffonei* genome (Capula 1994, 2004), which suggests a past hybridization and introgression of the two species followed by the extinction of *P. raffonei* on Vulcano Island. Therefore, *P. raffonei* is strongly believed to be distributed in the past on the whole (or at least on the mostern

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Fig. 1. Adult male of *Podarcis raffonei* from Strombolicchio Islet.

part) of the archipelago. On the other hand, *P. sicula* is nowadays common and widespread on the main islands and on several islets of the archipelago. It is an anthropochorous and invasive species, whose high colonisation capability and the competitive capacities during the colonization process, are confirmed by new recent records out of its distribution range (see Corti & Lo Cascio 2002, and references therein) and by some recent experimental evidences (Downes & Bauwens 2004).

Despite the lack of fossil evidences, it is highly probable that *P. sicula* could have reached and colonised the Aeolian Islands after the human settlement, which started 7,000 yr BP. In this perspective, the "persistence" of *P. raffonei* on Vulcano agrees with the recent anthropic colonisation of this island, which was steadily occupied by humans only in the 18th century. It is more difficult to explain the apparently "stochastic" distribution of both species on several small islets of the Aeolian Archipelago. Why on some islets *P. raffonei* still occurs and on others *P. sicula* is found (could the latter having replaced the autochthonous one)?

The aim of this paper is to discuss the possible causes of the present distribution pattern of these lizards on each single islet, analyzing historical and palaeogeographical data.

Study area

Apart from the seven main islands, the Aeolian Archipelago is composed by more than 30 "satellite" islets and rocks. Ten of these (Basiluzzo, Bottaro, Dattilo, Faraglione di Cala Fico, La Canna, La Nave, Lisca Bianca, Scoglio Faraglione, Spinazzola, and Strombolicchio) are inhabited by lacertid lizards (Corti *et al.* 1998, P. Lo Cascio, unpublished data). Furthermore, on Lisca Nera Islet lizards underwent extinction between the late 19th century and 1950s (Mertens 1955, Lanza & Corti 1996). The localisation of the islets and relative geographical data (surface and altitude) are given in Fig. 2.

Considering both geo-chemical characteristics and the age of formation, the islets are extremely diversified. Some of them are the remains of active volcanoes whose emersion occurred independently, while others got isolated due to erosive processes which definitively separate the islets from the main islands.

Geo-volcanological data

Basiluzzo and Spinazzola (off the NE coast of Panarea Island) were a unique rhyolitic endogenous dome, emerged about 60,000 yr BP (Gabbianelli *et al.* 1990, Ca-

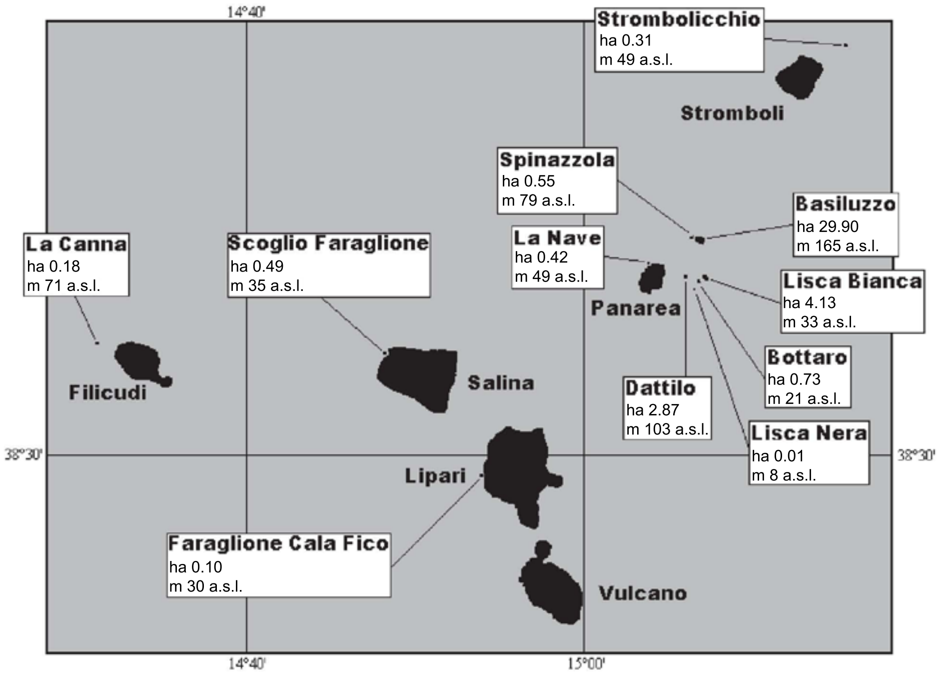

Fig. 2. Geographical data and localisation of the islets with lizards' populations.

