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Reptile entrapment in artificial irrigation constructs in Cyprus

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In a world of ever-expanding urban and agricultural development (Hassan and Lee, 2015; Rockström et al., 2017; Ramankutty et al., 2018), artificial constructs and human presence will continue impacting natural ecosystems and rural areas (Torres et al., 2016). The effect of human-made structures on biodiversity, especially in rural and semi-natural areas, has been well documented as it often results in a high number of animal deaths due to entrapment or injuries, as well as degradation of their habitat (Bárcenas-García et al., 2022; Wang et al., 2022). Among these structures, water supply and irrigation structures are essential for both humans and wildlife (Sueltenfuss et al., 2013; Aspe et al., 2016), especially in arid areas, as they can retain water during droughts, and thus sustain biodiversity (Chester and Robson, 2013; De Martis et al., 2016). However, these structures are designed exclusively for human use and lack features preventing wildlife entrapment (Albanesi et al., 2016; Bi et al., 2020; Littlewood et al., 2020). The impact of the irrigation ditches on wild fauna, including herpetofauna, has been acknowledged but systematic efforts to monitor or rescue the trapped animals are scarce (Enge, et al., 1996; Woinarski, et al., 2000; van Diepenbeek and Creemers, 2013; Perth and Kinross Ranger Service, 2012; Sherwell, 2018). In addition, the characteristics that attract reptiles to those artificial irrigation constructs (e.g., food, microclimate) have sparsely been studied (DiMauro and Hunter Jr., 2002; Manning, 2007; Garcia-Cardenete et al., 2014; Leon et al., 2015).

Reptiles, being ectotherms, are especially sensitive to changes in temperature and humidity (Rozen-Rechels et al., 2019; Jins et al., 2022), as well as to the physical aspects of their microhabitats (Quirt et al., 2006; Braun et al., 2018). In arid areas, resources for survival are mainly concentrated around water bodies (McLaughlin et al., 2017), especially during droughts (Bodmer et al., 2017; Vicente-Serrano et al., 2020). Irrigation constructs therefore constitute an ideal refuge for herpetofauna (Aspe et al., 2016; Riedener et al., 2016). Nonetheless, when those structures have steep or slippery walls, they can act as biodiversity traps (Garcia-Cardenete et al., 2014; Bi et al., 2020).

Cyprus, the third biggest Mediterranean island (9251 km^2, maximum altitude of 1952 m), is characterised by Mediterranean climate dominated by a hot and arid environment (Zittis et al., 2017). Cyprus hosts an extensive network of water-retaining constructs for civilian and agriculture use, including more than 100 dams (Thrasivoulou et al., 2014), and a total of 373 wetlands. Paphos district, where the study was conducted, covers an area of 1393 km^2 on the westernmost part of the island with unique geomorphology as it extends from the west coast of the island to the eastern foothills of the Troodos mountain range (Fig. 1). The district's natural water sources come from five major rivers and their associated dams while the liveability of the local agricultural sector relies on the artificial construct (e.g., concrete lined canals, pumping stations, underground water lines, boreholes) of the Paphos Irrigation Project (PIP) that provides water supply to more than 5000 ha of arable land (WDD, 1982, 2017).

The island of Cyprus hosts 20 native terrestrial reptiles (eleven lizards, eight snakes, one terrapin) including four island endemics (three lizards and one snake), and two endangered species (EN) according to the IUCN (Baier et al., 2013). The direct impact of artificial structures on reptiles is currently being investigated under a citizen science initiative for monitoring wildlife, albeit only for cases of vehicle collisions on roads (Zotos et al., 2018; Zotos and Vogiatzakis, 2018). Yet, dead or live reptiles (mainly snakes) trapped within irrigation canals or other water-related structures (e.g., water cisterns,

