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Abstract: The aim of this study was to compare the trophic behaviour and the social structure of Majorcan wild goats and feral goats present in the island of Majorca. The former are descendants of an ancestral goat ecotype introduced in the island in the late Neolithic, whereas feral goats come from domestic forms introduced recently from the Iberian Peninsula. The study was conducted in four localities of the Serra de Tramuntana, a mountain range located in the northwest of the island of Majorca. Behavioural data were collected in three seasons, summer, winter and spring of 2011-2013, and when goat activity is at its peak, i.e., three hours after dawn and before dusk. The following variables were recorded: group composition (males, females, and kids) and activity (feeding, walking, resting, and watching). The proportion of time spent on each activity and their frequency were obtained from focal samples. Multivariate analyses of variance (MANOVA) were used to simultaneously analyse the activity variables. A total of 155 observations of 85 herds were registered throughout the study. A similar behaviour pattern has been observed in this study for the two goat ecotypes, feral and wild, apart from some seasonal variations in feeding and resting activities. In summer, feral goats showed higher feeding efforts (duration and frequency) than wild goats; this might be related to a lower efficiency obtaining feeding resources by the former, whereas wild goats, that have inhabited the island for millennia, coexisting with vegetation in periods of lower forage abundance and quality, would be more efficient herbivores during restrictive periods. Average herd size for both ecotypes is smaller than that recorded for domestic goat herds, suggesting a relatively low browsing damage compared to the latter. Also, feral goats apparently have a higher gregarious behaviour than wild ones, which might relate to their domestic origin. Currently, the management of goats on the island is based on maintaining the wild ecotype and eradicate the feral one, whose impact on vegetation is supposedly worse. However, our results show a similar trophic behaviour by both ecotypes, so that their impact on vegetation should also be expected to be similar, indicating that this argument has not enough scientific basis.

Comparative study of trophic behaviour and herd structure in wild and feral goats living in a Mediterranean island: management implications

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Abstract

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similar trophic behaviour by both ecotypes, so that their impact on vegetation should also be expected to be similar, indicating that this argument has not enough scientific basis.

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1. Introduction

The arrival of goats (*Capra* sp.) to the island of Majorca is very ancient, and has documented between 2300 and 2050 BC during the Pre-Talaiotic culture (Seguí *et al.*, 2005). It has been postulated that the first goats introduced to the island gave rise to a local breed that remained in the wild until present, the so-called Majorcan wild goat (*Capra aegagrus [hircus]* ssp.). Currently, it is an important source of income through hunting activities in the island (Seguí *et al.*, 2005), being in the hunting grounds where the purest populations are conserved. The introduction of domestic breeds (*C. hircus*) in more recent times and their subsequent abandonment has led to the establishment of a large population of feral goats phenotypically clearly differentiated (Vives and Baraza, 2010). This abandonment took place in the 1960's, when tourism began to develop intensively. Goats may form feral populations in localities where they are abandoned, as keeping them as domestic stock is no longer valuable, and particularly where predators are absent or scarce (Parkes *et al.*, 1996), as it occurs in Majorca.

Herds of feral goats have a marked effect on the ecosystems they inhabit (Coblentz, 1978) and can be an economic and hunting resource (Forsyth *et al.*, 2009). In many places the feral goat is considered an invasive species (Parkes, 1993; Parkes *et al.*, 2002), foreign to the natural ecosystem and therefore its eradication is recommended in order to reduce the negative impact on the agricultural and natural ecosystems.

In the Serra de Tramuntana of Majorca, feral goats have been present for at least 50 years, according to farmers' accounts. In the past, both wild and feral goats were hunted alike on the island using an ancient technique called "cans i llaç" (dogs and loop), which consisted of a round up the goats with the help of dogs in cliffs and then catching them with a loop (Seguí, 2014). Nowadays, the way that goats are managed in the island differs according to their ecotype. Wild goats are only hunted using firearms in hunting areas, whereas feral goats are captured throughout the highlands using both techniques, dog and loop for kids, and firearms, in eradication campaigns.

