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Artificial water ponds and camera trapping of tortoises, and other vertebrates, in a dry Mediterranean landscape

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Abstract

Context. Mediterranean areas offer a mosaic of favourable microhabitats to reptiles (e.g. open zones, thorny bushes) and are considered as biodiversity hotspots for these organisms. However, in these dry and hot environments, reptiles remain sheltered most of the time. They generally escape observation, posing difficulties to perform inventories. Trap sampling or rock-turning surveys commonly used to detect reptiles entail important logistical constraints, may perturb fragile microhabitats, and are not appropriate for chelonians. Alternative simple and cost-effective methods are desired.

Aims. We tested the efficiency of camera trapping in a dry Mediterranean landscape, notably to detect threatened Hermann's tortoises. We tested whether small artificial freshwater ponds could attract animals in the field of view of the cameras to increase detectability. We also tested whether sand tracks survey around ponds could improve the method.

Methods. We used a small number of cameras with ponds (5 in 2011, 7 in 2012), thereby maintaining low logistical costs. We randomly filled three ponds and emptied three ponds every 7 days. We set the time-lapse function of each camera with an interval of 5 min and inspected the sand tracks every 2 or 3 days. We used information from 39 radio-tracked tortoises to better estimate the detectability performances of the camera–pond system.

Key results. This technique was effective to detect tortoises ($n = 348$ observations) and five other reptiles (among the 11 species present in the study area). Large numbers of birds and mammals were observed ($n = 4232$, $n = 43$ species at least), thereby increasing the biodiversity list of the surveyed area. We detected 28% of the radio-tracked tortoises present in the monitored area. Filled ponds were more attractive and sand track survey completed camera monitoring.

Conclusions. Camera trapping associated with small ponds represent a useful tool to perform rapid inventories of the fauna in Mediterranean habitats, especially to detect the emblematic Hermann's tortoise and other cryptic reptiles (e.g. snakes).

Implications. The low cost–efficiency ratio of this method allows performing multiple counting surveys, and thus may help collect robust data necessary to justify the protection of key habitats that are coveted by property developers.

Additional keywords: birds, mammals, reptiles, survey, *Testudo hermanni hermanni*, track survey.

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Introduction

Most biodiversity hotspots of Mediterranean regions are subjected to intensive anthropogenic pressures (e.g. rapid population growth) and are threatened by climatic changes (Myers *et al*. 2000; Debussche *et al*. 2009; García-Ruiz *et al*. 2011). Increasing conservation efforts in these areas is of paramount importance, and practical actions to protect key habitats against rapid urbanisation are essential (Cuttelod *et al*. 2009; Vimal *et al*. 2012). Indeed, many unprotected natural areas are coveted by property developers for their high value and to respond to intensive demographic increase (Catalán *et al*. 2008). In this tense context, one of the main difficulties faced by conservationists is to provide robust arguments for the protection of unprotected natural habitats before irreversible damages occur. Areas populated by a rich and diverse fauna, especially emblematic threatened species, attract considerable support from the public and, thus, offer strong fulcrum to set up protection programs (e.g. Ranius 2002; Harmelin-Vivien *et al*. 2015). Because these areas are facing persistent urbanisation pressures, fast biodiversity inventories are needed. Yet, performing appropriate inventories over large spatial scales is generally logistically impossible. Consequently, many areas where biodiversity is potentially rich and deserves urgent protection are not inventoried and, thus, remain defenceless. This is especially important for unprotected natural zones that play a key role in maintaining connectivity among populations (e.g. well protected areas represent a small proportion of natural habitats and are often patchy). Overall, improving the survey toolbox to rapidly detect key species is essential, especially elusive species with a high conservation status (e.g. IUCN red list).

Mediterranean regions shelter a rich fauna of endemic threatened reptiles, notably emblematic tortoises that benefit from a great popularity (Pleguezuelos *et al*. 2010; Couturier 2011). Surveying reptiles in a Mediterranean context is, therefore, important to defend yet unprotected habitats, and to protect unique herpetofauna *per se*. However, most reptiles are extremely cryptic and difficult to detect in the field. This constraint precludes the deployment of large-scale surveys (Kéry 2002). Automatic and cost-effective methods are urgently needed to circumvent these difficulties. In the present study, we tested a simple technique by combining automatic camera trapping with artificial water ponds, so as to increase the detectability of reptiles (and of other species) in a dry Mediterranean habitat. We assumed that individuals attracted by water would be more likely pictured and identified.

Camera trapping has been widely used to detect cryptic or rare species, or to survey poorly accessible areas (Carbone *et al*. 2001; Dillon and Kelly 2007; Rovero and Marshall 2009; Paull *et al*. 2011; Wearn *et al*. 2013). Nocturnal mammals and birds represent most of the species monitored with camera trapping (Srbek-Araujo and Chiarello 2005; O'Connell *et al*. 2010; Ariefiandy *et al*. 2013). Reptiles are generally too cryptic and poorly active to be effectively pictured, and thus might be inappropriate candidates for camera trapping. Nonetheless, cameras equipped with infrared triggers have been successfully used in large and relatively active reptiles (Komodo monitor, Ariefiandy *et al*. 2013), or in smaller species where individuals have been canalised by drift fences (Welbourne 2013; Welbourne *et al*. 2015). Cameras placed at the entrance of burrows have also been fruitfully used in *Gopherus* tortoises (Breininger *et al*. 1991; Guyer *et al*. 1997; Boglioli *et al*. 2003). Yet, many reptile species are small, very cryptic, and often inactive; individuals remain hidden within thick vegetation during displacements and they do not use easily localised burrows or pathways. Mediterranean snakes typically represent such very elusive species (Santos *et al*. 2007). Setting up drift fences might be efficient, but this adds substantial logistic constraints and costs. Furthermore, Mediterranean habitats often comprise complex assemblages of vegetation covers, uneven rocky substrates with abundant potential refuges, making complicated the selection of appropriate spots to position drift fences and cameras (cameras are usually placed along paths intensively used by animals).