lanchi *et al.* 1999) and successively fragmented due to erosive processes. The islets off the E coast of Panarea (Lisca Bianca, Dattilo, Bottaro, and Lisca Nera, Fig. 3) lie along a submerged crater rim, whose fumarolic activity had strongly altered their lavas. Lisca Bianca and Dattilo are mainly dacitic, while Bottaro and Lisca Nera are respectively andesitic and andesitic-dacitic. The emersion of this group (hereafter, "Lisca Bianca-group") started about 130,000-124,000 yr BP (Calanchi *et al.* 1999, Lucchi *et al.* 1999), but this eruptive centre continued to have explosive phases even after the emersion of the islets (probably until 10,000 yr BP), as indicated by the deposition of an andesitic-basaltic layer on the flat top of Basiluzzo and Lisca Bianca. La Nave (off the NW coast of Panarea) is an andecitic-dacitic dome belonging to the "Palaeo-Panarea" Volcano (155,000-125,000 yr BP), from which it was separated due to collapse and following erosive processes (Calanchi *et al.* 1999). Scoglio Faraglione is a basaltic fragment belonging to the "Perciato" formation (Salina Island), whose age is estimable as 20,000-40,000 yr BP. About 13,000 yr BP the islet was involved in the sub-Plinian eruption of the "Pollara" Volcano (De Rosa *et al.* 1989, Calanchi *et al.* 1993) which surely represented a great problem for the surviving of any faunistic element. Its separation from the main island took place after this eruptive activity. Strombolicchio (off the NE coast of Stromboli Island) is formed by andesitic-basaltic lavas which represent the neck of a volcano, emerged about 200,000 yr BP (earlier than the emersion of Stromboli) and later destroyed by erosive processes (Gillot & Keller 1993, Hornig-Kjarsgaard *et al.* 1993). Similarly, La Canna (off the W coast of Filicudi Island) has been recognised as the

Fig. 3. The "Lisca Bianca-group".

basaltic neck of an eruptive centre, active about 40,000 yr BP, and that successively underwent sea erosion (Santo *et al.* 1995, Tranne *et al.* 2002). Finally, Faraglione di Cala Fico represents a small part of the former W coast of Lipari Island, from which it probably separated relatively recently (Lucchi *et al.* 2004).

Vegetation

The vegetation of these islets is characterised by a quite wide variety both in terms of species richness and floristic assemblages. The smallest islets, such as La Canna or Faraglione di Cala Fico, are poorly covered and only few species occur. Strombolicchio, Spinazzola, and La Nave, formed only by very steep cliffs, display sparse halo-chasmophylous vegetation referred to the *Hyoseridetum taurinae-dianthetosum aeolici* or to the *Limonietum minutiflori*. The latter occurs also on the rocky cliffs of Scoglio Faraglione, whereas the top is covered by dense vegetation, referred to the *Senecioni bicoloris-Helichrysetum litorei*. Halo-nitrophilous formations dominated by chenopod species cover the plateaux of Lisca Bianca and Bottaro as well as most of Dattilo. Basiluzzo is characterized by a mosaic of xerophytic grassland referred to the *Hyparrhenietum hirto-pubescentis* and scattered spots of thermophilic shrubland dominated by *Pistacia lentiscus* and *Erica arborea* (Lo Cascio & Navarra 2003).

Palaeogeographical setting

The reconstructions of sea level variations for Late Pleistocene and Holocene show that from 18,000 yr BP to around 6,000-5,000 yr BP, the glacio-eustatic component of the sea level raised up to 120 m (Pirazzoli 1991, 1996; Mörner 1996; Fleming *et al.* 1998). Many records indicate, during the last 6,000 years, a relative stabilization of the sea level related to the decreasing melting process of the major ice sheets, and the sea level rising up to about 2 m (Nakada & Lambeck 1988, Lambeck 1993). Nevertheless the sea-level changes exhibited considerable spatial and temporal variability along the Tyrrhenian coasts (Lambeck *et al.* 2004, and references therein).

