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RESEARCH PAPER

Alien and invasive terrestrial vertebrate species on Corfu, Ionian Islands, Greece

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Abstract. The Ionian Island of Corfu is rich in both species and habitats, but is also under pressure from heavy tourism, substantial water abstraction, and increased development, all of which have caused both loss and fragmentation of habitats. In addition, invasive alien species (IAS) constitute a global problem and may cause substantial problems for indigenous wildlife, especially on islands. To be able to successfully control IAS it is important to identify them, report their status, and raise awareness as early as possible. Here we present the status of ten alien species reported from Corfu, four of which are considered as invasive, the coypu (*Myocastor coypus*), the raccoon (*Procyon lotor*), the Siberian chipmunk (*Tamias sibiricus*), and the American pond slider (*Trachemys scripta*). Measures required as outlined by the EU Working Group on Invasive Alien Species are briefly discussed.

Key words: coypu, raccoon, American pond slider, Siberian chipmunk, AIS

Introduction

Invasive alien species (IAS) are considered the second largest threat to biodiversity globally after habitat loss and they pose a great danger to many fragile ecosystems. IAS compete with indigenous species for resources such as food and breeding grounds and can disrupt and change native habitats (European Union 2017). Some IAS carry diseases that can be transmitted to native species, livestock, pets, or humans (Carter & Leonard 2002, Nardoni et al. 2011, Fratini et al. 2015). Others decimate crops and damage infrastructure and the cost of repairing such damage or impose control measures is high, €12 billion each year is estimated to be spent in the EU by member states to deal with problems involving IAS (Kettunen et al. 2008). Some IAS have been deliberately introduced for the pet trade, fur trade or for food, while others have arrived accidentally. Not all alien species are considered harmful and some are even judged beneficial. However, there are some that spread aggressively and can out-compete or reduce populations of indigenous species or hybridize with them (Biedrzycka et al. 2012). There are an estimated 14,000 alien species in Europe (Katsanevakis et al. 2015), 1,200-1,800 of these are considered invasive and of the 395 European native species listed in the IUCN red data book, 110 are considered threatened by IAS. Islands are particularly vulnerable due to a generally low number of species, and half of the 724 recorded animal extinctions over the past 400 years are island species (Island Biodiversity, https://www.cbd.int/island). Rapid reproduction and growth rates, high dispersal ability and capability of

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adapting physiologically to new conditions are common characteristics associated with IAS.

As many IAS can easily disperse across borders on the European continent, the European Union has adopted the so-called IAS Regulation (Regulation EU 2014) to coordinate joint efforts to tackle this problem across all member states. This binding regulation came into force in 2015 and details the sanctions and restrictions agreed by the member states. A list (European Union 2017) has been compiled and is regularly updated and the latest amendment was made in 2019.

The occurrence of marine IAS in Greek waters is well documented (Zenetos et al. 2009) and invasive plant species present in Greece have been identified in the DAISIE project (Arianoutsou et al. 2010). However, little field or surveillance work has been done to investigate the occurrence of vertebrate IAS in Greece and to our knowledge only one scientific review, based on questionnaires sent to different agencies and authorities, of a group of selected species has been published so far (Adamopoulou & Legakis 2016).

Four vertebrate species from the IAS species list have been reported (mainly unpublished data) from Corfu, the coypu (*Myocastor coypus),* the raccoon (*Procyon lotor),* the Siberian chipmunk (*Tamias sibiricus*), and the American pond slider (*Trachemys scripta*, Bruekers et al. 2006). Another alien vertebrate species, the Indian crested porcupine (*Hystrix indica)* has also been observed. The starred agama (*Laudakia stellio*), the common wall lizard *(Podarcis muralis*), and the Moorish gecko (*Tarentola mauritanica*) also occur on the island (see Stille & Stille 2017 for details).

Several alien avian species, mostly escaped pets, have been seen on Corfu, but few of them survive long and they do not reproduce. Two species have been intentionally introduced for hunting purposes and now breed in the wild, the common pheasant (*Phasianus colchicus*, hybrid of several mostly far-eastern subspecies) and the chukar partridge (*Alectoris chukar*). There is no indication of the native, black-necked subspecies of the common pheasant on Corfu (at least not since 1800), but from the late 20th century onwards thousands of hybrid birds of unknown origin have been released on the island. As with the pheasant, the release of the chukar partridge begun during the late 20th century.

In this study we present baseline information on the status of three of the four terrestrial vertebrate IAS reported from the island of Corfu and suggest control plans for these species.

Study area

Corfu is the northernmost (N 39.6243, E 19.9217) and second largest (585 km^2) of the Greek Ionian Islands, situated close to the Greek and Albanian mainland with a distance of approximately two kilometres at the closest part (NE Corfu) to Albania. The climate is Mediterranean, i.e. with warm to hot and dry summers and cool to mild and humid winters (Csa in the Köppen-Geiger classification) Peel et al. 2007.

Material and Methods

Information on the distribution of the island IAS was collected from February to December 2020 by direct observations in the field, including day and night road surveys, bioindicator examination, trail camera recordings, and in some cases third party documentation. The areas for the placement of the cameras were chosen to cover as many habitats as possible and to get an accurate picture of the distribution of the studied species across the island. Data was classified as direct observation of individuals (O), camera recordings (C), droppings (D), tracks (T) and other signs like diggings and food remains (S; Brown et al. 2004). All data were coded for species, age when possible, date and GPS coordinates (WGS84). In addition, data from previous observations (2010-2019) are presented. Maps were created using QGIS (Open Source Geospatial Foundation Project, https://www.osgeo.org).

This report is part of a project also investigating the occurrence and distribution of nine other terrestrial vertebrates on Corfu (unpublished data).

