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Brief Report

Associating Metrics of Hunting Effort with Hunting Rate: A Case Study with the Wild Boar *Sus scrofa*

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Abstract: Wild boar *Sus scrofa* populations have increased dramatically in recent decades throughout Europe. While hunting is widely used in management activities; it rarely has an important role in regulating and reducing wild boar populations. Therefore, increasing the efficiency of hunting is a compelling issue. In this study, we used a three-year dataset (2016–2018) on a wild boar population living in Campania (southern Italy) as a case study to explore how the hunting effort made in collective drive hunts affected the hunting rate, estimated as the number of individuals culled per day. We fitted a Linear Mixed Model, in which we included the number of wild boars culled per drive hunt as the dependent variable, and the number of beaters, shooters and dogs and the month during which hunting occurred as the predictors. A mean of 1.81 wild boars were culled per drive hunt. The number of culled animals per hunt increased with the increasing number of hunting dogs and with the progression of the hunting season (i.e., from October to December), whereas the number of beaters and shooters had no effect. Overall, we observed a low hunting rate. We suggest that adjusting the hunting calendar and reorganising wild boar collective hunts, e.g., through an appropriate management of the number and training of hunting dogs, are essential to increase the hunting rate. Our results can be useful for wildlife managers to enhance hunting contribution in counteracting the negative impact of wild boar.

Keywords: wild boar; hunting; drive hunt; statistical modelling; wildlife management

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1. Introduction

Wild boar (*Sus scrofa*) is among the most widely distributed large mammals in the world. In recent decades, populations have been expanding and increasing dramatically [1–3], thus enhancing problems such as damage to agricultural activities, spread of diseases, collisions with vehicles and disturbance or threat to biodiversity [4–7]. Therefore, limiting or controlling wild boar populations has become a common management goal throughout the world [2,8].

Despite being widely used as a management tool, regulated hunting appears to play a minor role in managing wild boar populations [9–12]; however, see [13]. Populations facing heavy hunting pressures are able to compensate by increasing the contribution of juveniles to the yearly recruitment, reducing the body mass threshold at which reproduction occurs and increasing the number of litters produced annually by adult females [14,15]. Selective hunting, targeted on specific individuals or classes of individuals, is widely suggested to regulate wild boar populations, although this topic has been largely debated [16–19], and appropriate efficient hunting strategies are needed.

In Italy, wild boar is typically hunted by drives with hunting dogs carried out from October to January [20]. This method involves a high number of hunters divided into shooters, armed in fixed positions, and beaters, who try to force wild boars to move towards shooters with the help of tracking dogs. At present, few studies have analysed the relationship between these variables (representing the hunting effort) and the hunting rate, in terms of the number of wild boars culled per day. The number of shooters has been suggested as the most important factor increasing the number of culled wild boar, whereas the effect of the number of beaters seems to be limited [21,22]. The usefulness of dogs remains unclear; in some cases, they do not increase the hunting success [21,22], in others, they seem to have a significant role, particularly at low wild boar densities [23–25]. Besides these factors, even the period during which hunting occurs (with consequent changes in climatic conditions) may be relevant in influencing the hunting success: in the case of wild boar, group hunting success is increased primarily by decreasing temperatures and by scarce rainfall [26].

Most research regarding this topic has focused on populations living in temperate or continental regions [21,22,26], while less attention has been paid to these aspects in the Mediterranean area [25]. In this study, we first summarize the results of drive hunts carried out in three hunting seasons in the Campania region (southern Italy), a Mediterranean area characterized in recent years by an increasing impact of wild boars, mainly represented by damage to croplands, collisions with vehicles and a detrimental effect of rooting on animal communities [27–29]. Then, we examine which hunting variables influence the hunting effectiveness, expressed as the number of culled animals. We make four predictions: (1) the number of culled wild boars would increase with an increasing number of shooters [21,22]; (2) the number of culled wild boars would increase with an increasing number of dogs [25]; (3) the number of culled wild boars would not increase with an increasing number of beaters [21,22]; (4) the number of culled wild boars would increase early in winter and with lower temperatures [26].