So as to adapt camera trapping to Mediterranean reptiles, we adopted a new approach, where we placed cameras to survey small areas without vegetation screen and we improved the attractiveness of the monitored spots. Increasing attractiveness is classically used to capture or survey animals, such as, for example, food-baiting spots monitored with cameras to detect ground-dwelling mammals (Paull *et al*. 2011). In the present study, we improved attractiveness with artificial ponds. Mediterranean climates are characterised by aridity and prolonged droughts. In summer, notably, freshwater is not easily accessible for reptiles because these organisms exhibit limited capacity to cross obstacles (e.g. roads) or to travel over long distances (Moulherat *et al*. 2014). Reptiles leave their shelter to drink from puddles during rainfall after drought and become visible (Bonnet and Brischoux 2008). We also placed sand pads around each pond to record walking tracks and, thus, to improve detection efficiency (Ballard *et al*. 2014). Although our primary aim was to inventory reptiles, notably the threatened Hermann's tortoise (*Testudo hermanni hermanni*), we expected to detect species belonging to various vertebrate taxa attracted by water ponds. Augmenting the biodiversity taxonomic list might reinforce the conservation value of targeted habitats, and represents a secondary objective of the present study.

We focussed on the Hermann's tortoise for two reasons. First, now being restricted to limited regions of south-eastern France (Livoreil 2009), this species benefits from international (Life and FEDER programs) and national conservation plans (Celse *et al*. 2014), notably to protect natural habitats (i.e. Natura 2000 network, Livoreil 2009). The recent classification of 5276 previously unprotected hectares as a national natural reserve for tortoises in an area subjected to intense anthropogenic pressures provides a striking example of the usefulness of using an emblematic species to protect habitats (http://www.reserves-naturelles.org/plaine-des-maures). Second, water shortage negatively affects growth and reproduction of tortoises (Peterson 1996; Henen 2002). Artificial freshwater ponds may relax these constraints and promote the maintenance of fragile populations.

In the present study we assessed (1) the efficiency of camera trapping (+water ponds) to detect Hermann's tortoises as well as other vertebrates and (2) the use of water troughs for drinking by Hermann's tortoises as well as other species. Our central objective was to improve the toolbox to survey reptiles, and other vertebrates, in the specific context of dry Mediterranean habitats.

Materials and methods

Study area

The 25-ha study area is characterised by a typical dry Mediterranean climate, with low precipitation (mean annual rainfall is 700 mm) and hot summer droughts (Ruffault *et al*. 2013). The substrate is calcareous; vegetation is represented by a mosaic of herbaceous meadows (40%), shrubs (15%), woodlands (29%) and vineyards (5%). A temporary natural shallow lake (3 ha) dries up in spring (usually in May). Therefore, during summer months, from June to September, freshwater availability is limited and tortoises tend to retreat into shaded woody areas (Bertolero *et al*. 2011). Our study period focussed in July and August (in 2011, the mean maximum temperature was 31.1°C, and 32.84°C in 2012), when freshwater is available only during rare rainfalls. The study area is situated in the north-western part of the distribution range of the Hermann's tortoise (Fig. 1). Water ponds were built to provide permanent source of freshwater to tortoises and other species during drought, and also to improve camera trapping. We do not provide precise information on the locality because the species is subject to illegal harvest.

Artificial water ponds

We used two types of freshwater ponds, including six small and three larger ponds.