Results

During 2020, over 200 fieldtrips were conducted and, in addition to direct observations, data were obtained from recordings from a total of 13 cameras used at 97 sites across the island (Fig. 1), representing 1,584 camera trapping days. Camera GPS coordinates and day activity per month is given in Table S1. Camera sites were selected using previous reports but were also chosen to cover a variety of habitats and as much of the island as possible while minimising human interference. While searching for suitable camera locations

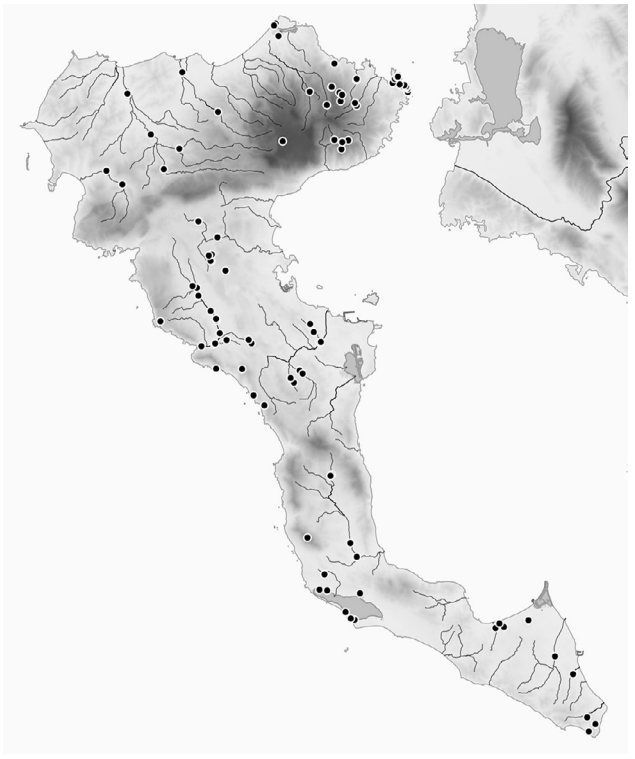

Fig. 1. Camera locations.

a large number of sites across the island were covered, including some 11,200 km of roads.

The common pheasant regularly breeds around Chalikiopoulou Lagoon and on the islet of Vido (Fig. S1). The chukar partridge is mainly found on Mount Pantokratoras, but birds (mainly solitary) have been seen in other localities (Fig. S2).

The Siberian or common chipmunk, which was frequently sold in pet shops, was observed at two localities in 2014, two specimens in Gouvia (J.T. Chaplin, pers. comm.) and one specimen at Chlomos (A. Robinson, pers. comm.; Fig. 2).

Indian crested porcupines were reported to have escaped from a small animal park near Felekas, central Corfu, but it was claimed by the animal park owner that they were recaptured. A live porcupine was observed twice in 2015 in Agios Markos (photo; C. Apergis & D. Vitouladitis, pers. comm.) and a dead specimen was found at Pantokratoras the same year (skull and dome spines preserved; I. Gasteratos, pers. observ.). A road-killed specimen was found near Felekas in 2017 and a live specimen was observed near Giatri (Facebook; C. Christopoulou Schwab, pers. observ.; Fig. 3). However, we have found no new indications or evidence for presence of chipmunks or porcupines on Corfu in this study.

Three IAS vertebrate species, the coypu, the raccoon and the American pond slider, were confirmed to be present on the island. Number of

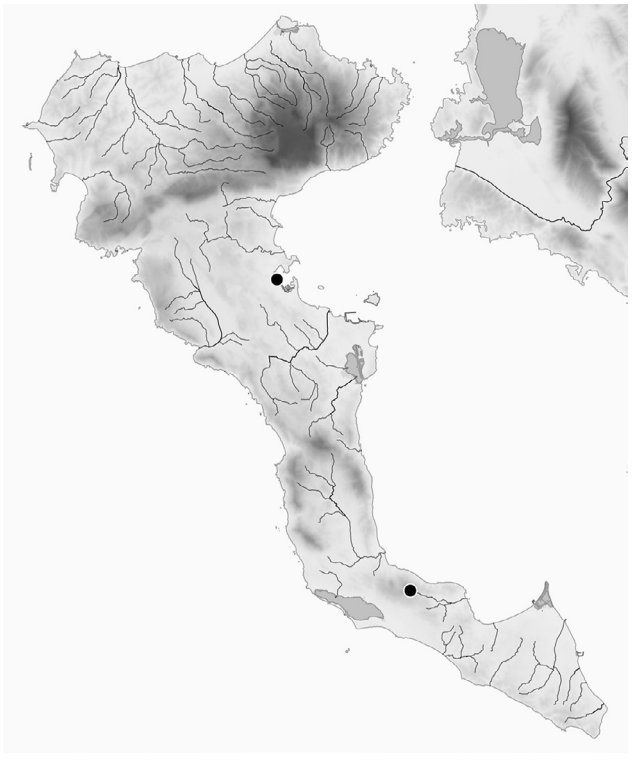

Fig. 2. Reports of Siberian chipmunk (*Tamias sibiricus*) on Corfu in 2014.

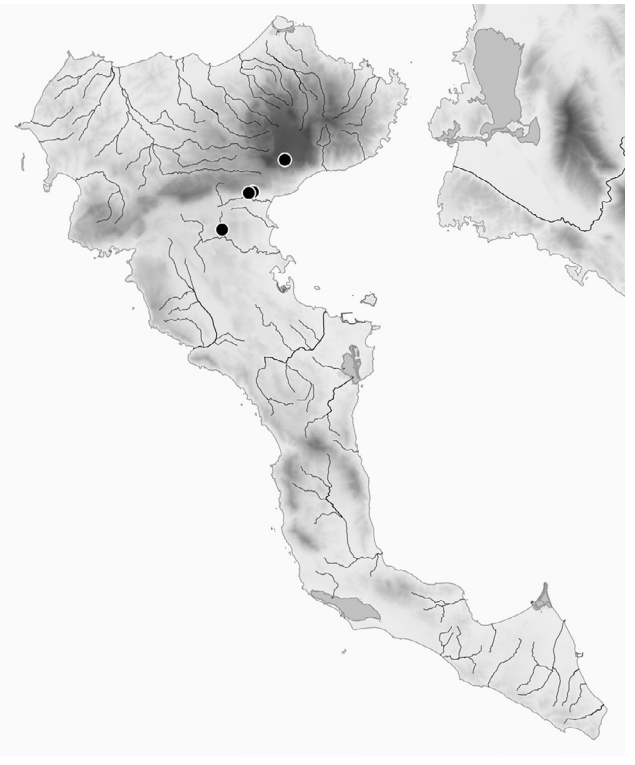

Fig. 3. Reports of Indian crested porcupine (*Hystrix indica*) on Corfu in 2015 and 2017.

Table 1. Records of coypu (*Myocastor coypus* 2020), raccoon (*Procyon lotor* 2014-2020), and red-eared slider (*Trachemys scripta elegans* 2015-2020). O – direct observations, C – camera recordings, D – droppings, T – tracks, S – other signs.

Species	Number of sites	Number of observation dates (number of individuals per date) (range : median)				
		O	C	D	T	S
M. coypus	60	19 (1-4:1)	26 (1-2:1)	-	18	3
P. lotor	10	13 (1-3:1)	6 (1-3:1)	2	2	-
T. scripta	8	20 (1-20:1)	-	-	-	-

sites and observations are shown in Table 1 and distributions in Figs. 4-6.

