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Investigating activity patterns of large-size mammals using opportunistic camera-trapping data

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Abstract

Camera traps are now widely used in scientific research and wildlife management. With an opportunistic application of this survey methodology it is possible to collect a large amount of data. This allows researchers to formulate hypotheses based on them. In particular, camera traps allow accurate analysis of the activity patterns of animal species by recording time and date.

Using the data collected with an opportunistic application of camera trapping, over a period of seven years, and using time and date metadata, we have formulated and verified hypotheses concerning the activity patterns of five species of large mammals and their association with certain ecological conditions, like seasonality, presence of possible competitor and presence of a predator. Given the opportunistic nature of the data, our results cannot be considered precise and accurate, but they can be used as a starting point for future studies aimed at analysing this ecological aspect of the species studied, in the area of interest.

Key words: activity / ungulates / wolf / camera traps / Apuan Alps

Analizzare i modelli di attività di grandi mammiferi utilizzando dati da un foto-trappolaggio opportunistico

Le trappole fotografiche sono uno strumento ormai ampiamente utilizzato nella ricerca scientifica e nella gestione faunistica. Con una applicazione opportunistica di questa metodologia di indagine è possibile raccogliere una grande quantità di dati. Ciò consente ai ricercatori di poter formulare delle ipotesi a partire dagli stessi. In particolar modo le fototrappole consentono di analizzare in modo accurato i modelli di attività delle specie animali, grazie alla registrazione di ora e data.

Utilizzando i dati raccolti con una applicazione opportunistica del fototrappolaggio, nell'arco di sette anni, ed utilizzando i metadati relativi ad ore e date, abbiamo formulato e verificato delle ipotesi riguardanti i modelli di attività di cinque specie di grandi mammiferi e la loro associazione con determinate condizioni ecologiche, come la stagionalità, la presenza di possibili competitori e la presenza di un predatore. Data la natura opportunistica dei dati i nostri risultati non possono essere considerati precisi ed accurati, ma possono essere utilizzati come punto di partenza per studi futuri volti ad analizzare questo aspetto ecologico delle specie studiate, nell'area di interesse.

Parole chiave: Attività / ungulati / lupo / fototrappole / Alpi Apuane

INTRODUCTION

The use of camera traps as a tool for the study of wildlife and for the study of animals ecology has increased significantly in recent years; at the same time, a wide variety of camera trapping applications have been developed for scientific research and wildlife management (Rovero and Zimmermenn, 2016; O'Connel *et al*., 2011).

Camera traps have enabled to determine many aspects of the ecological niches of many species, such as density and habitat use (Rovero and Marshall, 2009; Di Bitetti *et al.,* 2006), occupancy (Rovero *et al*., 2013a), activity patterns (Cruz *et al*., 2014; Van Schaik and Griffiths, 1996) and niche partitioning between species (Jácomo *et al*., 2004; Bianchi *et al*., 2016).

Depending on the specific study, the species to be studied and the desired objectives, the applications of camera trapping require accurate and well prepared sampling design (Hamel *et al*., 2012; Rovero *et al*., 2013b).

Studies focusing on a species or on a few ecological aspects generally use sampling designs (Di Bitetti *et al*., 2006; Bridges *et al*., 2004); on the other hand, multi-species studies use a more opportunistic sampling design (Ogurtsov *et al*., 2018; Gómez *et al*., 2005). However camera traps allow a wide range of data and information to be collected on a large number of species (Stein *et al*., 2008).

The possibility of having a large set of data available allows researchers to make hypotheses for other types of studies or to study another species, and this information can help in the design of a sampling survey.

In this work we used data collected with an opportunistic camera trapping in the mountain area of the Apuan Alps, in central Italy, over a long period of time, from 2011 to 2018, and we used this opportunistic data for the formulation of hypotheses. We focused our assumption and analyses on the activity patterns because the camera traps have the advantage of printed on their registration the exact time of the animals contacted and recorded (Van Schaik and Griffiths, 1996). Our hypotheses related to the activity patterns are focused on four species of wild ungulates present in the sampled area, roe deer (*Capreolus capreolus*, Linnaeus), red deer (*Cervus elaphus*, Linnaeus), mouflon (*Ovis aries musimom*, Pallas) and wild boar (*Sus scrofa*, Linnaeus) and one species of carnivore, the Apennine grey wolf (*Canis lupus italicus*, Altobello).

We have assumed that the activity patterns of the species is influenced by three factors: 1) the seasonality, 2) the presence of other ungulates species, and 3) the presence of their main predator. Therefore, our objectives were to verify whether, by analysing the data collected in an opportunistic survey, it is possible to formulate hypotheses and verify them.

