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Eur J Wildl Res (2010) 56:591–599
DOI 10.1007/s10344-009-0352-6

ORIGINAL PAPER

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Received: 28 October 2008 / Revised: 19 November 2009 / Accepted: 2 December 2009 / Published online: 23 December 2009

Abstract This paper studies the visits of wild fauna, the influence of vegetal cover and fencing at water site election, and consumption tendency in water troughs designed for small game species distributed in an agricultural Mediterranean area during the summers from 2002 to 2005. Red-legged partridges (*Alectoris rufa*), lagomorphs (*Oryctolagus cuniculus*, *Lepus granatensis*), and other autochthonous species (birds and wild canids) visited water sources throughout the study. The number of visits by target species was higher than non-game. Lagomorphs preferred protected troughs (with surrounding vegetal cover) while partridges opted for open ones (without cover). Fencing had no effect on the visits of birds and lagomorphs, but it did reduce the visits of wild canids. Harsh climatic conditions determined an increase in water consumption in summer. Before designing a water trough device for this fauna, managers should consider that (1) target and non-target species could try to make use of it, (2) water points should be adapted to target species self protection, (3) fencing can prevent undesirable visitors (particularly predators), and (4) water requirements increase in the harsh moments of the dry season.

Keywords *Alectoris rufa* · Lagomorphs · Open · Protected · Water troughs

Communicated by C. Gortázar

V. R. Gaudioso Lacasa · C. Sánchez García-Abad (✉) · R. Prieto Martín · J. A. Pérez Garrido · M. E. Alonso de La Varga
Research Group on Game Species Breeding and Management, Departamento de Producción Animal, Universidad de León, 24071 León, Spain
e-mail: csang@unileon.es

D. J. Bartolomé Rodríguez
Instituto Tecnológico Agrario de Castilla y León, Paseo Canalejas no. 77, 2º A 37001 Salamanca, Spain

Introduction

Water troughs (WT) of wild and game fauna are currently a widespread management tool in areas where drought periods are common. For example, many studies carried out on African herbivores (Owen-Smith 1996; Redfern et al. 2005; Ryan and Getz 2005; Chamaillé-Jammes et al. 2007), North American big game mammals (Brown 1994; McCarty and Bailey 1994), and small game mammals and birds (Schmidt and De Stefano 1996; Borralho et al. 1998) assert that the successful wildlife management of arid and semi-arid ecosystems requires an understanding of the relationship between surface water and animal populations and behavior. Furthermore, rapid climate change is worldwide with repeated extended droughts occurring more often in some parts of the world (McCarty 2001), so water management may become a crucial management tool in such a context (Walther et al. 2002).

In Spain, drought is frequent in Mediterranean areas characterized by their hot and dry summers (Olcina 1999) and since the 1980s, the rapid change in agricultural environments has meant the disappearance of field boundaries (Casas 2008), creeks, and other natural water sources (European Environment 1998). As a consequence, WT are a frequent management tool for small game species in most of the hunting areas except the north of Spain (Sánchez, personal observation). Assuming that water is one of the three fundamental needs of free-ranging wildlife, (food, water, and cover; Leopold 1933), it can be considered a limiting factor for wild species during the dry periods (Degen et al. 1983). Unfortunately, little research on WT programs for small game species in Spain has been reported and guidelines are needed for managers and hunters.

In the case of WT for small game, the influence of water provision on wildlife visits needs to be investigated as it is

known that WT are used not only by target and prey species (Smith and Henry 1985; Benolkin 1988), but also by non-game, frequently potential predators such as raptors (Schmidt and De Stefano 1996) and wild canids (Cutler 1996; De Stefano et al. 2000). Predators tend to kill their prey close to water points and prey show several behavioral adjustments to the risk of predation at water sources (Valeix et al. 2009).

Consequently, when the WT device is designed for small game, we have to investigate the water point selection by target species depending on the type of water provision point because the acceptance of WT could be determined by self protection. In this way, some studies carried out on chukar partridges in the US (*Alectoris chukar* Gray, 1830) confirm that the vegetal cover is one of the most important variables to be considered (Benolkin 1988; Larsen et al. 2007a). On the other hand, many managers have decided to fence the WT from predators (Sánchez, personal observation), but it is necessary to test the effect on target species and possible predators.

