

SHORT COMMUNICATION

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Good new(t)s: Rapid recolonization of a restored fish-invaded habitat by two newt species in southern Italy

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Abstract

1. Habitat modification and invasive species are considered some of the most impelling causes of the ongoing sixth mass extinction, especially in freshwater ecosystems. Artificial water troughs are, in this regard, particularly vulnerable environments, while being pivotal breeding habitats for many amphibian species. However, despite their well-known importance and their conservation concern, detailed information on the resilience of such ecosystems is lacking.
2. This note describes the events following the introduction of invasive fish species into a water trough in southern Italy and reconstructs the recolonization times of two newt species (*Lissotriton italicus*, *Triturus carnifex*) after disappearance of the fish a few months later.
3. As expected, both newt species were no longer observed in the water as soon as the fish were introduced in the trough. However, in contrast to previous reports, they recolonized it within 2 months of the last observation of fish and, in the case of *L. italicus*, bred shortly after.
4. Although the short permanence of fish in the trough may have facilitated the recolonization process, this event represents the fastest recolonization by newts of a restored habitat ever reported in the wild and sheds further insights on the resilience of amphibian species.

KEYWORDS

habitat management, invasive species, *Lissotriton italicus*, resilience, *Triturus carnifex*, water trough

1 | INTRODUCTION

Habitat modification and the introduction of nonnative species, often acting in synchrony (Didham et al., 2007), are among the most serious threats to biodiversity conservation (Falaschi et al., 2020). In such a context, humid habitats, especially smaller ones, are particularly fragile ecosystems that are degrading and disappearing at an alarming rate

because of the synergistic effects of climate change, habitat loss and invasive species (Kingsford et al., 2016).

Artificial water bodies can at least partially mitigate the effects of larger-scale habitat modifications (Chester & Robson, 2013; Oertli, 2018). Water troughs, for instance, are man-made structures used mainly for cattle drinking and are considered a key habitat for a large variety of animal species including aquatic invertebrates (Cerin

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et al., 2020) and amphibians (Buono et al., 2019; Garcia-Gonzalez & Garcia-Vazquez, 2011). In Mediterranean regions such as southern Italy, water troughs are often the main (if not the only) permanent water source available and therefore represent the preferred breeding site for several amphibian species, including many threatened ones (Caballero-Díaz et al., 2022; Romano et al., 2010), as well as an important dispersal route (Romano et al., 2023).

Despite their importance in conservation terms, the persistence of such structures is often endangered by the abandonment of traditional farm practices, chemical cleaning and the introduction of nonnative species such as fishes (Romano et al., 2010; Romano et al., 2014). Fish introductions in historically fishless habitats are an extremely serious threat for amphibians that can lead to population decline and even local extirpation (Kats & Ferrer, 2003). In environments such as water troughs, where escape space and shelter cover are minimal, fish introduction triggers an almost instantaneous avoidance response in amphibians, resulting in water abandonment and decreased sexual activity (Winandy et al., 2015). However, fish eradication from such small isolated water bodies like these can be easily implemented when compared to larger and more complex habitats (Tiberti et al., 2019).

Although several studies show the successful recolonization by amphibians of restored habitats from where nonnative fishes have been eradicated (Bosch et al., 2019; Denoël & Winandy, 2015; Knapp et al., 2007; Vredenburg, 2004), data regarding the timing of the above response vary widely (Denoël & Winandy, 2015), and mechanisms driving colonization are poorly understood (Miró et al., 2020). This short note reports the recolonization of a water trough in southern Italy by two newt species following nonnative fish disappearance. To the best of our knowledge, this is the most detailed reconstruction of the events preceding and following the disappearance of an invasive species and the first to show it in an artificial water trough.

2 | METHODS

The water trough examined is situated in Fragneto Monforte (Province of Benevento, Campania, southern Italy). It has a total length of 12.25 m, width of 1.45 m and a water level of at most 38 cm (Figure 1). At the time of the first survey (24th March 2021), the trough presented aquatic vegetation growing inside and a thin layer of organic benthos (e.g., dead leaves, twigs and loam) on the bottom. Bramble bushes (*Rosa canina*, *Rubus ulmifolius*) and a small reedbed were found in the immediate proximity of the trough while the large-scale landscape consists mainly of cultivated fields, orchards and sparse human settlements. Water flow is ensured by a rivulet flowing on top of a low concrete aqueduct while the overspill drains into a ditch on the opposite side.