MATERIAL AND METHODS

Study area

In our work we have analysed the opportunistic camera trapping data collected in the Apuan Alps, a mountain range in north-western Tuscany, in Italy (Fig. 1).

Over most of the surface area of this mountain range there is the homonymous natural park, with a surface of 500.32 km^2; 206.35 km^2 of protected area and 293.97 km^2 of contiguous area.

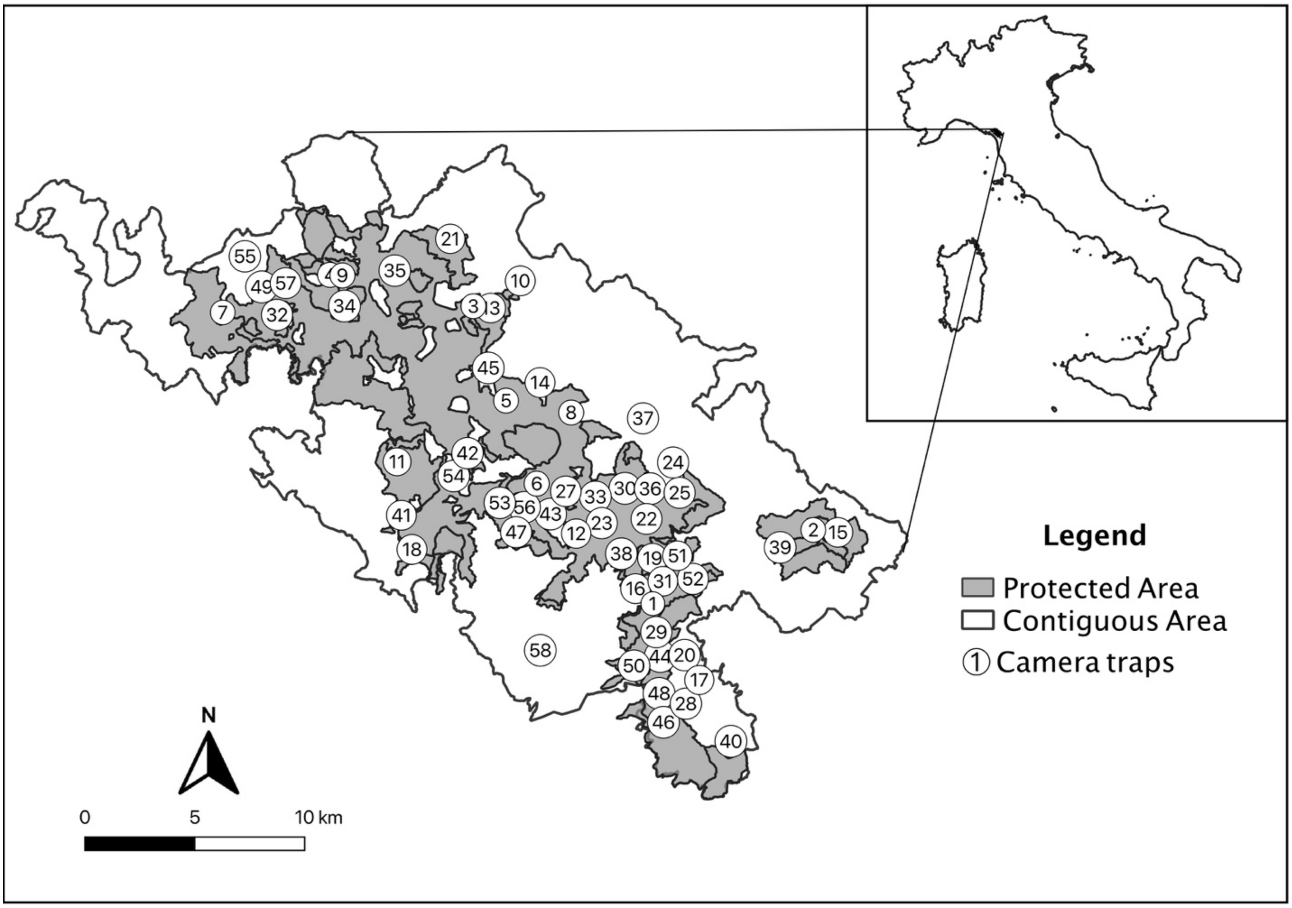

Fig 1. Map of the study area in north-western Tuscany, Italy. In the circled number are shows the camera trap stations numbered by the Appendix Table. The black border represents the contiguous area and the grey area represent the protected area of Apuan Alps regional park.

The Apuan Alps are situated between the coast of the Ligurian sea (approximately 10 km away) and the northern part of the Apennines (approximately 20 km away), and because of this position the chain has particular geomorphological characteristics and a particular vegetation.