When considering Spain, some regions have expended resources for game species WT programs in recent years; Castilla-La Mancha, for example, where hunting and shooting generate tourism and leisure activities in rural areas (Bernabéu 2000), supported the construction of 1,841 water points in 2006 (El Digital Castilla La 2007). However, the considerable monetary effort made by local governments, hunters, and managers for the maintenance of wild fauna during dry seasons may not have many benefits because some observations and available data are not enough to estimate the real effects of this management tool. The impacts, positive or negative, are still being questioned, with the need for more research.

With the aim of developing artificial water sources designed for red-legged partridge (*Alectoris rufa* Linnaeus, 1758), wild rabbit (*Oryctolagus cuniculus* L.) and Iberian hare (*Lepus granatensis* Rosenhauer, 1856), a research project was carried out from 2002 to 2005 in a Mediterranean arid climate area during the summer months. The aims of this study were: (1) to evaluate the visits of wild fauna in WT, (2) to test the effect of vegetation cover on the use of WT by target species, (3) to see whether fences against predators on WT use are effective, and (4) to study climatic effects on water consumption.

Materials and methods

Study area

This study was carried out on 'Finca Coto Bajo de Matallana' (308 ha, Fig. 1), a private cultivated area in Valladolid, northwest Spain (lat 41° 53′ 45″N, long 4° 52′ 50″W). The area has two streams which dry up, from May to October. The terrain is mostly flat, but the altitude ranges from 771 to 820 m a.s.l. This environment includes bushy and arboreal plants (Fig. 2) as well as cultivated lands with sunflowers (*Helianthus annuus*), lucerne (*Medicago sativa)*, and barley (*Hordeum distichon*).

Climatic conditions

The climate is Mediterranean dry continental (Papadakis 1966) with hot dry summers, harsh winters, and an annual mean rainfall of 455 mm (INM 2006). The rainfall cycle is irregular, with some damp years followed by extended periods of drought similar to the rest of the Castilla y León region (Manrique 1992). During the months of June, July, and August, no rainfall is frequently recorded and average monthly temperatures rise to above 35°C.

Wild fauna and management

Before beginning data collection every summer, one census was carried out on the whole property in early March with the aim of determining the density per hectare of each target species, possible predators, and the presence of other wildlife (Table 1). Following mapping method (Peiró 1997), the transects covered the area of the property (308 ha) with 15-20 walking people distributed in a line who maintained distances of about 10 m between one another and of about 15 from the outer ones to both limits of the counting strip. The density of target species and hunted predators was estimated with Kelker method (Gortázar et al. 2002; Onrubia 2009), using the formula $D - n/(2L \cdot W)$, where '*D*' is the animals density per hectare, '*n*' is the number of animals seen inside a 50 m counting strip and 'LW' is the surface of the counting strip in 50 ha units. Non-hunted predators were surveyed from driven line transects conducted during the census (Beja et al. 2009) with a length of 7.13 km at a speed of about 10 km/h. All animals observed were identified and counted, and their location was recorded in 1:5,000 maps, discarding observations outside the limits of the study area. The abundance of non-hunted species was indexed from the number of individuals counted during the driven transect (7.13 km).

According to the radio tracking studies carried out in the same study site on red-legged partridge (Pérez et al. 2004; Alonso et al. 2005; Pérez 2006), Iberian hare (Bartolomé 2002), and wild rabbit (Díez et al. 2004) and the censuses, the most common predators were fox (*Vulpes vulpes* L.), Iberian wolf (*Canis lupus signatus* Cabrera 1907) birds of prey such as common kestrel (*Falco tinnunculus* L.), goshawk (*Accipiter gentiles* L.), barn owl (*Tyto alba* Scopoli, 1769), sparrow hawk (*Accipiter nisus* L.), and

