

Impact of the small Indian mongoose on native amphibians and reptiles of the Adriatic islands, Croatia

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Abstract

We studied impacts of the introduced small Indian mongoose *Herpestes auro-punctatus* on the herpetofauna on six islands in the Adriatic Sea, Croatia, comparing abundances of reptiles and amphibians on three islands with the mongoose to those on three islands without the mongoose. We used four types of sampling surveys: distance-constrained surveys, visual encounter surveys, special searches and accidental trapping. The horned viper *Vipera ammodytes* and Balkan green lizard *Lacerta trilineata* were absent from two mongoose-infested islands (Korčula and Mljet) and rare on the third (Hvar); they were common only on the mongoose-free island where they had historically been present (Brač). The European green toad was absent from one mongoose-infested island, where it had historically been present and rare on the other two. It was common on two of the three mongoose-free islands. Other herpetofaunal species were either very scarce or completely absent on the three mongoose-infested islands. Most of these species also occur on the mainland but are already scarce there; some are strictly protected under Appendix II of the Berne Convention. The recent spread of the mongoose to the European mainland suggests the need for urgent control to protect vulnerable herpetofauna.

Introduction

Extinctions of island species as a result of anthropogenic impacts are well documented (Vitousek, 1988; Whittaker & Fernández-Palacios, 2007). Island species generally have small populations, restricted genetic diversity and narrow ranges (Blondel, 1995), so even small changes can considerably affect their survival (Vitousek, 1988). Two major causes of the decline of island species are habitat degradation caused by human development and introduction of non-native predators. In a review of amphibian and reptile extinctions that have occurred since 1600, Honegger (1981) found that most were island taxa. Henderson (1992) attributed most extinctions/extirpations of West Indies amphibians and snakes on large islands to the loss of habitat but those on small islands to introduced predators, especially the small Indian mongoose *Herpestes auro-punctatus*.

The small Indian mongoose has been touted as one of the world's 100 worst invasive species (IUCN, 2000). Native to Asia, it was introduced to many islands in the Pacific and Indian Oceans and the Caribbean Sea, mostly in the late 19th and early 20th centuries, primarily in order to control rats in sugar cane fields. However, the success of the mongoose in this endeavor is questionable as rat numbers continue to be high (Hinton & Dunn, 1967). The other reason the mongoose was introduced was to control native poisonous snakes: a pit viper, habu *Trimeresurus flavoviridis*

on several islands in Japan, the fer-de-lance on the West Indian islands of Martinique (*Bothrops lanceolatus*) and St Lucia (*Bothrops caribbaeus*) and the horned viper *Vipera ammodytes* on several islands in the Adriatic Sea. However, because the mongoose is a generalist predator, it also preys on other native species and is blamed for the decline and extirpations of many native species on islands. There are many reports of population reductions of reptiles and amphibians caused by the mongoose, but there is usually controversy over whether the mongoose is truly the main culprit (Corke, 1992; Hays & Conant, 2007).

In the Adriatic Sea, the mongoose was introduced in 1910 to Mljet Island and subsequently to several other islands (Korčula, Hvar, Čiovo, Škrda) and the mainland Pelješac Peninsula. It is currently spreading along the Dalmatian coast and has reached the Neretva River in the north (Barun, Budinski & Simberloff, 2008) and Albania in the south. Other introduced mammalian predators on the islands are black rats *Rattus rattus* and feral cats, but their effects on the Croatian fauna are not documented. In addition to introduced predators, nearly all larger islands in Croatia have a native predator, the stone marten *Martes foina*. Therefore, native Croatian species have evolved in the presence of the stone marten, and they have confronted introduced predators, but the population impacts of these predators are unknown.

The impact of a particular introduced predator is hard to isolate when others, such as rats, are present. Fortunately, in the southern part of the Adriatic, Dalmatia, the mongoose has been introduced to some but not all islands. It is therefore possible to compare mongoose-free and mongoose-infested islands to attempt to determine if factors other than mongoose presence can account for how native amphibian and reptile abundance differs between these two classes of islands. That was the purpose of this study.