The vegetation includes a clear prevalence of wood cover, mainly of broad-leaved trees, chestnut and beech woods. There are also large areas occupied by open environments at high altitudes and in the southern area of the mountain range (Garbari and Bedini, 2006; Ferrarini, 1972).

The substrate is mostly of calcareous origin, with an alternation of siliceous substrates.

The annual temperature varies from a minimum of about -10°C in winter to a maximum of about 35°C in summer.

Data collection and Dataset selection

Since 2011, opportunistic camera trapping has been carried out as part of the monitoring and conservation of wildlife by rangers and technicians in the study area.

In the period from 2011 to 2018, 58 camera trap stations were used (Fig. 1), with a total sampling effort of 11280 camera traps day (Appendix table), and were collected 6137 independent records of wild ungulates and wolves. Due to the opportunistic origin of this data, we filtered them and we have generated a more uniform and homogeneous dataset with which to verify our hypotheses.

Firstly, we have selected a time interval as our sampling period, and we therefore excluded the camera trap sites that do not fall within this seven-month interval. We selected a period of seven month, from 1 May and 30 November, because in this time interval are found at least 70.00% of total record during the interval between 2011 and 2018.

When we found our sampling period, we selected the most representative sites with a relative abundance index (RAI) for each station, given by the ratio between the number of recordings of the species and the sampling effort in which the camera was active. For each species we excluded sites that had a RAI value lower than the first decile of all sites where that species was recorded.

Activity patterns

If activity period is influenced by ecological variables, such as seasonality and presence of other species, one expects an association between the activity pattern and the environmental factors, such as seasonality and interspecific interactions.

In the analysis of activity we assumed that ungulates changes their activity pattern in relation a three different factors: 1) seasonality and seasonal changes of photoperiod; 2) presence of other ungulates species; and 3) presence of predator, such as Apennine grey wolf.

Camera traps printed on recorded files the exact time of the registration, allowing to attribute each recording to one of the three following periods in which we have divided the daily cycle: daytime, twilight and night. We defined twilight as the hours that coincide with sunrise and sunset according to the nautical twilight 102°, daytime as the hours between sunrise and sunset and as night the hours between sunset and sunrise.

Firstly we used the selection ratio (w) (Manly *et al.*, 2002), to established if a species are diurnal, crepuscular or nocturnal; if $w_i < 1.00$ indicates that the species tends to avoid being active at that time of day, instead if $w_i > 1.00$ the species selects that period of the day for its activities (Bu *et al.*, 2016; Gerber *et al.*, 2012). For the association between activity period and seasonality we divided our selected sampling period in two different season: the first season runs from May 1 to July 31, and second season runs from August 1 to November 30.

During the two seasons the three periods differ in term of durations and times, in accord with light/dark cyclic variations.

For each species we have analysed the data in the years when the species had a large enough number of records (n >30).

For the association between the activity patterns and the presence of other ungulates species we used the records of the two species with greater distribution and records, namely roe deer and wild boar. We compared the association between activity periods of these two species when other ungulates, red deer and mouflon, are absent ("control condition"), with the activity periods when the other ungulates are present.

To verify this association we used the record collected in the period 2014-2016, since in these years all species present a sufficient number of data.

Finally, we analysed the association between activity pattern of roe deer and wild boar and the presence of a predator. We made two different comparisons: 1) we compared the activity of roe deer and wild boar at sites where the presence of the wolf was not recorded with their activity at sites where the presence of the wolf was recorded by camera traps (spatial association); 2) we compared the activity patterns of the two ungulates before (2011-2013) and after the predator became a stable presence (2014-2018) in the study area (temporal association)

The associations were tested using a non-parametric statistic test of contingency table analysis (χ^2 test), with significant level $\alpha = 0.05$. Analysis of activity pattern and associations were performed with the open-source software Rstudio (http://www.r-project.org/).

RESULTS

Dataset selected

Our selected dataset is composed by 4309 (70.21% of total records) records of wild ungulates and wolves, collected in a total 41 camera trap stations (on a total of 58 locations) with a sampling effort of 10067 camera trap days.

Roe deer was recorded 695 times (16.13% of records) in 21 camera sites in the period 2013-2018, red deer 189 times (4.39% of records) in 5 camera sites in the period 2014-2017, mouflon 287 times (6.66% of records) in 8 camera sites in the period 2013-2017, wild boar was recorded 2532 times (58.76%) in 32 camera sites in the period 2011-2018; and wolf was recorded 606 times (14.06%), in 24 camera station in the years between 2014 and 2018.

Activity pattern

With the quantification of the selection ratio we can observe that roe deer has a crepuscular and diurnal activity; red deer has a predominant crepuscular activity and nocturnal activity; mouflon has a diurnal and crepuscular activity; wild boar has a nocturnal and crepuscular activity (w=1.28); and wolf presents a nocturnal and crepuscular activity (Table 1).