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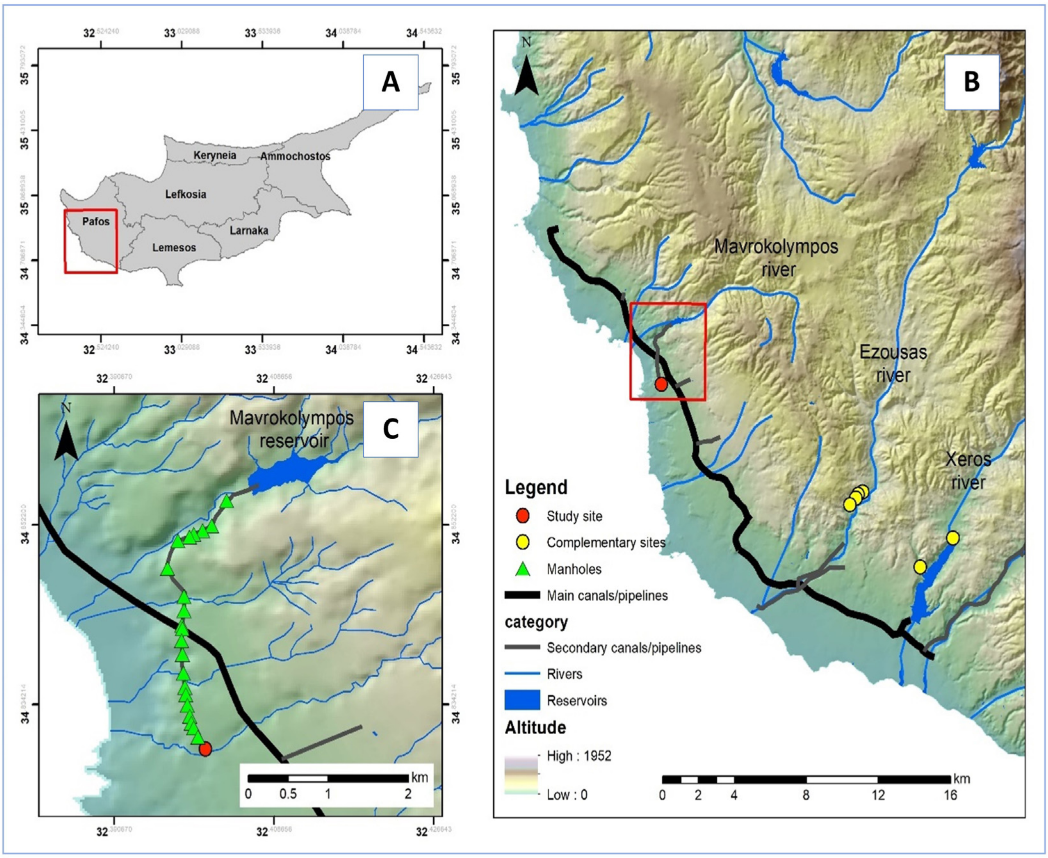

Figure 1. (A) Map of Cyprus, indicating the study area at Paphos district. (B) Geophysical characteristics of the study area with information on the Paphos Irrigation Project (PIP) and the complementary sites. (C) Details of the canal extending from the Mavrokolympos reservoir to the study site with indications on the numerous maintenance manholes.

concrete wells, pipeline trenches, drainage gullies) are a common problem in Cyprus that remains to be properly addressed. In most of the cases, snakes are spotted by public workers during maintenance visits or by farmers at the irrigation structures of their premises.

To examine the impact of artificial irrigation structures on reptiles, we used the Paphos Irrigation Project (WWD, 1982) as a case study. From November 2019 to October 2020, we systematically monitored an irrigation channel in the area of Kissonerga at Paphos district (Fig. 1) on a weekly basis (mean = 7.3 days; range = 5–12 days). This channel is a 3.5 km long underground canal with inspection manholes every ca. 200m, ending in a concrete construct (2 x 4 x 2 m) with openings on its sides for overflow, and two trapdoor openings at its end. Inside the construct, water flows and eventually accumulates underneath the trapdoor areas forming pools of varying depth depending on the season, with a maximum of 1.5 m. There are metal, rusted bars between the two trapdoors, where debris is often caught up, and metal steps for maintenance purposes (Fig. 2). We systematically monitored this artificial structure.

During each survey and for each trapped reptile we encountered, we recorded the species name, the number of individuals, and their condition when found (alive or dead). The irrigation channel was visited 48 times in total and at 40% (19) of the visits, reptiles were found entrapped within the artificial structure (Fig. 3).