Methods

Study area

Field work was conducted on six islands in the southern part of Adriatic Sea: Mljet, Korčula, Hvar, Lastovo, Brač and Dugi Otok; the first three have the mongoose and the last three do not. These islands are relatively similar in surface area (Mljet: 100 km², Korčula: 270 km², Hvar: 299 km², Lastovo: 53 km², Brač: 394 km², Dugi Otok: 114 km²), elevation, geology, climate and vegetation. All these islands have a similar history of human occupation, similar agricultural practices and similar timing of introduction of most exotic species. Their landscape is a fine-grained mosaic of shrublands, scrublands, forests and small agricultural fields. Shrublands (maquis) are dense thickets of evergreen sclerophyll shrubs and small trees dominated by *Quercus ilex*, *Fraxinus ornus*, *Phillyrea latifolia*, *Pistacia terebinthus*, *Myrtus communis*, *Arbutus unedo*, *Laurus nobilis*, *Erica arborea*, *Lonicera implexa*, *Lonicera etrusca*, *Tamus communis*, *Smilax aspera*, *Rubia peregrina*, *Olea europaea oleaster* and *Asparagus acutifolius*. Scrublands (garrigue) are dominated by *Cistus incanus*, *Cistus creticus*, *Cistus salvifolius*, *Cistus monspeliensis*, *Er. arborea*, *Erica multiflora*, *Spartium junceum*, *Calicotome villosa* and *Rosmarinus officinalis*. Forests are dominated mostly by *Pinus halepensis*. Most local agriculture consists of olive groves and vineyards, with a few small vegetable fields with rich soil. All transects reported below run through all four vegetation types, but the proportion of each type may vary among transects.

Methods

We conducted sampling surveys on each island to assess the relative abundance of snake, lizard and frog species. Because the species ranged from active foragers to sit-and-wait (ambush) predators, from diurnal to nocturnal and from fully terrestrial to semi-aquatic, and occurred over a wide range of abundances, we used four different sampling surveys: distance-constrained surveys, visual encounter surveys, special searches and incidental trapping. Active sampling plays an important role in herpetofauna studies, especially for agile and larger species. Using diverse types of sampling surveys was essential in order to survey different species, several of which were very scarce (Guyer & Donnelly, in press).

For distance-constrained surveys (transects), we used narrow, 2.5 km dirt roads as our main transects. On each island we selected three transects each running through all four

vegetation types described above. A single researcher (I. B.) walked the transect at a constant pace, once a day at mid-morning, and recorded all reptiles sighted within 1 m on either side. We surveyed each transect once in April 2008 and once in May 2008. We recorded wind speed, cloud cover and air temperature at the beginning and end of each survey using a Kestrel 3000 Pocket Weather Meter (Nielsen-Kellerman Co., Boothwyn, PA, USA). We did not conduct surveys if there was excessive cloud cover, high wind or high or low air temperature. We surveyed one transect per morning, starting about 2 h after sunrise. We ran multiple regressions in JMP, version 8 (SAS Institute Inc., Cary, NC, USA) to test if weather conditions affected abundance of two species of lizards that were counted only on transects: the Dalmatian wall lizard *Podarcis melisellensis* and the sharp-snouted rock lizard *Dalmatolacerta oxycephala*. Only April or May counts are shown, whichever was highest, and abundance data were summed for all three transects.

We recorded visual encounter surveys during walking and driving. We recorded mileage upon arrival on each island to ensure that we did not drive more on some islands than on others. We conducted additional walking surveys while checking traps. All islands had the same number of transects and traps, so we did not walk more on certain islands. We did not conduct visual surveys for reptiles at night.

Because we had observed many adult European green toads *Bufo viridis* and common tree frogs *Hyla arborea* around ponds on Brač and Lastovo, we conducted targeted searches for these species during day and night around ponds on the other four islands.

We sampled the European glass lizard *Pseudopus apodus* in traps that were part of a small mammal survey. We set up a trapping system of INRA and ratière live traps (Guédon, Bélair & Pascal, 1990) on each island consisting of 30 traps at 30 m interval along the narrow dirt roads used as transects, as described above. To cover each side of the road, we placed every other trap on the opposite side of the road. We ran the trapping system for three days and three nights in April and again in May 2008. We marked locations so that in May traps were located exactly as in April. We baited all traps with a mixture of oat-flakes, peanut butter and sardine oil, changing baits once during the 3-day period or just after rain. We checked each trap early in the morning and late in the evening before sunset to catch mostly nocturnal small mammals but also the diurnal mongoose.