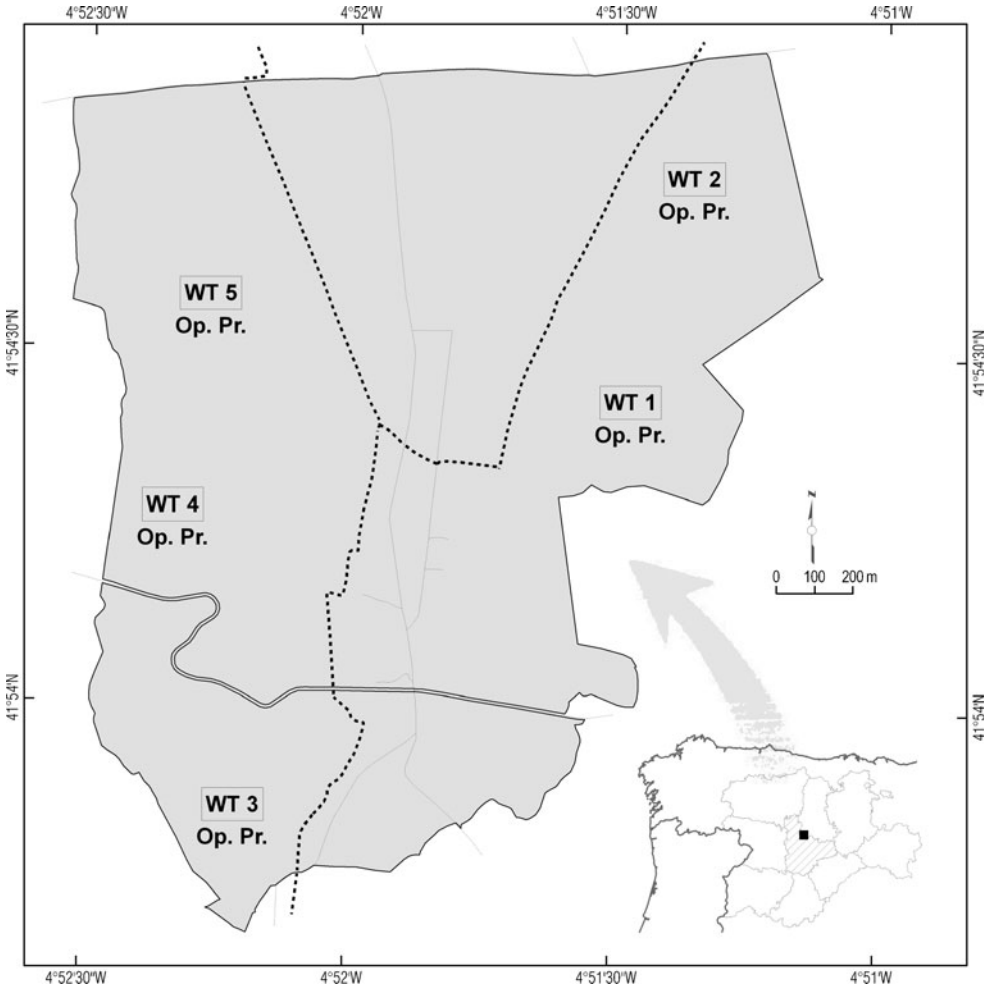

Fig. 1 Location and map of the study area in Northwest Spain. Each water trough device (*WT*) had two troughs, one open (*Op.*), and the other protected (*Pr.*). The *dotted lines* in the map indicate the streams

short-toed eagle (*Hiraaetus pennatus* Gmelin, 1788). Only foxes and common kestrels breed in the study area.

Since 1996, hunting and agricultural management policies were carried out. Hunting was not allowed and a minimum legal control of predators was carried out:

Fig. 2 Typical landscape of the study site: pseudo steppe and bushy areas

Table 1 Density of target species, hunted-predators and abundance of non-hunted predators at the study site from 2002 to 2005 (early March)

Density (indiv.ha^{-1})	2002	2003	2004	2005
Red-legged partridge	0.4	0.6	0.85	0.93
Wild rabbit	1.19	1.47	1.57	2.19
Iberian hare	0.03	0.02	0.03	0.024
Predator control: *N* indiv. captured/indiv.ha^{-100}				
Foxes	3/1.62	3/1.92	2/2.72	1/1.29
Ravens	21/8.44	16/7.46	14/10.06	23/9.41
Feral dogs	2/0.32	1/0.97	5/1.29	0/0
Abundance of non-hunted predators: *N* ind.ha^{-100}				
Iberian wolf	0.7	0.32	0.32	0.7
Common kestrel	2.1	1.41	2.1	0.14
Goshawk	2.1	2.45	1.05	1.75
Barn owl	1.75	4.2	3.85	2.45
Sparrow hawk	0.7	0.45	0.3	0
Short toed eagle	1.05	1.75	0.7	2.1

