Eaten or beaten? Severe population decline of the invasive lizard *Podarcis siculus* (Rafinesque-Schmaltz, 1810) after an eradication project in Athens, Greece

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Abstract

Invasive species have been recognised as an important hazard to native communities. Amongst the mitigation measures that have been proposed to confront biological invasions, eradication projects are certainly the most drastic. In this short communication, a successful eradication project against a recently established population of the Italian wall lizard (*Podarcis siculus*) in Athens, Greece, is reported. To this aim, the Hellenic Herpetological Society received unforeseen aid from stray cats and, possibly, from the Ocellated skink (*Chalcides ocellatus*) and vegetation growth. Within three years, the initial thriving *P. siculus* population has shrunk to very few individuals.

Key Words

cat predation, invasive, Italian wall lizard, urban biodiversity
may menace other lizards in more direct ways, such as hybridisation (Capula 1993, 2002), behavioural interference (Downes and Bauwens 2002) or even predation (Cattaneo 2005; Capula and Aloise 2011). It has excellent dispersal abilities (Vignoli et al. 2012) and, taking advantage of anthropogenic activities, constantly broadens its distribution (Deichsel et al. 2010; Silva-Rocha et al. 2012).

In 2014, a new introduced population was discovered in Athens, Greece (Adamopoulou 2015), probably coming from the Adriatic region (Silva-Rocha et al. 2014). As such, the newly found Athenian population represented a peril for Greek endemic lizards e.g. on Aegean islands (Lymberakis et al. 2018). The alien lizard colony was discovered in March 2014 inside an artificial park in Palaio Faliro, within a narrow, sandy zone (90 × 15 m) between a crowded beach and a tram-line (37°55’9.38”N, 23°42’0.50”E). In 2011, this area was planted with mostly exotic vegetation. Trees and shrubs such as oleanders (Nerium oleander), yuccas (Yucca aloifolia) and desert fan palms (Washingtonia filifera) grew quickly and soon covered the focal area. Three years later, upon its discovery, the lizard population size was estimated at approximately 60 adults and numerous subadults (Adamopoulou 2015). During later visits in 2015, it seemed to have undergone rapid growth, presumably due to high food availability (e.g. plant fruits, insects and even organic wastes).

Several approaches have been proposed for the management of “newcomer” urban biodiversity, including eradication (Gaertner et al. 2016). Eradication projects have been applied in numerous cases and places (Genovesi 2005) and, despite the often high costs in carrying them out successfully (human effort, time, financial cost), they have been proven useful (e.g. Guo 2006; Howald et al. 2007). In 2015, the Hellenic Herpetological Society (HHS) launched an eradication project in order to prevent further expansion of P. siculus. Here, we report the successful outcome of this project. The HHS adopted the eradication procedure undertaken on the invasive P. siculus in the United Kingdom (Hodgkins et al. 2012) that consisted of quick action and removal of invasive individuals. In this case, thanks to the rapid action undertaken by the British National Trust, the establishment of a P. siculus population was prevented.

From April 2015 through July 2018, members of HHS and students of the National and Kapodistrian University of Athens (NKUA) visited the site regularly under appropriate weather conditions. Visits were scheduled during the morning hours of the lizards’ peak activity. Researchers walked slowly back and forth throughout the area, visually inspecting all available microhabitats. Lizards were caught by noosing. Captured individuals were transported to NKUA facilities, used in ecological, physiological and behavioural studies before being euthanised, according to the guidelines of AVMA (2013) and deposited to the Herpetological Collection of the NKUA Zoological Museum. A total of 204 lizards (66 males, 85 females and 53 juveniles) (Table 1) were collected. During the last 2 surveys (summer 2018), fewer than 10 lizards were seen per visit. Almost all of them were found outside the area in which the population was situated at the beginning. They were located in two small well-defined areas at the periphery of the park. The first spot was a sandy area (53 × 3.5 m) occupied entirely by sour fig, Carpobrotus sp., an invasive plant widely spread in the Mediterranean coast and forming dense mats. The second one is impenetrable wire netting rubble (4 × 2 m). No individual was found inside the park where the colony was first detected. Though not complete, the removal of large numbers of the introduced lizard seemed to halt the initial demographic increase. However, in this effort, there were some unexpected allies: cats, skinks and vegetation.