The coypu was first reported from the island in 2004 at Corfu Town near the port (photo Department of Forestry of Corfu; Gasteratos 2020). During this study, coypus were recorded from 60 sites spread across the island and adding data from previous years increases the number of sites to 114 (Fig. 4). The species is found in most wetlands, both inland (rivers, ponds and lakes) and coastal (brackish and marine areas), and it is active all year round. Most camera observations show activity between 20:00-07:00, but individuals are also on occasions found active during the day (eight out of 50 observations). Both direct sightings and camera observations with a few exceptions only show single individuals. Signs from smaller groups of animals occurring together in the form of footprints and feeding activity (digging) have been recorded from the Korission Lagoon, the River Potamos and the Savoura Pond. However, we have no quantitative data on population size and have so far not found any obvious signs of bank destruction or feeding damage on native vegetation. Many farmers on Corfu complain about crop damage caused by coypus, but there are no reports or information on the level of damage to crops.

Raccoons are known to have been kept as pets on Corfu, and we recently encountered a young specimen in captivity, imported from Thessaloniki. The first verified report of free ranging raccoons dates to around 2014 (Monastery of Myrtiotissa; Father Daniel, pers. comm.), and there are additional later reports from further north along the coast (M. Lloyd & P. Jacks, pers. comm.; C. Linge,

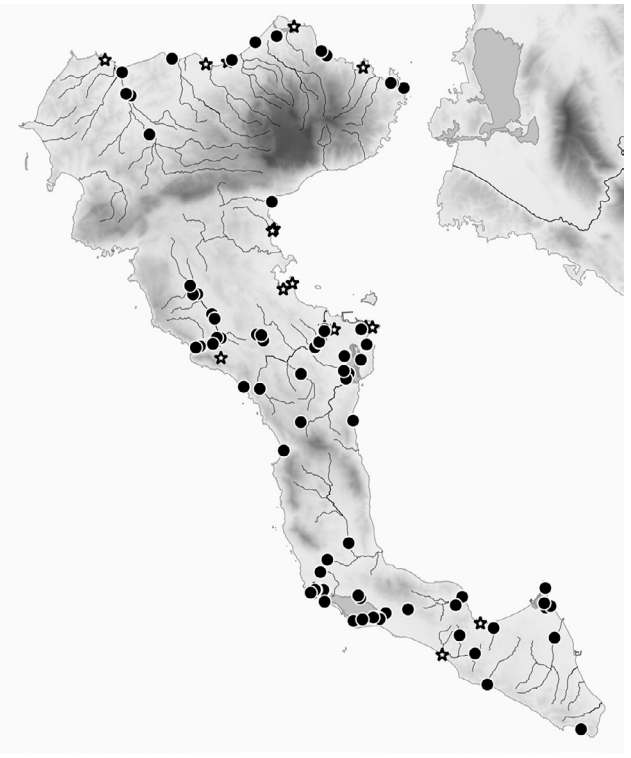

Fig. 4. Distribution of coypu, *Myocastor coypus*, on Corfu (black dots 2020, stars 2015-2019).

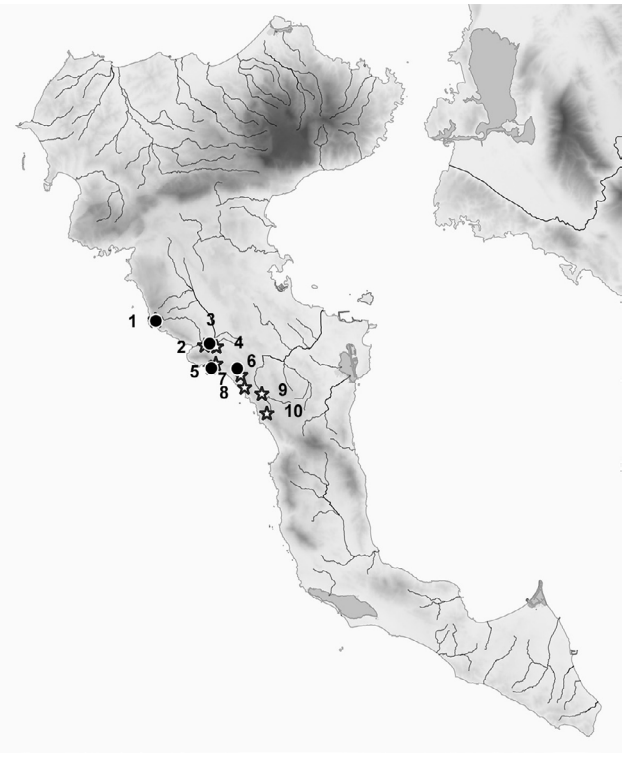

Fig. 5. Distribution of raccoon, *Procyon lotor*, on Corfu (black dots 2020 study, stars third party reports 2014-2020).

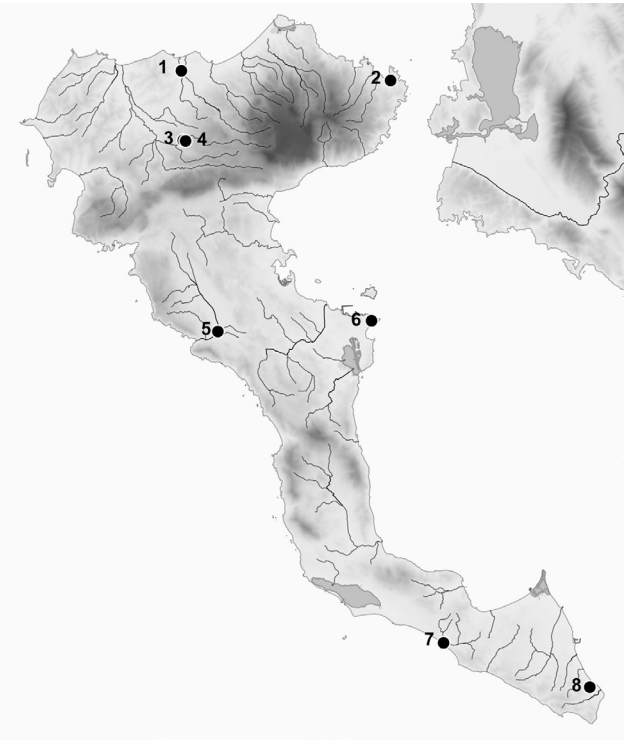

Fig. 6. Distribution of American red-eared slider, *Trachemys scripta elegans*, on Corfu 2020.

pers. comm.). There are ten confirmed site reports from West Corfu and one unconfirmed report from North-west Corfu. In this study we found evidence for raccoons from four sites, all restricted to a coastal area on the west coast between Agios Gordis and Giannades, including the lower part of the River Ropa (Fig. 5). Three of the observations were from areas where cat food was provided by humans.

