

## The decline of the Aeolian wall lizard, *Podarcis raffonei*: causes and conservation proposals

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**Abstract** Investigations carried out in the Aeolian Islands (off north-east Sicily) during 1989–99 gathered evidence strongly indicating that the endemic Aeolian wall lizard *Podarcis raffonei* is close to extinction. Competitive exclusion by the lizard *Podarcis sicula*, which has been introduced by man, habitat degradation, and possibly reduced genetic variability and inbreeding, were the main causes for the decline of the species. For the Aeolian wall lizard to recover from its threatened status and

to prevent further decimation of populations, collection and trade in the species should be prohibited, and an education programme for local people should be promoted. An integrated project involving habitat protection and captive breeding is needed to secure the species in the wild for the future.

**Keywords** Aeolian Islands, Aeolian wall lizard, *Podarcis raffonei*, *Podarcis sicula*, reptiles, Sicily.

### Introduction

Species endemic to islands have a relatively higher risk of extinction than species occurring on large land masses (Reid & Miller, 1989). For this reason the conservation and management of island species are particularly important.

The Aeolian wall lizard *Podarcis raffonei* is an endangered lacertid endemic to the Aeolian Islands, north-east of Sicily in the Tyrrhenian Sea (Capula, 1994a). The Aeolian Archipelago is of volcanic origin and made up of seven large ( $\geq 338$  ha) islands, Lipari, Salina, Vulcano, Stromboli, Filicudi, Alicudi, Panarea, and several islets each  $< 29$  ha. It is separated from Sicily by a wide, deep sea channel (distance between Vulcano Island and the closest coast of Sicily = 22 km; c. 500–600 m below sea level (Fig. 1). It seems that these islands emerged during the Pleistocene and could have been connected, for short periods at least, to Sicily and the southern Italian peninsula (Pasa, 1953; Sacchi, 1961; Barberi *et al.*, 1974). These islands are also inhabited by the Italian wall lizard *Podarcis sicula*,

which is widespread in the archipelago and occurs elsewhere in Sicily, Italy, along the Adriatic coast of Dalmatia, and on a number of Tyrrhenian and Adriatic islands (Lanza, 1968; Henle & Klaver, 1986; Capula, 1994b; Turrise & Vaccaro, 1998).

*P. raffonei* is morphologically and genetically related to *P. wagleriana*, and its full specific status has only recently been recognized (Capula, 1994a). *P. raffonei* and *P. wagleriana* are sibling species that probably diverged from a common ancestor (Capula, 1994a). *P. wagleriana* is endemic to Sicily, Egadi Islands and Stagnone Islands, but it does not occur on the Aeolian Islands (Fig. 1).

*P. raffonei* can be assumed to be the native lacertid lizard in the Aeolian Archipelago because it seems to have colonized the area during the Middle Pleistocene (Capula, 1994a, c), whereas the occurrence of *P. sicula* in the Aeolian Islands is probably a result of introduction by humans. This is supported by allozyme data (Capula, 1990, 1994a), which indicate relatively low genetic divergence between the Aeolian and Sicilian populations of the species. In addition it is well known that *P. sicula* has a broad ecological tolerance (Nevo *et al.*, 1972) and has been introduced by humans to several Mediterranean islands (Gorman *et al.*, 1975; Corti *et al.*, 1989; Capula, 1994b; Sá-Sousa, 1995). These data suggest that the colonization of the archipelago by *P. sicula* has occurred in historical times.

*P. sicula* occurs on all large islands as well as on some islets of the Aeolian Archipelago (Capula, 1992, 1993, 1994a; Corti *et al.*, 1997). *P. raffonei* currently appears to be confined to one large island (Vulcano), where it occurs sympatrically with *P. sicula*, and to three small islands (Strombolicchio, Scoglio Faraglione and La Canna),