Association between seasonality and activity patterns of four wild ungulates was a statistically significant, to indicate that the four ungulates have a different activity patterns in the two different seasons. In roe deer the association was extremely significant (χ^2=15.33, df=2, p-value= 0.00047); in red deer it was extremely significant (χ^2=17.261, df=2, p-value= 0.00018); in mouflon it was very significant (χ^2=12.178, df=2, p-value= 0.00227); and in wild boar it was extremely significant (χ^2=75.492, df=2, p-value < $2.2e^{-16}$) (Fig. 2, Table 1).

Wolf does not show a significant statistically association (χ^2=3.9375, df=2, p-value = 0.1396), to indicate that the wolf do not have a different activity pattern in the two seasons.

During the years between 2014 and 2016, we recorded only roe deer and wild boar ("control condition") in 9 camera trap sites; red deer was present in 5 sites; and mouflon was present in 7 sites. Between the presence, or absence, of red deer and the activity patterns of roe deer there is a statistically significant association (χ^2=10.918, df=2, p-value= 0.00426), to indicate that the roe deer is influenced by the presence of red deer; while in wild boar there is not a statistically significant association (χ^2=0.32177, df=2, p-value= 0.8514), to indicate that the activity of wild boar is not influenced by the presence of red deer (Fig. 3, Table 2).

Between the presence, or absence, of mouflon and the activity patterns of roe deer and wild boar there is a statistically significant association (roe deer: χ^2=14.767, df=2, p-value= 0.00062; wild boar: χ^2=11.927, df=2, p-value= 0.00257) to indicate that the roe deer and wild boar are influenced by the presence of mouflon (Fig. 3, Table 2).

The spatial association between activity of roe deer and presence of wolf is not statistically significant (χ^2=2.8974, df=2, p-value= 0.2349); and is statistically significant for wild boar (χ^2=11.003, df=2, p-value= 0.00408) (Fig. 4, Table 2).

The temporal association between activity pattern and years before (2011-2013) and years after the stable presence of the wolf (2014-2018), is statistically significant for roe deer (χ^2=7.853, df=2, p-value= 0.01971), and is extremely statistically significant for wild boar (χ^2=14.766, df=2, p-value= 0.00062) (Fig. 4, Table 2).

DISCUSSION

In accordance with previous studies (Pagon *et al.*, 2013) and in discord with others (Mustoni *et al.*, 2017), we found that roe deer has mainly both crepuscu-

Table 1. Number of records (selection ratio w) and the statistically test χ^2 for the three periods in the first season (1 May – 31 July) and in the second season (1 August – 30 November). Categories determined by selection ratio: Cr= Crepuscular; D= Diurnal; N= Nocturnal.

Species	*n* (*w*) in periods Daytime	Twilight	Night	Category	χ^2 test (*df*= 2)
Season 1 (May-Jul.)					
Roe deer	191 (1.01)	82 (1.35)	52 (0.70)	Cr/D	13.598, *P*< 0.01
Red deer	9 (0.28)	37 (3.52)	10 (0.78)	Cr	82.923, *P*< 0.001
Mouflon	46 (1.21)	15 (1.23)	4 (0.27)	Cr/D	10.416, *P*< 0.01
Wild boar	114 (0.42)	166 (1.91)	184 (1.73)	Cr/N	214.10, *P*< 0.001
Wolf	28 (0.45)	32 (1.55)	49 (1.96)	N/Cr	48.618, *P*< 0.001
Season 2 (Aug.-Nov.)					
Roe deer	168 (1.04)	104 (1.35)	98 (0.75)	Cr/D	16.73, *P*< 0.01
Red deer	13 (0.22)	53 (1.91)	67 (1.42)	Cr/N	66.895, *P*< 0.001
Mouflon	108 (1.11)	65 (1.41)	49 (0.62)	Cr/D	18.938, *P*< 0.01
Wild boar	234 (0.26)	631 (1.47)	1203 (1.64)	N/Cr	908.47, *P*< 0.001
Wolf	97 (0.46)	126 (1.20)	274 (1.55)	N/Cr	129.73, *P*< 0.001