The available literature on the behaviour of goats describes a very similar social behaviour between wild and feral populations (Shackleton and Shank, 1984). Therefore, we would not expect much difference between the behaviour of feral goats and the Majorcan wild goats, but due to different handling both ecotypes receive, their behaviour could be different. The main objective of this study was to compare the trophic behaviour and the social structure of Majorcan wild goat and feral goat herds present in the island of Majorca. The identification of food habits and routines, as well as the social structure of both ecotypes, might allow us to establish proper management scenarios for both goat ecotypes.

2. Methodology

2.1. Study area

The study was conducted in four localities of the Serra de Tramuntana, a mountain range located in the northwest of the island of Majorca. It ranges 90 km and stretches in a southwest-northeast direction, with a surface of 800 km². The highest peak is Puig Major, 1,445 m above sea level (a.s.l.) (39° 48' 27" N, 2° 47' 36" E). The entire mountain range was listed as a World Heritage Site by UNESCO in 2011.

113

114 The climate is typically Mediterranean, with two rainy seasons (spring and autumn), a
115 hot dry summer and a warm dry winter. Spatial variation of rainfall is significant, with
116 a maximum of 1400-1600 mm per year located in the central sector of the mountain,
117 with drier points not exceeding 300-350mm in coastal areas. The annual average
118 temperature ranges from 16 to 18 ° C in the lower parts of the mountain. The four
119 areas considered in this study are located in the lower part of the mountain range
120 between 77 m and 439 m. a.s.l. The perennial tussock grass *Ampelodesmos*
121 *mauritanica* dominates the vegetation community. Several shrub species, such as
122 *Chamaerops humilis*, *Olea europaea* var. *sylvestris*, or *Pistacia lentiscus* are
123 scattered over the territory, mainly close to caves and rock shelters. This plant
124 community is characteristic of the giant reed thicket succession (*Smilaco balearicae*-
125 *Ampelodesmetum mauritanicae*), according to Rivas-Martínez *et al.* (1992).

126

127 Two study areas, Formentor and Victoria (Figure 1), are hunting estates where
128 animals are selected according the breed traits of the Majorcan wild goat (Decree
129 91/2006 of the Council of Majorca). The animals survive year round with the
130 resources of the estates, without any food supplementation, but subject to disease
131 control. The stocking rate of these areas was calculated from data provided by the
132 managers (Figure 1). These goats are considered as *Capra aegagrus* by some
133 authors, because of their wild status (Seguí and Payeras, 2002; Masseti, 2009), but
134 some others argue that they are feral populations of ancient domestic stocks, and
135 should be included in the domestic species *Capra hircus* (Giannatos *et al.*, 2006).
136 The other two study areas have been occupied for decades by feral domestic goats
137 (Figure 1). These animals are not subject to any form of management, except by
138 some sporadic attempts to control populations by the island authorities. In that case,
139 the stocking rate was estimated from field observations.

140

2.2. Data collection

Data were collected in three seasons, summer, winter and spring of 2011-2013. An observation point was assigned to each one of the four study sites, with ample visibility of areas usually used by goats. Data were collected 3 hours after dawn or before dusk, when goat activity is at its peak, as usually happens in other ungulates (e.g. Carranza *et al.*, 1991; Cassinello, 2000).

When a goat herd was sighted, group composition and age-sex classes (number of adult males and females, and kids) were registered. Behavioural data of adult males and females were collected following the methodology established by Altmann (1974) and Martin and Bateson (1986). It consisted in a series of focal samples where the behaviour of a given individual was registered in a paper sheet. Focals were 15 minutes long, and allowed the continuous recording of individuals' activity, i.e., feeding, walking, resting and watching. Both duration and frequency of behaviours were thus estimated. In order to minimize the possibility of recording the same individual or herd more than once, we alternated our visits to the different observation points.

2.3. Statistical analysis

The proportion of time spent on each activity and their frequency were obtained from focal samples. Spearman correlation analyses of the response variables (feeding, walking, watching, and rest) were estimated. Because the lack of normality of data (Shapiro-Wilk test, $P < 0.05$), the square root transformations + 0.5, arcsine of the square root, and logarithm plus one were applied to frequencies, proportions, and absolute values, respectively. To reduce the effect of sampling area, the standardised values of variables (Z values) as regards the sampling area were

calculated. Multivariate analyses of variance (MANOVA) were used to simultaneously analyse four dependent variables: feeding, walking, watching, and resting. The independent variables considered in the model were season, ecotype, and sex. The Roy's Max Root test was used to estimate the significance of the effect in the MANOVA. Furthermore, for those variables showing significant differences, one-way and two-way factorial ANOVA were performed, and least square means of the levels estimated.

