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An improved pitfall trap design for large-scale removal of invasive *Podarcis siculus* on Mediterranean islets

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Abstract

Pitfall traps are widely used to capture surface-active reptiles, but standard designs may involve logistical constraints and risks of trap-induced mortality when used intensively under extreme environmental conditions. Efficient trapping systems are particularly important in management programmes targeting invasive lizards on small islands, where large numbers of individuals must be removed, while minimising bycatch and heat-related mortality. Here, we describe a modified pitfall trap design developed during a large-scale removal campaign, targeting the invasive Italian wall lizard (*Podarcis siculus*) on two small Mediterranean islets (Aeolian Archipelago, Italy). The modified traps include a removable upper chamber for rapid specimen retrieval, an integrated shading system and structural elements designed to reduce predator access and trap overheating. A total of 346 traps were deployed and activated for 88 days (30,448 trap-days) between June and November 2025, yielding 4,965 captures of *P. siculus* (mean 14.4 individuals per trap; 0.16 individuals per trap-day) with very low mortality (< 1.5%) and limited arthropod bycatch (< 10% of traps). Mean trap inspection time was 38 s per trap, allowing two operators to inspect the entire network daily in 1 h 50 min on average, thereby facilitating rapid trap inspection and lizard retrieval in large-scale operations. All traps remained structurally stable throughout deployment. Our results indicate that the modified trap design provides a robust, low-cost and low-mortality option under extreme Mediterranean summer conditions and appears especially suitable for large-scale intensive management and removal programmes targeting invasive lacertid lizards on small islands.

Key Words

Invasive species management, lizard removal, Mediterranean islands, pitfall trapping, trapping efficiency

Introduction

Pitfall traps are widely used for sampling terrestrial reptiles, particularly small, surface-active lizards (Maritz et al. 2007; Willson 2016) and represent the most practical option for large-scale removal of surface-active lacertids. However, standard flush-mounted designs present several operational and animal welfare challenges that may limit their efficiency in intensive management programmes. Manual retrieval of individuals from ground-level containers is time-consuming and complicates bait management and trap maintenance. Open, unshaded trap chambers may expose captured animals to potentially lethal temperatures under extreme summer conditions (Turner

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et al. 2023) and the absence of a protective cover may facilitate predation on trapped individuals. Furthermore, conventional designs are typically non-selective, resulting in incidental captures of non-target arthropods.

These limitations become particularly critical in large-scale removal programmes targeting invasive lacertids on small Mediterranean islands, where trapping systems must combine high capture efficiency with minimal by-catch and reduced trap-induced mortality, while also coping with stringent logistical constraints, such as extreme summer heat and the need for sustained trapping effort over extended periods.

In the Mediterranean Basin, the Italian wall lizard *Podarcis siculus* has been widely introduced outside its native range and has been implicated in competitive displacement of native lizard species (Herrel et al. 2008). In the Aeolian Archipelago, this species represents one of the main threats to the critically endangered endemic Aeolian wall lizard (*Podarcis raffonei*), whose remaining populations survive on a few small islets (Ficetola et al. 2021). In this system, *P. siculus* is considered a threat not only because of competition, but also because it can hybridise with *P. raffonei* (Capula 1993, 1994; Capula et al. 2002; Ficetola et al. 2024; Paris et al. 2024). Within the EOLIZARD conservation programme, intensive capture and translocation-based removal of invasive *Podarcis siculus* was carried out on two Aeolian islets to establish a *P. siculus*-free sanctuary for the re-introduction of native endemic lizards, thereby ultimately reducing pressure on the critically endangered *P. raffonei*. This action was supported by previous genetic evidence showing that the *P. siculus* populations from Lisca Bianca and Bottaro are not distinct from those of nearby Panarea (Berrilli et al. 2024), the island selected as recipient site for translocated individuals. In this context, the trapping system needed to be scalable, rapid to inspect and capable of minimising trap-induced mortality under extreme summer conditions.

