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SHORT COMMUNICATION

Test of the efficacy of two chemical repellents in the control of Hermann's tortoise nest predation

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Abstract The survival of the tiny native population of the western Hermann's tortoise *Testudo hermanni hermanni* at the Albera Nature Reserve is threatened by nest predation. The initial purpose of this work was to test the efficacy of a commercial chemical repellent aimed at carnivores in the control of this predation. A total of 128 artificial nests containing quail eggs were distributed among eight 625-m^2 plots. There were four control plots and four plots protected by repellent devices in a natural nesting area of the Albera; each plot contained 16 nests. All the nests, including the protected ones, were depredated after only 4 days. Due to the major role of the wild boar *Sus scrofa* as predator in this experiment, we decided to assess, by means of a second experiment (n=160 artificial nests, 20 nests/plot), the efficacy of a specific repellent for this mammal combined with the initial repellent. The only noticeable effect of the combination of repellents was to delay predation, although after 4 days almost all protected nests had been depredated. We found both repellents unsatisfactory for reducing nest predation, necessitating the search for other methods of predator control.

Keywords Nest predation · Endangered population · Non-lethal control · *Testudo hermanni hermanni*

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Introduction

Historically, the western Hermann's tortoise *Testudo hermanni hermanni* was widely distributed in the lowlands of the western Mediterranean Basin (Fèlix et al. 2006). As a result of human pressure (land use changes, wildfires, illegal harvesting, road casualties, etc.), the subspecies has disappeared from most regions and is currently considered to be globally endangered (European Reptile & Amphibian Specialist Group 1996). The only remaining native population of the tortoise in the Iberian Peninsula is found in the Albera mountain range, a protected area in the Eastern Pyrenees (Catalonia, Spain). For the last few years, the Catalan government's Department of the Environment has supported several field studies aimed at a better understanding of the ecology of this tortoise population and to lay the foundations for future in situ conservation. It was in the course of these studies in 2005 that we found 48 tortoise nests in grasslands within the protected area, all of which showed clear signs of predation (Vilardell et al. 2006). Moreover, in 2007, 162 natural nests were found depredated within the Albera Nature Reserve (personal observation and Bertolero personal communication) which contained an estimated number of 567 eggs. Indeed, several authors identify predation as the main threat driving negative population dynamics in this subspecies (Madec 1995; Bertolero et al. 2007). High nest predation likely ensures the number of young recruited into these populations will be insufficient to

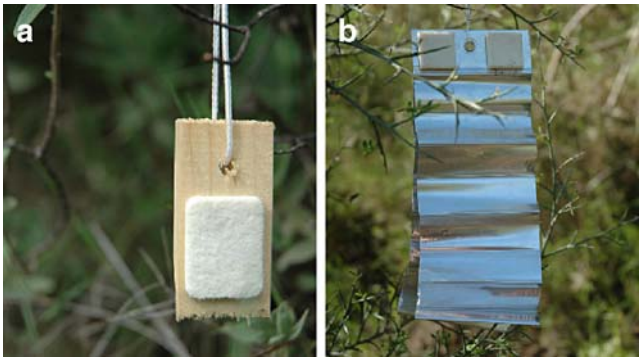

Fig. 1 **a** Design of the device where the repellent for carnivores was applied. **b** Commercial device for wild boar

ensure sustained population persistence. Thus, understanding mechanisms of nest predation may help to assess the level of threat and to determine the predatory species so that steps to reduce predation can be implemented. In addition, an experimental approach is necessary to test the efficacy of existing methods to reduce predation. Chemical repellents are one of the few options for predator control that offer ethical, legal and conservation advantages over lethal control (Ormerod 2002; Macdonald and Baker 2004; Baker et al. 2005). However, the effectiveness of these kinds of repellents has not been adequately tested in natural environments (Barlow 2000). The purpose of this work was therefore to evaluate potential nest predation and to assess the efficacy of commercial chemical repellents in the control of Hermann's tortoise nest predation.