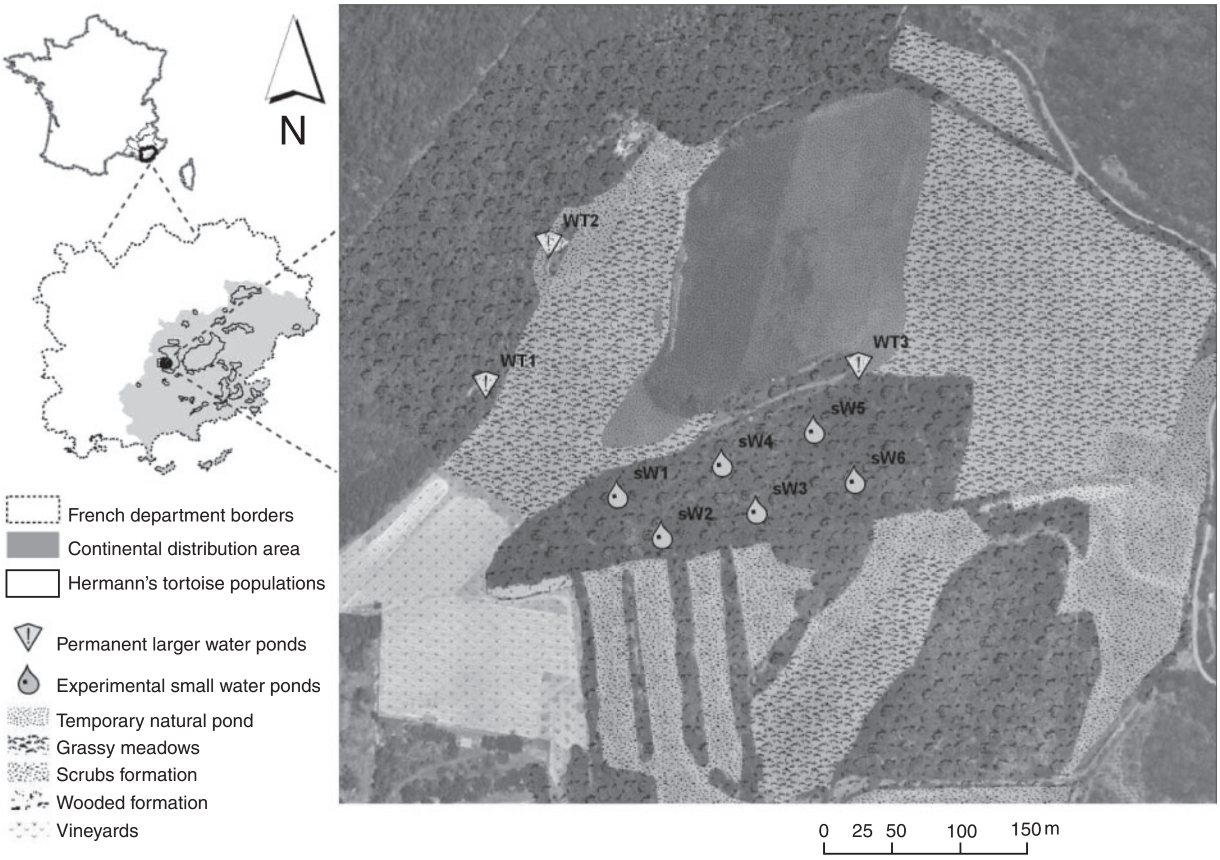

Fig. 1. Study site and location of the ponds. Small ponds (sW1–sW6) are located in the wooded formation in the middle of the study area, larger ponds (WT1–WT3) are situated on the forest edge.

(1) In late spring 2011, we placed six small water ponds in homogeneous wooded habitat used by tortoises during summer (Fig. 1). They were made with concrete bowls (0.25 m^2, 10 cm depth), with the edge set at the ground level and easily accessible to reptiles. A surface of 1 m^2 of sand was placed around each pond to record tracks. Ponds and their camera were spaced 50–80 m apart. This distance was greater than the mean daily distance travelled by tortoises in the study area (30–40 m; Ballouard and Caron 2013). This design enabled us to examine the level of independence among ponds because many tortoises could be individually identified in the pictures. A lack of independence (e.g. many individuals observed in different ponds) would suggest increasing the distance among ponds. To assess possible influence of water on detection probability, we randomly filled three ponds and emptied three ponds every 7 days from the last week of June to the second week of September (i.e. 11 weeks) in 2011 and 2012. These small ponds were used for camera-trap surveys and track surveys.

(2) Three concrete larger ponds were built in forest edge in winter 2011. These three ponds were primarily built to fulfil conservation recommendations (Life Program European Project; Fig. 1). Being based on a slightly different design, they offered complementary data to the six small ponds. Each pond had a surface of 2.5 m^2 and a depth of 30 cm. A surface of 2 m^2 of sand was placed around each pond to record tracks. In addition, a fence was placed around each pond to prevent intrusion by wild boars or dogs. The mesh (200 mm) allowed the circulation of reptiles, including adult tortoises. These three ponds were filled up with water the last week of June, at the beginning of the survey period, and were used for track surveys in 2011 and 2012, with one surveyed by a camera trap in 2012.

All the ponds were installed with the margin set to the ground to provide an easy access to water for small terrestrial species (e.g. lizards, small tortoises).

Camera trapping and sand-track survey

Surveys of the small ponds were performed using camera trapping and sand-track records. Five camera traps (PlotStalker, @Moultrieproduct, USA) were set in 2011, and six in 2012, to monitor these small ponds. The cameras were attached to nearby trees, pointing to the pond and covering an average area of 7–10 m^2, thereby encompassing the whole sand area and part of the surrounding habitat. In 2012, we used an additional camera trap (HC 500, Reconyx, inc, US) to survey one of the larger ponds. Thus, a total of five cameras were used in 2011 (91 days of camera trapping) and seven in 2012 (79 days of camera trapping). We used focal sampling (Altmann 1974) and set the time-lapse function of each camera with an interval of 5 min. This time setting permitted to limit inflation of pictures of the same individual; indeed, tortoises that are the main target of our study are slow-moving animals. *Testudo hermanni* is diurnal in our study area (Bertolero *et al*. 2011); thus, the six PlotStalker cameras recorded pictures from 0700 hours (sunrise) to 2000 hours during the summer season from the last week of June to the second third week of September in 2011 (12 weeks) and to the second week of September in 2012 (11 weeks). The HC 500 camera trap worked continuously (24 h per day) to survey nocturnal species (2012 only). Pictures were downloaded every 12 days. Animals were identified to the species level when possible and to a broad taxonomic level otherwise (e.g. 'snake', 'Parus sp' or 'Chiroptera'). The usefulness of identifying individuals to a broad taxonomic level (morphospecies) has been validated for biodiversity assessments (Lecq *et al*. 2015). Tortoise pictures were examined to determine individual characteristics, including body size, number painted or injuries on the shell and the presence of transmitter (see below).

Sand tracks were recorded almost every day during summer in 2011 (58 days of sand inspection) and every 2 or 3 days in 2012 (33 days of sand inspection) owing to logistic constraints. After each recording, the sand was swept. Sand tracks remained visible during several days, except under strong rain or strong wind conditions. Theoretically, tortoise, snake, lizard and bird sand tracks should be easily distinguished from each other. However, tracks could be assigned to a given species only for the tortoise because only one species occurs in the study site. Furthermore, the width (W) of the tracks enabled us to estimate tortoise body size (shell width, SW). We measured track width at three different points and averaged the values. Using calibration in captivity, we could distinguish small and juvenile tortoises ($SW < 50$ mm), intermediate (juvenile or subadults) ($50 < SW < 80$ mm) and large adult tortoises ($SW > 80$ mm).