Here, we describe a modified pitfall trap design, which was developed and tested during an intensive removal campaign of *Podarcis siculus* on two small Aeolian islets. These modified traps were designed to increase trapping efficiency, reduce handling time and minimise heat-related mortality during large-scale invasive lizard management operations. Our aim is to present a practical trap configuration that may facilitate intensive invasive lizard management in remote island systems.

Materials and methods

This activity was conducted on two small volcanic islets near Panarea (Aeolian Islands, Italy), Lisca Bianca (ca. 20,000 m^2) and Bottaro (ca. 3,000 m^2). Panarea is one of the seven main islands of the Aeolian Archipelago, about 50 km off the northern coast of Sicily. Both sites are characterised by low Mediterranean scrub, exposed rock and areas of bare volcanic soil. Summers are very hot and freshwater is absent except for rainfall. Meteorological measurement in the site indicated that, in the period between 6 June and 23 September, daily maximum temperatures were constantly above 30 °C (except for one day) and 11.5 mm of rain fell in the same period.

A total of 346 pitfall traps (304 on Lisca Bianca, 42 on Bottaro) were installed approximately 8 m apart across the accessible plateau areas of the islet. Each trap consisted of a removable plant pot (20 cm high, 12 cm upper diameter, 9 cm lower diameter) placed inside a PVC tube (20 cm high, 11 cm internal diameter) permanently buried flush with the soil surface. Resting on the edge of the tube, the pot protrudes slightly from the ground. At the bottom of the tube, an aluminium dish (5 cm high, 10 cm diameter) contained fruit juice used as bait. When fruit juice is used, the base of the pot rests inside the dish with minimal direct immersion (few millimetres) and the drainage holes of the pots (about 5 mm × 10 mm) allow scent diffusion and liquid availability for hydration of the captured lizards, while keeping the capture chamber almost completely dry, thanks to the raised bottom. A white polypropylene roof (20 cm × 20 cm) elevated 5–10 cm above ground with three metal stakes reduced direct solar exposure and protected captured lizards from avian predators (Fig. 1). Traps could be closed with a plastic cap of the same diameter as the pot, allowing the traps to be deactivated and reactivated as needed without removing them from the ground. The total cost of the trap components is about six euros.

Traps were individually numbered and remained active for a cumulative total of 88 days between 6 June and 6 November 2025. Inspections (n = 43) were conducted as weather conditions permitted. The length of the intervals between inspections varied, but, generally, we managed to visit the traps every second day (mean: 2.2 days, min: 1 day, max: 10 days). During each check, the roof was lifted, the pot removed and the captured lizards transferred into breathable bags by gently inverting the pot. The bait dish was visually inspected and replenished with small quantities of fruit juice as needed. Arthropods were released. Captured lizards were stored in bags, maintained in ventilated and dark containers, transported to Panarea, counted and released in multiple sites across the inhabited areas of the island within a few hours of capture as an authorised and necessary translocation measure within the EOLIZARD conservation project.

Results

A total of 4,965 lizards were captured during 88 days of trap activity, corresponding to 30,448 trap-days. Of these, 4,371 individuals were captured on Lisca Bianca and 594 on Bottaro. Across all traps (n = 346), mean capture was 14.4 lizards per trap over the study period, with daily captures per trap ranging from 0 to 13 individuals. The overall capture rate was 0.16 lizards per trap per day. Most captures occurred during the first days following trap activation. Capture frequency, especially of adult lizards,