Table 1. Sex and age of Podarcis siculus caught during the removal events in Palaio Faliro, Athens, Greece.

<table>
<thead>
<tr>
<th>Month of removal events</th>
<th>Number of lizards removed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
</tr>
<tr>
<td>April 2015</td>
<td>9</td>
</tr>
<tr>
<td>May 2015</td>
<td>13</td>
</tr>
<tr>
<td>October 2015</td>
<td>13</td>
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<tr>
<td>December 2015</td>
<td>2</td>
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<tr>
<td>November 2016</td>
<td>1</td>
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<tr>
<td>February 2016</td>
<td>1</td>
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<tr>
<td>March 2016</td>
<td>5</td>
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<tr>
<td>June 2016</td>
<td>2</td>
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<td>March 2017</td>
<td>4</td>
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<tr>
<td>May 2017</td>
<td>2</td>
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<td>July 2017</td>
<td>2</td>
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<td>October 2017</td>
<td>4</td>
</tr>
<tr>
<td>June 2018</td>
<td>5</td>
</tr>
<tr>
<td>July 2018</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>66</td>
</tr>
</tbody>
</table>

In the Mediterranean, cats frequently prey on lizards and, especially on islands, represent one of the main threats for native lizards (Medina and Nogales 2009; Li et al. 2014). Cats have been reported preying on European populations of P. siculus (Salvador 2015) and (together with other factors) have facilitated the decrease and eradication of introduced populations in the US (Burke and Deichsel 2008). Numerous stray cats (around 20) in the park were frequently seen catching lizards (Fig. 1). We strongly believe that this “paw of help” was an important factor in the decrease of the P. siculus population.

Another possible accessory to the eradication was the Ocellated skink, Chalcides ocellatus (Forsskål, 1775), which also occurs in the area in great densities. Chalcides ocellatus has been reported to prey on Filfola lizard, Podarcis filfolensis (Bedriaga, 1876), juveniles on Lampione Island, Italy (Carretero et al. 2010). Podarcis siculus juveniles are chased and eaten by other skink species in the introduced US populations (Burke and Deichsel 2008). Thus, it would be reasonable to expect that the much larger C. ocellatus would also prey on P. siculus.
Besides dynamic predation, the constant growth of the mostly exotic vegetation has created a canopy that greatly reduces the sunlight reaching the ground, thus decreasing the thermal suitability of the habitat. *Podarcis siculus* is a precise and accurate thermoregulator that maintains relatively high body temperatures (Van Damme et al. 1990; Tosini et al. 1992). It prefers open areas (Salvador 2015; Sindaco et al. 2016); in highly vegetated habitats, its populations have been reported to maintain low densities, mainly due to the low environmental temperatures (Ouboter 1981). The effectiveness of thermoregulation of the Athenian population was the highest ever achieved by a *Podarcis* lizard (Kapsalas et al. 2016). During 2014, the source site was nearly an open area with scattered seedlings and palm trees; lizards were either on bare sand or climbing on palm trees. In 2018, the vegetation in the park was lush and did not provide lizards with sufficient basking sites (Figs 2A, B). The few remaining individuals, not accidentally, were found only in the two marginal spots, where sour fig mats and wire netting rubble offer places for thermoregulation and protection from cats.

In summary, the Athenian colony corroborated the general pattern of other *P. siculus* introduced populations that thrive in disturbed or highly altered habitats (Burke and Deichsel 2008). Since eradication of alien reptile populations is virtually impossible once they are established (Kraus 2009), human efforts should be rapid and focused on eradicating the invasive species as soon as they are detected to prevent further expansion. Regarding the Athenian population, it seems that the combination of biotic factors (heavy predation pressure by stray cats and possibly by the skink, as well as by deterioration of habitat thermal quality), together with the eradication project run by HHS, account for its dramatic decline. This case may represent a paradigm of how human actions, in synergy with natural causes, may show positive results in controlling an invasive reptile population within urban environments.

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