Surveys were conducted on average every 3 weeks, with visits occurring between late morning and early afternoon. Newt presence was confirmed by means of visual inspection and no dip-netting was performed. However, if newts were not immediately observed, the benthic layer of leaves was gently moved to inspect the space underneath. No handling of individuals was undertaken.

3 | RESULTS

During the first survey (24th March 2021), Italian newts (*Lissotriton italicus*) and Italian crested newts (*Triturus carnifex*) were observed inside the trough. Other species observed nearby included green frogs (*Pelophylax* sp.), barred grass snake (*Natrix helvetica*) and several aquatic invertebrates, including some of conservation interest such as the Mediterranean freshwater crab (*Potamon fluviatile*). Both *L. italicus* and *T. carnifex* were recorded continuously throughout the year, with neither aestivation nor hibernation

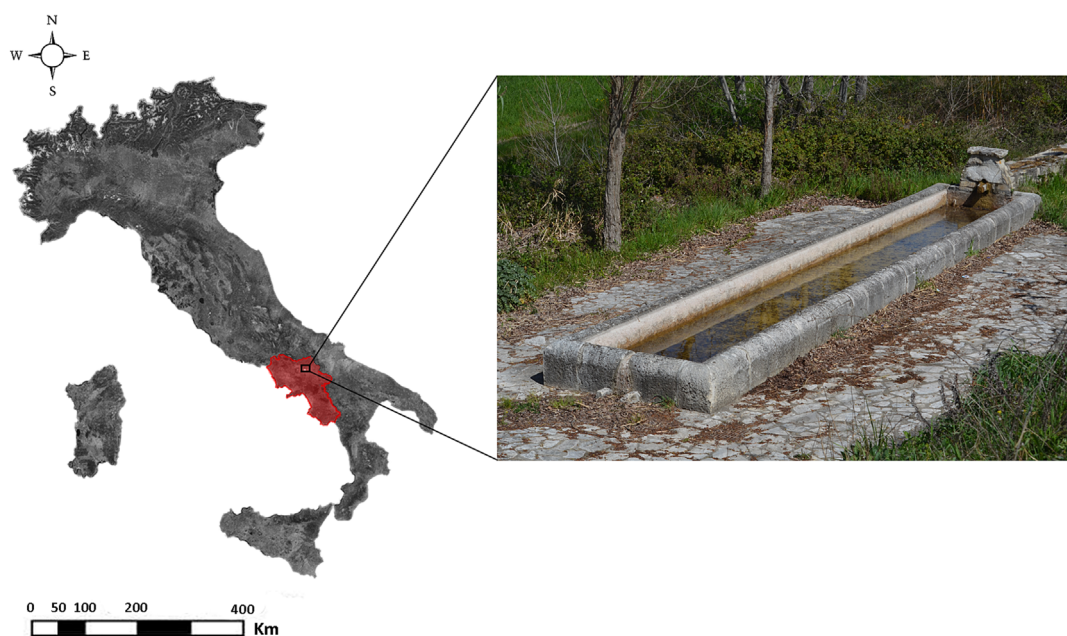


FIGURE 1 Position and depiction of the study site in Campania, southern Italy.

occurring, as often happens when water is available all year round (Scillitani et al., 2004). During spring 2021, both species successfully bred.

On 12th July 2022, four fishes (Cyprinidae) were seen for the first time inside the water trough. Three individuals had an estimated total length of 15 cm, and although identification to the species level was not possible, they appeared to belong to the same species. The remaining individual (estimated total length: 20 cm) was identified as a carp (*Cyprinus* sp.). The trough appeared also cleared of all the aquatic vegetation as well as of the benthos accumulated at the bottom while most vegetation from the surrounding space had been mechanically removed. On the same day, both newt species and all macro-invertebrate fauna appeared to be missing. The study site was subsequently visited on eight different occasions between July and November, confirming the persistence of fishes and without recording newts or invertebrates. Also, the water assumed a murkier colouration.