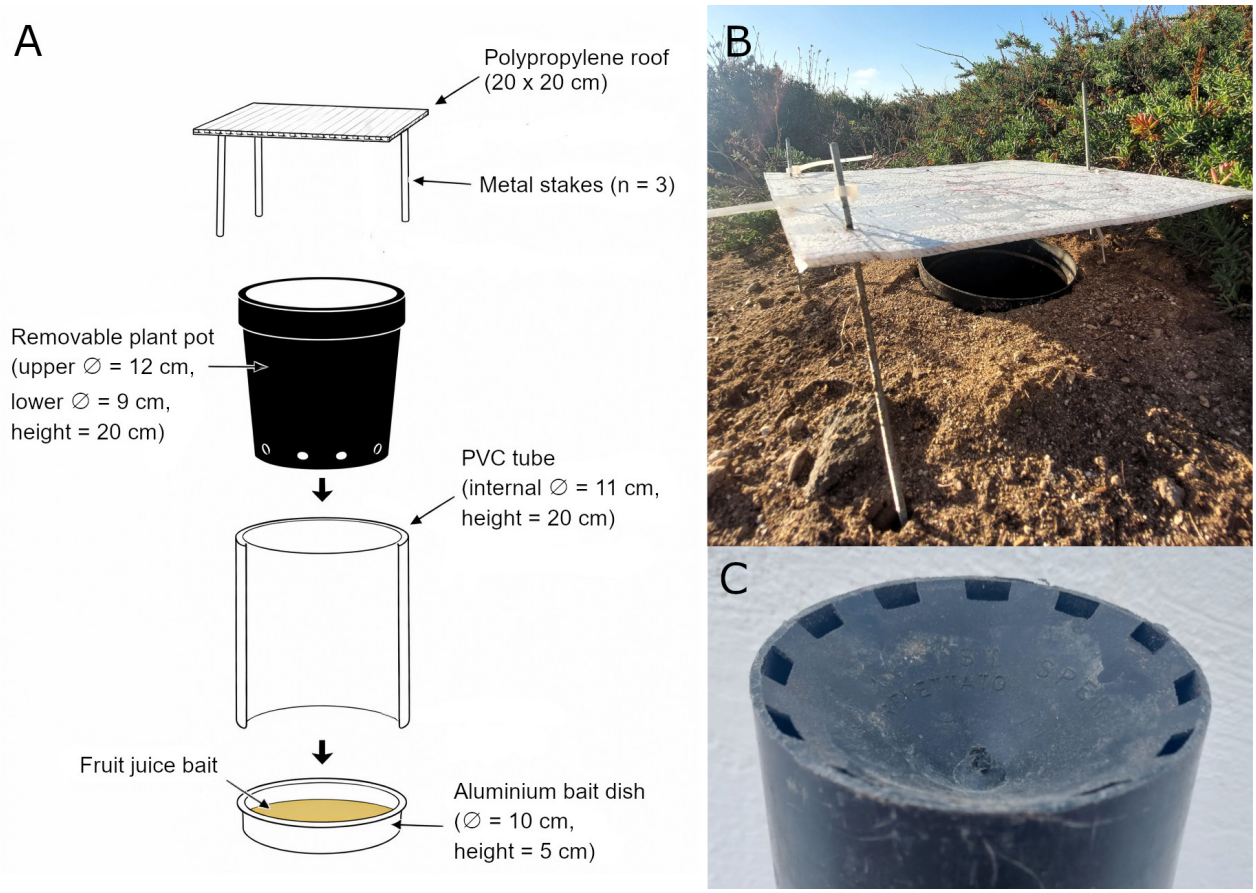

Figure 1. Trap structure. Schematic cross-sectional view of the modified pitfall trap (**A**), one trap active on Lisca Bianca (**B**) and detail of the pot bottom (**C**).

declined progressively as removal reduced local population size. The number of captured small juveniles slightly increased in the first weeks of activity (in response to new births and reduced presence of adults in the traps), then it decreased progressively.

Mean inspection time was 38 s per trap (including lizard collection, bait replacement, occasional bycatch removal and movement to the next trap), enabling a team of two operators to complete daily trap management in 1 h 50 min on average. Across 43 inspection events, total field effort for trap inspection, lizard handling and bait maintenance amounted to 157 h 36 min (person-hours). Arthropod bycatch was sporadic and limited to a few hundred individuals across 30,448 trap-days, with a mean per trap close to zero and < 10% of traps containing arthropods during inspections. Captured arthropods (mainly ants and beetles) were always found alive and released. A total of 74 lizards (1.5% of captures) were found dead in traps. No obvious signs of dehydration were observed in captured lizards and no mortality peaks were associated with the longest intervals between inspections or with the highest summer temperature events recorded during the study period, when maximum temperature exceeded 35 °C. All traps remained structurally intact throughout the study. No soil collapse, flooding or trap damage occurred and traps remained operational for 100% of the active period.