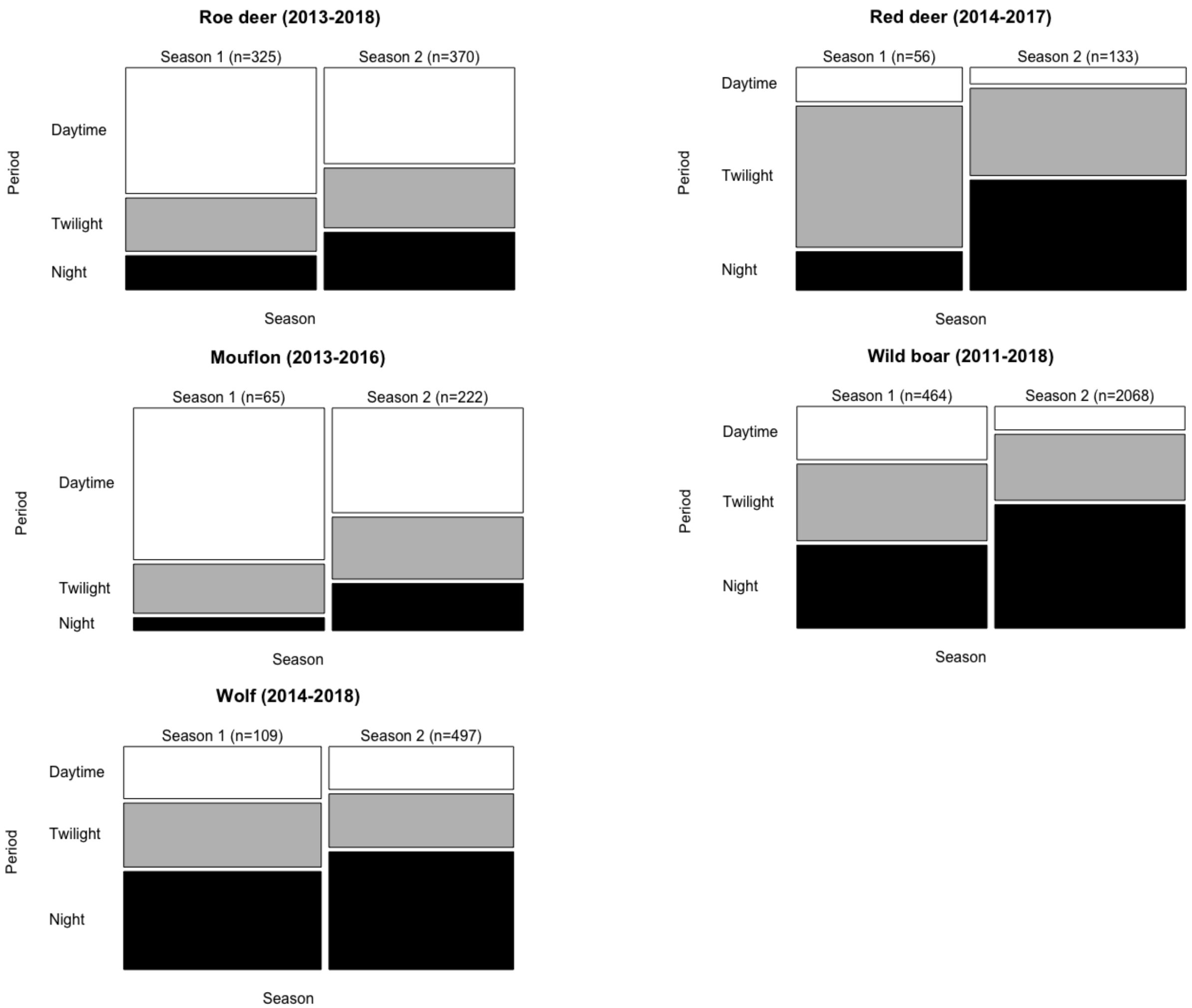

Fig. 2. Proportion of record in the three periods of daily cycle in the two different season of roe deer (top left), of red deer (top right), of mouflon (middle left), of wild boar (middle right), and of wolf (bottom left). White = Daytime; grey = Twilight; black = Night.

Table 2. Comparison of proportion of records (%) of roe deer and wild boar in the three periods of the day under the four different condition: presence of red deer, presence of mouflon, presence of wolf and years before and after the stable presence of wolf; and statistically test χ^2. D = Daytime; T = Twilight; N = Night.

Species							**Test χ^2 (df = 2)**
		Red deer			**No Red deer**		
	D	T	N	D	T	N	
Roe deer	43.0	35.2	21.8	50.7	44.8	4.5	10.918, P = 0.004
Wild boar	17.3	36.9	45.8	19.1	36.5	44.4	0.32177, P = 0.8514
		Mouflon			**No mouflon**		
	D	T	N	D	T	N	
Roe deer	44.2	25.6	30.2	50.7	44.8	4.5	14.767, P < 0.001
Wild boar	10.0	37.7	52.3	19.1	36.5	44.4	11.927, P = 0.0025
		Wolf			**No wolf**		
	D	T	N	D	T	N	
Roe deer	42.1	39.5	18.4	45.5	48.5	6.1	2.8974, P = 0.2349
Wild boar	14.4	37.8	47.8	36.1	33.3	30.6	11.003, P = 0.004
		Before wolf			**After wolf**		
	D	T	N	D	T	N	
Roe deer	28.6	39.3	32.1	43.6	41.8	14.5	7.853, P = 0.0197
Wild boar	6.2	37.4	56.4	16.2	38.8	45.0	14.766, P < 0.001

lar and diurnal activity. In partial accordance with previous research (Kamler *et al.,* 2007; Georgii and Schröder, 1983) and in discord with others (Mustoni *et al.,* 2017), red deer shows a crepuscular and nocturnal activity. Mouflon in this study shows a partial different activity pattern respect previous researches (Pipia *et al.*, 2008) because shows a mostly diurnal activity and lower crepuscular activity. Wild boar,