The last time the one *Cyprinus* sp. was recorded was on 11th November 2022. while on 23rd January 2023, the three smaller fish were also missing, with their last positive sighting 32 days earlier (22nd December). On the same day in January 2023, the presence of at least four individuals of *L. italicus* was once again reported, while on 21st February, a *T. carnifex* male was also observed, followed by the appearance of a female on 6th March. It was not possible to obtain any information regarding the disappearance of the fish as to whether they were removed or died naturally (i.e. poor water conditions, predation). Finally, on 19th April, *L. italicus* larvae were detected. Hence, considering a time-gap of about 10 to 30 days between oviposition and hatching (Tripepi et al., 1998), it is likely that courtship happened shortly after the species returned to the trough. The main events, days and dates are summarized in Table 1.

4 | DISCUSSION

To the best of our knowledge, this observation represents the fastest natural recolonization by amphibians of a fish-invaded habitat ever reported in the wild. Most of the literature on the topic suggests a gap of circa 4 to 10 years before amphibians return to a habitat once invaded by predatory fishes (Denoël & Winandy, 2015; Knapp et al., 2001; Knapp et al., 2007; Tiberti et al., 2019; Vredenburg, 2004), with the fastest exception being 1 year (Miró et al., 2020). Our note furtherly, and substantially, shortens this gap.

The mechanisms leading to newt recolonization are still somewhat unclear (Miró et al., 2020), but once a degraded habitat is restored to its previous status, recolonization is believed to be possible only given the presence of alternative safe sites to which animals might have moved (Denoël et al., 2016) or adjoining populations that can act as an immigration-source for new individuals (Vredenburg, 2004). Although the newts could have abandoned the trough and followed the watercourse to the next closest water pool, due to the particularly rapid recolonization times, we believe it more likely that, in this specific case, the animals moved to a terrestrial habitat, such as stone crevices and moss-patches in the humid spots at the base of the aqueduct, and survived in the immediate proximity of the trough. This behaviour confirms the need to combine the conservation of aquatic ecosystems, required for reproduction and long-time survival, with maintaining suitable terrestrial habitats that might act as short-term refuges for the species and be necessary to increase the population's resilience (Porej et al., 2004).

Naturally, we are aware of the particular conditions of our study site that could have influenced the results, namely, the localized scale and the relatively brief persistence of the invasive species within the trough. While the former is not a limitation per se but rather a characteristic of this habitat, the latter is more complex to

TABLE 1 Summary of the main events described.

Date	Event	Infographic
24/03/2021 to 22/06/2022	<i>Lissotriton italicus</i> and <i>Triturus carnifex</i> continuously observed	
12/07/2022	First observation of fishes and disappearance of newt species	
11/11/2022	Last observation of <i>Cyprinus</i> sp.	
28/11/2022	<i>Cyprinus</i> sp. no longer detected	
22/12/2022	Last observation of small fish specimens	
23/01/2023	Small fish no longer detected and first new observation of <i>L. italicus</i>	
21/02/2023	First new observation of <i>T. carnifex</i>	
19/04/2023	Recorded presence of <i>L. italicus</i> larvae	

disentangle. Early intervention to remove invaders is known to affect the efficacy of the measure (Falaschi et al., 2020); however, whether this also contributes to the recolonization time is unknown. Because all the studies reporting recolonization times in amphibians describe situations in which fishes had been present for at least 10 years before eradication began (Denoël & Winandy, 2015; Miró et al., 2020; Tiberti et al., 2019; Vredenburg, 2004), it is not possible to know whether recolonization time is proportional to the disturbance persistence of the invasive species.

Although anecdotal, we believe this observation is an important addition to our scant knowledge of amphibian recolonization processes and provides further evidence of their resilience. Furthermore, it suggests the importance of timing management when it comes to invasive species eradication programmes as well as the value of continuous monitoring schemes, without which it would not be possible to detect early signs of habitat degradation.

AUTHOR CONTRIBUTIONS

Michele Chiacchio: Conceptualization; investigation; writing—original draft. **Giuseppe Paudice:** Investigation; writing—review and editing. **Andrea Senese:** Investigation; writing—review and editing. **Valerio Giovanni Russo:** Conceptualization; investigation; writing—review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no datasets were generated or analysed during the current study.

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