Number of hunted-predators captured is also given

foxes in February, magpies (*Pica pica* L.), and carrion crows (*Corvus corone* L.) in May, and feral dogs (*Canis lupus familiaris*, L.) throughout the year, following the regional law. The property has perimeter fencing, there were 16 feeding troughs with cereals (one per 20 ha), 15 strips of cereal crops distributed throughout the property (barley, wheat, and lucerne, 0.2 ha average size), crops were free of herbicides (Potts 1985), no grazing was allowed in potential nesting habitat and harvesting (June, early July) was never carried out at night (The Game Conservancy Limited 1992).

Water trough description

Following Leeuw et al. (2001) and Wakefield and Attum (2005), WT were designed to increase water availability for small game species. Data collection was based on the aim of not disturbing wild fauna.

Five WT were used throughout this study. They were situated at different locations (Fig. 1); there was one WT per 60 ha and they were all distributed at a distance of more than 500 m from any other natural water point existing in the area, although the streams in the study site dry up during the summer.

One of the aims of this study was to investigate the effect of vegetal cover on small game use (Benolkin 1988; Moreno et al. 1996; Pongrácz and Altbäcker 2000; Larsen et al. 2007a), thus, each WT had two water troughs (Agrocinegética Modelo S.L., Spain), situated in two different environments; one called open and the other called protected (Fig. 3) and the distance between them was 50 m. The vegetation around the protected troughs covered the area of a circle centered at the water source with a radius of 3–5 m and the species were brambles (*Rubis idaeus*), rockroses (*Cistius albidus*), and brooms (*Cytisus scoparius*).

Each WT was composed of basic and secondary elements (Fig. 3). The basic elements were a main water tank of 400 l, two measuring tanks of 25 l (one per water trough), plastic pipes, and the water troughs in a very strict way. Secondary elements were white beach sand (2 m^2), to search for signs of animals or evidence of kills (excrements, tracks, feathers, carcasses, and feather piles) and escape metal bars with the aim of preventing drowning of small birds and chicks (Wilson and Hannans 1977).

In order to test the effect of fencing on the use of WT, a fence with a height of 1.5 m and 20 cm^2 entrances was placed in all WT in 2004 and 2005. This fence protected 1 m^2 of the beach sand surface. Finally, with the aim of checking water loss due to natural evaporation, one disused WT was set up (it could not be used by wild fauna) and obtained the difference in each water trough subtracting the evaporated water.

Data collection

One weekly visit to each water trough was carried out during the summer seasons (from 15 June to 15 September) from 2002 to 2005. Each year, in May, each trough was tested with the aim of preventing failures and water losses during data collection.

Knowing that lagomorphs are crepuscular and nocturnal (Villafuerte et al. 1993) and that the red-legged partridge starts its activity in the morning (Pintos et al. 1985), thus, each trough was visited around midday (1130–1230 h). The purpose of this visit was to register the tracks in the sand and to take the appropriate measures of the small tanks in order to determine the water consumption. Once the visit had finished, the small tanks were refilled and the beach sand was cleaned. A total of 12 visits were made during each season to each water trough (n=10) so, by the end of the study, a total amount of 480 visits were carried out. Following the De Stefano et al. method (2000), all signs (excrements, tracks, feathers, trails, scats, carcasses, and bones) and observations by species or species groups were recorded in order to determine visiting species. Because it was not possible to determine if the sign was from one or several individuals, it was decided not to attempt to determine the number of individuals which may have visited a trough.

Due to the signs obtained, four groups were formed in order of importance: lagomorphs, red-legged partridge, other birds, and wild canids (Table 2). The high number of red-legged partridge signs collected (especially tracks and excrements) justified them having their own group. As it was not easy to differentiate the tracks and excrements of hares and rabbits, both species where included in the lagomorphs, though wild rabbit density was higher than Iberian hare. The red fox, the Iberian wolf, and the feral dog were included in the wild canids group.

Average daily values of maximum and minimum temperature, relative humidity, and rainfall were registered in a weather station located in the study area (Urbaso S.L., Spain) with the aim of evaluating its effect on average water consumption.