A total of 25 individuals (19 snakes and 6 lizards) were found trapped within the irrigation channel. The higher number of entrapped reptiles (total and average) observed during a single visit, was recorded during the spring season (March – May, 2020) (mean: 1.4; range: 1-3). The most frequently trapped snake was the Cat Snake (*Telescopus fallax),* followed by the Large Whip Snake (*Dolichophis jugularis*) and the Coin Snake

Figure 2. An overview of the outside and inside area (A and B) of the main sampling site, at the Kissonerga area. The concrete construct has openings to allow water overflow, and rusted metal bars inside the channel. Other artificial irrigation construct (e.g. the Marathounta 2 site) have narrower and deeper openings that are filling seasonally with water (C and D). Reptile species commonly found entrapped in the irrigation channel are the *Hemorrhois nummifer* (E) and the *Tellescopus fallax* (F). Photos by Antreas Kourides.

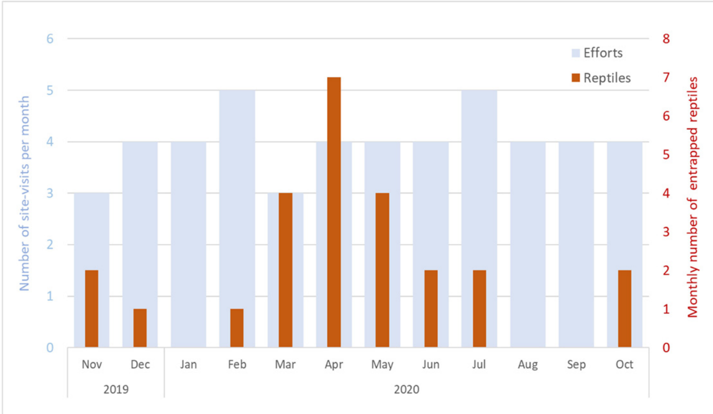

Figure 3. Number of site visits per month (in light blue), as a proxy of effort, and monthly number of reptiles found entrapped (in orange).

(*Hemorrhois nummifer)* (Fig. 4). Interestingly, for the two large-sized colubrids *H. nummifer* and *D. jugularis,* small-sized young individuals (less than 1 m total length) were more frequently entrapped (>80%) than larger individuals. From the six lizards that were recorded, five were Kotschy's Gecko (*Mediodactylus kotschyi*) and one Snake-eyed Lizard (*Ophisops elegans*).

In addition, we complemented our systematic monitoring with opportunistic visits at six sample sites from two nearby areas, Marathounta (4 sites) and Finika (2 sites) (Fig. 1). These six sites included smaller and narrower irrigation constructs with varying depths, characterised by limited concrete infrastructure, a heavy trap door for the workers, and small holes allowing reptiles to enter and be trapped in the constructs (Fig. 2). Visits to the complementary sampling sites were sporadic (15 in total) and were conducted once a month in May, June, and August 2020. During 11 of those visits (ca. 75%), 20 reptiles were observed entrapped within the manholes, namely three small-sized snakes (*Hemorrhois nummifer*, *Dolichophis jugularis* and an unidentified snake skeleton), eight lizards (five *Phoenicolacerta troodica*, one *Laudakia cypriaca*, one *Acanthodactylus schreiberi*, and one unidentified lizard skeleton) and nine amphibians (six *Bufotes viridis*, and three *Pelophylax bedriagae*).

This first reptile and amphibian entrapment study for the island Cyprus shows that in the span of ca. 7 days,

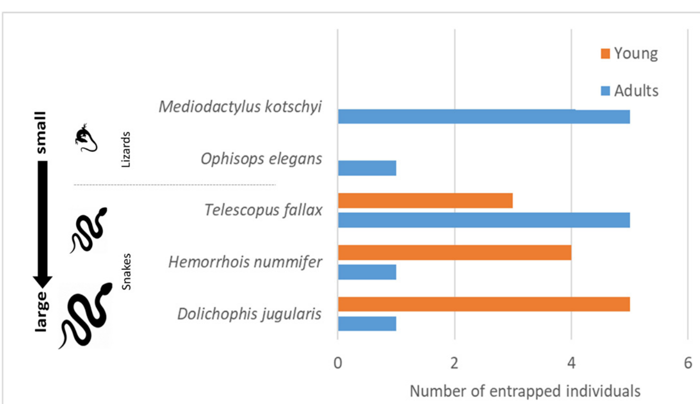

Figure 4. Number of young (orange) and adult (blue) individuals per species found entrapped within the studied irrigation channel. The species are ordered by size on the *y* axis.