Tortoise monitoring

Tortoise population has been monitored since 2010 in the study area. Individuals were detected by sight, captured by hand, measured, permanently marked and released (Livoreil 2009; Ballouard *et al*. 2013). From 2010 to 2012, we captured 156 tortoises (48 adult females, 30 adult males, 75 juveniles and 3 unsexed adults). During 2011/2012, we painted ID-numbers on the shell of a subsample of 20 individuals for distant identification during camera trapping. Another subsample of 39 adults (20 females and 19 males) was radio-tracked in 2010 ($n = 19$), 2011 ($n = 12$) and 2012 ($n = 8$), during the main active season (May to the end of August). Details regarding field procedures, notably radio-tracking, are provided elsewhere (Livoreil 2009; Lecq *et al*. 2014).

Data analysis

We compared the detection of animals using pictures versus sand tracks where both techniques were used simultaneously (5 in 2011 and 7 in 2012). Because, in most occasions, (86%) pictured tortoises were identified individually (e.g. using painted ID-numbers, radio-tracked tortoises), it was possible to minimise pseudo-replicates during analyses for this species. For other reptiles, snakes and lizards, marked variations in body size enabled us to discriminate individuals. Consequently, for reptiles in general, successive pictures of the same individual could be identified and they were assigned to a single visit. Because tortoises and snakes move slowly and are relatively easy to identify individually, the term 'visit' was reliable for these organisms. Birds and small mammals are very similar to each other at the species level and are highly mobile; individuals may well have been counted more than once and the term 'visit' could not be used. Thus, pseudo-replicates could not be discarded in these species and all observations were retained in the analyses.

To better assess detectability, we estimated the number of tortoises that could actually visit artificial ponds. We used the home-range information obtained on radio-tracked individuals (minimum convex polygon, MCP-100%; Hayne 1949). For the 39 radio-tracked tortoises, we considered that any pond situated out of their home range (mean ± s.d., 4.3 ± 1.0 ha in males, 4.1 ± 0.6 ha in females, Ballouard and Caron 2013) was not accessible (i.e. out of reach because of low probability for the tortoise to encounter the pond). For the other monitored tortoises ($n = 117$), we considered that when the nearest location of a tortoise to a pond was greater than the radius of the mean home range calculated on radio-tracked tortoises (147 m, Ballouard and Caron 2013), the pond was not accessible. Most ponds were small and may have not been detected by tortoises, even when included in the home range. To better assess how pictured reptiles were attracted by water ponds, we considered visits when the individual was observed drinking versus not. Snakes and lizards were rarely observed and were pooled for several analyses. Depending on the question addressed, we considered the following three different groups of reptiles: (1) all reptiles, (2) squamates (snakes and lizards) and (3) tortoises.

Because of logistic limitations (small number of cameras), we did not place additional cameras randomly in the study area in 2011 and 2012. Yet, empty ponds provided a surrogate to test the effect of water attractiveness (see Results). In summer 2015, in addition to three cameras placed near filled pond, we randomly placed two cameras (30 days of camera trapping) in the study site, to further assess the attractiveness of ponds. Most of the analyses were based on contingency tables and χ^2-tests (e.g. using sand tracks, pictures or visit counts); we used Yates correction when cell(s) contained a small sample size ($n < 5$). We examined the relationship between the total number of pictures recorded per visit and the number of pictures taken while the tortoise was drinking, with Pearson correlation test. Statistical analyses were performed with Statistica 12.1 (StatSoft France 2013).

Results

Camera trapping

In 2011 and 2012, we respectively recorded 881 (1.4% of the total number of pictures) and 3129 (3.8%) positive pictures (i.e. picture with at least one animal). From a total of 4232 animal observations, we identified at least 49 vertebrate species (Table 1, Fig. 2). Birds provided most of the positive pictures ($n = 3682$), whereas mammals ($n = 550$) and reptiles ($n = 355$, plus 23 pictures with two species) were pictured less often. Most of the reptiles were represented by tortoises ($n = 348$), snakes were observed on 42 occasions and lizards on five occasions (Table 1 provides details). During night-time, the Reconyx

Table 1. Positive observations recorded with camera trapping
In most cases, individuals were pictured repeatedly (see text)

Bird	*N*	Mammal	*N*	Reptile	*N*
Erithacus rubecula	409	*Sciurus vulgaris*	384	*Testudo hermanni*	348
Cyanistes caeruleus	403	*Felis silvestris catus*	66	*Natrix natrix*	12
Turdus merula	371	*Rattus rattus*	42	*Malpolon monspessulanus*	11
Garrulus glandarius	365	*Glis glis*	7	*Rhinechis scalaris*	3
Parus major	218	*Martes martes*	7	*Natrix maura*	2
Parus sp.	191	*Vulpes vulpes*	7	*Lacerta bilineata*	5
Lophophanes cristatus	73	*Apodemus sylvaticus*	6	Unidentified snake	14
Phasianus colchicus	51	*Rodentia*	5		
Sitta europaea	43	*Martes foina*	4		
Streptopelia turtur	18	*Chiroptera*	2		
Accipiter gentilis	17	*Sus scrofa*	1		
Columba palummbus	15	Unidentified	19		
Turdus philomelos	14				
Luscinia megarhynchos	13				
Asio otus	12				
Sylvia borin	11				
Picus viridis	10				
Ficedula hypoleuca	9				
Sylvia atricapilla	6				
Fringilla coelebs	6				
Serinus serinus	4				
Periparus ater	3				
Coracias garrulus	3				
Troglodytes troglodytes	2				
Motacilla alba	1				
Emberiza sp	1				
Carduelis cannabina	1				
Alcedo atthis	1				
Aegithalos caudatus	1				
Poecile palustris	1				
Phoenicurus ochruros	1				
Passerine species	300				
Unidentified	1108				
Total	3682		550		395

camera pictured 327 birds, 104 mammals and nine snakes, but no tortoises (as expected). Four potential predators of tortoises were detected (*Vulpes vulpes*, *Martes mates*, *Martes foina*, *Sus scrofa*), although on few occasions only ($n = 20$, Table 1) and mainly during night-time (ponds filled) and, thus, with little overlap of the tortoise activity time.