Adult red-eared sliders (*Trachemys scripta elegans*) were found at eight sites (Fig. 6), and juveniles (carapace < 100 mm) at only one of these. At most localities only a few individuals have been observed. The exception is the Savoura Pond where we have occasionally recorded up to 25 individuals during a visit. This pond also holds a small population of European pond turtle *Emys orbicularis* (probably less than 25 individuals) as well as a much denser population of Balkan pond turtle *Mauremys rivulata* (> 100 individuals). Juveniles have sporadically been observed at the Ropa Valley site since 2015, the latest two in 2019.

It is possible that the pond slider reproduces on the island, but there is no evidence to support this as the few juveniles found may have been released from captivity. Turtles were regularly sold in the 1990s in pet shops as well as at local fairs on the island, but we have not seen any since around 2015. The effect of *T. scripta* on the native species on the island is unknown, but at the two main localities of concern all three species still co-exist. The Savoura Pond (locality 2) has the densest *T. scripta* population, but this pond may be less of a dispersal problem as it is effectively separated from other waters. Ropa Valley (locality 5), on the other hand, which has four major artificial ponds (golf course) is crossed by the River Ropa, potentially enabling dispersal over a wide area.

The distribution of the turtle is well documented through other studies in which most potential habitats on the island have been surveyed (Stille & Stille 2017, 2020). We have not observed any increase in adults and juveniles over the past ten years, and the number of localities seems to be stable. The only record of a subspecies, the yellow-bellied slider *Trachemys scripta scripta*, is from a small ornamental pond in the town of Kerkyra.

None of the three other non-native reptiles found on the island, the common wall lizard, the Moorish gecko, and the starred agama, are listed as invasive. They all have reproducing populations but also limited distributions. The starred agama was introduced at least 100 years ago but is only found in the central parts of Corfu, primarily in rocky and inhabited places, and there is no evidence for any obvious negative effects. The other two lizards have extremely limited distributions in or near the city of Kerkyra. Interestingly, the starred agama, the common wall lizard, and the Dalmatian algyroides (*Algyroides nigropunctatus*) occur syntopically in the centre of the city and have done so for decades (Stille & Stille 2017).

As to the common pheasant and the chukar partridge, both are alien species but no obvious adverse effects have been observed that can be related to their presence. However, the chukar partridge could pose a problem if a reintroduction of the native rock partridge (*Alectoris graeca*) would be considered as these species can hybridise (Barilani et al. 2007, Gandolfi et al. 2017).

Discussion

The coypu or nutria is a herbivorous, semiaquatic rodent with a natural distribution in Argentina, Bolivia, southern Brazil, Chile, Paraguay and Uruguay (Ehrlich 1967, Kinler et al. 1987, Kinler 1992, Aulagnier et al. 2009). It was introduced to Europe in the 19th century for the fur trade and has escaped or been deliberately released from

captivity and is now established in 19 countries where it has colonised various types of wetlands (Carter & Leonard 2002). It is included in the list of the 100 worst invasive species in the world (Lowe et al. 2000) and it is considered a major pest and is estimated to cost around €65 million each year in damage and management in Europe. Coypus have been raised in captivity in Greece (Aliev 1967) and according to Ehrlich (1967) individuals were observed in the wild in a variety of habitats between 1948 and 1966 and wild coypu populations were reported from Northern Greece by Mitchell-Jones et al. (1999). According to a Pan-Hellenic survey conducted in 2011 and 2016, coypus were recorded from more or less all wetlands in Western and Central Greece (Adamopoulou & Legakis 2016) and the species has been documented from two localities in the Butrint National Park in Albania in 2013 (Bego et al. 2018).

As the coypu has been recorded from a total of 114 sites (60 from 2020, Table 1, Fig. 3) on Corfu it can be concluded that this species is firmly established on the island. However, actual population size is hard to estimate as mainly single animals have been observed at each sighting, but a conservative population estimate would be at least 200 individuals. The first coypu, a single individual, on Corfu was recorded in 2004, but colonization from the mainland may have occurred several times. As there are no fur farms on the island, and as we have found no evidence that coypus have escaped or been released from captivity, an initial "lag phase" followed by a sharp increase in population growth would be expected. The common reed (*Phragmites australis*) and *Elodea* spp., both staple food for the coypu (Prigioni et al. 2005), are common on the island (Flora Ionica Working Group 2016) and as the rodents can feed on many other plant species, food does not seem to be a limiting factor for population growth. Also, as for most introduced species, the coypu has no or few potential predators on the island, which eliminates another factor that could have kept population growth down. The risk of a continuous recolonization by coypus from the mainland must be considered high, not only because of the animal's excellent swimming ability and high tolerance of marine conditions, but also because of the island's close proximity to the mainland.

The observed distribution, where the species occupies most types of waters all over the island (Fig. 4), is to be considered as concerning and as a potential threat to several native species, especially animals dependent on, or plants growing in association with, reed belt habitats. The coypu is reported to disrupt natural habitats and alter the composition of local plant communities (European Union 2017). It also degrades riverbanks, destroys irrigation systems, and disturbs and destroys floating bird nests by using them as resting places (Panzacchi et al. 2007, Bertolino & Viterbi 2010, Bertolino et al. 2011).

The coypu serves as reservoir for several pathogens that can spread to native species, humans, pets, and livestock (Nardoni et al. 2011, Sergio et al. 2016). The nematode *Strongyloides myopotami* causes nutria itch, causing dermatitis and severe rash in humans (Burnam & Mengak 2007). It also acts as host for the bacteria *Leptospirosis interrogans*, causing leptospira infection (Watkins et al. 1985), and as reservoir for *Pitrufquenia coypus* (Wittenberg et al. 2005) and *Toxoplasma gondii* (Nardoni et al. 2011). The sheep liver fluke (*Fasicola hepatica*), tularemia bacteria (*Francisella tularensis*), blood fluke tapeworms, sepsis (LeBlanc 1994, Jojola et al. 2005) and *Chlamidia* and *Salmonella* (Bounds et al. 2003) can also be transmitted by the coypu. As revealed by our camera observations many of the islands native mammals regularly visit the same sites as the coypu, and so do sheep and goats, which enhances the risk of transmission of the various pathogens from potentially infected coypus. As coypus have also recently been found in estuaries close to beaches and tourist resorts, there is an elevated risk for transmission of e.g. nutria itch to humans.