40% of the sites contained at least one trapped reptile, a percentage that increases rapidly (ca. 75%) in the case of opportunistic surveys in manholes. Based on our findings, we roughly estimate that the irrigation canal of Mavrokolymbos reservoir (3.5 km with a total of 30 manholes) would trap around 750 individual reptiles a year (25 entrapped reptiles in a year in one artificial structure), while the Paphos Irrigation Project (36 km), could easily trap ten times that number. Unsurprisingly, cases of entrapments increased in number during spring when reptile activity is at its peak.

In addition to seasonality, our results indicated that smaller snakes are more often found entrapped within concrete irrigation structures. The most commonly found entrapped snakes were *T. fallax* and juvenile *H. nummifer* and *D. jugularis*, all slim and not exceeding one meter in length (Zotos et al., 2023). This outcome might relate to population age structures in the reptile species from the study area (more juveniles than adults), different behaviours in the two age groups, or constraints of their body sizes (small snakes find it easier to enter but difficult to exit climbing steep concrete surface). More research is needed to clarify the above hypothesis.

The species ecology may also contribute to explain why some reptiles enter and get trapped in the artificial construct in the first place. The European Cat Snake (*T. fallax*) is often associated with human presence and is often found in yards and old house ruins. Human-made constructs are parts of its natural habitat (Nicolaou et al., 2014). It was the species most often found entrapped, and its small size its ability to escape, and increased the risks of drowning.

The Large Whip Snake (*Dolichophis jugularis*) is the longest species of snake in Cyprus (up to 3 m long). We only found one adult trapped, while seven juveniles/ subadults were rescued. Adults of this species, with their large bodies and outstanding climbing abilities (Nicolaou, et al., 2014), would be able to escape more easily from the irrigation constructs than young individuals, which would explain the higher percentage of young individuals getting trapped.

The Coin Snake (*H. nummifer*) was the third most frequently entrapped species. This species occupies natural habitats but strongly prefer sites with water presence, as it is often found near rivers and streams (Nicolaou et al., 2014; Zotos et al., 2023). As Paphos, and specifically the Kissonerga area, display very arid conditions, especially during the hottest months of the year, the coin snakes struggle to find water sources and are lured into the irrigation constructs by the constant water flow, humidity, and possibility of prey. Despite its muscular body, the shorter length of the coin snake (Arnold and Ovenden, 2002) makes escaping from irrigation constructs a hard ordeal even for adult individuals.

Our findings highlight that, in Cyprus, artificial irrigation constructs have a considerable impact on reptiles. Because systematic surveys of the artificial constructs were lacking, this conservation issue and its impact was poorly known. For the case of Cypriot herpetofauna, further systematic research must be conducted on more irrigation constructs at a wider range of areas, land use types, and ecosystems, to grasp the magnitude of this phenomenon. Future visits to monitoring sites should be conducted at least twice a week, especially during the spring and summer months when reptiles are more actively hunting and seeking nesting sites, thus being more inclined to get trapped in irrigation constructs.

To facilitate monitoring and reduce reptiles' deaths within irrigation constructs in Cyprus, we propose setting up a citizen science initiative targeted towards monitoring sites and releasing entrapped reptiles. Those initiatives have been successful across Europe and should now be implemented in Cyprus (Perth and Kinross Ranger Service, 2012; van Diepenbeek and Creemers, 2013; Sherwell, 2018; Helldin and Petrovan, 2019; Schmidt, et al., 2020). Among its aims, this initiative should discover and report problematic constructs, remove trapped herpetofauna, and add getaway structures (van Diepenbeek and Creemers, 2013; McInroy and Rose, 2015) to reduce entrapment risks by assisting the escape of reptiles.

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