Visits of reptile (tortoises and snakes pooled) represented 22.5% of the total number of positive reptile pictures, showing that individuals were pictured repeatedly. The total number of visits increased from 2011 (17 visits) to 2012 (65 visits) ($\chi^2 = 6.09$, d.f. = 1, $P < 0.05$, restricting analysis to the five ponds monitored both in 2011 and 2012). Most visits corresponded to tortoises ($n = 54$), whereas snakes ($n = 26$) and lizards ($n = 3$) were less represented. Several pictures contained more than one individual; hence, the total number of visits calculated for the reptiles pooled ($n = 82$) slightly differs from the sum calculated per group ($n = 83$).

Tortoise ID was determined for 17 individuals (15 adults and 2 juveniles, corresponding to 46 visits, 56% of the total). Eleven individuals were observed once (i.e. a single visit), two individuals three times, two individuals six times, and one individual 17 times. Tortoise ID was not available for nine visits. Only one identified tortoise visited two different ponds. Other identified tortoises repeatedly visited only one pond. This suggests that each camera detected a specific subset of tortoises, independently from the other cameras.

Sand-track survey

We recorded a total 50 tortoise sand tracks (Table 2). Although walking track-survey effort decreased from 2011 to 2012 ($n = 402$ and $n = 298$ sessions respectively), track records increased from 17 in 2011 to 33 in 2012 ($\chi^2 = 5.12$ d.f. = 1, $P < 0.05$). The width of the tracks was measured on 44 occasions, with eight corresponding to juvenile tortoises (estimated mean SW = 40.5 ± 6.4 mm), 23 to medium-sized tortoises (mean SW = 64.6 ± 6.09 mm) and 13 to larger tortoises (mean SW = 87.6 ± 8.3 mm). Snake and lizard tracks were not accurately recorded.

Camera trapping versus sand-track survey

Among the pictures of a tortoise recorded on the days that sand was inspected ($n = 28$ visits), 14 (50%) were associated with