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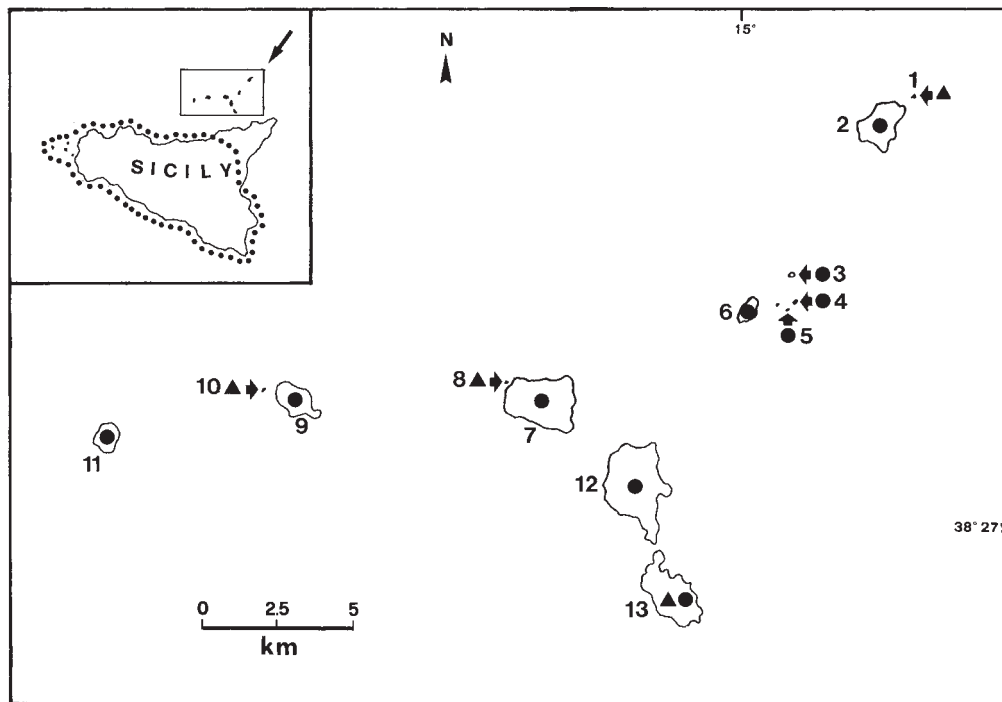
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**Fig. 1** Distribution of *Podarcis raffonei* (triangles) and *P. sicula* (circles) in the Aeolian Islands. 1 = Strombolicchio, 2 = Stromboli, 3 = Basiluzzo, 4 = Lisca Bianca, 5 = Bottaro, 6 = Panarea, 7 = Salina, 8 = Scoglio Faraglione, 9 = Filicudi, 10 = La Canna, 11 = Alicudi, 12 = Lipari, 13 = Vulcano. Insert shows location of the study area and the distribution of *P. wagleri* (dotted line).

where it is the only extant lacertid lizard (Capula, 1994a). The biology of *P. raffonei* is poorly known (Di Palma, 1980; Capula & Luiselli, 1997), partly because of its rarity.

*P. raffonei* has a very reduced range, and at present the species seems to be rapidly declining (Capula, 1998). In this paper we analyse the causes of this decline and suggest conservation measures on the basis of data gathered during several years of work in the Aeolian Islands and from the literature.

## Methods

To investigate the present occurrence of *P. raffonei* and the existence of any unknown relict populations, field investigations were carried out on all large islands (Lipari, Salina, Vulcano, Stromboli, Filicudi, Alicudi and Panarea) and on six islets (Basiluzzo, Bottaro, Lisca Bianca, La Canna, Scoglio Faraglione and Strombolicchio). Observations were made during a 10-year research period (1989–99) in the main potential habitats of *P. raffonei*, i.e. grassy areas with dense bushy vegetation (Genistetum tyrrheniae plant association: *Erica arborea*, *Arbutus unedo*, *Spartium junceum*, *Genista tyrrhena*, *Cistus salvifolius*, *C. monspeliensis* and *C. creticus*) and volcanic rocky zones with scarce bushy vegetation, far from cultivated land and rural villages. All observations were

carried out during springtime (April and May) or at the end of summer (September). A total of 120 days (12 days per year) were spent in the field. Each potential habitat was surveyed by conducting random walks for four hours a day (between 08.00 and 12.00 and between 15.00 and 18.00). Lizards were captured by hand, identified, sexed and photographed (*P. raffonei* and *P. sicula* are similar in most anatomical features, but differ slightly in colour pattern; *P. raffonei* typically has dark markings on its throat — these markings are also evident in specimens preserved in alcohol — while *P. sicula* has a throat that is white and unspotted). After identification the lizards were released in the place where they had been collected. No specimen was intentionally killed or damaged during this study.