The raccoon is a Central and North American opportunistic omnivorous species with a natural distribution from Panama in the south to Canada and Alaska in the north (Glanz 1991, Gehrt 2003). The species was intentionally brought to Europe for the fur trade, for hunting purpose, or to "enrich" the native fauna. It was first introduced to Germany in the late 1920s (Lutz 1996) and then to the former USSR between 1936 and 1958 (Aliev & Sanderson 1966). The raccoon has been a popular animal in zoos, and it is often kept as a pet and escaped or released pets are the major introduction routes for the species today (Garcia et al. 2012, Mori et al. 2015). In central Europe, the raccoon population has grown exponentially with an increase of 300% since the 1990s (Salgado 2018), and in Germany it has grown by 12-17% annually since introduction in 1934, now numbering around a million (Jernelöv 2017).

Raccoons are now present in 16 EU-states and in 27 European countries, but not all countries have established populations (European Union 2017). Raccoons are opportunistic and can survive in a wide range of habitats, they are intelligent and resourceful and can cause damage even in their native range and the population density in some urban areas in North America have been as high as 100 individuals/km^2 (Beltrán-Beck et al. 2012). The animals are known to feed on many types of prey, including birds and turtles, and can cause damage to fruit trees, vineyards and corn fields (Beasley & Rhodes 2008). They also eat eggs and chickens and raid garbage bins in search for food and may, like the coypu, function as vectors for or carry diseases that can be transmitted to other wildlife, humans, livestock, and pets (Beltrán-Beck et al. 2012, Stope 2019). Infestation with the raccoon roundworm (*Baylisascaris procyonis*), a gastrointestinal nematode widespread among raccoons in central Germany, can cause fatal disease in humans (Heddergott et al. 2020)

In their native range raccoons have been found to prey on sea turtle eggs of the species *Caretta caretta*, *Chelonia mydas*, *Dermochelys coreacea*, and *Eretmochelys imbricata*, all listed as either vulnerable, endangered, or critical endangered in the IUCN red list (Davis & Whiting 1977, Ratnaswamy & Warren 1998, US Fish and Wildlife Service 2007a, CABI 2020). Predation on eggs from threatened species such as the American crocodile (*Crocodylus acutus*; US Fish and Wildlife Service 2007b) and Audubon's crested caracara (*Polyborus plancus audubonii*; US Fish and wildlife Service 2009) has been reported as well as predation on the threatened fish Sonora chub (*Gila ditaena*; Stefferud 1992).

The distribution of the raccoon on Corfu (Fig. 5) is much more limited than that of the coypu, but there is a reproducing population present on the west coast as a female with cub was documented at locality 6 (Fig. 5, Fig. S3), and young individuals have also been reported from locality 1 and 5 (S. Perrot & Father Daniel, pers. comm.).

As raccoons are omnivorous, they pose a threat to more native species than does the coypu. It is highly probable that the common practise of openly feeding stray and free ranging cats, together with open garbage bins containing left-over food and open fly tips, benefits the spread of the raccoon (Prange et al. 2003). As raccoons were first recorded in the wild on Corfu around 2014 or possibly somewhat earlier (Gasteratos 2020, Father Daniel, pers. comm.), they have not had as long as the coypu to disperse. It is also possible that the animals remain closer to the human settlements, where they were first released or have escaped from, if food is readily available. There are no official reports of presence of raccoons in the wild on mainland Greece.

Pond sliders (several subspecies, especially *T. s. elegans*) are freshwater turtles native to Eastern and Central North America (Bringsøe 2006) that were imported to Europe in large numbers for the pet trade from the 1950s until the 1990s (Ficetola et al. 2012). Import of these turtles to Europe was banned in 1997, but they may still occur in the pet trade. Many have escaped or been deliberately released into the wild and they are now present in 22 EU countries (European Union 2017). The pond slider is omnivorous and competes with native species for food, basking, and nesting sites (Arvy & Servan 1998, Cadi & Joly 2003, 2004, Alarcos Izquierdo et al. 2010). It uses a wide range of freshwater habitats in its natural range but prefers large, quite waters with soft bottoms and abundant aquatic vegetation (Bringsøe 2006). It is considered to be highly adaptable and able to inhabit brackish waters as well as man-made ponds and canals (Somma et al. 2009). They can also survive and even thrive in polluted rivers rich in organic residue (Ferronato et al. 2009).

The pond slider is considered a threat to the near-threatened European pond turtle (Cadi & Joly 2003) and a continuous release into the wild is believed to enhance the risk of spreading parasites, such as nematodes, to native species (Hidalgo-Vila et al. 2009). Pond sliders have been banned from sale in USA as they are considered as potential vectors for salmonella (Hidalgo-Vila et al. 2008).

In Greece, the red-eared slider has been reported from Attica, Corfu, Crete, Kos, Zakynthos, Peloponnese, Chios, Ikaria and Rhodes (Bruekers 1993, Bruekers et al. 2006, Zenetos et al. 2009, Stille & Stille 2017, Hellenic Herpetological Society 2020) and the yellow-bellied slider from Zakynthos (Urošević 2014), from Crete and Kos (Balej & Jablonski 2006-2014), and Corfu (this report). Turtles are generally released in waterbodies close to urban or suburban areas (Arvy & Servan 1998, Cadi et al. 2004, Bringsøe 2006), and sometimes they are released into ponds or pools as a form of decorative element (Semenov 2010). Successful

breeding has been reported from central and southern Europe (Cadi et al. 2004, Perez-Santigosa et al. 2008, Standfuss et al. 2016), including Kos in Greece (Bruekers et al. 2006).

The pond slider, like the coypu, are spread across Corfu, but has so far only been recorded in eight water bodies and in all but one locality only a few individuals have been observed. As most sites are distant from each other (Fig. 5) we conclude that the animals have been released at each site independently. Juvenile specimens have been observed at one locality (locality 5, Fig. 5), but we have no evidence that successful reproduction occurs on the island and have not found any indications of an increase in population size from previous investigations (Stille & Stille 2017, 2020). We have not found any evidence that the pond slider poses an immediate threat to the two native species on the island, but if more animals are released into sensitive areas this could have an adverse effect on the European pond turtle, a species that may already have competition from the islands' second native, and more common, species, the Balkan pond turtle. The climate on Corfu is favourable for many non-native turtles and given time, reproduction is likely to occur, which could lead to a situation like the one in Spain. In the Valencia area 23,000 specimens of exotic invasive turtle species were caught between 2011 and 2013, with a 20-fold increase in caught turtles from 450 in 2003 to about 9,000 in 2013, demonstrating the potential and rapid increase in population size (Laymen's report 2014).