2. Materials and Methods

2.1. Study Area

This research was conducted in the Campania region, which extends over 13,671 km^2 in southern Italy (41°30′–39°59′ N, 13°45′–15°48′ E) (Figure 1). Elevation ranges from sea level to 1923 m asl. The climate is Mediterranean, with hot, dry summers and moderately cool rainy winters. The mean annual temperatures range from 10 °C in the mountainous interior to 17 °C along the coast; the highest temperatures occur in July and August, and the lowest ones from December to February [30]. Land cover is dominated by arable lands (55%) and woodlands (28%, almost exclusively including deciduous species), the former characterized by low altitudes, the latter by hilly and mountainous areas. Other natural areas (rocks, scrublands and pastures) and urban areas cover 9% and 8% of the area, respectively [31].

The wild boar is widespread in Campania, with an estimated density of 5.9–7.4 individuals per 100 ha [32]. Wild boar hunting is performed in five hunting districts (hereafter: HDs+. Avellino, Benevento, Caserta, Salerno 1 and Salerno 2) (Figure 1), three days a week (Thursday, Saturday and Sunday) from the 1 of October to the 31 of October, and two days a week (Thursday and Sunday) from the 1st of November to the 31st of December, for a total of 30–31 days per hunting season. Hunters usually do not select individuals between sex and age classes, although shooting piglets is fairly unpopular [32,33]. Areas in which hunting is banned, including protected areas, restocking areas, oases and military areas, constitute 28% of the regional territory (Figure 1).

2.2. Data Collection—Characteristics of Drive Hunts

We collected the hunting notebooks containing the description of drive hunts carried out in three hunting seasons, from 2016 to 2018. The hunting notebooks have been prepared by our working group. They were compiled by a head of the hunting team for each hunting day reporting: the number of participants, number of dogs, number of animals shot, sex and age. The data were validated by a veterinarian from the Department of Veterinary Medicine and Animal Production, University of Naples Federico II. The registers are kept in the offices of the Campania Region. We analysed data regarding date, HD, the number of hunters (distinguishing between shooters and beaters), the number of dogs and the number of killed wild boars.

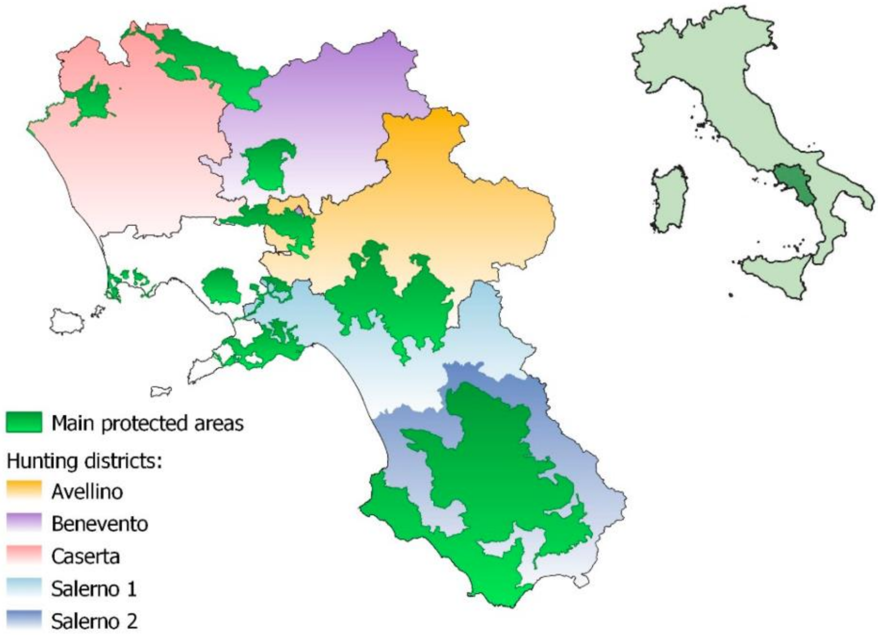

Figure 1. Location of the study area (Campania, southern Italy) and hunting districts.