Statistical analyses

The Metwin 2.0© computer program was used to process climatic data while water consumption was analyzed by one-way analysis of variance (ANOVA) so as to assess the significance of water consumption differences between years and open and protected troughs. The Newman–Keuls test was chosen for post-hoc comparison of years (Garrido 2001). In order to examine the relationship between the presence and the absence of species the non-parametric test, chi-square (χ^2 test, Canavos 1986) was used with the computer program SPSS© (version 14.0) for Windows©. Differences with $P<0.05$ were considered significant.

Fig. 3 Water trough device: **a** main water tank and measuring tanks, **b** plastic pipe, **c** water trough and escape metal bars, **d** protected trough with fence (2004–2005), and **e** open trough without fence (2002–2003)

Results

Wild fauna visits

Taking into account the total number of visits made (n= 480), a high percentage of the visits revealed presence of lagomorphs (61.875%) and red-legged partridge (58.54%) as opposed to other birds (22.5%) and wild canids (9.375%). Excrements and tracks of these animals were found, including a record of an attack on a water trough after finding serious damage at the site and even observed unmistakable bite marks on the pipes. Pigeon (*Columba livia* Gmelin, 1789), wagtail (*Motacilla alba* L.), skylark (*Alauda arvensis* L.), great grey shrike (*Lanius excubitor* L.), magpie (*Pica pica* L.), hoopoe (*Upupa epops* L.), greenfinch (*Carduelis chloris* L.), and blackbird (*Turdus merula* L.) were incorporated in the group for other birds. Only a few pellets of barn owl (*Tyto alba* Scopoli, 1769) were collected and therefore, it was decided to include these birds in this group.

On one hand, the chi-square test showed that there were no differences between the presence of lagomorphs and red-legged partridge groups (χ^2=0.74, P=0.37), while on the other hand, there were differences between their presence compared with the other groups considered (χ^2= 426, P<0.05). Differences between the presence of other birds and wild canids were also found (χ^2=24.35, P<0.05).

Water trough choice: effect of vegetal cover and fencing

Three hundred and forty six visits were recorded in open troughs and 384 in protected ones. As was expected, there were no differences in the total number of visits to open and protected troughs (χ^2=0.36, P=0.51). Using the same analysis, it was possible to confirm that red-legged partridge visits were higher in open troughs (χ^2=7.89, P<0.05) whereas lagomorphs opted for protected ones (χ^2=23.36, P<0.05). In the case of other birds and wild canids, there were no differences in their visits between open and protected troughs (χ^2=0.48, P=0.74, χ^2=6.25, P=0.66).

With regard to the effect of fencing, it was possible to find a decline in wild canids tracks in 2004 and 2005 and there were differences between 2002–2003 and 2004–2005 periods (χ^2=30.04, P<0.05). No differences were found in

Table 2 Daily average water consumption (mean± SD) and the total number of visits and signs collected at all WT and open/protected troughs (protected on the right), per year studied (n=480)

Year	2002		2003		2004		2005		Total
Average w.c. (L.)	1.79±1.26 (a)		1.95±1.30 (a)		1.75±0.77 (a)		3.29±1.41 (b)		2.19±1.38
Average o/p w.c. (L.)	2±1.25/1.58±1.25		2.11±1.25/1.79±1.34		1.75±0.77/1.75±0.98		3.38±1.38/3.2±1.41		2.31±1.34/2.03±1.42
Lagomorphs	79		83		53		82		297
	31	48	34	49	22	31	36	46	123 174
	ET: 26 T:5	ET:47 T:1	ET: 34	ET:44 T:5	ET:22	ET:21 T:10	ET:35 T:1	ET: 42 T:4	
Red-legged partridge	68		47		95		71		281
	33	35	24	23	51	44	35	36	143 138
	T: 24 ETF:9	T: 31 ET:4	T: 23 EF:1	T:15 ETF:8	T: 43 ET:8	T: 32 ETF:12	T: 32 ET:3	T: 23 ETF:14	
Other birds	26		25		30		27		108
	15	11	14	11	16	14	12	15	57 51
	E: 12 ET: 3	EF: 6 T:5	ET: 14	EF:9 T: 2	ET: 16	ETF: 8 ET:6	ET: 12	ETF: 11 T:3	
Wild canids	14		26		2		3		45
	8	6	15	11	0	2	0	3	23 21
	E: 8	ET: 4 T:2	ET: 8 T:7	ET:11		E:2		E: 3	
Total	87	100	87	94	89	91	83	100	346 384

E excrements, *T* tracks, *ET* excrements and tracks, *EF* excrements and feathers, *ETF* excrements, tracks, and feathers

lagomorphs (χ^2=1.70, P=0.19), red-legged partridge (χ^2= 3.26, P=0.7), and other birds (χ^2=0.43, P=0.51).