As many of Corfu's wetlands are connected by extensive network of rivers, storm drains and ditches all three animals discussed here can use these to disperse. The coypu is already found in many of them and raccoons have also been recorded hunting in the River Ropa, not too far from where the animals were first sighted.

Rapid eradication of newly emerging populations of IAS or management of established populations are measures recommended by the EU for its member states (European Union 2017). As there is no established action plan to handle this problem on the island at present, one is urgently needed to be adopted. The plan must be firmly established with local authorities and follow a tiered structure similar to that recommended for the surveillance program of alien invasive species (Working Group on Invasive Alien Species 2017). Training and employment of a small, selected group of trappers/hunters working for and reporting to relevant local authorities and following strict guidelines that comply with applicable rules and laws is necessary to successfully come to terms with the spread of the discussed species.

With respect to the coypu, it is especially important to find facts concerning threats to reed belts as this particular habitat is used as nesting sites for many birds and as breeding and hunting ground for the endangered Eurasian otter (*Lutra lutra*), a species still found on Corfu (Galanaki et al. 2019, Stille et al., unpublished data). A female coypu can produce her first litter at an age of only three months and can produce offspring several times each year (CABI 2020). These are all traits that may eventually lead to a population explosion like the one in Italy (Bertolino & Viterbi 2010). Females often establish local stationary groups in areas rich in food, such as coastal wetlands, and these areas should be prioritized for further studies and control measures. Further, it is vital to create awareness and to inform the public and pet shop owners, not only on the prevailing rules and regulations, but also of the damage and destruction that IAS can cause to the environment if they continue to be released into the wild. As islands are particularly sensitive to the spread of IAS it is essential that an eradication program is initiated as soon as possible. Corfu is an island that, in geological terms, quite recently separated from the mainland and therefore lacks endemic species, but it has a high level of biodiversity. The island is subject to pressures from intense tourism and development of tourist resorts, which have led to considerable habitat loss, degradation of wetlands and fragmentation of habitats. An uncontrolled spread of IAS would add to these problems and place more pressure on the environment and on the island's indigenous species. Fortunately, the number of observed individuals of each of the three IAS species discussed is still manageable and successful eradication should, therefore, be possible and achievable within a reasonable budget.

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Literature

Adamopoulou C. & Legakis A. 2016: First account on the occurrence of selected invasive alien vertebrates in Greece. *BioInvasions Rec. 5: 189–196.*

Alarcos Izquierdo G., Flechoso del Cueto F., Rodríguez Pereira A. & Lizana M. 2010: Distribution records of non-native terrapins in Castilla and León region (Central Spain). *Aquat. Invasions 5: 303–308.*

Aliev E.F. 1967: Numerical changes and the population structure of the coypu, *Myocastor coypus* (Molina 1782), in different countries. *Säugetierkd. Mitt. 15: 238–242.*

Aliev F.F. & Sanderson G.C. 1966: Distribution and status of the raccoon in the Soviet Union. *J. Wildl. Manag. 30: 497–502.*

Arianoutsou M., BazoServans I., Delipetrou P. & Kokkoris Y. 2010: The alien flora of Greece: taxonomy, life traits and habitat preferences. *Biol. Invasions 12: 3525–3549.*

Arvy C. & Servan J. 1998: Imminent competition between *Trachemys scripta* and *Emys orbicularis* in France. *Mertensiella 10: 33–40.*

Aulagnier S., Haffner P., Michell-Jones A.J. et al. 2009: Mammals of Europe, North Africa and the Middle East. *A & C Black Publishers Ltd., London.*

Balej P. & Jablonski D. 2006-2014: Balcanica info. Downloaded on September 2020. *http://en.balcanica.info/*

Barilani M., Sfougaris A., Giannakopoulos A. et al. 2007: Detecting introgressive hybridisation in rock partridge populations (*Alectoris graeca*) in Greece through Bayesian admixture analyses of multilocus genotypes. *Conserv. Genet. 8: 343–354.*

Beasley J. & Rhodes O. 2008: Relationship between raccoon abundance and crop damage. *Hum.-Wildl. Interact. 2: 248–259.*

Bego F., Saçdanaku E., Pacifici M. & Rondinini C. 2018: Small terrestrial mammals of Albania: distribution and diversity (Mammalia, Eulipotyphla, Rodentia). *Zookeys 742: 127–163.*

Beltrán-Beck B., Garcia F.J. & Gortázar C. 2012: Racoons in Europe: disease hazards due to the establishment of an invasive species. *Eur. J. Wildl. Res. 58: 5–15.*

Bertolino S., Angelici C., Monaco E. et al. 2011: Interactions between coypu (*Myocastor coypus*) and bird nests in three Mediterranean wetlands of Central Italy. *Hystrix 22: 333–339.*

Bertolino S. & Viterbi R. 2010: Long-term cost-effectiveness of coypu (*Myocastor coypus*) control in Piedmont Italy. *Biol. Invasions 12: 2549–2558.*

Biedrzycka A., Solarz W. & Okarma H. 2012: Hybridization between native and introduced species of deer in Eastern Europe. *J. Mammal. 93: 1331–1341.*

Bounds D.L., Shefry M. & Mollett T.A. 2003: Nutria. In: Feldhamer G.A., Thompson B.C. & Chapman J.A. (eds.), Wild mammals of North America: biology, management and conservation. *John Hopkins University Press, Baltimore: 1119–1147.*

Bringsøe H. 2006: NOBANIS – invasive alien species fact sheet – *Trachemys scripta*. Downloaded on November 2020. *https://www.nobanis.org/*

Brown R.W., Lawrence M.J. & Pope J. 2004: Animals tracks, trails & signs. *Hamlyn, London.*

Bruekers J. 1993: Turtles on the Greek island Kos. *De Schildpad 19: 38–50. (in Dutch)*

Bruekers J., Uijtterschout G. & Brouwer A. 2006: Erstnachweis einer natürlichen Vermehrung der Rotwangen Schmuckschildkröte (*Trachemys scripta elegans*) auf der griechischen Insel Kos. *Schildkr. Fokus 3: 29–34.*

Burnam J. & Mengak M.T. 2007: Managing wildlife damage: nutria (*Myocaster coypus*). *Warnell School of Forestry and Natural Resources Athens, Georgia.*

