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Seasonal Variation of Wild Ungulates Abundance in a Hunting Ban Beech Forest. The Case Study of Amiata Mountain - Central Italy

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Abstract: Several studies focused on the impact of ungulates on agricultural systems but the magnitude of their antagonistic role in forest renovation dynamics has long been underestimated and rarely considered. Ungulate species abundance is susceptible to seasonal variations according to their autecology, human management choices and territorial planning. Therefore, the appropriate choice of counting period is crucial. In this case study, we used camera traps to assess wild boar and roe deer seasonal abundance variations in a 600 hectares hunting ban beech forest (95.48%) in southern Tuscany managed for timber production. Camera-trapping sessions were performed in both early summer and autumn. The roe deer abundance index is higher in early summer, although statistically not significant, potentially affecting seedling survival. Inversely, wild boars significantly ($F = 79.125$; $p = 0.001$) increase their abundance at the local scale in autumn when, probably according to the ecology of fear, they temporary shift home range toward refuge areas. In autumn, high density of wild boars can reduce seed availability at local scale. Further analysis assessing the correlation between seasonal wild ungulates abundance and forest regeneration rate are in progress, based on data recorded within and around three fenced sample plots.

Keywords: camera trapping; CPUE; density estimation; relative abundance index; seasonal density variation; REM; roe deer; wild ungulates; wild boar

1. Introduction

The impact of wild ungulates on forests was taken into account starting from the second half of the twentieth century [1–3] when the exponential growth of their populations started driven by mountainous area abandonment and consequent secondary forest successions [4–6]. These species can affect forest regeneration, structure and functioning in different way according to their feeding behaviour [7,8]. The final cumulative effects can be positive, neutral or negative on the basis of their density, ecosystem stability and forest management strategy [8,9]. However, the antagonistic role of these species has long been underestimated and rarely considered [10]. A recent study [8] demonstrated that effects on forest are more negative as ungulate abundance increase. A rapid neutral to negative shift of effects when ungulates density reach a threshold of 15 roe deer, 2.3 red deer and 4.3 wild boars per km^2 occurs. The count of each species should be performed when the forest is potentially sensitive to species-specific feeding behaviour and when highest is the abundance of the species at the local scale.

Here we present only preliminary results from the first step of an in progress multi-year project aimed to assess the eventual relation existing between seasonal wild ungulates abundance and beech (*Fagus sylvatica*) forest regeneration rate in a ban hunting context.

In this preliminary stage, we used camera traps (CTs) aiming to: (i) assess wild boar (*Sus scrofa*) and roe deer (*Capreolus capreolus*) relative abundance; (ii) asses eventual seasonal abundance variations useful to define the best moment for counting each species; (iii) estimate their absolute abundance (density); (iiii) assess seasonal movement rate and time spent by each species in foraging activity within the field of view of CTs.

2. Materials and Methods

2.1. Study area

The study was conducted within a mountain area of 560 hectares on the East face of the Amiata Mountain that is an isolated volcanic relief located in Siena province (south of Tuscany region – Italy). A monospecific beech (*Fagus sylvatica* L.) forest (95.48%) principally covers the study area. The area approximately extends from 42°52′35.00′′ to 42°54′09.00′′ N and from 11°37′17.00′′ to 11°38′27.00′′E.

The altitude ranged between 1116 and 1731 meters a.s.l. typically lying in the Fagetum phytoclimatic band. Forest is subjected to shelterwood cutting silvicultural system for timber production and it results rather homogeneous for both ecological conditions and anthropic management. The area is integrally hunting ban due to the regional low 3/1994 that identifies the area as a wildlife protection zone.

