Use of water troughs by wild rabbits (*Oryctolagus cuniculus*) in a farmland area of north–west Spain

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Armenteros, J. A., Sánchez–García, C., Alonso, M. E., Larsen, R. T. & Gaudioso, V. R., 2015. Use of water troughs by wild rabbits (*Oryctolagus cuniculus*) in a farmland area of north–west Spain. *Animal Biodiversity and Conservation*, 38.2: 233–240.

Abstract

*Use of water troughs by wild rabbits (*Oryctolagus cuniculus*) in a farmland area of north–west Spain.*— Installation of water troughs is a common approach to increase densities of small game species in the Iberian peninsula but little is known about the watering patterns of target species, such as the wild rabbit (*Oryctolagus cuniculus).* Using camera trapping, we monitored the use of water troughs by wild rabbits over 228 weeks in three consecutive periods, from June to October in 2008, 2009 and 2010, on farmland in north–west Spain. Wild rabbits used 43% of the water troughs. A significantly higher number of rabbits were observed drinking at troughs surrounded by shrub cover than at those in open fields. Most drinking events were recorded from July to September (98%), though the use of water troughs was not clearly related to weather. Wild rabbits drank mainly during the morning (52% of rabbits), less so in the evening and at night, and rarely in the afternoon. Wild rabbits were photographed together with red–legged partridges (*Alectoris rufa*) in 6% of photographs. These findings suggest water troughs are useful for species such as wild rabbits and should be allocated close to shrub areas.

Key words: Camera traps, Cover, Game management, Water trough, Wild rabbit

Resumen

*Uso de bebederos por parte del conejo de monte (*Oryctolagus cuniculus*) en un paisaje agrícola en el noroeste de España.*— En la península Ibérica, los bebederos son una herramienta de gestión de hábitat muy frecuente para incrementar las densidades de especies de caza menor, aunque el comportamiento de ingestión de agua de las especies "diana" no se ha estudiado en profundidad, como es el caso del conejo de monte *(Oryctolagus cuniculus).* Estudiamos el uso de bebederos por parte de conejos de monte durante 228 períodos de una semana en tres períodos consecutivos (junio–octubre) de 2008, 2009 y 2010 en un paisaje agrícola de noroeste de España, utilizando cámaras de fototrampeo. Los conejos utilizaron el 43% de los bebederos y se observó un número significativamente mayor de conejos bebiendo en bebederos rodeados por cobertura vegetal en comparación con bebederos situados en campos abiertos sin dicha cobertura vegetal. La mayoría de los conejos que bebieron fueron fotografiados de julio a septiembre (98%), si bien la utilización de bebederos no se relacionó claramente con la climatología. Los conejos bebieron principalmente durante la mañana (52% de los conejos) no tanto durante la tarde y noche, y raramente durante el mediodía. Los conejos se fotografiaron junto con perdices rojas (*Alectoris rufa*) en el 6% de las fotografías. Estos hallazgos sugieren que los bebederos son útiles para el conejo y otras especies con necesidades hídricas similares y que debieran ser colocados cerca de zonas con cobertura vegetal arbustiva.

Palabras clave: Cámaras de fototrampeo, Cobertura vegetal, Gestión cinegética, Bebedero, Conejo de monte

Received: 5 V 15; Conditional acceptance: 9 VII 15; Final acceptance: 31 VIII 15

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ISSN: 1578–665 X
eISSN: 2014–928 X

Introduction

During the last decades, considerable efforts have been made in the Iberian Peninsula to improve the management of small game species. These animals play a key role in ecosystems and hunting such species is a crucial economic activity in many rural areas (Arroyo et al., 2012; Ferreira et al., 2014). One of the most commonly used approaches to preserve populations of small game species in Spain is the installation of water troughs (Arroyo et al., 2012; Ferreira et al., 2014), defined as free–standing water supplied artificially for wildlife. One key–stone species in the Mediterranean Basin is the wild rabbit (*Oryctolagus cuniculus,* hereafter rabbit), (Delibes–Mateos et al., 2008). Although rabbits can endure extended periods of drought (Hayward, 1961; Cooke, 1982) and distance to drinking water does not seem to affect their abundance in any season in Central Spain (Rueda et al., 2008), their reproduction has been correlated with environmental temperature and water content of the vegetation (Gonçalves et al., 2002). Furthermore, many gamekeepers and wildlife managers claim that rabbits frequently use water troughs when water is scarce. In the past, water troughs mainly targeted red–legged partridge (*Alectoris rufa*) populations and they were not aimed at rabbits as water availability is not generally considered a major constraint for this species (Hayward, 1961). However, in their study about the frequency of use and cost–effectiveness of habitat management techniques in rabbit populations in Iberia, Ferreira et al. (2014) found that water troughs also targeted rabbits. They suggested that supplying water would maximise returns from a set budget.