CABI 2020: Invasive species compendium. *CAB International, Wallingford.*

Cadi A., Delmas V., Prieevot-Julliard A.C. et al. 2004: Successful reproduction of the introduced slider turtle (*Trachemys scripta elegans*) in the South of France. *Aquat. Conserv. 14: 237–246.*

Cadi A. & Joly P. 2003: Competition for basking places between the endangered European pond turtle (*Emys orbicularis galloitalica*) and the introduced red-eared slider (*Trachemys scripta elegans*). *Can. J. Zool. 81: 1392–1398.*

Cadi A. & Joly P. 2004: Impact of the introduction of the red-eared slider (*Trachemys scripta elegans*) on survival rates of the European pond turtle (*Emys orbicularis*). *Biodivers. Conserv. 13: 2511–2518.*

Carter J. & Leonard B.P. 2002: A review of the literature on the worldwide distribution, spread of, and efforts to eradicate the coypu (*Myocastor coypus*). *Wildl. Soc. Bull. 30: 162–175.*

Davis G.E. & Whiting M.C. 1977: Loggerhead sea turtle nesting in Everglades National Park, Florida, USA. *Herpetologica 33: 18–28.*

Ehrlich S. 1967: Field studies in the adaptation of nutria to seasonal variations. *Mammalia 31: 347–360.*

European Union 2017: Invasive alien species of Union concern. Downloaded on October 2020 *https://ec.europa.eu/environment/nature/pdf/IAS_brochure_species.pdf*

Ferronato B.O., Marques T.S., Guardia I. et al. 2009: The turtle *Trachemys scripta elegans* (Testudines, Emydidae) as an invasive species in a polluted stream of southeastern Brazil. *Herpetol. Bull. 109: 29–34.*

Ficetola G.F., Rödder D. & Padoa Schioppa E. 2012: In: Francis A. (ed.), A handbook of global freshwater invasive species. *Taylor & Francis Group, Abingdon: 331–339.*

Flora Ionica Working Group 2016: Flora Ionica – an inventory of ferns and flowering plants of the Ionian Islands (Greece). Downloade on November 2020. *https://floraionica.univie.ac.at*

Fratini F., Turchi B., Ebani V.V. et al. 2015: The presence of *Leptospira* in coypus (*Myocastor coypus*) and rats (*Rattus norvegicus*) living in a protected wetland in Tuscany (Italy). *Vet. Arh. 85: 407–414.*

Galanaki A., Kominos T., Zogaris S. et al. 2019: Presence of the Eurasian otter *Lutra lutra* on the islands of Greece: a review. *Folia Zool. 68: 246–252.*

Gandolfi A., Crestanello B., Fagotti A. et al. 2017: New evidences of mitochondrial DNA heteroplasmy by putative paternal leakage between the rock partridge (*Alectoris graeca*) and the Chukar partridge (*Alectoris chukar*). *PLOS ONE 12: e0170507.*

Garcia J.T., Garcia F.J., Alda F. et al. 2012: Recent invasion and status of the raccoon (*Procyon lotor*) in Spain. *Biol. Invasions 14: 1305–1310.*

Gasteratos I. 2020: Changes in ecosystems of Corfu. Some examples. *Scientific-Educational Conference Biodiversity, Ionian University, Corfu. (in Greek)*

Gehrt S.D. 2003: Raccoon and allies. In: Feldhamer G.A., Thompson B.C. & Chapman J.A. (eds.), Wild mammals of North America: biology, management and conservation. *John Hopkins University Press, Baltimore: 611–634.*

Glanz W.E. 1991: Mammalian densities at protected versus hunted sites in Central Panama. In: Robinson J.G. & Reford K.H. (eds.), Neotropical wildlife use and conservation. *University of Chicago Press, Chicago: 163–173.*

Heddergott M., Steinbach P., Schwarz S. et al. 2020: Geographic distribution of raccoon roundworm, *Baylisascaris procyonis*, Germany and Luxembourg. *Emerg. Infect. Dis. 26: 821.*

Hellenic Herpetological Society 2020: Museum of natural history of Crete. Downloaded on August 2020. *gr.herpatlas.org*

Hidalgo-Vila J., Díaz-Paniagua C., Pérez-Santigosa N. et al. 2008: Salmonella in free-living exotic and native turtles and in pet exotic turtles from SW Spain. *Res. Vet. Sci. 85: 449–452.*

Hidalgo-Vila J., Diaz-Paniagua C., Ribas A. et al. 2009: Helminth communities of the exotic introduced turtle, *Trachemys scripta elegans* in southwestern Spain: transmission from native turtles. *Res. Vet. Sci. 86: 463–465.*

Jernelöv A. 2017: Raccoons in Europe (Germany). In: Jernelöv A. (ed.), The long-term fate of invasive species. *Springer, Cambridge: 217–230.*

Jojola S., Witmer G. & Nolte D. 2005: Nutria: an invasive rodent pest or valued resource? In: Nolte D.L. & Fagerstone K.A. (eds.), Proceedings of the 11th Wildlife Damage Management Conference. *University of Nebraska, Lincoln: 120–126.*

Katsanevakis S., Deriu I., D'Amico F. et al. 2015: European alien species information network (EASIN): supporting European policies and scientific research. *Manag. Biol. Invasion 6: 147–157.*

Kettunen M., Genovesi P., Gollasch S. et al. 2008: Technical support to EU strategy on invasive alien species (IAS). *Institute for European Environmental Policy, Brussels.*

Kinler N.W. 1992: Biology and ecology of nutria. *Proceedings of the 13th annual meeting of the American Society of Wetland Scientists, New Orleans.*

Kinler N.W., Linscombe G. & Ramsey P.R. 1987: Nutria. In: Novak M., Baker J.A., Obbard M.E. & Malloch B. (eds.), Wild furbearer management and conservation in North America. *Ontario Trappers Association, Toronto: 326–343.*

Laymen's report 2014: Life Trachemys. Project LIFE + Trachemys (LIFE09 NAT/ES/000529). *http://agroambient.gva.es/documents/91061501/161355510/Informe+LAYMAN+LIFE+Trachemys+-+ENGLISH/791b50a1-d0e6-4dd8-8765-5f554cac91a9*

LeBlanc D.J. 1994: Nutria. In: Hygnstrom S.E., Timm R.M. & Larson G.E. (eds.), Prevention and control of wildlife damage. *The University of Nebraska, Lincoln: B71–B80.*

Lowe S., Browne M., Boudjelas S. & De Poorter M. 2000: 100 of the world's worst invasive alien

species: a selection from the global invasive species database, vol. 12. *IUCN/SSC Invasive Species Specialist Group. http://www.issg.org/pdf/publications/worst_100/english_100_worst.pdf*