2.3. Statistical Analyses—Factors Influencing the Effectiveness of Drive Hunts

We analysed factors influencing the number of wild boars culled in drive hunts by modelling the effect of four predictors: the numbers of shooters, the number of beaters, the number of dogs and month (included as a factor term). In particular, we fitted a Linear Mixed Model (hereafter: LMM), including all the predictors mentioned above as fixed factors, and year as a random factor. Since the variable "month" has three categories (i.e., October, November and December), we used binary dummy variables setting November as a standard [34]; in this way, comparing the central month (i.e., November) with the previous one (i.e., October) and the following one (i.e., December), we may highlight the existence of a monthly trend in the number of animals culled per drive hunt. We considered the potential multicollinearity among predictors using Pearson's correlation coefficient, retaining a threshold value of $r > |0.7|$ [35]. None of the pairwise comparisons resulted in a higher correlation value; therefore, we included all the variables in the LMM. The response variable was modelled for dependence on predictor variables using the model selection procedure based on the Akaike Information Criterion corrected for small sample size (AICc) [36]. Models were ranked and scaled by the differences with minimum AICc (ΔAICc) and Akaike weights (ωi) for each i-model [37]. Models with $\Delta\text{AICc} \leq 7$ were used to develop model averaging [38]. The relative importance of predictor variables (ω) was measured by the sum of Akaike weights of the models in which each variable appeared [37].

All statistical analyses were performed using R software version 3.3.2 [39], with "lme4" and "MuMIn" packages [40,41].

3. Results and Discussion

3.1. Characteristics of Drive Hunts

A total of 28,134 wild boars were culled during the study period. The number of hunting teams and hunters increased by 10% and 15%, respectively, from 2016 to 2018 (Table 1).

Table 1. Annual variation in descriptors of drive hunts carried out in Campania (southern Italy) during three hunting seasons (2016–2018).

Data	2016	2017	2018	Total
Wild boars culled	9320	9148	9666	28,134
Hunting teams	245	251	270	766
Hunters	6631	6979	7621	21,230
Hunters per hunting team	27.06	27.80	28.23	27.72
Hunting days available	7595	7781	8100	23,476
Hunting days used (%)	5111 (67.3%)	5165 (66.4%)	5263 (65.0%)	15,539 (66.2%)
Wild boars culled per team per season (SD)	38.04 (28.93)	36.40 (26.21)	35.80 (22.81)	36.71 (25.98)
Wild boars culled per hunter per season	1.41	1.31	1.27	1.32
Wild boars culled per drive hunt (SD)	1.82 (2.00)	1.77 (2.13)	1.84 (2.30)	1.81 (2.15)

Drive hunts were performed on two-thirds of the hunting days available, and involved an average of 17.7 ± 4.8 (standard deviation SD) hunters, divided into 15.2 ± 4.4 shooters and 2.5 ± 1.2 beaters, and 8.2 ± 4.9 dogs. The number of animals culled per hunting team and per hunter per season showed a slight decrease along the study period, while the number of animals culled per drive hunt remained relatively constant (Table 1). In all the years, with the advance of the hunting season, we observed a progressive increase in the number of wild boars culled per drive hunt, with a minimum in October (mean 1.50, range 1.37–1.63), intermediate values in November (mean 1.91, range 1.77–2.06) and a peak in December (mean 2.17, range 2.06–2.24) (Figure 2).