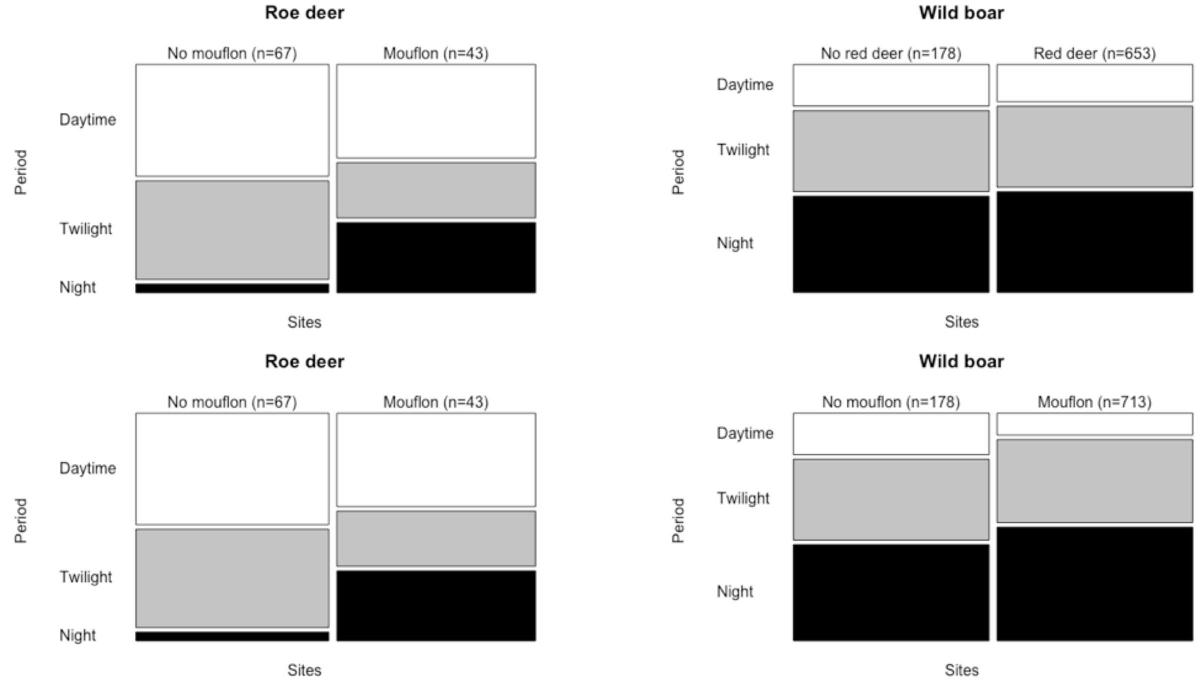

Fig. 3. Proportion of records of activity of roe deer (on the left) and wild boar (on the right) in the two different condition, in presence of other ungulates species, in order: presence of red deer, presence of mouflon. White = Daytime; grey = Twilight; black = Night.