## Results

Our investigations only allowed us to confirm the existence of *P. raffonei* on the islands reported by Capula (1994a). The species survives only on one large island (Vulcano, 2120 ha) and three non-inhabited tiny islands, Strombolicchio (0.19 ha), 1.6 km north-east of Stromboli, Scoglio Faraglione (0.5 ha), 0.3 km west of Salina, and La Canna (1 ha), 1.5 km west of Filicudi (Plate 1). The status of the populations occurring on these islands and



**Plate 1** The volcanic rock islet La Canna, 1.5 km west of Filicudi Island (Photo by Massimo Capula).

the number of specimens captured on each island over the ten-year research period are reported in Table 1 and Fig. 2, respectively.

On the large island (Vulcano) over the entire ten-year research period we only captured 26 *P. raffonei* specimens (12 males, 8 females and 6 juveniles). These individuals occurred in two small, isolated populations in the Vulcanello Peninsula and the Gran Cratere area. In contrast, we found *P. sicula* in natural and degraded habitats throughout Vulcano, and captured more than 700 adult specimens of this lizard.

Each of the three tiny islands inhabited only by *P. raffonei* (Strombolicchio, Scoglio Faraglione and La Canna) support a small number of lizards (estimated to be  $20 \leq N \leq 60$ ), probably because of the very limited area of each island (<2 ha).

*P. raffonei* was only observed in rocky areas with maquis-type vegetation (Plate 2), and never in degraded habitats or on cultivated land. It must be stressed that the areas characterized by habitat disturbance related to human activity were inhabited only by *P. sicula*.

## Discussion

The present data indicates that the Aeolian wall lizard *Podarcis raffonei* is the most threatened lizard in Italy, and possibly in the whole of Europe (see also Corti *et al.*, 1997; Gasc *et al.*, 1997; Capula, 1998; Corti & Lo Cascio, 1999). This underlines the importance of preserving the species, its genetic diversity and the habitat of the Aeolian Islands.

Analysis of the literature (Bruno, 1988; Capula, 1992, 1993, 1994a; Corti *et al.*, 1997; Lo Cascio & Navarra, 1997; Capula, 1998; Corti & Lo Cascio, 1999) indicates that there are four main pressures on the species that can be listed as contributory factors to extinction: competitive exclusion by the lacertid lizard *Podarcis sicula* introduced by humans, habitat degradation, collecting and trade, and highly reduced genetic variability and inbreeding.

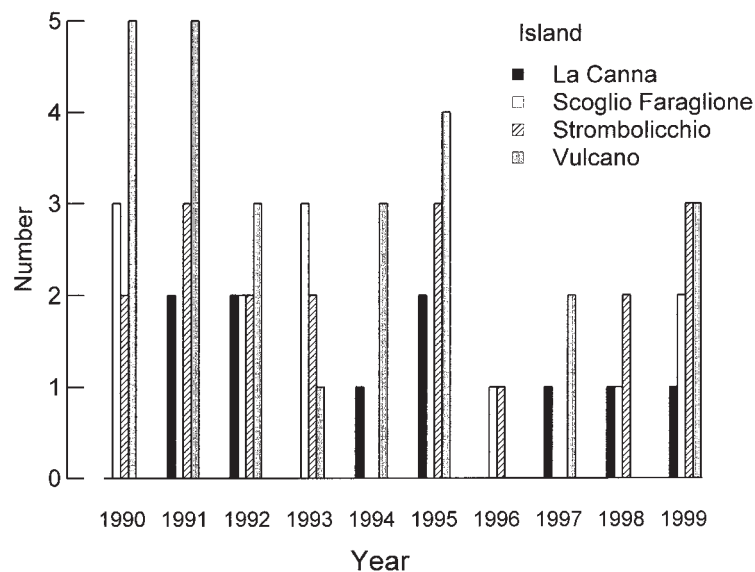
**1. Competitive exclusion** The results of electrophoretic investigations (Capula, 1993, 1994a) and comparative species distributions in the Aeolian Islands (Capula, 1992) show that the recent invader *P. sicula* probably competed with *P. raffonei*, greatly reducing the range of the latter and causing the extinction of most of its populations. We lack data on the past distribution of *P. raffonei*, but from its occurrence on three tiny islands (Strombolicchio, La Canna and Scoglio Faraglione) and its absence from the adjacent islands of Stromboli, Filicudi and Salina respectively (Fig. 1) it can be inferred that this lizard has become extinct on the large islands and was able to survive only on those small islands that were not colonized by *P. sicula* (Table 1). On Lipari Island, where *P. raffonei* was not detected, Capula (1993) showed that some specimens of *P. sicula* were characterized by an electrophoretic allele typical of *P. raffonei*. This may be the result of past hybridization and introgression, followed by the extinction of *P. raffonei* on the island (Table 1).