Discussion

The modified pitfall trap design has proven effective for intensive lizard removal in the two Mediterranean islets. Capture rates were high during the initial phase of trapping and declined progressively as population size decreased, indicating efficient depletion under sustained trapping effort. These results indicate that the trap design provides a practical and efficient solution for large-scale trapping of invasive lacertid lizards under harsh Mediterranean summer conditions.

Operational efficiency was notable. A very short inspection time allowed the daily management of 346 traps in less than 2 hours by two operators, demonstrating the logistical feasibility of large trapping networks even in remote island settings. The removable capture pot facilitated rapid extraction of individuals without the need to reach them into ground-level containers, reducing handling time and simplifying bait management. This configuration facilitates faster lizard retrieval and trap servicing than conventional flush-mounted systems (although no direct quantitative comparison was performed), an important advantage when large trap networks must be inspected frequently. All traps remained structurally intact throughout the 5-month deployment, confirming the suitability of the design for friable volcanic substrates and minimising maintenance requirements.

Arthropod bycatch was limited, suggesting that the raised rim and structural configuration was associated with low non-target captures under the conditions of this study. Obviously, more insects might be captured in sites with higher insect diversity and abundance. Mortality of lizards was low despite extreme summer temperatures and no dehydration events or heat-related mortality peaks were observed, indicating that the combination of shading and trap configuration may have helped to limit thermal stress under the study conditions (Read and Kearney 2016). These characteristics are particularly relevant in intensive removal programmes, where trapping systems must minimise collateral impacts on non-target organisms and animal welfare, while maintaining high operational efficiency.

Although the design proved highly effective under arid, volcanic island conditions and for ground dwelling, partially herbivorous lacertid lizards, its performance in wetter environments, compact soils or for other species remains to be tested. In this regard, the low mortality observed here may partly reflect the relatively high resistance of *P. siculus* to dehydration compared with other *Podarcis* species (Garcia-Porta et al. 2019) and higher mortality could occur in less tolerant taxa. Different bait types, such as animal bait, have also been successfully tested in other insular *Podarcis* species (Nunes et al. 2022). In addition, no direct quantitative comparison with traditional pitfall traps was conducted and the overall effectiveness of the removal campaign in terms of population reduction remains to be assessed. Nevertheless, the high number of captures obtained during the campaign, combined with the very low mortality rate, suggests that the modified configuration performs well under demanding field conditions. To our knowledge, the only previously published actives removal campaign targeting *P. siculus* was conducted in Athens, Greece (Adamopoulou and Pafilis 2019) and in Buckinghamshire, Britain (Hodgkins et al. 2012), using different approaches and at much smaller scales. Further applications in different ecological contexts would help clarify the broader applicability of this configuration.

Overall, the modified design offers a practical and scalable option for intensive invasive lizard removal or translocation-based management in remote island settings, particularly where rapid inspection, low mortality and minimal maintenance are critical. In island systems where invasive reptiles threaten endemic species, efficient trapping systems are often essential for enabling sustained management actions.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

Artificial Intelligence (AI) use

The authors accept full responsibility for the content of the manuscript, including the disclosure of any use of AI.
Regarding the use of AI in the preparation of this manuscript, the authors declare the following: GPT
Used for: Figures, tables and charts
AI has been used for drawing the schematic cross-sectional view of the modified pitfall trap (Fig. 1A)

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Author contributions

Conceptualization: PB, LV, DS. Data curation: PB, AAL, DB, BG, FC. Formal analysis: PB, VGM. Funding acquisition: PB, DS, LV. Investigation: FC, AAL, PB, DB, VGM, PB, BG. Methodology: PB, LV, DS, VGM, PB. Validation: AAL, BG, DB, FC. Writing - original draft: PB, PB, VGM. Writing - review and editing: LV, BG, DS.

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Data availability

All of the data that support the findings of this study are available in the main text.