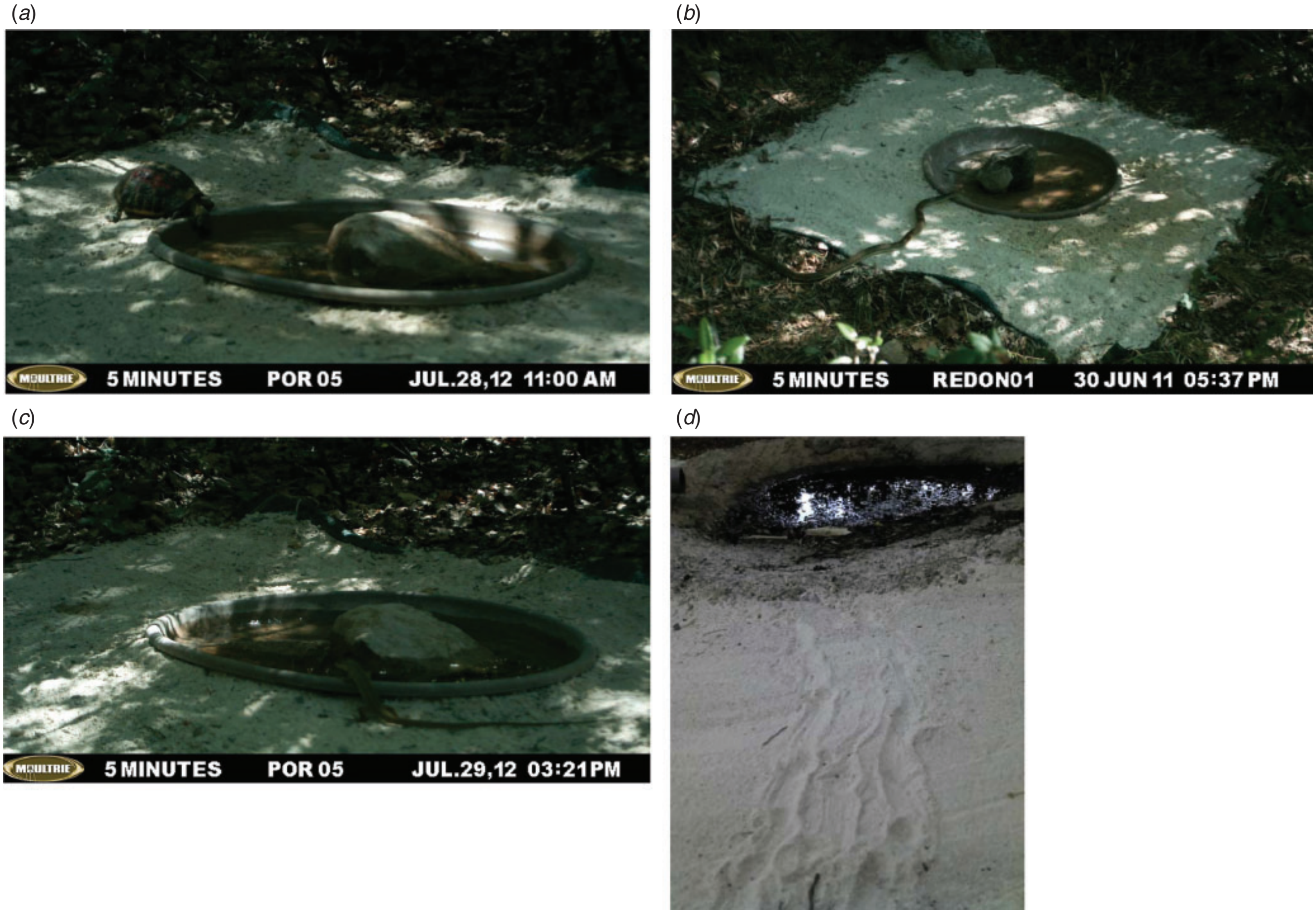

Fig. 2. Pictures of reptiles coming to drink at a small pond (sWT). (*a*) *Testudo Hermanni* marked with paint (male, A280), 29 June 2012 at 1737 hours; (*b*) *Malpolon monspessulanus*, 30 June 2011 at 1737 hours; and (*c*) *Lacerta bilineata*, 29 June 2012 at 1521 hours. (*d*) Tortoise tracks towards one of the WTs.

Table 2. Numbers of free-ranging tortoises observed using camera trapping (i.e. visits) or sand-tracks around artificial ponds

Camera versus sand-track records were obtained independently (alone, e.g. camera functioning but sand not inspected) or simultaneously (combined, sand-tracks checked the day when positive pictures were obtained, camera functioning when sand-tracks were found). When information from both survey techniques was available (combined), consistent positive information (picture + sand-track) was obtained in approximately half of the cases

Parameter	Alone	Combined	Both positive
Visits (pictures)	26	28	14
Sand-tracks	26	24	14

sand tracks (Table 2). From the total number of tracks recorded when a camera was functioning ($n = 24$), 14 (61%) were associated with a picture of a tortoise. Thus, broadly, 39% of the tortoise visits detected using sand tracks were not detected using cameras (suggesting that reducing the time lag between pictures would have added information). Overall, combining both methods increased detectability; the estimated total number of visits using both methods was thus 90 (54 pictured visits plus 10 sand tracks recorded when tortoises were not pictured and 26 sand tracks when cameras were not set up).

Influence of water availability

Considering positive pictures (all species pooled), ponds were more attractive when filled with fresh water (Fig. 3). This effect was marked in mammals (84% of pictures taken at filled ponds, $\chi^2 = 2094.3$, d.f. = 1, $P < 0.001$), birds (92%, $\chi^2 = 248.9$, d.f. = 1, $P < 0.001$), and snakes + lizards (91%, $\chi^2 = 32.4$, d.f. = 1, $P < 0.001$).

In tortoises, no clear pattern emerged; 41% of the pictures were taken at empty ponds. In 2011, 74% of the tortoise pictures were recorded at filled ponds, and only 36% in 2012. Considering small ponds that were randomly filled and drained, and taking into account only visits, did not markedly change the results, in that 54% of the visits ($n = 25$) were recorded near filled ponds (Yates corrected $\chi^2 = 2.18$, d.f. = 1, $P = 0.139$).

The two cameras randomly placed in 2015 without pond revealed that only 10 pictures (<0.01%, total $n = 8640$ pictures during a total number of 60 trapping days) were positive (all vertebrates pooled), whereas 850 pictures were positive using the three cameras set near filled pond (6.5%, $n = 12960$ pictures during 90 trapping days).

Drinking behaviour

Focusing on visits (thus, on reptiles) most observations were recorded near filled ponds, although mostly of individuals that were not observed drinking (23 drinking versus 59 not; $\chi^2 = 10.5$, d.f. = 2, $P < 0.01$). Considering squamates specifically (i.e. snakes and lizards), visits did not correspond systematically to drinking individuals ($n = 13$ drinking versus $n = 10$ not drinking visits, $\chi^2 = 0.39$, d.f. = 1, $P = 0.5$). In tortoises, most visits corresponded to non-drinking individuals ($n = 28$ versus $n = 10$; $\chi^2 = 5.5$, d.f. = 1, $P < 0.05$).

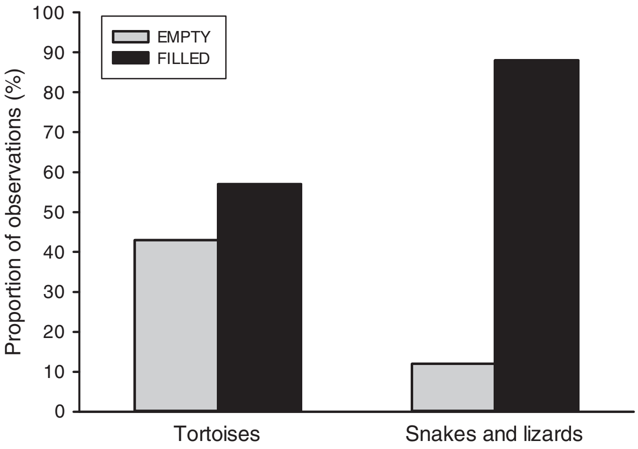

Fig. 3. Influence of water on the detectability of reptiles, combining camera trapping and sand tracks. Grey bars indicate the proportion of individuals detected when ponds were empty, black bars indicate the proportion of individuals detected when ponds were filled.

Influence of season and time

Most of the visits (54% of tortoises, 67% of snakes and lizards) were recorded in August (Fig. 4). In 2012, the number of tortoise visits decreased drastically after a major precipitation event 27 of August (considering the proportion of ponds visited before and after rain; Yates corrected $\chi^2 = 5.07$, d.f. = 1, $P < 0.05$). A similar event did not occur in 2011. Tortoises were essentially active from 0900 hours to 2000 hours, with a peak activity occurring between 1400 hours and 1600 hours. Snakes were observed during the day without a clear activity peak (Fig. 5).