Climatic effects on water consumption

Average daily water consumption at each trough was 2.19± 1.38 l taking each year into account (Table 2), ranging from 1.75 to 3.39 l. Using one-way ANOVA, differences between years for the average daily water consumption were found ($F_{(1,476)}$=42.51, P<0.05). Newman–Keuls test indicated significant differences between the first 3 years (2002, 2003, and 2004) and the last years (2005; Table 2). Analyses of daily water consumption in open and protected environments showed that there were significant differences and consumption was higher in opened ($F_{(3,476)}$= 43.57, P<0.05). As was expected, higher water consumption was recorded in the driest and hottest periods of each summer (Fig. 4), and a significant correlation was detected between average daily water consumption and the maximum and minimum temperatures as well as the relative humidity recorded in the study area (P<0.05). Furthermore, no significant correlation was detected between consumption and rainfall (P>0.05).

Discussion

Wild fauna visits

Experimental results show the predominance of lagomorphs and partridge groups at all water troughs throughout the whole study and confirm the use WT during the dry seasons by the red-legged partridge, which agree with Rito and Borralho (1997), Borralho et al. (1998), and lagomorphs (Hayward 1961) though these mammals can endure harsh drought. It is also believed that one of the most important problems in the wild red-legged partridge management in Spain is water necessity for chicks because of the high requirements during growth (Rito y Borralho et al. 1998), and this occurs during summer.

Although the number of visits by other birds was lower than lagomorphs and partridges, the results suggest a frequent use by game and non-game birds (Casas et al. 2006) though, in this study, the red-legged partridge was not observed.

This work also found visits by wild canids. However, tracks and excrements were not frequently found once the fence was set up (2004–2005). The interpretation of this fact in the 2002–2003 period seems complex as no evidence of predation was found. Taking into account the home range of these predators and the possibility of covering several kilometers per day (Gortázar 1998), it was probable that they had gone to other water sources, such as streams or ponds, when thirsty. Surprisingly, these animals attacked a WT in

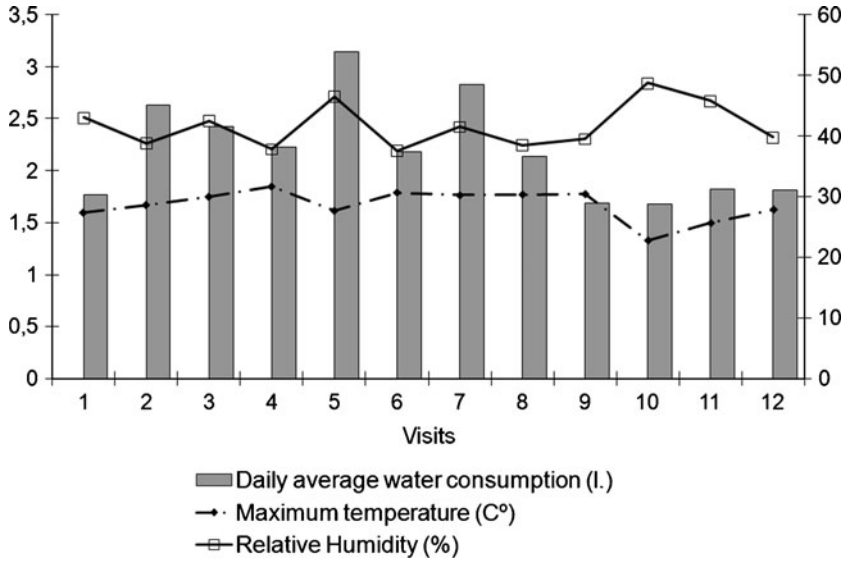

Fig. 4 Average values of daily water consumption (L.), maximum temperature (°C) and relative humidity (%) considering 12 weekly visits each summer throughout the study (2002–2005)

2003, which suggests that were possibly looking for water. This finding agrees with findings by De Stefano et al. (2000), who argues that predators were probably attracted to wildlife WT to drink rather than hunt, but this result was obtained in arid and harsher environments where canids should have a higher water need. In any case, our research concerning this potential adverse impact will be continued, as an incorrect WT planning may be favored by predators (James et al. 1999).