Materials and methods

The study area (42°24′40″ N, 3°3′15″ E, 170 m above sea level) comprises a grassland habitat within the Albera Nature Reserve. This is in an area with a high breeding concentration of *T. hermanni hermanni* where we had previously discovered the 48 depredated nests.

We tested the relative efficacy of commercial chemical repellents claimed to be efficient at repelling species that are potential predators of Hermann's tortoise nests. The first product used was Schwegler©, which targets carnivores. Indeed, previous studies documented that the beech marten *Martes foina*, the fox *Vulpes vulpes* and the common genet *Genetta genetta* were the major nest predators (Budó et al. 2003) of this species.

In June 2006, during the period of tortoise second clutches (Bertolero et al. 2007), 128 artificial nests were evenly distributed among eight rectangular 625-m^2 plots (16 nests per plot) that were spaced 15 to 20 m apart. The artificial nests consisted of a hole (8 cm deep, 6 cm in diameter) containing three quail *Coturnix coturnix* eggs filled with soil, replicating a natural nest. Once filled, nests were sprinkled with 15 mL of a solution containing tortoise urine and excrement, to simulate female behaviour during nest building (Vilardell et al. 2006). The fluid repellent was applied to cotton attached to wooden devices (Fig. 1a) hung from branches 15 cm above the ground, following the manufacturer's directions for use. The devices were distributed around the perimeter of the four treatment plots 2 m apart, totalling 25 devices per plot. The other four plots, having no repellent, served as controls.

Due to the major role of the wild boar *Sus scrofa* as a predator in this experiment (see below), we decided to assess the efficacy of a second repellent (Stop Jabalí© Hagopur GmbH) in a new experiment in September 2006, during the tortoise hatching season. For this experiment, we distributed 160 artificial nests among the eight plots (20

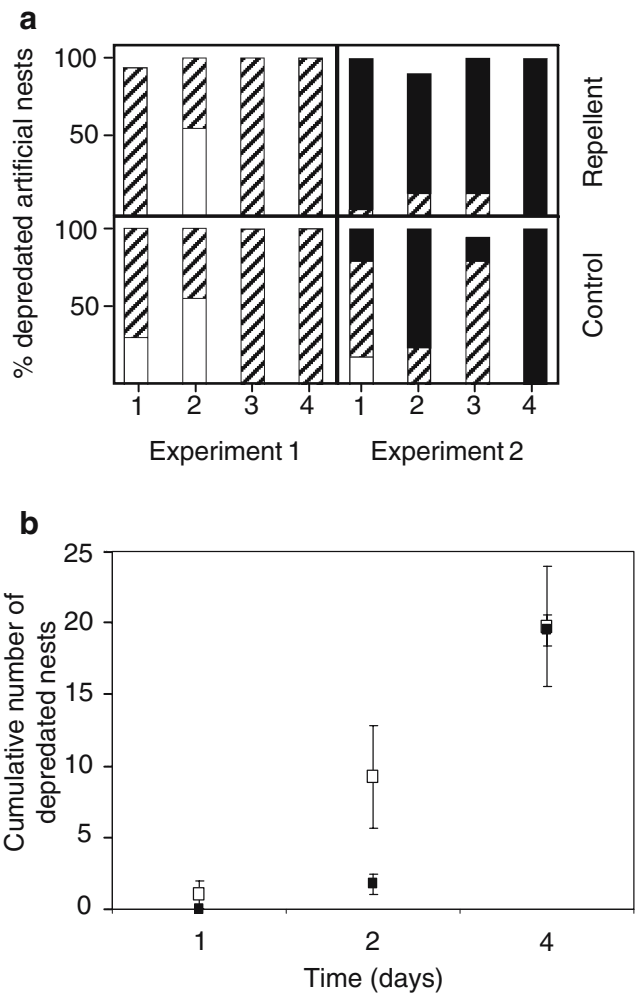

Fig. 2 **a** Cumulative percentage of depredated artificial nests at treatment and control plots (*1* to *4*) during the two experiments (*open*, *striped* and *black bars*, depredation after 1, 2 and 4 days, respectively). **b** Cumulative number of depredated artificial nests (means±standard error) at treatment (*black squares*) and control (*white squares*) plots along the first 4 days of the second experiment