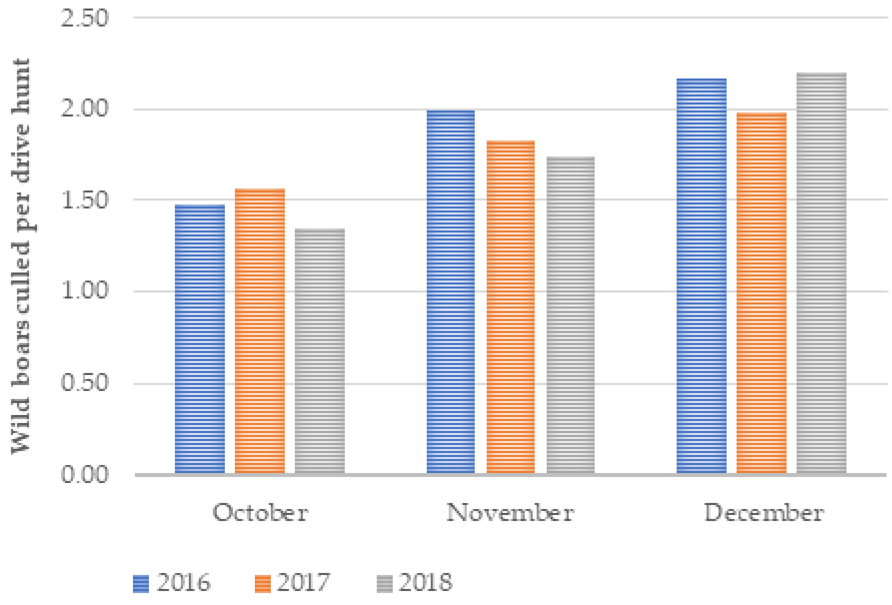

Figure 2. Monthly variation in the number of wild boars culled per drive hunt in Campania (southern Italy) during three hunting seasons (2016–2018).

3.2. Factors Influencing the Effectiveness of Drive Hunts

Four models with ΔAICc ≤ 7 were used to develop model averaging (Table 2).

The variables "month" and "number of dogs" were the most important ones explaining the number of boars culled per drive hunt, in that those same factors were present in all four models (ω = 1.00). Hunting rate was influenced by the month during which hunting occurred, being lowest in October and highest in December, and it was positively and significantly correlated with the number of dogs (Table 3). The number of shooters and of beaters had lower importance and an uncertain effect (Table 3).

Table 2. Ranking of models describing the number of wild boars culled per drive hunt in Campania (southern Italy). Model selection was based on the corrected Akaike's Information Criterion (AICc) (only models with ΔAICc ≤ 7 are shown).

Model	AICc	ΔAICc	ωi
Number of dogs, month, number of shooters	61,679.25	0.00	0.52
Number of dogs, month, number of shooters, number of beaters	61,680.76	1.51	0.25
Number of dogs, month, number of beaters	61,682.20	2.95	0.12
Number of dogs, month	61,682.29	3.04	0.11

Table 3. Coefficients of model predictors, after model averaging of the candidate models (SE: standard error; ω: predictor weights). Predictors have a significant effect when the 95% Confidence Intervals do not include zero.

Predictors	Coefficients	SE	95% Confidence Intervals	ω
Intercept	1.187	0.106	0.979; 1.395	–
Month (November)				1.00
October	−0.379	0.043	−0.464; −0.294	
December	0.235	0.046	0.144; 0.326	
Number of dogs	0.063	0.005	0.054; 0.072	1.00
Number of shooters	0.012	0.007	−0.003; 0.026	0.77
Number of beaters	0.016	0.023	−0.029; 0.061	0.37

3.3. Discussion

In recent years, European areas have been affected by a strong growth in the wild boar population, with an increased impact of the species on human activities and biodiversity; therefore, it is essential to develop effective strategies to manage these conflicts. Hunting is often believed to act effectively in limiting and managing wild boar populations [42]. However, hunting rarely produces significant results, as it often targets classes of individuals which give a scarce contribution to the yearly recruitment, harvest rates are too low or because hunters are reluctant to accept the reduction in numbers of a game species [10,11,43,44].