To analyse the observed frequency of encounter of the different herd types in the two ecotypes of goats, a Chi squared test was used. Moreover, the herd size, transformed with logarithm plus one, was evaluated by ANOVA, taking into account the effects of season, type herd, and goat ecotype. The mean differences between levels of factors included in this analysis were evaluated by least squares. Statistical analyses were performed with JMP statistical software, version 8.0 (JMP 8.0 SAS Institute, 2008).

3. Results

A total of 155 observations were taken throughout the study. A significant difference was obtained between proportion variables (Table 1).

The MANOVA analysis of the proportions and frequencies showed that the interaction between season and goat ecotype was significantly related to the behaviours observed (Table 2). The walking and watching variables had no significant differences, showing a mean of 16.9 ± 1 and 14.8 ± 1.3 for percentage and 0.7 ± 0.04 and 0.5 ± 0.03 for frequency, respectively.

Our results showed that the percentage of time devoted to feeding by both ecotypes was lower in spring than in winter and summer ($F_{(5,138)} = 2.93$, $P = 0.01$); however, the feral domestic goats devoted more time to feeding in summer than the Majorcan wild goat, Figure 2 (LS Mean Differences Student t).

As regards feeding frequency (Figure 3), the Majorcan wild goat showed a higher frequency in winter than in spring and summer ($F_{(5,138)} = 3.50$, $P = 0.005$), while the feral domestic goats did not show significant differences for this trait. Differences between ecotypes were only found in summer, when feral goats showed a higher feeding frequency than wild ones.

It was observed that the resting frequency for both goat ecotypes was higher in spring than in winter and summer; however, in winter feral domestic goat resting frequency was greater than that of the Majorcan wild goat ($F_{(5,138)} = 4.16$, $P = 0.001$; Figure 4).

A total of 85 herds were observed during the study. Out of these, 37 corresponded to feral goat herds and 48 were wild goat herds. The observed herds were grouped into three categories: mixed (herds made up of males, females and kids), males (herds composed only by males), and females (herds made up of females with or without kids). The Chi squared test for herd type showed differences in the proportion of herd type sightings ($\chi^2_{(7,81)} = 70.39$, d.f.=3, $P < 0.0001$). In the case of wild goats, it was observed that the frequency of finding mixed herds was greater than that of female and male herds, respectively ($P < 0.05$). As for feral goats, the frequency of finding either mixed herds or female herds was higher than that of male herds ($P < 0.05$, Figure 5a).

The size of the herds is shown in Figure 5b. Mixed and female herds were larger in

feral than in wild goats ($P<0.05$), whereas the opposite occurs with male herds, which were significantly larger in wild ($P<0.05$).

4. Discussion

This study undertakes for the first time a comparative study of trophic behaviour and herd structure of two goat ecotypes inhabiting the island of Majorca; i.e., feral goats introduced in recent times and Majorcan wild goats, the descendants of an ancestral goat which was introduced to the island more than 4000 years ago (Seguí et al., 2005). Subtle differences between both ecotypes are reported, but we conclude that their effects on the ecosystem should be similar.

4.1. Activity patterns

Our results have revealed that during their peak activity goats devote most of the time feeding, as it has been reported in other goat populations (Askins and Turner, 1972). It is also expected that goats spend the longest feeding time when in shrublands, due to their small bite size and the fact that leaves are spread out between and within the branches (Kenney and Black, 1984).

Feeding time was inversely related to the time devoted to other activities, and was also affected by season. Both goat ecotypes spent more time feeding in summer and winter than in spring. This difference could be associated to the low quality of forage during these periods, along with an increase of energy requirements in order to maintain their body temperature regulation (Alados, 1986; Alados and Escós, 1987). The reduction of the sunlight period during winter would also determine an increase of feeding time (Valentine, 1990). In addition, in summer goats showed a relatively

high activity period at midday, probably due to the decrease of disturbances caused by tourists, hunters and mountain trackers (personal observation). During their peak activity period feral goat feeding time and frequency were higher than those of wild goats in summer. This fact might be related to a lesser efficiency by feral goats in the use of vegetation during this restricted season, compared to that of wild goats, which have inhabited the island for millennia, coexisting with vegetation in periods of lower forage abundance and quality (Pérez-Obiol, 2003; Seguí et al., 2005; Bartolomé et al., 2014).