Research has found visits of part of the known wild fauna in the study site at all WT in accordance with studies carried out in the US (Rosenstock et al. 1999, 2004) and Australia (James et al. 1999). Nevertheless, tracks of raptor and mustelid species were expected to be found in the sand, but only two raptor pellets were detected at one trough. This result does not agree with the findings by Korchert et al. (1988) and Cutler (1996), but perhaps the differences between landscapes at the study sites (our study site had more vegetation and raptors did not nest near the WT) and the climatic conditions (harsher and longer drought periods in US) could explain these differences.

It is interesting to note that the number of visits by game was higher than non-game species. However, the limitations of our study are assumed and, in the future, new observation methods will be included such as video cameras and infrared illuminators for night-time observations (Rosenstock et al. 2004; Larsen et al. 2007b). It is suspected that some animals have not been detected, as species of birds, mustelid, and reptiles.

Water trough choice: effect of vegetal cover and fencing

The researcher observed that all water troughs were used throughout the study and the results yield statistically significant differences between choices shown by target species: partridges opted for open and lagomorphs protected ones.

In the case of partridges, we disagree with Benolkin (1988) and Larsen et al. (2007a) because they stated that water trough choice in chukar partridges is strongly influenced by the shrub canopy cover, so the destruction of security cover around water troughs would preclude establishment and use by chukars. Nevertheless, both types of troughs were used by red-legged partridges and open were preferred in our study. We are led to believe that red-legged partridges could quickly detect an avian predator at open troughs and escape if necessary, which is due to the high avian predation rates shown in studies carried out at the same study site, using wild partridges (Pérez 2006). On the other hand, a relationship between lagomorphs choice and predation rates was established as Moreno et al. (1996) and Pongrácz and Altbäcker (2000) observed that rabbits choose open environments at night as it is effective against terrestrial predation while protected environments could be safer during the day. From our results, the influence of terrestrial and air predation caused the high level of visits by lagomorphs to protected troughs can be concluded.

It is encouraging to see that the findings of this study have provided some support to the assumption that WT choice by prey species is based on self-protection strategies (Larsen et al. 2007a). A follow-up of the present study could examine the effect of shrub characteristics (height and density) and other ecological and behavioral reasons that could have had a final influence on partridges, lagomorphs, and other birds choice.

The use of the fence had no influence in the tendency of wild fauna presence, except in the case of wild canids. The reduction of tracks found was due to the fence, as it was designed to prevent terrestrial predators from consuming water.

Climatic effects on water consumption

The influence of climatic factors on water consumption seems unquestionable in this study because when the maximum temperature rose to above 30°C and the relative humidity was almost 50% (usually 15 July–15 August), average daily consumption increased considerably. A possible reason which could explain the consumption differences between the first 3 years (2002, 2003, and 2004) and the last year (2005) is the harsh drought period recorded this year, the driest season in Spain since 1947 (INM 2006).

This finding is particularly significant as it indicates that drinking water (Leopold 1933) is necessary when the water obtained from the food is not enough to offset water loss (Hayward 1961; Bartholomew and Cade 1963; Degen et al. 1983; Degen 1987).

Conclusions

The WT used in this study are visited by the red-legged partridge, lagomorphs, and other species of non-game birds in summer, especially during extended drought periods, although target species visits are higher than non-game. Managers should consider the effects of surrounding vegetal cover on water source choice by prey species because the results revealed that partridges prefer using open trough and lagomorphs-protected troughs. Moreover, WT fencing is recommended as it has no effect on small game use and reduces wild canids visits, a possible adverse impact.

Acknowledgments This work was financially supported by the Junta de Castilla y León (Spain). We also thank Ignacio Prieto Sarro (Carthography Service of the University of León), Juan Antonio Olmedo for his faithful support, and Donal J. Savage and Courtnee L. Henry for their help with the English version of this manuscript. Special thanks are extended to the two reviewers of the manuscript for their constructive comments.

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