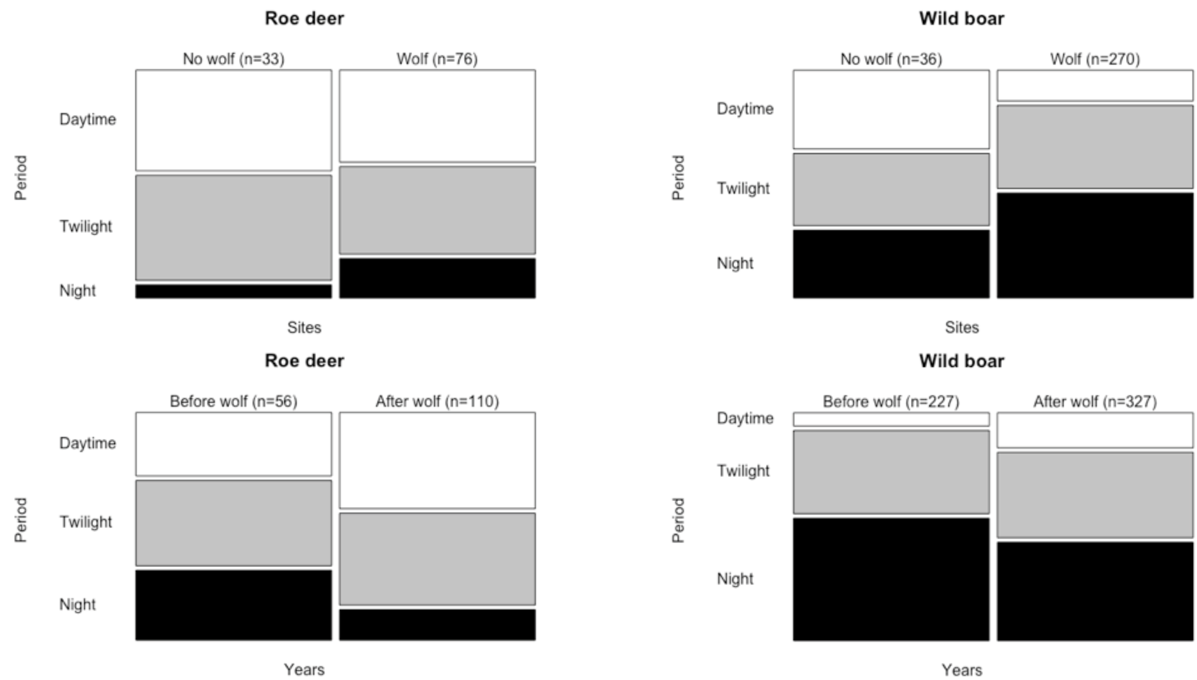

Fig. 4. Proportion of records of activity of roe deer (on the left) and wild boar (on the right) in the two different condition of presence of predator, in order: presence of wolf, and years before and after wolf. White = Daytime; grey = Twilight; black = Night.

in accordance with previous studies (Russo *et al*., 1997; Caruso *et al*., 2018; Boitani *et al*., 2018) has exhibits a mainly both nocturnal and crepuscular activity (Table 1).

The analyses show that the activity pattern of the four ungulates species examined changes their activity pattern in concordance with the seasonal variation of photoperiods.

But the two different seasons examined correspond with two particular phases of the annual biological cycle of ungulates (Mustoni *et al*., 2017), which may further influence the activity patterns of ungulates species (Kamler *et al*., 2007; Pipia *et al*., 2008).

Interspecific interactions between wild ungulates can occur in various forms, generally the two most evident modes of interaction in large herbivores are competition or facilitation (Latham, 1999) but generally negative interactions (*e.g.* competition) between ungulates occur when we are in the presence of non-native species, and therefore in the absence of a co-evolution (Ferretti and Mori, 2019).

In accord with the previous consideration our results about the association between activity pattern of roe deer and wild boar and the presence of other species, such as mouflon and red deer, show that roe deer was influenced by both species, while wild boar was influenced only by presence of mouflon. The influence of red deer on roe deer activity could be considered positive because roe deer increase its nocturnal activity, growing up the potential overlap with red deer, who had a mostly nocturnal and crepuscular activity (Table 1). On the other hands, mouflon, an allochthonous species in the study area (Lucchesi *et al*., 2007) with a mostly diurnal and crepuscular activity (Table 1), causes a decreasing of diurnal activity in roe deer and wild boar.

Predation risk is an important factor that can influenced the activity pattern of prey species (Dias *et al*. 2018; Harmsen *et al*., 2011; Caravaggi *et al*., 2018); and changes the activity periods can be an anti-predator strategy. In this regard, our results obtained with a comparison of activity of roe deer and wild boar and the presence of their main predator, Apennine grey wolf, suggest an influence of predator on its prey.

Temporal correlation between years before and after the arrival of wolves in the study area shows that both roe deer and wild boar changes their activity patterns. In the years preceding the stable presence of the wolf (2011-2013) the roe deer and wild boar have higher levels of nocturnal activity than after the arrival of the predator (2014-2018), and the decreasing of nocturnal activity probably is attributable to the highly nocturnal activity of wolf (Table 1) (Torretta *et al.,* 2017).

On the contrary of these results, the spatial correlation between sites with wolf and sites without the presence of wolf shows that roe deer and wild boar increasing partially its nocturnal activity where predator is present respect the sites where the wolf is not recorded by camera trap.

But the difference between the results of these two different correlations could be attributable to the different number of records used for the analyses of association.

The activity patterns of wild animals can be influenced by other factors, such as human disturbance (Ikeda *et al*., 2015; Oberosler *et al*., 2017), or physiological status (Pipia *et al*., 2008), which we have not considered, but these factors may be cause to further change on activity patterns.