nests/plot). We used commercial aluminium devices containing wild boar repellent (Fig. 1b), in addition to new devices containing the Schwegler© carnivore repellent, at the four treatment plots. Aluminium devices were hung on branches 1 m above the ground and 3 m apart around the plot perimeters, according to the manufacturer's user guide. In both experiments, all the nests were visited at regular time intervals to determine whether predation had occurred and, on the basis of tracks and other signs, to identify the predator. During the first 15 days, the nests were visited daily; thereafter, they were visited weekly for up to 3 months, which coincided with the duration of the incubation. In both experiments, we used the type of digging and predation, as well as animal footprints and excrement in the vicinity of the artificial nests to identify predatory species.

Results

Predation started as early as the first night in the control plots. In the first experiment, using carnivore repellent, all the nests except one in all eight plots were depredated after only 4 days. The pattern of temporal predation was similar between control and treatment plots (Fig. 2a). The main predator was the wild boar in both control and treatment plots (98.7% of all depredated nests), but the common genet and the beech marten were also responsible for some predation in control plots (2.5% of the depredated nests in controls).

In the second experiment (carnivore and wild boar repellent), 98.8% of the nests in the four control plots and 97.5% in the four treatment plots were depredated after 4 days (Fig. 2a). Only three nests survived the entire 3 months of the study. The unprotected nests showed a quicker predation rate than protected nests (Fig. 2b), but this effect was very short-lived as most nests were depredated within 4 days. The predation in the second experiment was due to four species: wild boar, common genet, beech marten and fox, although we found a lower occurrence of wild boar in both the control and treatment plots (84.7% of all depredated nests).

Discussion

We demonstrate here that the two commercial chemical repellents tested were ineffective in protecting simulated tortoise nests from predation. Our results are similar to previous efficacy experiments for commercial repellents like Renardine© for coyotes *Canis latrans* (Zemlicka and Mason 2001). The repellents we used delayed predation for a brief period; but, even so, almost all the nests were depredated after 4 days. This pattern is likely due to a progressive loss of the repellent's effectiveness as its concentration in the air is reduced over time. Predators may also get used to the olfactive cues of the repellent or may demonstrate behavioural mechanisms for avoiding toxins or chemical repellents. We suspect that repellents for carnivores could have attracted wild boar during the experiments. The unsatisfactory results we obtained forced the nature reserve's management to look for other control methods. Indeed, depredation in natural nests of *T. hermanni hermanni* was estimated to be 53% in the Albera (Budó et al. 2003), whereas in artificial nests it was 57% and 97% in dispersed and concentrated nests, respectively, located in the Maures massif (Madec 1995). Therefore, an alternative to reduce nest predation may be a suitable habitat management to create new nesting areas in order to diminish nest concentration: a particularly suitable action in the present context of revegetation following an extensive fire in 1986.

Our results show that wild boar can be a main predator of Hermann's tortoise nests, in addition to carnivores, traditionally cited as nest predators (Budó et al. 2003). Although predation of eggs and hatchlings by wild boars has been reported as a threat to Mediterranean tortoise populations, a quantitative assessment is still lacking (Corti and Zuffi 2003). Wild boar is an abundant species in the Albera protected area (Budó et al. 1997) and the main animal hunted there. Special permits, such as those often granted in Catalonia to reduce wild boar damage to crops, could be used to keep boar families away from the tortoise nesting areas during the incubation period.

Other approaches offer potentially non-lethal ways to manage mammalian nest predators (Reynolds and Tapper 1996). Food supplementation close to nest concentrations may be a useful technique, allowing predators to consume those resources instead of nest contents, as has been shown in ducks from upland habitats (Greenwood et al. 1998). Decision-making in the management of the declining Hermann's tortoise population is complex, however, because multiple threat factors must be addressed. Habitat loss and habitat degradation as a result of land use changes, wildfires, illegal harvesting, road casualties, altered predator communities and altered predator–prey ratios all harm this tiny population (Budó et al. 2003, 2004).

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