Access to ponds by tortoises

We estimated that 24 radio-tracked tortoises (13 females and 11 males) were likely to use at least one artificial pond; the home range of the 15 other radio-tracked tortoises did not include any pond. Considering the other tortoises monitored via mark–recaptures ($n = 117$; 28% were recaptured at least once), 37 were observed less than 147 m away from a pond. Thus, we broadly estimated that 61 individuals of the 156 marked may have been detected by the cameras. Overall, we estimated that the cameras enabled us to identify 28% ($n = 17$ ID recorded) of the marked tortoises that had access to the ponds. Because we could not identify individuals in more than 50% of the visits, this proportion is likely to have under-estimated detectability, mixing up an unknown proportion of marked and unmarked pictured tortoises.

Discussion

The objective of the present study was to improve the technical capacities to automatically detect tortoises (and other species) in a dry Mediterranean landscape, so as to perform rapid and cost-effective surveys. We did not aim to provide accurate estimates of tortoise detectability (mark–recapture studies are

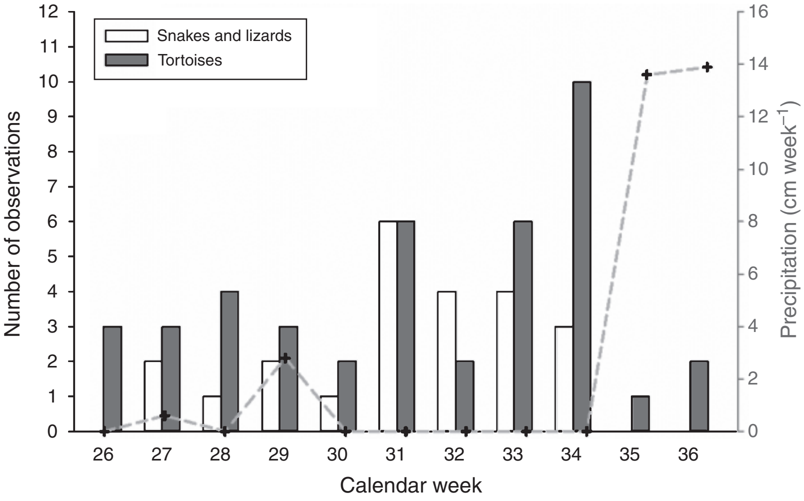

Fig. 4. Influence of precipitation (black crosses) on the detectability of reptiles (bars), combining camera trapping and sand tracks during the 2012 summer. Numbers on the *x*-axis indicate calendar week numbers (#26 corresponds to late June, #36 to early September). Reptiles regularly visit ponds during drought and rarely do so following strong rainfalls.

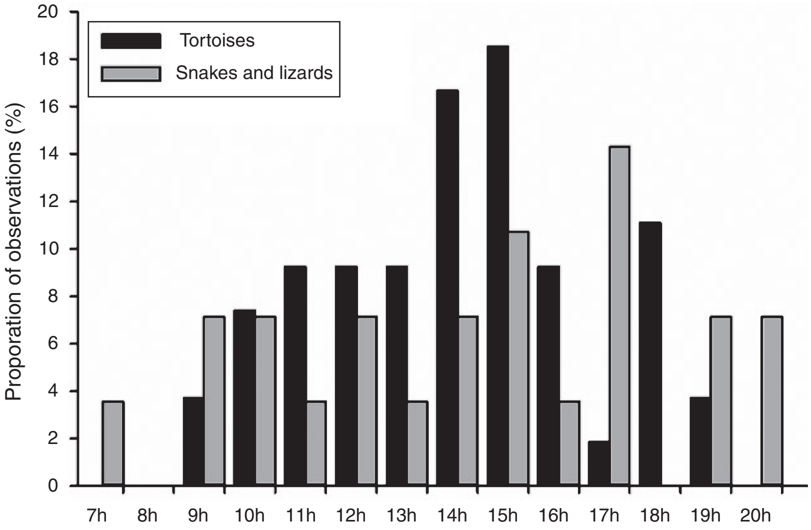

Fig. 5. Influence of time (hour) on the detectability (% of records) of reptiles. The data obtained with camera trapping and sand-track surveys were pooled; 2011 and 2012 summers were also pooled.

irreplaceable for that; Bonnet *et al*. 2016*a*). Our main results clearly showed that small pond–camera trapping represents a useful technique in this endeavour, notably to detect cryptic reptiles belonging to medium-sized or small taxa. Indeed, although most observations were represented by highly active endotherms (mammals and birds), we were able to regularly observe reptiles over two consecutive summers. Obtaining a similar amount of data under similar field conditions using other observation techniques would have required a considerable research effort. For instance, to sight and capture 156 tortoises in the study area, 1140 field-survey hours were necessary, and only five snakes were observed. For extremely elusive species (i.e. snakes), camera trapping represents a logistically simple alternative to long field sessions; 80 h were necessary to examine and classify the pictures. Setting up the small ponds required limited efforts (1 day for two people), funding (10€ per pond, 150€ per camera trap), and was efficient. In terms of inventory costs, the advantage of camera trapping was substantial because this technique permitted collection of abundant information on mammals, birds and reptiles (both during day and night time for endotherms), without employing different field experts to survey each of these taxa, and without obtaining permits to set up capture-traps (e.g. for mammals) or drift fences (e.g. for reptiles). Indeed, detecting elusive species generally requires experienced fieldworkers without fully eliminating observer biases (Fitzpatrick *et al*. 2009). On average, 500–1000€ per day are required to hire one or two well trained field workers, and surveys are usually conducted during several sessions of 2–3 days each at least. Using camera trapping limits observer biases (e.g. pictures are archived and can be examined by different observers). In addition, human presence is minimised and, thus, environmental disturbance is limited using camera trapping. The fact that several pictured individuals could not be identified to the species level (snakes notably) was not problematic. Indeed, rapid visual assessments based on the visual identification of species or morphospecies permit repeated surveys over time (thanks to limited logistic and limited population impact), to take into account major sampling biases, and thus to use robust estimators of species richness (e.g. Chao estimates; Lecq *et al*. 2015). Relying on volunteers to examine the pictures may further decrease logistical constraints and enhance public involvement for conservation (Albergoni *et al*. 2016). In addition, the use of water is likely cheaper, lasts longer, and should have a limited impact on the wildlife compared with classical food baits (Dunkley and Cattet 2003).