Studies in the red–legged partridge have shown that water troughs surrounded by shrub cover are used to a greater extent than those in open fields. It has also been observed that weather plays a role, with a higher number of visits to troughs in summer months (Sánchez–García et al., 2012b).

A better understanding of rabbit watering patterns could optimize the installation and use of water troughs, not only for the benefit of endangered predators that rely on rabbits, such as the Iberian lynx (*Lynx pardinus*) (Ferreira et al., 2010), but also for reared rabbits released for both hunting and conservation purposes (Sánchez–García et al., 2012a).

Aiming to produce guidelines for best watering practices for small game species, we evaluated the use of water troughs by rabbits to (1) confirm their use by this species, (2) to investigate the effects of trough location in shrub cover or open fields on use by rabbits, (3) to assess whether drinking behaviour is affected by weather, and (4) to study the daily watering patterns of the species.

Material and methods

Study area

This study was conducted from late spring to early autumn (June–October) over three consecutive years (2008/09/10) on private farmland of 308 ha in the province of Valladolid in north–west Spain (lat 41° 53′ 45″ N, long 4° 52′ 50″ W, 'Finca Coto Bajo de Matallana'). The area is a typical pseudo–steppe of northern Spain with mostly flat terrain (altitude range 771–820 m a.s.l.). The climate is dry Continental Mediterranean, characterized by harsh winters and hot and dry summers, with an annual mean rainfall of 455 mm (AEMT, 2014). Historically, extended periods of drought have been recorded in the area from June to September. The study area has two small streams but these dry up in summer months and only flow after occasional storms.

Shrub areas accounted for 38% of the area, cultivated fields for 37%, arboreal plants for 23%, and the remaining 2% for uncultivated areas, farm buildings and tracks. The main cultivated species were sunflowers (*Helianthus annuus*), lucerne (*Medicago sativa*) and winter cereal (mainly barley, *Hordeum distichon*).

Game management

The area was actively managed for small game densities and other wildlife from 1996 to 2008. A full time gamekeeper was employed and hunting was not allowed. Legal control of predators was conducted all year round following regional law —especially during the game bird breeding season (February–May)— and included magpies (*Pica pica*, L.), carrion crows, (*Corvus corone* L.), foxes (*Vulpes vulpes*, L.), feral dogs (*Canis lupus familiaris*, L.) and cats (*Felis catus*, L.), and brown rats (*Rattus norvegicus*, L.). Fifteen strips of mixes of barley, wheat (*Triticum* spp. L.), lucerne and common vetch (*Vicia sativa* L.) (0.2 ha average size), were distributed throughout the area. Management practices included the restricted use of herbicides, no livestock grazing at potential nesting habitats for farmland birds, and harvesting delays until early June and only in daytime. Additionally, 16 feeding troughs with wheat grain were distributed every 15–20 ha in autumn and winter.

Due to repeated outbreaks of myxomatosis and rabbit haemorrhagic disease, numbers of rabbits were dramatically reduced in late 1980s (Olmedo, pers. comm.). A re–establishment programme was carried out from 1996 to 2002, using translocated rabbits established in artificial warrens (Díez, 2005; Fernández–Olalla et al., 2010). In 2008, 27 active warrens were detected and rabbits occupied 70% of the study site. Using the Kelker method, rabbit density (rabbits/ha) was estimated at 2.1 in 2008, 3.4 in 2009 and 1.36 in 2010 (Lacasa et al., 2010).