We also identified the gut contents of all 57 mongooses trapped in May and April on Mljet, Korčula and Hvar. Prey items were categorized into the following major taxonomic groups: mammals, birds, snakes, lizards, invertebrates and plants. Mammals were classified to species based on comparison with reference hair samples; birds could not be identified (only small or finely chewed feathers were found); lizards were classified to species when possible and invertebrates to order.

Results

We recorded 15 species of Reptilia and two species of Amphibia (Table 1). Two additional reptile species (grass

Table 1 Species of reptilia and amphibia (rows) on islands (columns)

	Mongoose present			Mongoose absent		
	Mljet (31)	Korčula (21)	Hvar (5)	Brač	Lastovo	Dugi Otok
Frogs and toads						
European green toad <i>Bufo viridis</i>	X	X (2)	X (4)	X (65)	X (18)	X (1)
Common tree frog <i>Hyla arborea</i>	–	X (16)	X	X	–	X (28)
Marsh frog <i>Pelophylax ridibundus</i>	X	–	–	–	–	–
Turtles						
Hermann's tortoise <i>Testudo hermanni</i>	X	X (1)	X	X	–	–
European pond terrapin <i>Emys orbicularis</i>	X	–	–	–	–	–
Marsh frog <i>Pelophylax ridibundus</i>	X	–	–	–	–	–
Lizards						
Dalmatian wall lizard <i>Podarcis melisellensis</i>	X (155)	X (91)	X (30)	X (68)	X (352)	X (49)
Sharp-snouted rock lizard <i>Dalmatolacerta oxycephala</i>	X (53)	X (29)	X	X (1)	X (84)	–
Moorish gecko <i>Tarentola mauritanica</i>	–	–	X (33)	–	–	–
Balkan green lizard <i>Lacerta trilineata</i>	–	X	X (2)	X (50)	–	–
Turkish gecko <i>Hemidactylus turcicus</i>	X	X	X	X	X	X
Anatolian worm lizard <i>Blanus strauchi</i>	–	–	X	–	–	–
European glass lizard <i>Pseudopus apodus</i>	X	X (1)	X (19)	X (57)	X (12)	X (54)
Snakes						
European cat snake <i>Telescopus fallax</i>	X	X	X (1)	X	–	X
Balkan whip snake <i>Hierophis gemonensis</i>	X	X (1)	X (14)	X (3)	–	X (7)
Montpellier snake <i>Malpolon insignitus</i>	X (3)	X (3)	X (1)	X (2)	–	X (8)
Four-lined snake <i>Elaphe quatuorlineata</i>	X	X	–	X (4)	–	–
Aesculapian snake <i>Zamenis longissimus</i>	X (1)	–	X (1)	X (7)	–	–
Leopard snake <i>Zamenis situla</i>	–	X (2)	–	–	–	X (3)
Horned viper <i>Vipera ammodytes</i>	X	X	X (2)	X (2)	–	–
Smooth snake <i>Coronella austriaca</i>	X (2)	–	–	X	–	–
Large whip snake <i>Dolichopsis caspius</i>	–	–	–	–	X (26)	–
Grass snake <i>Natrix natrix</i>	–	X	X	X	–	X

X indicates species historically present on an island (Kryštufek & Kletečki, 2007), and in parentheses are the numbers of individuals found on an island. For snakes, amphibians, turtles and the Balkan green lizard *L. trilineata*, we report the total number found in April and May. For three species of small lizards, *P. melisellensis*, *D. oxycephala* and *T. mauritanica*, which were counted only on transects, we report the highest number recorded for the island for either April or May.

snake *Natrix natrix* and Anatolian worm lizard *Blanus strauchi*) and one amphibian species (marsh frog *Pelophylax ridibundus*) have been reported on some islands, but we did not find them. We also trapped 57 small Indian mongooses on three islands. Mongooses were most abundant on Mljet, and abundance was five times less on Hvar (Table 1). Weather conditions (cloud cover, wind speed and air temperature) were not significant determinants of the numbers of the two lizard species encountered only on transects, the Dalmatian wall lizard ($F_{3,33} = 1.17$, $P = 0.3371$) and the sharp-snouted rock lizard ($F_{3,33} = 1.6287$, $P = 0.2035$).