According to Capula (1992) the pattern inferred from the negative correlations between the spatial distributions of the species in the Aeolian Islands is supported by the analysis of habitat differences. There is niche overlap between *P. sicula* and *P. raffonei*, which results in negative competition effects.

**2. Habitat degradation** Many changes have taken place in the insular environment, especially with the development of modern human activities (Racheli, 1976; Lo Cascio & Navarra, 1997). Areas with dense maquis-type vegetation are highly reduced on all islands as a result of drastic habitat alteration caused by humans during the last century (deforestation, fire, agricultural activities,

**Table 1** Comparative status and distribution of *Podarcis raffonei* and *P. sicula* in the Aeolian Islands. (1) Extinction presumed from the occurrence of some alleles typical of *P. raffonei* in the genome of *P. sicula* from Lipari (see text); (2) extinction presumed from the occurrence of *P. raffonei* on the neighbouring Islet Scoglio Faraglione; (3) extinction presumed from the occurrence of *P. raffonei* on the neighbouring Islet Strombolicchio; (4) extinction presumed from the occurrence of *P. raffonei* on the neighbouring Islet La Canna.

Island	Area (ha)	Species	Status
Lipari	3750	<i>Podarcis sicula</i>	Common and widespread
		<i>Podarcis raffonei</i> ssp. (?)	Extinct (1)
Salina	2650	<i>Podarcis sicula</i>	Common and widespread
		<i>Podarcis raffonei</i> ssp. (?)	Extinct (2)
Vulcano	2120	<i>Podarcis sicula</i>	Common and widespread
		<i>Podarcis raffonei antoninoi</i>	Critically Endangered
Stromboli	1228	<i>Podarcis sicula</i>	Common and widespread
		<i>Podarcis raffonei</i> ssp. (?)	Extinct (3)
Filicudi	933	<i>Podarcis sicula</i>	Common and widespread
		<i>Podarcis raffonei</i> ssp. (?)	Extinct (4)
Alicudi	510	<i>Podarcis sicula</i>	Common and widespread
Panarea	338	<i>Podarcis sicula</i>	Common and widespread
Basiluzzo	29	<i>Podarcis sicula</i>	Common and widespread
Bottaro	6.8	<i>Podarcis sicula</i>	Common and widespread
Lisca Bianca	5	<i>Podarcis sicula</i>	Common and widespread
La Canna	1	<i>Podarcis raffonei cucchiarai</i>	Critically Endangered
Scoglio Faraglione	0.5	<i>Podarcis raffonei alvearoi</i>	Critically Endangered
Strombolicchio	0.19	<i>Podarcis raffonei raffonei</i>	Critically Endangered



**Fig. 2** Number of *Podarcis raffonei* captured and released on the islets of La Canna, Scoglio Faraglione and Strombolicchio and the island of Vulcano from 1990 to 1999.

urbanization and touristic activities). In several cases regeneration of natural areas is poor, and this may be attributed to fire and grazing pressure.

Vulcano is one of the most degraded Aeolian Islands, having suffered intense habitat alteration during the last 50 years (Racheli, 1976; Bruno, 1988). On this island *P. sicula* is widespread and abundant, and seems to have replaced most of the original populations of *P. raffonei*.