Experimental design

We used the methodology established in a previous project on water troughs for small game species (Lacasa et al., 2010). Water was supplied from a fibre cement water tank connected to the concrete water troughs by means of plastic pipes. The tank was refilled at the beginning of each summer (400 l of capacity). All troughs were surrounded by a 1.5 m

Fig. 1. A. Example of a 'protected' water trough: 1. Metal fence; 2. Trough; 3. Plastic pipe; 4. Water tank; and 5. Camera trap. B. Images of three rabbits drinking at the same time; C. Two drinking rabbits (possibly one juvenile); and D. A rabbit and a red–legged partridge.

Fig. 1. A. Ejemplo de un bebedero con cobertura vegetal: 1. Valla metálica; 2. Bebedero propiamente dicho; 3. Tubería plástica; 4. Depósito de agua; 5. Cámara de fototrampeo. B. Imágenes de tres conejos bebiendo al mismo tiempo; C. Dos conejos bebiendo (posiblemente uno de ellos juvenil); D. Un conejo y una perdiz roja.

high metal fence with 20 cm^2 entrances, a design shown to have no effect on use by small game species (Lacasa et al., 2010) (fig. 1). For practical reasons, the location of troughs was not changed during the study periods. The estimated cost of the water supply, not including maintenance, was 3.5 €/ha/year.

We studied five pairs of water troughs (total 10 troughs), located in five plots of 50–60 ha. All troughs were placed at a minimum distance of 500 m from the streams. Aiming to assess whether shrubs surrounding water troughs had any effect on the number of rabbits using them, in each plot we placed one of the water troughs among shrub cover (referred to as protected troughs) and the other at a distance of 50 m in an open field (referred to as open troughs), not surrounded by shrub cover. At the protected troughs, the shrubs were kept at a distance of 3–5 m. Average shrub and tree height across plots was 2.2 m ± 0.8 SE. Specific species were brambles (*Rubus* spp.), broom (*Cytisus* spp.) and pine trees (*Pinus* spp.).

To assess the effects of weather on weekly drinking patterns of rabbits, data collection was carried out from June 15th to October 10th of each study year. Based on data from an on–site weather station (Urbaso S.L., Spain), this was the driest period of the year, with limited rainfall. Maximum temperatures were above 35ºC, and relative humidity was under 60%, though conditions were hottest and driest in July and August.

The water troughs were designed for use by the main small game species in the Iberian peninsula: red–legged partridge, rabbit and Iberian hare (*Lepus granatensis)*. As red–legged partridges and rabbits were present in all the plots during the study period (Iberian hares were found at much lower densities), and as previous research has shown small game species use the same water troughs (Lacasa et al., 2010), we expected partridges and rabbits to be photographed together at the plots and possibly drinking at the same time.

Data collection

We used digital motion–sensing cameras (Bushnell Trailscout Pro©, Bushnell Trophy©) to photograph wildlife visiting water troughs. We started with six cameras in 2008, but had eight in place in 2009 and

10 in 2010. During the first two years (2008 and 2009), cameras were alternated between plots, sampling a total of 8 and 10 camera trapping weeks per trough, respectively. In 2010, the troughs were monitored over 20 camera trapping weeks. We thus aimed to monitor a total of 380 camera trapping weeks (80 in 2008, 100 in 2009 and 200 in 2010). The two water troughs at each plot were monitored simultaneously. Cameras were placed at a distance of 2–3 m from the trough, and correct camera triggering was ensured. The time lapse between consecutive photographs was 30 seconds.

Rabbits were not marked, so although it was assumed that the same animals would be photographed more than once, each photograph was considered a separate event. Time and date stamps, total number of rabbits, and drinking behaviour of each individual were recorded for each photograph. In a previous study conducted in captive–reared rabbits at the same study site, it was observed that daily and seasonal activity patterns were affected by air temperature (ºC), relative humidity (%) and wind speed (meters/second) (Díez, 2005). In the present study, we therefore downloaded weekly average values of these variables together with cumulative rainfall from the weather station located in the study area (www.fieldclimate.com) to assess their influence on the use of water troughs.

Statistical analysis

The unit of analysis used was the number of rabbits photographed at drinking each trough per week (hereafter camera–trapping week). As we expected rabbits to visit the plots but not to use the water troughs, we considered that the trough was used when any number of rabbits (one or more) was photographed drinking. Although rabbits were subject to different weather conditions as summer progressed, the same water troughs at similar locations were studied each year, so we were unable to rule out the possibility that the same rabbits visited the troughs. Hence, the χ^2–test, (Canavos, 1986) was used to test whether location of water troughs had an effect on the number of rabbits photographed drinking.