Snakes

The total number of snake species among the islands is 10, but not all species are present on all islands (Table 1). If we look just at the total number of snakes on each island, Mljet and Korčula (each with six snakes), stand out as having three times fewer individuals recorded than Hvar, Brač, Lastovo and Dugi Otok, which have 19, 18, 26 and 18, respectively (Fig. 1). We found no snakes on transects except for two large whip snakes *Dolichopsis caspius* on Lastovo,

where this species is very numerous (26 individuals). We found all other snakes either during road surveys or in traps. In our surveys, we found no horned vipers on Mljet and Korčula, but we found two individuals on Hvar and two on Brač. We also did not find the four-lined snake *Elaphe quatuorlineata* on Mljet and Korčula, but on mongoose-free Brač we found four individuals, three road kills and one incidental encounter. We found no individuals of the Balkan whip snake *Hierophis gemonensis* on Mljet, but we found one individual on Korčula, 14 on Hvar, three on Brač and seven on Dugi Otok.

Lizards

We observed a total of seven lizard species on the six islands, but not all lizard species are present on all islands (Table 1). In addition, we did not find the Turkish gecko *Hemidactylus turcicus*, which has been recorded on the islands. It is nocturnal, and we did not survey at night. The largest lacertid lizard on these islands is the Balkan green lizard *Lacerta trilineata*. We found no individuals on Korčula and only two on Hvar. On Brač, we frequently encountered it on

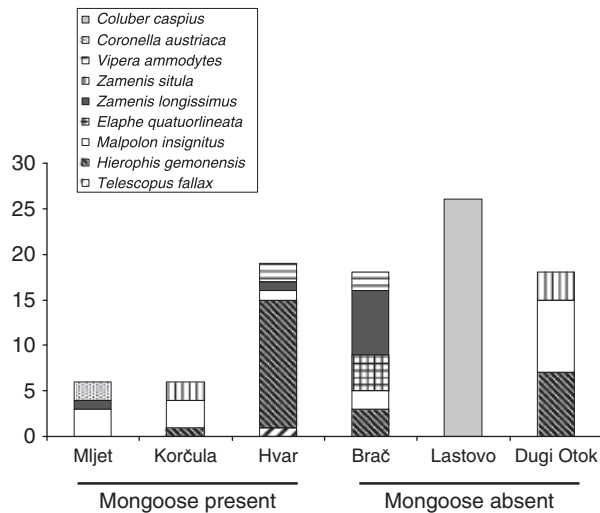


Figure 1 Total number of snakes recorded for the surveyed islands.

transects (26) and found many during visual surveys (50). The sharp-snouted rock lizard was not recorded on Hvar, one was recorded on Brač, and on Mljet, Korčula and Lastovo it was numerous. We recorded 33 Moorish geckos *Tarentola mauritanica* on Hvar. The European glass lizard has been recorded on all six islands. We did not find it on Mljet, and its abundance on Korčula was much lower than on the other four islands. The abundance of all species of lizards among transects within islands varied; some of this variation may be attributed to habitat differences.

Amphibians

Only four species of amphibians inhabit these six islands (Table 1). The European green toad was historically present on all six; we found a few specimens on Korčula and Hvar but only after extensive targeted search around ponds and inside man-made water containers. Similar searches produced none on Mljet (and the local biologist has seen none). On Brač and Lastovo, we found many specimens of this species on transects, conducting road surveys, or while checking traps. On Dugi Otok, we found just one individual of this species, but this is the only island where it did not rain while we were sampling. On all islands but Dugi Otok, it rained either in April or May when we were present. Frogs are more active when it rains, and our data are consistent with this pattern. On the two islands where the European green toad is numerous we recorded higher numbers when it rained (Brač 12, Lastovo 53) than when it was dry (Brač 5, Lastovo 12).