2.2. Data recording

A stratified sampling procedure was adopted to choose camera traps (CTs) locations, we adopted (Moeller et al., 2018). A fishnet of 1.5 x 1.5 km grids was generated overlapping the study area. The grid covering all three characterizing forest classes was chosen and divided into nine equal sections. We placed one CT (MultiPIR-12) into each sub-plot randomly, ensuring that number of CTs into each forest class was proportional to forest class representativeness. Certain CTs detection radius (r) and angle (θ) were determined by field test [11,12] resulting in 5.41 m and 1.13 radians. However standard approach expects, for wild boar in particular, counting during the summer [13], CT sessions were performed in June and in November.

2.3. Relative abundance index and density estimation

The trapping rate (TR) was computed as follow and multiplied for 100 as in Rovero and Marshall [14]:

$$\text{TR} = \frac{\text{y}}{\text{t}} \times 100 \quad (1)$$

where y is the total number of independents photographic events and t is the total detection effort computed as follow:

$$\text{t} = \frac{CTS\ number \times haours\ of\ work}{24\ hours} \quad (2)$$

REM rescales linearly the trapping rate (y/t) to population density considering two main biological variables, the average group size (AGS) and average daily range (ADR: km/day) and two CTs parameters, detection radius (r) and angle (θ). We used the following REM equation [15] to estimate roe deer and wild boar density (D) starting from TR (y/t):

$$\text{D} = \frac{\text{y}}{\text{t}} \times \frac{\pi}{DR \times r \times (2+\theta)} \quad (3)$$

As expected for social species D is corrected for the average group size. ADR and ART were considered as useful indices of two behaviours: feeding or moving between habitats searching resources.

2.4. Statistical analysis

We defined 4 seasons-species subsets for which to assess TR and to estimate D: summer roe deer (SRD), autumn roe deer (ARD), summer wild boar (SWB) and autumn wild boar (AWB). For each subset, ADR and ART were also assessed. Average trapping rate (ATR), ADR and ART and the respective variances were computed, separately for each subset, considering three repetitions of equal duration in both summer and autumn. The one-way ANOVA with bootstrapping (1,000 iterations) was used to assess, by species between two seasons, differences in trapping rate (TR) and others behavioural parameters (MGS, ADR and ART). The overall variance of REM density estimation was computed with non-parametric bootstrap re-sampling CTs locations with 10,000 replacement as in Rowcliffe et al. [15].

3. Results and discussion

During the summer session, 64 and 32 independent photographic events were recorded for roe deer and wild boar respectively, while in autumn they were 20 and 171 respectively.

In Table 1 a summary of camera trapping effort, records, TR and average trapping rate (ATR) for each one of the four season-species subset, were reported.

Table 1. Camera trapping effort in days (t), total independent events (y) for each species, total trapping rate (TR) and average trapping rate (ATR) for each season-species subset. ATR is reported as mean ± SE.

Season – species[1]	t	y	TR[2]	ATR
SRD	185	64	34.59	34.51±5.53
ARD	213	20	9.39	9.45 ± 3.12
SWB	185	32	17.30	17.33 ± 1.52
AWB	213	171	80.28	79.07± 4.48

[1] SRD = summer roe deer; ARD = autumn roe deer; SWB = summer wild boar; AWB = autumn wild boar. [2] TR = (y/t) x 100.

Roe deer and wild boars' abundance (Table 1) showed an inverse trend with roe deer TR higher in summer then in autumn, and WB abundance index higher in autumn then in summer (Figure 2). The average group size (AGS) and the average daily range (ADR), that are the independent variables required to estimate REM density starting from TR, are reported in Table 2 for each season-species subset. In the same table, ART and REM density estimates were also reported.

Table 2. Average group size (AGS), average daily range (ADR), average resting time (ART) and REM density estimates for each season-species subset. Estimates were reported as mean ± SE except REM density for which the 95% confidence interval (C.I.) was provided.