Camera trapping combined with small water ponds was effective at detecting marked tortoises (~28% of the known tortoises located on the vicinity of the ponds). Although we did not detect the majority of the tortoises that were likely to occur in the studied area, this result is particularly encouraging considering the very low detectability of the species during classical visual surveys (Couturier *et al*. 2013). Our observations included individuals from different size and presumably age classes. The detection of otherwise elusive juveniles suggests that reproduction occurs in the surveyed population, providing additional arguments to protect the area. Sand track–picture comparison revealed that some individuals were missed by the cameras (42%), notably juveniles. Sand track offered complementary information, but required frequent inspections of the ponds by field workers. Further tests to optimise picture cadence are necessary.

In the current study, six species of reptiles (4 snakes, 1 lizard and 1 tortoise) from the 11 species known to occur in the area were observed. However, lizards known on the area (e.g. *Chalcides striatus*) were not detected, probably because we set the cameras + ponds in shaded woody areas to focus on tortoises in summer, whereas most lizards prefer open sunny and rocky habitats. In a study focusing on water catchments in dry habitats, Mesa-Zavala *et al*. (2012) recorded three different reptile species among 29 reptile species known to occur in the area. Using small ponds enabled us to focus on small spots and thus increased the likelihood of positive observations. Although not performed simultaneously to the 2011/2012 surveys, and thus precluding robust comparison, the controlled experiment conducted in 2015 showed that small water ponds were effectively attractive. The comparison of filled versus empty ponds in 2011 and 2012 provided further evidence that water played a role in increasing the detectability of animals. Yet, the high number of observations of tortoises inspecting empty ponds was puzzling. Tortoises may remember the location of the ponds and examine them in search of potential water.

The attractiveness of the artificial ponds during drought, the drastic decrease in positive observations immediately after 2011 rainfall, and frequent observations of drinking animals demonstrated that fresh water was appealing (Bonnet and Brischoux 2008). Water availability can influence tortoise female fecundity (Loehr *et al*. 2007) and hatchling survival (Hambler 1994; Henen 2002). Another positive aspect of providing water ponds is that individuals should take less risk and may save energy because they can easily find fresh water in the core of their home range (Ferns and Hinsley 1995; Longshore *et al*. 2009).

The distance among cameras–ponds units was relatively small (50–80 m), but tortoises can travel important daily distances (40 m per day on average), may move among ponds and thus bias the inventories. Nonetheless, our results showed that each camera worked relatively independently from the others in sampling tortoises (only one individual was captured at two different ponds). This suggests that they were complementary in their detecting power, and that even small areas are better sampled by using a set of cameras rather than only one. This may also explain the high detectability of the system we used (~28% of individuals observed). Despite overlapping home ranges, each tortoise may follow specific routes (not identical to those used by conspecifics) that do not necessarily transect more than one pond emplacement. Thus, clusters of cameras were more effective at detecting tortoises than were isolated cameras.

Possible negative impacts of the small ponds (e.g. attracting predators) were not supported by observations. We found no dead animals (e.g. drowned, the flat shape of the water bowls was likely important), no remains of killed animals (e.g. abundant feathers) and pictured no predation events.

In addition to reptiles, the extensive list of the species observed may assist in proposing conservation plans. We recorded at least 49 species representative of the main vertebrates of the study area (Table 1). Our abundant results suggested that several bird and mammal species were abundant and that they intensively used the ponds (Table 1). Thus, protecting habitat essential for tortoises may also help protect other reptiles and a rich community of birds and mammals. Especially because the Hermann's tortoise is considered as an umbrella species (Roberge and Angelstam 2004). Combining camera trapping and small artificial water ponds appears to be an efficient technique to describe important component of the vertebrate biodiversity and to promote the conservation status of yet unprotected habitats in a dry Mediterranean landscape.

Conclusions

Camera trapping combined with small artificial ponds, possibly complemented with a sand-tracks survey, offers a means to survey reptiles in a dry environment. Pond–camera trapping may help limit the use of more invasive methods, such as rock turning, for instance, that inevitably perturbs fragile microhabitats (McGrath *et al*. 2015). Although imperfect (as any technique), this method could improve the toolbox to survey reptiles, including tortoises. It can be used to perform rapid reptilian biodiversity inventories (Lecq *et al*. 2015) or to monitor the impact of habitat changes caused by lack of forest management through site-occupancy analyses (Bonnet *et al*. 2016*b*), or fires on reptile communities, for example (Santos *et al*. 2015). Similarly, cost-effective simple techniques are needed to evaluate conservation programs, such as reinforcement or reintroduction actions (Pagnucco *et al*. 2011; Ballouard *et al*. 2013). Our study has provided a baseline that requires further tests and improvements; however, with modest efforts we obtained encouraging results. Further studies may notably compare camera trapping with the use of concrete slabs, which is an effective technique for surveying snakes, lizards and tortoises (Arida and Bull 2008; Lelièvre *et al*. 2010; Ballouard *et al*. 2013; Bonnet *et al*. 2016*b*), so as to select the most appropriate technique(s) under different situations.

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