In our study area, the number of boars culled per drive hunt (±SD) was quite low, being much smaller than elsewhere in Europe (e.g., 2.74 ± 3.24 [21]; 4.6 ± 2 [45]; 6.67± 5.84 [22]) and comparable only with that reported by Acevedo et al. [46] in northern Spain. Together with a low hunting rate, one-third of the hunting days available were not used by hunters. Local laws define the minimum number of participants (which is different among HDs, ranging between 11 in the HD "Salerno 2" and 20 in the HD "Caserta") mandatory to perform drive hunts; particularly on working days (i.e., Thursday), hunting teams struggled to reach this number, being obliged to give up the drive hunt numerous times [32]. We also hypothesize an effect of bad weather conditions on the low hunting effort. Heavy rain is known to affect both the behaviour of ungulates, which commonly respond by seeking cover to save energy and reduce heat loss [47,48]. Hunters are also expected to be discouraged to hunt in adverse conditions (e.g., during heavy rain), which can also affect wild boar detectability [42,49].

This study revealed that the part of the hunting season and the number of dogs were central in explaining the hunting rate. Three of our four predictions were supported by results: the number of culled wild boars was positively correlated with the number of dogs (prediction 2 supported), but not with the number of beaters (prediction 3 supported), and the hunting effectiveness was higher with lower temperatures (prediction 4 supported). On the other hand, we did not find any effect of the number of shooters (prediction 1 rejected).

An increase in the hunting rate in colder months is common throughout the world [26,50,51]. In our study area, during the hunting season, mean monthly temperatures decrease from 17 °C in October to 9 °C in December. When temperatures are warm, high-latitude and mountain ungulates generally decrease their activity and detectability, as they exhibit thermoregulation stress and decreased health, in relation to which they select densely vegetated areas, seek shade in rugged terrain or move to higher altitudes [52,53]. However, wild boar can live across a wide range of environmental conditions [54,55]. Therefore, we believe that temperature does not represent a limiting factor; still, we hypothesize that hunting dogs, rather than wild boars, are negatively affected by high temperatures. Indeed, external conditions do influence the scent-marking behaviour [56–58], making it more or less difficult for dogs to detect the target scent particles, thus affecting detection probability. In particular, hot weather leads dogs to increased panting, resulting in a decreased ability to detect scents and rapid exhaustion [58,59]. Nevertheless, dogs significantly improved hunting success in Campania; indeed, they can greatly improve the detection rate of activity targets, being able to perform effectively in different situations, in all terrain and in densely vegetated areas [59,60].

Different from our initial predictions, we did not find any effect of the number of shooters on the number of culled boars. We could have no data on the extension of driven hunting areas. However, we argue that the low number of shooters (if compared with other studies, e.g., [22,61,62]) combined with the Mediterranean environment, dominated by maquis and woods characterized by poor visibility, did not provide an adequate coverage of the hunting area, allowing for wild boars to escape among shooters without being detected.

3.4. Management Implications

The management of game species is a complex process, driven by the interactions between the dynamics of natural processes and stakeholders' decision making [13,42]. Both these components cannot be omitted when planning management actions in order to control population growth. With this study, we highlighted which factors determined the hunting rate in our study area—an essential point if hunting is to provide a useful and efficient service to the ecosystem and society. Based on our results, we recommend postponing the hunting season for a month (i.e., from November to January) to improve the efficacy of dogs. Certainly, increasing the number of dogs would guarantee higher hunting bags; nonetheless, the use of drive hunts with numerous dogs is controversial since it may lower harvest selectivity [17,21,63] and cause a severe disturbance to wildlife, affecting the population dynamics, behaviour, genetic structure and life history of both target and non-target species [62,64,65].

In consideration of this, even when hunting teams do not reach the minimum number of participants or have to carry out drives with few hunters, different hunting techniques may be used. For example, a single hunt with the aid of bait could be efficient for targeted and selective hunting, particularly in low-forested areas [66]. Alternatively, the so-called "girata" involves the use of a single, well-trained bloodhound, whereas a single beater explores a small area (5–20 hectares), flushing boars towards a limited number of shooters (no more than seven to eight).

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