We pooled data from all years from water troughs where rabbits were photographed to assess whether the number of rabbits photographed drinking per trough per week was related to mean values of air temperature, relative humidity, wind speed or cumulative rainfall. To do this, we used Pearson's correlation coefficient.

We used sunrise and sunset times of the central date (day 15) for each month and grouped photographs of drinking rabbits into four periods of the day: two in the morning (three hours before sunrise and three hours after sunrise, six hours in total), and two in the evening (three hours before sunset and three hours after sunset, six hours in total*)*. Hence, afternoon and night periods were defined as the remaining time between morning and evening periods of time (Lee et al., 2010). To assess the possible effects of the time of day on the number of rabbits photographed drinking, we fitted a GLMM (Agresti, 2007) of the number of rabbits photographed drinking per month, with Poisson error, logarithmic link, ln(possible number of photographs taken for each period of the day), month, period of time (morning, afternoon, evening and night) as fixed factors and year as random factor. Differences with $p < 0.05$ were considered significant and all tests were carried out using SPSS© (v. 17.0 for WINDOWS©, IBM Corporation©).

Results

After subtracting incidents of cameras and trough malfunctioning ($n = 152$), we monitored troughs during 228 camera–trapping weeks, with a total of 1,546 camera–trapping days. The most common problems were camera malfunctions, photographs not valid for analysis (over–exposure), failures in the water supply, damage to a water system by wild boar (*Sus scrofa)* or stray dogs (*Canis lupus familiaris*), and combinations of these problems. Rabbits were photographed during 134 camera–trapping weeks (59%, $n = 228$*)*, taking 3,359 photographs depicting 5,738 rabbits (table 1). From these, 599 rabbits were photographed drinking in 57 camera–trapping weeks (43%). These rabbits were mainly single individuals (95% of photographs), although we also observed rabbits in pairs (4.9% of photographs) and one group of three rabbits (0.1% of photographs) (fig. 1*).*

The number of rabbits photographed drinking was significantly higher at protected troughs than in open fields in all years ($p < 0.001$; table 1). In 2008 and 2010, no rabbits were photographed drinking at open troughs. In protected troughs, 10.5% of the rabbits were seen drinking, while in open troughs, 0.03% of rabbits were seen drinking (table 1). Owing to the few rabbits photographed at troughs in open fields ($n = 4$), we pooled all these troughs for the remaining analysis.

The number of rabbits photographed drinking per trough per week was not significantly correlated to any of the weather variables recorded: air temperature ($r = 0.08$, $p = 0.38$), relative humidity ($r = – 0.13$, $p = 0.15$), wind speed ($r = – 0.03$, $p = 0.67$), or rainfall ($r = 0.02$, $p = 0.75$). No month*period interaction effects were found for the number of rabbits photographed drinking per week (table 2). When pooling all years, drinking rabbits were photographed from July to September (98% of the rabbits), though a higher number were photographed in August (54%). Morning was the period of the day with the highest number of rabbits photographed drinking (52%), followed in order by evening (20%), night (19%) and afternoon (9%) (fig. 2).

We observed rabbits and red–legged partridges together in 202 photographs (2008, $n = 35$; 2009, $n = 55$; 2010, $n = 112$), drinking at the same time on three occasions (fig. 1). Most of these photographs (88%) were taken in the morning and early afternoon (7 am–12 am). The remaining photos (12%) were taken in the afternoon–evening (2 pm–8 pm). No photographs of Iberian hares were taken.

Table 1. Number of camera–trapping weeks (N), photos, rabbits, drinking rabbits per year and location, and comparison of the number of drinking rabbits photographed between open and protected water troughs using the χ^2–test. (The number of camera–trapping weeks in which rabbits were photographed is given in brackets.)

Tabla 1. Número de períodos de una semana (N), fotos, conejos, conejos fotografiados bebiendo por año y tipo de localización junto con la comparación del número de conejos fotografiados bebiendo entre los bebederos situados a campo abierto y los rodeados por cobertura vegetal utilizando el test χ^2. (El número de períodos de una semana en los que se fotografiaron conejos está entre paréntesis.)