Stomach contents

We examined contents of 57 mongoose stomachs. Nineteen stomachs were empty. The rest usually had combinations of vegetation (four), unidentifiable hair (five; one identified to *Apodemus sylvaticus*), bones (three) or bird feathers (three),

snake skin (one) and invertebrates (24, mostly beetles in Cetonidae and the Egyptian grasshopper *Anacridium aegyptium*). Many stomachs had reptile remains that were easily identified to species: Dalmatian wall lizard (12), Moorish gecko (three) and Balkan whip snake (one). In a single mongoose stomach from Hvar we found one Balkan whip snake, one Dalmatian wall lizard and one Moorish gecko. In another stomach of a mongoose from Korčula we found three Dalmatian wall lizard individuals and many invertebrates. Overall, three mongooses from Mljet had reptiles in their stomachs, as did six from Korčula and four from Hvar. Only mongooses from Hvar had snakes in their stomachs, and we caught by far the fewest mongooses on this island (five compared with 31 and 21 for Mljet and Korčula, respectively). This is a very small sample size, but it does reflect the higher abundance of snakes on Hvar compared with Mljet and Korčula.

Discussion

Snakes

Historical records show the horned viper was very frequently encountered on Mljet, which was known as the 'island of snakes' (Tvrtković & Kryštufek, 1990). We do not know the initial abundance of other species present on islands before the mongoose introduction but we are certain that the horned viper's high abundance on Mljet in 1910 warranted such concern among authorities that the mongoose was introduced to control this snake. In our surveys we did not find a single viper on Mljet or Korčula, where the mongoose has been present since 1910 and 1927, respectively (Tvrtković & Kryštufek, 1990), but Budinski *et al.* (2008), after extensive search, found one on Mljet in 2007. On Brač, the only mongoose-free island where it was historically present, we found it, but rarely. This species is listed as strictly protected under Appendix II of the Berne Convention, which sets out to conserve wild flora and fauna and their natural habitats by all member states of the Council of Europe, European Union and several other neighboring countries. Our result is not surprising, because extirpations or extinctions in the Caribbean of *Alsophis* and *Liophis* snake species have occurred primarily on those islands with mongoose populations (Sajdak & Henderson, 1991). We were surprised to find two individuals on Hvar, where the mongoose has been present since c. 1970 (Tvrtković & Kryštufek, 1990). However, extensive talks with local hunters revealed that they have been conducting island-wide yearly predator control for several years. The reduced number of mongooses trapped in our study (Table 1) and the survival of the horned viper on this island may reflect this activity.

Island size may be critical in determining whether an extirpation occurs (Henderson, 1992). This factor could also explain why on Mljet (which is almost three times smaller than Korčula and Hvar), we found significantly fewer individual snakes, and not nearly as many species as historical records show (Tvrtković & Kryštufek, 1990).

Henderson (1992) noted that there are no recorded post-Columbus extirpations of *Alsophis* or *Liophis* snakes on any island that has remained mongoose-free, whereas mongoose-infested islands have recorded a mean number of 0.78 extirpations (range 0–2). Our islands show a similar pattern. We found no extirpations of snakes on islands without the mongoose, suggesting that human land development is not the only or even main cause of the reduction in snake diversity on Mljet and Korčula.

In addition, the recorded high or low abundance of several snake species can be explained by their life histories. For example, the eastern Montpellier snake is known as the fastest European snake and when threatened hisses loudly and for long periods; it may also flatten and inflate the front of the body and spread the neck. We believe this behavior disrupts the predatory behavior of the mongoose, and it might be the reason this species is still present on islands with the mongoose.