Lutz W. 1996: The introduced raccoon *Procyon lotor* population in Germany. *Wildl. Biol. 2: 228.*

Mitchell-Jones A.J., Amori G., Bogda Lowenowicz W. et al. 1999: The atlas of European mammals. *T. & A. D. Poyser, London.*

Mori E., Mazzab G., Menchetti M. et al. 2015: The masked invader strikes again: the conquest of Italy by the Northern raccoon. *Hystrix 26: 47–51.*

Nardoni S., Angelici M.C., Mugnaini L. & Mancianti F. 2011: Prevalence of *Toxoplasma gondii* infection in *Myocastor coypus* in a protected Italian wetland. *Parasit. Vectors 4: 240.*

Panzacchi M., Bertolino S., Cocchi R. & Genovesi P. 2007: Population control of coypu *Myocastor coypus* in Italy compared to eradication in UK: a cost-benefit analysis. *Wildl. Biol. 13: 159–171.*

Peel M.C., Finlayson B.L. & McMahon T.A. 2007: Updated world map of the Köppen-Geiger climate classification. *Hydrol. Earth Syst. Sci. 11: 1633–1644.*

Perez-Santigosa N., Díaz-Paniagua C. & Hidalgo-Vila J. 2008: The reproductive ecology of exotic *Trachemys scripta elegans* in an invaded area of southern Europe. *Aquat. Conserv. 18: 1302–1310.*

Prange S., Gehrt S.D. & Wiggers E.P. 2003: Demographic factors contributing to high raccoon densities in urban landscapes. *J. Wildl. Manag. 67: 324–333.*

Prigioni C., Balestrieri A. & Remonti L. 2005: Food habits of the coypu, *Myocastor coypus*, and its impact on aquatic vegetation in a freshwater habitat of NW Italy. *Folia Zool. 54: 269–277.*

Ratnaswamy M.J. & Warren R.J. 1998: Removing raccoons to protect sea turtle nests: are there implications for ecosystem management? *Wildl. Soc. Bull. 26: 846–850.*

Regulation EU 2014: Regulation No 1143 of the European Parliament and of the Council of 22 October 2014 on the prevention and management of the introduction and spread of invasive alien species. Downloaded on November 2020. *https://eur-lex.europa.eu/eli/reg/2014/1143/oj*

Salgado I. 2018: Is the raccoon (*Procyon lotor*) out of control in Europe? *Biodivers. Conserv. 27: 2243–2256.*

Semenov D.V. 2010: Slider turtle, *Trachemys scripta elegans*, as invasion threat (Reptilia; Testudines). *Russ. J. Biol. Invasions 1: 296–300.*

Sergio A.Z, Di Cerbo A., Gazzonis A.L. et al. 2016: Parasitic and bacterial infections of *Myocastor coypus* in a Metropolitan area of Northwestern Italy. *J. Wildl. Dis. 52: 126–130.*

Somma L.A., Foster A. & Fuller P. 2009: *Trachemys scripta elegans*. USGS nonindigenous aquatic species database. Downloaded on September 2020. *https://nas.er.usgs.gov/queries/CollectionInfo.aspx?SpeciesID=1261*

Standfuss B., Lipovšek G., Fritz U. & Vamberger M. 2016: Threat or fiction: is the pond slider (*Trachemys scripta*) really invasive in Central Europe? A case study from Slovenia. *Conserv. Genet. 17: 557–563.*

Stefferud J.A. 1992: Sonora chub (*Gila ditaenia*). *U.S. Fish and Wildlife Service, Phoenix.*

Stille B. & Stille M. 2017: The herpetofauna of Corfu and adjacent islands. *Edition Chimaira, Frankfurt.*

Stille M. & Stille B. 2020: The dragonflies of Corfu. *Edition Chimaira, Frankfurt.*

Stope M. 2019: Wild raccoons in Germany as a reservoir for zoonotic agents. *Eur. J. Wildl. Res. 65: 94.*

Urošević A.A. 2014: Report of two subspecies of an alien turtle, *Trachemys scripta scripta* and *Trachemys scripta elegans* (Testudines), Emydidae: sharing the same habitat on the island of Zakynthos, Greece. *Ecol. Montenegrina 1: 268–277.*

US Fish and Wildlife Service 2007a: Hawksbill sea turtle (*Eretmochelys imbricata*). 5-year review: summary and evaluation. *US Fish and Wildlife Service USA, Jacksonville. https://www.cabi.org/isc/FullTextPDF/2011/20117202445.pdf*

US Fish and Wildlife Service 2007b: Endangered and threatened wildlife and plants; reclassification of the American crocodile distinct population segment in Florida from endangered to threatened. *US Fish and Wildlife Service USA, Arlington. https://www.govinfo.gov/content/pkg/FR-2007-03-20/pdf/E7-5037.pdf#page=1*

US Fish and Wildlife Service 2009: Crested caracara (*Caracara cheriway*). 5-year review: summary and evaluation. *US Fish and Wildlife Service USA, Vero Beach. https://www.cabi.org/isc/FullTextPDF/2013/20137204859.pdf*

Watkins S.A., Wanyangu S. & Palmer M. 1985: The coypu as a rodent reservoir of leptospira infection in Great Britain. *J. Hyg. 95: 409–417.*

Wittenberg R., Kenis M., Blick T. et al. 2005: An inventory of alien species and their threat to biodiversity and economy in Switzerland. *CABI Bioscience Switzerland Centre*

report to The Swiss Agency for Environment, Delémont.

Working Group on Invasive Alien Species 2017: *https://ec.europa.eu/transparency/regexpert/index.cfm?do=news.open_doc&id=6282*

Zenetos A., Pancucci-Papadopoulou M.A., Zogaris S. et al. 2009: Aquatic alien species in Greece 2009: tracking sources, patterns and effects on the ecosystem. *J. Biol. Res. (Thessalon.) 12: 135–172.*

Supplementary online material

Fig. S1. Known breeding areas for common pheasant (*Phasianus colchicus*; square = 2 × 2 km).

Fig. S2. Known areas for chukar partridge (*Alectoris chukar*; square = 2 × 2 km).

Fig. S3. Raccoon female with cub.

(https://www.ivb.cz/wp-content/uploads/JVB-vol.-70-1-2021-StilleM.-et-al.-Figs.-S1-S3.pdf)

Table S1. Excel file with coordinates for camera and species coordinates (https://www.ivb.cz/wp-content/uploads/JVB-vol.-70-1-2021-StilleM.-et-al.-Table-S1-1.xlsx)