Despite walking time being inversely related to feeding time, this trend was not observed for walking frequency. In fact, walking frequency showed a positive correlation with feeding time, and could be explained because walking activity is fundamentally related to browsing, when goats have short walks in order to locate new feed sources (Arnold and Dudzinski, 1978).

Moreover, both walking time and frequency were directly related to watching time. This is expected because when goats are in motion they are more visible to potential threats like hunters, dogs or even tourists. No differences between the two goat ecotypes were observed for watching activity, despite one of the ecotypes is subject to a higher hunting pressure, as wild goats are hunted for recreational purposes, and feral goats following eradication programs, that allows them to be culled throughout all the year (Mayol, 2013).

Animals tend to be lying down during resting time. Time devoting to resting was the least observed behaviour during the peak activity periods, as expected. Resting frequency depended on the season of the year, with the highest resting frequencies being observed during spring, precisely when feeding duration and frequency show the lowest values, probably because of the superior forage quality characteristic of

280 this season. Animals ruminate while resting, therefore it is expected that goats spend
281 additional time in spring for rumination while spending less time feeding. Conversely,
282 during winter and summer, both goat ecotypes rested less time and less frequently,
283 in agreement with reports by other authors (Arnold and Dudzinski, 1978), who
284 proposed that animals reduce their resting time at relatively high or low
285 temperatures; however our data were exclusively registered during goats' peak
286 activity periods so that conclusions are not definitive on this issue. Feral goats resting
287 time is similar to that of wild goats, but is less frequent, and is a more frequent
288 behaviour in domestic goats (Shackleton and Shank, 1984). The fact that wild goats
289 have shorter resting periods than feral or domestic goats could be associated with
290 the wildness degree.

292 4.2. Structure of herds

294 The structure of herds observed in both goat ecotypes in the Serra de Tramuntana of
295 Majorca follows the pattern reported for other feral goat populations (Parkes, 1984;
296 Shi *et al.*, 2005), as well as the one usually observed in other wild goat populations
297 (Shaller, 1977). The basic social unit is generally an adult female and her offspring,
298 which associate with similar groups in a given area (O'Brien, 1988). The average
299 herd size in this study was higher than that reported in other goat populations
300 (Granados, 2001; Suances, 2010), although we found clear differences between both
301 goat ecotypes.

303 Females and mixed herds were larger in feral goats than in wild ones, which is in
304 agreement with the expected higher gregariousness characteristic of domestic
305 ungulates (Shackleton and Shank, 1984). However, feral male herds were
306 significantly smaller than those of wild goats. This is probably as a result of ancient
307 domestication processes, which has been postulated to lead to a certain sedentary

behaviour, so that migrating bachelor male groups tend to disappear (Martínez *et al.*, 2014).

In this study, feral goats showed variations in herd size across the year, as reported previously by Shi *et al.* (2005) and Suances (2010), being greater in summer and winter. Gregariousness is a condition that allows information to be transmitted within herds (Wilson *et al.*, 1975), a condition quite frequently reported in feral goats. Goats tend to follow older individuals in periods of food shortages and higher drought, as the location of better food and water sources can be transmitted from older individuals to younger ones (O'Brien, 1988). This could be an explanation for the increased size of the study feral goat herds in summer and winter. On the contrary, herds of wild goats had similar sizes throughout the year. As mentioned previously, it is likely that wild goats are more efficient in searching for food in less favourable seasons. This appears to be reinforced by the vegetation management in hunting estates, where burning and clearing are applied occasionally for improving forage quality. Other studies have observed a constant herd size during the year of goats living on islands in favourable conditions (Shackleton and Shank, 1984).

4.3. Management implication

Our study may give some clues to understand the comparative behaviour of feral and wild goats in islands. There has been a tendency in the island of Majorca to keep native wild goats, whereas to eradicate feral populations on the grounds that the latter causes severe damage to vegetation. However, and according to this study, both goat ecotypes have a very similar trophic behaviour, so that their impact on vegetation should be expected to be similar. The slight differences observed may suggest that wild goats are better adapted to the plant community present on the island.