Lizards

Elevated numbers of the Balkan green lizard in areas where the mongoose is controlled or absent are also evidence that the mongoose has a strong impact on at least some native reptiles and that trapping the mongoose does increase native reptile numbers. The Balkan green lizard is very abundant on other Adriatic islands where the mongoose is absent (A. Barun & I. Budinski, pers. obs.), but these (Cres, Lošinj, Krk) were not part of our study. The mongoose is present on the island of Čiovo where the Balkan green lizard was historically present. A. B. and I. B. visited Čiovo several times from 2004 through 2009 during spring, summer and fall months and found no Balkan green lizards. This lizard is quite numerous on the mainland along the coast, but we do not know its status where the mongoose is present. The Balkan green lizard is morphologically and ecologically similar to the ground lizard *Ameiva polops*, which was eliminated from the main island of St Croix after the introduction of mongoose in 1884 but persists on neighboring smaller islands lacking mongooses (Henderson & Powell, 2009). In Viti Levu, Fiji, the mongoose is believed to have extirpated two native skinks *Emoia nigra* and *Emoia trossula* (Brown & Gibbons, 1986; Zug, 1991).

Comparing small lizards on different islands is difficult because lizards are prey to many different predator species and their abundance might be inversely correlated with predator abundance (snakes, larger lizards, including the European glass lizard, and the mongoose). For example, the low abundance of the Dalmatian wall lizard on Brač might be due to high abundance of its native predators (several snake species and the European glass lizard) and/or competition with the much larger Balkan green lizard. On Mljet, the overall lower abundance of the Dalmatian wall lizard could be attributed to competition with the sharp-snouted rock lizard, which is also numerous on this island (Fig. 2). It is difficult to draw overall conclusions about population impacts on small lizards, but we know that the mongoose preys on them because we found many in mongoose stomachs.

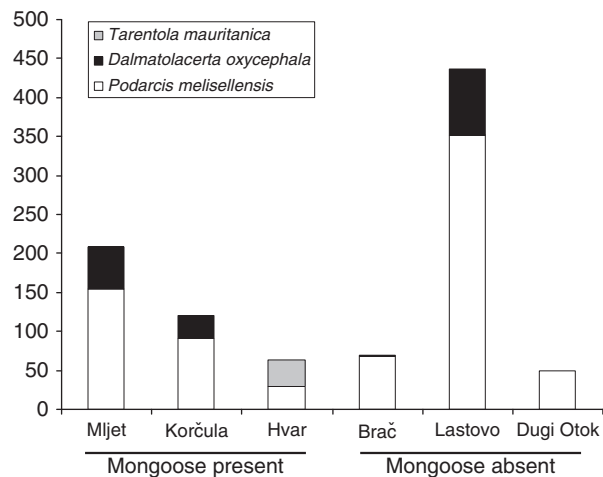


Figure 2 Total number of small lizards (*Podarcis melisellensis*, *Dalmatolacerta oxycephala*, *Tarentola mauritanica*) recorded for the surveyed islands.

Henderson (1992) noted that in the West Indies *Anolis* lizards are regularly preyed upon, but he was unaware of any species of *Anolis* whose numbers seemed drastically reduced owing to predation by native or introduced predators. While conducting similar walking transects to ours, Case & Bolger (1991) found that the abundance of a diurnal lizard was 100 times higher on seven Pacific islands without the mongoose than on 11 islands with the mongoose. We believe our failure to observe a similar pattern resulted from the uneven distribution of predator and competitor species on several of our islands, and the small number of sampled islands (three) that had the mongoose. It would have been difficult to increase our sample size because there are only two other islands in the Adriatic with mongoose populations, and they are very small.

It is difficult to sample the European glass lizard on transects when numbers are very low. We have discovered that this species, when abundant, is readily attracted to bait, because we found it frequently in traps set for small mammals and the mongoose. This species is very rare on Korčula and was not recorded on Mljet, but it was numerous on all other islands (Table 1). We are aware of no other studies that examine the impact of the mongoose on legless lizards.