			Number of rabbits photographed		Number of drinking rabbits photographed	
Year	N	Photos	Open	Protected	Open	Protected
2008	42 (24)	269	0	1,042	0	138
					$\chi^2 = 15.55$, $p < 0.001$	
2009	110 (58)	716	34	1,446	4	135
					$\chi^2 = 21.31$, $p < 0.001$	
2010	76 (52)	2,374	86	3,130	0	322
					$\chi^2 = 11.19$, $p < 0.001$	
	228 (134)	3,359	120	5,618	4	595

Discussion

We confirmed that rabbits tended to use protected troughs over those in open spaces. Use of troughs was highest from July to September, and most photographs were taken during the morning. Although rabbits survive conditions of water restriction (Hayward, 1961; Cooke, 1982), we observed drinking behaviour in 43% of the troughs where rabbits were detected. Our results confirm moderate use of troughs by rabbits, a finding in agreement with a previous study in the same area using different methodology (Lacasa et al., 2010). However, we did not study rabbit activity at plots without troughs so we are unable to determine whether water was the main reason for visiting the plots. At troughs

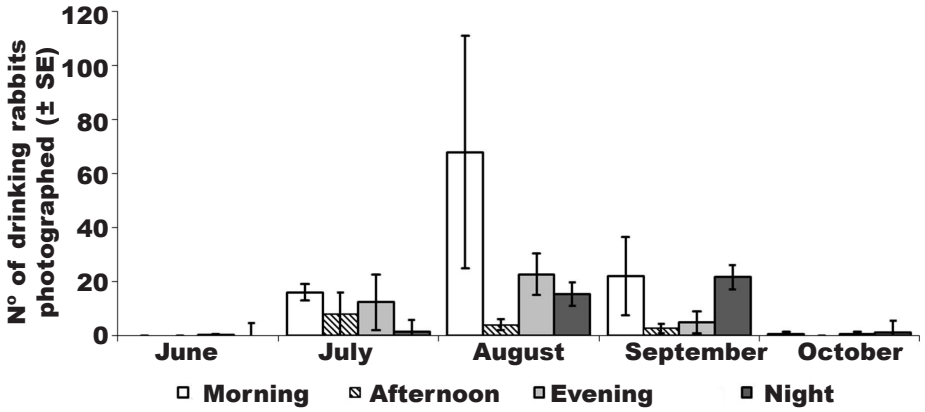

Fig. 2. Mean number of drinking rabbits photographed (± SE) per month during the four periods of the day (morning, afternoon, evening and night).

Fig. 2. Media del número de conejos fotografiados bebiendo (± ES) por mes durante los cuatro períodos del día estudiados (mañana, mediodía, tarde y noche).

Table 2. Results of the GLMM models explaining variation in number of drinking rabbits photographed in relation to month, to period of the day, and to interaction between month and period of the day: *W*. Wald statistic; *F*. F statistic.

Tabla 2. Resultados de los modelos lineales generalizados mixtos para explicar la variación en el número de conejos fotografiados bebiendo en relación al mes, al período del día y a la interacción del mes con el período del día: W. *Estadistico W;* F. *Estadistico F.*

Fixed term	*W*	*F*	*p*
Month	46.91	$F_{4, 38}$ = 11.73	< 0.001
Period	30.97	$F_{3, 38}$ = 10.32	< 0.001
Month*period	12.76	$F_{12, 38}$ = 1.06	0.416

where no drinking behaviour was recorded, rabbits may have been attracted by other reasons, such as cooler temperatures around shrub cover. Our results should be considered with caution as the location of troughs did not change during the summer. Further studies are needed to address individual drinking patterns and to evaluate drinking behaviour at Iberian locations with a different climate.

As expected, most drinking rabbits were detected at protected troughs (only two open troughs were used), also in agreement with the previous study conducted in the same area (Lacasa et al., 2010). These findings suggest that protected troughs offer safer conditions for watering, in accordance with the anti–predator strategy of this species (Moreno et al., 1996). The number of rabbits drinking at open troughs was very low, suggesting rabbits prefer closed troughs more than other trough visitors such as red–legged partridges and chukar (*Alectoris chukar*) partridges (Larsen et al., 2007; Larsen et al., 2009; Sánchez–García et al., 2012b). These findings suggest the location of troughs should therefore be considered in management strategies targeting rabbits. Our results are in line with other studies showing the high need for cover and refuge for this species (Moreno et al., 1996; Lombardi et al., 2007).