336

337 Our data suggest that feral goat populations, which originally came from domestic
338 stocks, maintain certain social structures that resemble their domestic origin, such as
339 a relatively high level of gregariousness, although average herd sizes of both wild and
340 feral goats in the island are lower than the average size reported for domestic goat
341 herds. Herbivore large herds, as it is usually the case of livestock, are likely to have
342 severe impacts on vegetation (Orueta, 2003), especially in habitats with no history of
343 intense herbivory; whereas herbivory caused by small herds is usually beneficial
344 (see, e.g., Anderson *et al.* 2007). However, in an island where herbivore ungulates
345 have been around since before the arrival of man, as it is the case of Majorca
346 (Alcover *et al.*, 1999), endemic plant species have been subjected to browsing and
347 have evolved with the presence of these herbivores.

348

349 Browsing signals have traditionally been seen as detrimental for environmental
350 conservation if they are related to overgrazing, desertification, and their consequent
351 contribution to climate change and loss of biodiversity (Mancilla-Leytón, 2014).
352 However, goat browsing behaviour, when in moderate intensity, has been shown to
353 maintain and enrich plant communities, particularly in comparison with other
354 domestic ungulates. High food selection and a strong preference for browsing enable
355 goats to reduce the variation of energy and protein in their diet caused by
356 environmental or management conditions (Fedele *et al.*, 1993). Moreover, because
357 of this versatility of grazing/browsing behaviour, goats are able to effectively control
358 invasive plant species, while at the same time select a diet that meets their nutritional
359 requirements (Mancilla-Leytón *et al.*, 2013). However, as an increase of both wild
360 and feral goat populations in the study area may cause serious damage to
361 vegetation, the practice of traditional hunting with dog and loop might help to regulate
362 feral goat populations. This is why we would suggest preserving, or even promoting,
363 this type of ancestral hunting in Majorca.

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Figure captions

Figure 1. Sample location

Figure 2. Proportion of time devoted to feeding for goat ecotype and season (values are mean $\pm$ SE).

Figure 3. Feeding rate for goat ecotype and season (values are mean $\pm$ SE).

Figure 4. Resting rate for goat ecotype and season (values are mean $\pm$ SE).

Figure 5. (a) Herd type size for goat ecotype, (b) Herd size for goat ecotype in each season sampled (values are mean $\pm$ SE).

511 Tables

512

513 Table 1. Spearman correlation values of the proportion of time devoted to four

514 different behaviours

515

516 Table 2. Results of MANOVA explaining the effects of season, sex class, and

517 ecotype on behaviour frequencies and proportions (F approximate value, degrees of

518 freedom and P-value are reported).

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520

Table 1.

Activity	Feeding	Walking	Watching
Walking	-0.4224***		
Watching	-0.6189***	0.1761*	
Resting	-0.4803***	-0.2549**	0.0698*

* $P > 0.05$; ** $P < 0.01$; *** $P < 0.0001$

Table 2.

MANOVA				
Effect	Approx. F	df* 1	df2	P
Proportions				
season	3.01	5	129	0.01
ecotype	0.76	5	128	0.58
sex	0.92	5	128	0.45
season*ecotype	3.14	5	129	0.01
season*sex	1.66	5	129	0.15
ecotype*sex	0.62	5	128	0.68
season*ecotype*sex	0.19	5	129	0.48
Frequency				
season	4.99	5	129	<0.001
ecotype	0.67	5	128	0.65
sex	0.58	5	128	0.71
season*ecotype	2.92	5	129	0.01
season*sex	1.49	5	129	0.18
ecotype*sex	1.21	5	128	0.3
season*ecotype*sex	0.91	5	129	0.48

* df = Degrees of freedom

Figure

Area name	Location	Altitude (m a.s.l.)	Stocking rate (head/ha)
1.-Trapa	39°36,044" N 002°21,543"E	258-373	0.77
2.-Sant Vicenç	39°55,540" N 003°03,122"E	77	0.25
3.-Formentor	39°56,997" N 003°09,633"E	147	0.33
4.-Victoria	39°51,860" N 003°09,694"E	89	0.65

Figure

Figure

Figure

a)

b)

Ecotype within herd type

Ecotype within season