Unfortunately, no detailed data are available for the last sea level variations occurred in the SE Tyrrhenian Sea. In particular, for the Aeolian Archipelago, most of the recent studies focus mainly on marine terraces deposited on present-day sub-aerial zones (Bernasconi & Ferrini 1988, 1989; Corselli & Travaini 1989; Lucchi 2000; Lucchi *et al.* 1999, 2004). As this archipelago is a tectonic active area, an accurate reconstruction of its former shorelines may be problematic because of many unpredictable and uncertain factors (*e.g.*, uplifts, local subsidence, collapses, local tectonic evolution, etc.). Nevertheless, modelling the separation events of the islets necessarily follows the isopleths curves, even if the present bathymetry not always corresponds thoroughly to the past topography of the studied area. At the same time, we considered the volcanic events and/or vertical movements related to each islet and/or islets' group, in order to obtain a palaeogeographical setting as reliable as possible. The models were drawn out using the high-resolution electronic chart system of Cmapecs® software (version 4).

According to the present submarine morphology, three main "clusters" of isolation episodes can be recognised. The earliest concerns Basiluzzo and Spinazzola, included in Panarea isopleth of –80 m. The other islets eastward of Panarea (the "Lisca Bianca-group") are located within the isopleth of –50 m. The isolation from Panarea could have happened between 10,000 and 8,000-7,000 years ago, resulting therefore earlier than the human colonisation of the Aeolian Islands (Fig. 4). A similar isolation age could be considered also reliable for Strombolicchio and La Canna, which are located within the isopleth of –50 m from Stromboli and Filicudi respectively. A third group, for which only a recent isolation age could be hypothesised, includes La Nave, Scoglio Faraglione, and Faraglione di Cala Fico, located within the isopleth of –10 m, formerly owning to Panarea, Salina, and Lipari respectively.

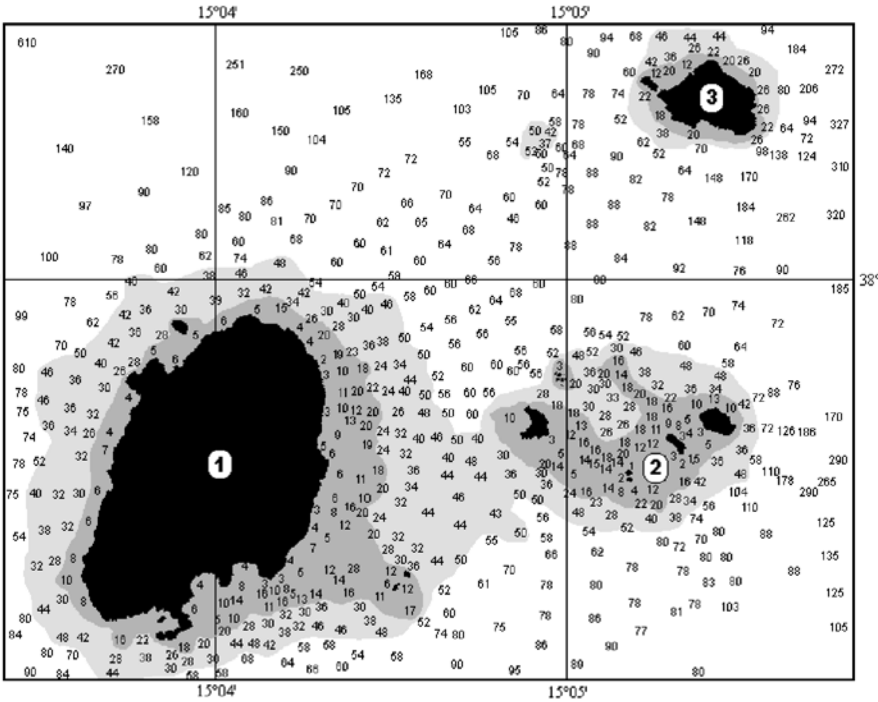

Fig. 4. Probable extension of the shorelines of Panarea and its satellite islets earlier than the human colonisation of the Aeolian Archipelago (along the isopleths of –50 and –20 m). 1) Panarea-La Nave; 2) "Lisca Bianca-group"; 3) Basiluzzo-Spinazzola.