Therefore our results must be consider as preliminary, even if in accordance with previous researches. In conclusion we can says that an opportunistic camera trapping allowed hypotheses formulation and their verification, but for the opportunistic origin of data and the differences of records used in the analyses, the results obtained are not to be considered precise and definite.

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Appendix Table. Camera trap stations used in the period 2011-2018 in the Apuan Alps and their sampling effort. For all camera trap station is indicated the sampling effort for years and for seasons in a years; and is indicated which species is recorded in the station during the years. 1= species recorded; NULL= species not recorded. W = winter, Sp = Spring, Su = Summer, A = Autumn.

ID	site	2011				2012				2013				2014				2015				2016				2017				2018				Total	wild	roe	red	mou-	
		W	Sp	Su	A	W	Sp	Su	A	W	Sp	Su	A	W	Sp	Su	A	W	Sp	Su	A	W	Sp	Su	A	W	Sp	Su	A	W	Sp	Su	A	effort	boar	deer	deer	flon	wolf
1	POR	17		33	48	41																												139	1	1		1	
2	MPD	17		32	28	48																												125	1	1			
3	RDG			32	2																													34	1				
4	GRN			26	14																													40	1	1			
5	CRV			23	1																													24	1	1	1		
6	CAM	10		23	32	44	11																											120	1	1		1	1
7	GBC	10			17	48																												75		1			
8	CDC	10			9	79			19	34		10	91	22		80	65	10		13	91	10			54	90	92	92	91	80	29	87	8	1166	1	1	1	1	1
9	CVN	10			8	67																												85	1	1			
10	TNT	10			8	28					41			10	39	90	91	89	6	36	91											21	8	568	1	1	1		1
11	PFB	10			9	51																												70					
12	MSC					53			24	73	63	29	46	69	15		84			86	68	10		22	91	80	92	92	25					1022	1	1		1	1
13	CMP					51	17	12										10			25		27	92	6	64	88	72	52					516	1	1	1		1
14	BOA						17	12		6	57				39	30		10	60	92	91	79	43	23	33							52		644	1	1	1		1
15	PCS						17	12																										29	1	1			
16	CDS						17	12																										29	1	1			
17	PRT						17	16								40						3	40											116	1	1			
18	FGT						17	16																										33	1				
19	PTR									38	19			49																				106	1	1		1	
20	RCC										40															8			34					82		1			
21	CST									10			46	6		11	43	10		18	91	25	4	53		10			82	80	43			532	1	1	1		1
22	BDP									10			23	10			1	40	5															89	1	1		1	
23	PIZ													34	15	16	8																	73					1
24	SAA														29			30																59	1	1			
25	RCH														29																			29					
26	TOS														11	41	48																	100					1
27	FOT															65	74	10		78	91	10		37	44			27	55		28			519	1	1		1	1
28	COZ															26																		26		1			
29	MTN															43																		43	1				1
30	RVZ													10		27	91	79	52	62														321	1	1		1	1
31	FPT													10		5	91	79	59	92	54													390	1	1		1	1
32	CPC																42	6	33															81	1				1
33	RUD													10			44	89	43	83	91	29	15	92	44	84	92	92	91					899	1	1		1	1
34	VNC																17					55	37	43	91	90	92	92	91	80	58	67		813	1	1			1
35	SER															33																		33					
36	PGL																	10		30	91													131	1	1		1	1
37	CMG																			27														27	1				
38	TMB																			2	25													27	1			1	
39	PPL																	3																3					
40	LUC																					9	83	58										150	1	1			
41	PQL																					28	36											64					1
42	GBB																						23	62										85	1	1			1
43	RCR																									10			20	29	81	92	9	241	1	1		1	1
44	FDP																									50	92	70	13					225	1	1		1	1
45	ANT																							49										49	1	1			1
46	FSV																									10			13	37				60					1
47	CPL																												16					16					1
48	FDT																									10			13	62	92	44		221	1	1			1
49	CRD																									10	79	92	91	80	92	92	9	545					1
50	GTC																													9	29			38	1	1			1
51	AIT																															21		21	1	1			
52	ALV																															35	1	36	1	1		1	1
53	BTG																															27		27					1
54	FGB																													18	41		2	61					1
55	TNR																															21	3	24	1		1		1
56	PMR																															19		19					1
57	POZ																													48	71			119					1
58	SAS																													10			51	61	1	1			1
	tot.	**94**	**0**	**169**	**176**	**510**	**113**	**80**	**43**	**171**	**220**	**39**	**206**	**230**	**177**	**507**	**699**	**475**	**258**	**619**	**809**	**258**	**308**	**531**	**363**	**516**	**627**	**629**	**687**	**533**	**564**	**578**	**91**	**11280**	**41**	**37**	**7**	**15**	**34**