**3. Collection and trade** The threat of over-collection, mainly for scientific purposes but also for commercial interest, exists for all populations of *P. raffonei*, although there is no precise documentation (Lo Cascio & Navarra, 1997; Capula, 1998). This threat is probably magnified by the taxonomic status of the lizard, which is endemic to the Aeolian Archipelago, and by its present rarity and localization. Unfortunately, collecting specimens of



**Plate 2** Typical habitat (maquis-type vegetation) of *P. raffonei* in the Gran Cratere area of Vulcano Island (Photo by Massimo Capula).

*P. raffonei* is still not regulated by law, and control on remote sites (e.g. the tiny islands) remains difficult.

**4. Reduced genetic variability and inbreeding** The populations of *P. raffonei* have levels of genetic variability (polymorphism and heterozygosity) relatively lower than those of the related *P. sicula* from the Aeolian Archipelago and *P. wagleriana* from Sicily and Egadi Islands (Capula, 1994a). The severe reduction in genetic variability of *P. raffonei* has also been confirmed by molecular analyses (Oliverio *et al.*, 1998). It could be a result of either genetic drift or isolation, as supported by the fact that three out of four populations of the species occur on tiny volcanic islands, each characterized by a very limited area (<2 ha) and each separated from the others by a wide sea channel (Fig. 1). Moreover, these populations might also be threatened by inbreeding, as only a small number of lizards inhabit the islands.

In recent years there have been no important initiatives launched that attempt to save *P. raffonei* from extinction. The lizard and its habitat are still not protected by Italian law or by any international convention concerning conservation and protection of vertebrate fauna. Only Strombolicchio Islet and the Natural Reserve of the Montagne delle Felci e dei Porri, on Salina Island, are mentioned in the conservation plans of a regional law (Legge Regionale della Sicilia n. 98, 1981). *P. raffonei* requires protection, and a conservation action plan needs

to be implemented. The species may yet be saved from extinction if the following recommendations are acted upon:

- The last wild populations should be officially protected as soon as possible by creating reserves embracing the non-inhabited islets Strombolicchio, Scoglio Faraglione and La Canna, as well as the Gran Cratere area and the Vulcanello Peninsula on the island of Vulcano. Tourism should be strictly regulated, and access to the small islands should be prohibited.
- Collection and trade for scientific and commercial purposes should be forbidden by full legal protection (regional and/or national law) to reduce the risk of depletion of wild populations. Such a law should be properly implemented, and a local education programme should be promoted.
- Habitat conservation measures should be instigated (i) by monitoring and managing areas where the natural habitat of the species (maquis-type vegetation of the *Genistetum tyrrheniae* plant association) still persists, and (ii) by allowing regeneration of the original plant cover where it has been destroyed by over-grazing and fire.
- Control of the presence of alien fauna and prevention of intentional or accidental introductions of predators and competitor species (e.g. *Podarcis sicula*) is required.
- As previous studies indicated the presence of four subspecies in the archipelago (Capula, 1994a) (Table 1), suggesting that different islands may represent local genetic units, it is necessary (i) to avoid any kind of

habitat stress (fire, urbanization or touristic activities) on the islands inhabited by the species and to provide for habitat restoration, (ii) to prevent gene flow between islands, and (iii) to plan captive breeding programmes to ensure that, when required, only *P. raffonei* of the appropriate population are introduced on islands. It will be necessary to consider the ethical implications of removing individuals for capture breeding from already small populations (e.g. some of the populations may already be too small to justify the removal of enough individuals to make captive breeding practical).

- Continuity of scientific studies on relict populations should be promoted in order to document annual fluctuations in population parameters, not only for lizards but also for their predators (e.g. the snake *Coluber viridiflavus*, which is widespread in the Aeolian Islands).
- *P. raffonei* should be included on the IUCN Red List of Threatened Species (Hilton-Taylor, 2000) as Critically Endangered, as it is facing an extremely high risk of extinction in the wild in the immediate future, under criteria B1 + 2; i.e. its area of occupancy is estimated to be <10 km<sup>2</sup> (B), and it is severely fragmented (1) and continuing decline is inferred in its area of occupancy (2) (IUCN, 1994).

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