Historical setting

The information on the historical scenario of the islets, on the contrary, is more detailed. The archaeological investigations carried out in 1920s by De Fiore (1921, 1925) showed that Basiluzzo and the "Lisca Bianca-group" were visited by fishermen and/or hunters since the Upper Neolithic (6,000 yr BP). On these islets, human settlements occurred during the Hellenistic and Roman ages (Bernabò Brea 1949; Cavalier 1985, 1991a, 1991b). Some of these may be related to the exploitation of local thermal springs, as suggested by the finding of probable thermal ruins submerged between the islets of Lisca Bianca and Dattilo (Bellia *et al.* 1987, Gabbianelli *et al.* 1990). The present localisation of these structures (at –14 m) suggests that a strong subsidence occurred in this area during almost the last 2,000 years, which associated to the erosive processes could have remarkably modified the former extension of the islets (see Fig. 4). Subsidence also involved the SE shore of Basiluzzo, where a presumabily defensive building dating back to the Roman age is nowadays located at about –2 m (Bernabò Brea 1985, G. Käpitan pers. comm. 1993). This islet was almost certainly seasonally inhabited, as demonstrated by the occurrence of a villa of the II century A.D. (Libertini 1921, Bernabò Brea & Cavalier 1977). After a long period during which the supremacy of the North-African pirates in the Southern Tyrrhenian Sea constituted a severe limit for human settlement on the peripheral and vulnerable islands of the archipelago, the agricultural use of Basiluzzo in early 17th century is documented by La Rosa (1784). Some travellers, who visited this islet between late 18th and middle 19th centuries, reported the presence of few inhabitants in a small rural settlement, which probably was visited only seasonally (Spallanzani 1793, Smyth 1824, Dumas 1842). The agricultural use of Basiluzzo was extended until late 19th century (Habsburg Lothringen 1895), while the "Lisca Bianca-group" was exploited because of sulphur mine and grazing land for goats and sheep (Lojacono-Pojero 1878, Habsburg Lothringen 1895).

All the above data indicate that a prolonged human presence occurred on the islets off the NE and the E coasts of Panarea. Contrariwise, it did not happen on the inaccessible and smaller rocks, such as La Canna, La Nave, Scoglio Faraglione, and Strombolicchio. The latter is characterised by the following recent history: the top of this islet was demolished using dynamite to build a light-house at the end of the 19th century, and its elevation was reduced from 70 circa to 49 m a.s.l.

Discussion

It is strongly believed that uninhabited islets and rocks should have represented potential "refuges" where *Podarcis raffonei* could has been preserved from competition with

P. sicula. Palaeogeographical data show that some islets (La Canna, Strombolicchio) were separated from the main contiguous islands before the beginning of the human colonisation of the archipelago, while this is still doubtful for Scoglio Faraglione. However, the persistence of *P. raffonei* on this islet can be explained by the gradual spread over of *P. sicula* on each island, as demonstrated by the present sympatry of both species on Vulcano.

As the Aeolian Wall Lizard was probably distributed on the whole archipelago, populations of this species could have occurred also on the islets off the E and NE coast of Panarea. Palaeogeographical data (Fig. 4) indicate that the separation of the "Lisca Bianca-group" from the main island occurred approximately at the same time for La Canna and Strombolicchio, while for Basiluzzo-Spinazzola probably earlier. Anyway, the natural process of isolation did not represent a sufficient boundary to preserve the autochthonous species on these islets. The common historical traits shown by the satellite islands of Panarea suggest that the human presence has been the most prominent factor which has influenced the present-day faunal composition.

Thus, the occurrence of *P. sicula* on the Aeolian islets seems to coincide with the human settlement (or exploitation) on the micro-insular environments. As the unexploited or inaccessible islets, such as Scoglio Faraglione, La Canna and Strombolicchio (for the latter, almost until the building of a lighthouse in the late 19th century) are still occupied by the autochthonous *P. raffonei*, means that men is playnig the most important role in the present distribution of the Aeolian lizards.

These findings can be added to a more wider scenario already shown for many other Mediterranean islands (Corti *et al.* 1999a, 1999b). Once more, the lizard populations of Lisca Bianca and Bottaro show different characteristics which were used

Fig. 5. Adult male of *Podarcis sicula* from Lisca Bianca Islet.

to describe them as two distinct subspecies (Mertens 1952) (Fig. 5). Even if their taxonomical value is still under debate (see Corti & Lo Cascio 2002, and references therein), this leads to exclude a recent colonisation of these islets by *P. sicula* according to the differentiation time recorded for other lizards (Malhotra & Thorpe 1991) or for the genus *Podarcis* (Castilla 2000).

The very fragile equilibrium in which the last alive populations of *Podarcis raffonei* occur suggests the need of immediate protection measures to avoid further anthropic pressure, specially on the micro-insular environments, and accidental introductions of allochtonous lizards. The only possible survival of micro-insular populations can be assured by the constitution of strictly protected areas (*e.g.*, as in the case of the Aeolian Archipelago the constitution of a: Riserva Naturale Integrale).

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