Sub-sets	Variable for REM estimation			REM
Season – species[1]	AGS (n°)	ADR (km/day)	ART (seconds)	D (animals/km^2)
SRD	1 ± 0.00	15.6 6± 1.03	52.79 ± 9.25	10.405 (4.482-17.348)
ARD	1.27 ± 0.09	19.79 ± 4.32	18.14 ± 3.72	1.264 (0.206-2.601)
SWB	2.35 ± 0.11	18.75 ± 0.77	21.38 ± 0.69	5.825 (1.943-10.792)
AWB	2.66 ± 0.14	37.13 ± 4.00	41.22 ± 2.99	9.931 (5.595-14.239)

[1] SRD = summer roe deer; ARD = autumn roe deer; SWB = summer wild boar; AWB = autumn wild boar.

Both the species did not show evident changes in groups dimension (AGS) and composition. During the summer, roe deer were solitary according with the territorial (males) and parental (females) phase of the species biological cycle. Also in autumn roe deer were principally alone, except 2 cases when they resulted in group of three individuals composed of mother with the new-born and the female of the previous year. Differently, wild boars moved in groups during both seasons according with the after births phase of the biological cycle and the typical social structure of the species. Only in 18% of the total cases, alone males were photographed.

The results of variance analysis are reported in Table 3 also reporting the statistical significance of the above-observed differences between ATR, AGS, ADR and ART.

Table 3. Season effect (F-test at p = 0.05) on average trapping rate (ATR), average group size (AGS), average daily range (ADR) and average resting time (ART). Significant differences are bolded.

Dependent variable		ATR		AGS		ADR		ART	
Species	**Effects**	***F***	***p***	***F***	***p***	***F***	***p***	***F***	***p***
RD[1]	Season	6.844	0.059	3.419	0.138	0.395	0.564	4.566	0.099
WB[2]	Season	79.125	**0.001**	1.409	0.301	9.467	**0.037**	19.638	**0.011**

[1] Roe deer and [2] wild boar.

The variance analysis (Table 3) did not confirm the expected seasonal variation in roe deer abundance (Tab. 1). Differently, high significant seasonal ($p \leq 0.01$) effect on wild boar ATR and ART was confirmed by ANOVA. A less significant seasonal effect ($p < 0.05$) was also recorded on wild boar ADR. The food exploitation hypothesis [16,17] climate-limiting factors [18] and hunting disturbance [19–22] are all possible drivers of wild ungulates home range shifting, and temporal abundance variation at the local scale. According to the ecology of fear [23] animals try to avoid predation risk shifting their home range toward refuge areas limiting, temporary, their movements outside the sphere of influence of the refuge [24]. Contrary, when, the fear pulse stops, normally at the end of the hunting season (end of January), resources within the refuge decrease and adverse climatic conditions start, wild boars shift progressively their distribution in plain and hills areas searching for food with higher energetic value with a lower research effort [25]. In this case, the study area is hunting ban and the autumn (November) corresponds to both the fruits fall period and the beginning of hunting. Therefore, we considered plausible that the significant increase of the wild boar abundance index recorded during the autumn session, may be depended on the combined effect of both resources' availability and hunting disturbance. Regardless the reasons that are out of the main purpose of the present paper, wild boars concentration should be seriously considered because it could determine a significant reduction in seeds available for forest regeneration [26]. Above-ground plant material represents the higher food supply percentage for wild boar, and fruits and seeds are the most represented [27,28]. According with this evidence, we recorded a significant longer time spent by wild boars in feeding within the field of view of the cameras during autumn, corresponding with the *Fagacee* seeds fall periods, then in summer when wild boars were only observed moving between habitats.

5. Conclusions

In conclusions, aiming to investigate and define relative (TR) or absolute (Density) abundance threshold beyond which wild ungulates affect negatively ban haunted mountain beech forest regeneration, our preliminary results suggest significantly higher TR and D for wild boar in autumn compared to early summer, and an inverse trend for roe deer, although without significant differences. For the above reasons wild boar counts should be performed in autumn when its significant increase in abundance, at the local scale, can reduce seed available for forest regenerations. Differently, the abundance of roe deer in ban haunted mountain beech forest, should be investigated in late spring - early summer when it seems plausible higher potentially affecting seedling survival because the selective browsing attitude of this species.

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