The number of rabbits photographed drinking per trough per week was not clearly associated with the weather variables studied, though the number of drinking rabbits was highest in August. It may be that rabbits did not need water when food moisture content met their needs, a notion demonstrated in small species of birds (Degen et al., 1984). We did not study food moisture, however, and this is one of the main limitations of this study. It is likely that the strips of game crops distributed throughout the property and delayed crop harvesting (end of June) resulted in quality herbaceous communities with adequate water content. This might explain the higher number of drinking rabbits photographed from July to September, especially in August, when food moisture may have been depleted. We cannot rule out the possible effects of different rabbit density and activity across months on the number of rabbits observed drinking, but it is known that rabbits reduce breeding activity in summer (Gonçalves et al., 2002) and the activity rate observed in captive–reared rabbits at the same site was very low during the second half of the year (Díez et al., 2013). Our study was carried out from late spring to early autumn only. It could be of interest for future research to investigate water needs throughout the whole year.

Rabbits drank mainly during the morning in all months, followed by evening and night drinking behaviour recorded during the afternoon was very low. The drinking pattern was similar to the general activity pattern observed in wild populations (Villafuerte et al., 1993) and in the pattern for reared rabbits in the same area (Díez, 2005), both of which showed lower drinking activity in the afternoon and evening. Rabbits and other lagomorph species are known to be inactive during harsh climatic conditions (Mykytowycz & Rowley, 1958; Wallage–Drees, 1989), so it is possible that rabbits were reluctant to use the troughs during the hottest and driest periods of the day, which in our study site were late morning to early evening. Rabbits may have conducted other activities in the evening and at night, such as foraging (Mykytowycz & Rowley, 1958; Villafuerte et al., 1993), watering then during the morning before resting. Neither can we rule out effects of the predator community on rabbit watering behaviour (at the study site mainly foxes and raptors, see Lacasa et al., 2010). In the grey partridge (*Perdix perdix*), the use of feeders is higher at dusk and dawn when diurnal and nocturnal predators are respectively less active or not yet active (Potts, 2012).

As expected, we photographed rabbits and red–legged partridges around troughs at the same time, mainly during the morning and early afternoon, the time of the day when partridges concentrate their visits to the troughs (Sánchez–García et al., 2012b). The small number of photographs showing the two species drinking simultaneously could be attributed to the size of the trough, which allowed a limited number of animals at the same time. We did not observe any antagonistic behaviour between species and *in situ* observations suggest that rabbits and partridges shared the same trough. Further studies at other sites using models with a larger water area (such as small ponds) are needed to confirm the simultaneous use of watering sites rabbits and partridges.

Owing to rabbits' frequent use of water troughs in our study and the possible effectiveness of this strategy when compared to other techniques (Ferreira et al., 2014), game managers and practitioners aiming to favour rabbit populations through water supply should allocate troughs close to shrub cover and ensure that water is supplied during the summer. For management or research purposes, human visits to water troughs should be conducted between 11 and 16 h in areas with a similar climate as this is the period of the day when rabbits are less active and drink less.

The use of water troughs for wildlife has been widely questioned as it can be viewed as a disturbance of natural ecological processes, but available research does not always support negative effects (Simpson et al., 2011). Although water troughs may help to increase rabbit density, further research is needed to understand the effects of water supply on rabbit ecology and to determine the factors triggering the use of troughs by rabbits (such as lack of food moisture). Such knowledge could help adapt management decisions to different scenarios.

Acknowledgements

This study is part of the first author´s doctoral thesis. We wish to thank the Junta de Castilla y León, Excma. Diputación de León and Caja España for partial funding of the field study. We also thank J. A. Olmedo, Kaat Brulez, the Excma. Diputación de Valladolid and Fundación Caja Madrid. Special thanks are extended to the reviewers for their comments, E. J. Tizado for statistical advice and J. M. Lomillos and F. Escalera for their patience and sense of humour during data collection.

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