Amphibians

Many authors have shown that amphibians are rare when the mongoose is present. On Amami-Oshima island, Japan, the Amami tip-nose frog *Rana amaminensis*, Otton frog *Rana babina subaspera* and Ishikawa frog *Rana ishikawae* were all scarce in areas that had been invaded by the mongoose long ago (Watari *et al.*, 2006). The edible frog *Leptodactylus pentadactylus* has been extirpated from three Caribbean islands with the mongoose but is still present on two mongoose-free islands (Barbour, 1930). The mongoose is implicated in the decline of the two native frogs

(*Platymantis vitianus* and *Platymantis vitiensis*) in Fiji (Kuryawa *et al.*, 2004). Therefore, it is not surprising that the three frogs (European green toad, common tree frog and marsh frog) were either very scarce or completely absent on three mongoose-infested islands in the Adriatic. A survey conducted in spring and fall of 2007 in the National Park of Mljet found the marsh frog only in a lake (Budinski *et al.*, 2008). This species is aquatic during the day, so it is unsurprising that it was found in the lake, but it is surprising that neither survey found it away from the lake. April 2008 had above average annual rainfall, so our recorded low abundance of this species was not because of a dry year.

Stomach contents

Even though we have no clear evidence that the mongoose preys on the species that are in low abundance, the gut content analyses show that the mongoose does prey on reptiles. On Amami-Oshima, the mongoose preys chiefly on insects and birds throughout the year, but on amphibians and reptiles more frequently in summer and on mammals in winter (Yamada & Sugimura, 2004). We have sampled during spring and early summer, so many reptiles in the mongoose guts might reflect the season.

Conservation implications

Assessment of responses to mongoose predation is often complicated by the presence of multiple native predator or competitor species, other management activities and/or human habitat alterations. In our study, several other predator species were present on all islands: feral cats, black rats and the stone marten. The decrease in abundance and extirpations of reptile and amphibian species are not due to predation by rats because there is no significant difference in rat abundance between mongoose-free and mongoose-infested islands (A. Barun & D. Simberloff, in prep.), and we have no evidence to suggest that the feral cat populations are the same or different and/or being controlled on any islands. The stone marten is mostly nocturnal, so it would have little to no impact on the diurnal snakes and lizards we studied. Also, abundances of the Balkan green lizard, the European glass lizard and most snake species are much higher on islands with just the stone marten, rats and cats, but not the mongoose (Lastovo, Dugi Otok, Brač, Cres, Krk, Lošinj) (A. Barun & I. Budinski, pers. obs.).

Long-term survival of amphibian and reptile species with low densities, such as several of those recorded on Adriatic islands, is questionable, and in the long run those species may be doomed to local extinction (Vitousek, 1988). Species that are historically present but unrecorded in our research are possibly already locally extinct or they might be restricted to areas or marginal habitats where we did not sample. It is important to note that most amphibian and reptile species we studied also occur on the mainland and are already in low numbers, and some are strictly protected under Appendix II of the Berne Convention. Amphibian populations along the Croatian coast are mostly isolated in

small karstic ponds and threatened with local extinction because of the drying up or overgrowth of these ponds (Janev Hutinec *et al.*, 2006). If the mongoose continues to spread along the coast it will threaten not only amphibians and reptiles but also many other conservation projects. The demonstrated impact of the mongoose on island herpetofauna should be considered in light of the recent spread of this predator to the European mainland (Barun *et al.*, 2008). Once introduced elsewhere, the mongoose has spread very rapidly, and its presence on the Balkan Peninsula, which is a hotspot of European biodiversity, should raise alarms for other faunas too (see Hays & Conant, 2007 for a review of the impact on other groups).

In sum, although interactions among multiple species confound interpretations of many of the patterns we have documented, our evidence is strong that the small Indian mongoose considerably affects several species, in particular several snake species, the Balkan green lizard, and the European green toad. Noteworthy is that the horned viper (a protected species) and the Balkan green lizard, though rare on Hvar, are apparently more common there than on the other two mongoose-infested islands (Korčula and Mljet). Alone among these islands, Hvar has been the site of an informal, private campaign to hunt and trap mongooses, and it is possible that this campaign has permitted larger populations of at least these two reptiles. If this is so, it suggests that an expanded, systematic effort to eradicate or at least suppress mongoose populations on these islands, under the auspices of the Croatian government, would substantially and rapidly benefit some reptile populations. Finally, the demonstrated impact of the mongoose on the herpetofauna of these islands lends urgency to the need to confront the expanding population of this carnivore, which has recently spread south on the mainland to Montenegro and Albania and has established a toehold on a much smaller Croatian island far to the north of those we studied (Barun *et al.*, 2008).

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