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Estimating Population Density of Roe Deer *Capreolus capreolus* (L.) (Artiodactyla: Cervidae) for Better Management: Comparison of Three Methods

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Abstract: Information regarding abundance and density of populations is necessary for their effective management and monitoring. The most commonly applied method on hunting grounds in the state hunting and forestry enterprises in Bulgaria is the spring census, i.e. counting the individuals of the game species in an area. To test its credibility, we studied the density of roe deer within a suitable area in the State Hunting Enterprise „Shiroka polyana", Western Rhodopes, Bulgaria, between April 2016 and July 2017, applying three different methods: 1) direct observations; 2) track counts in the snow; 3) camera traps, using the random encounter model (REM). The obtained results from the three methods were very similar: 1) direct observations –3.2 ind./km^2; 2) track counts –3.0 ind./km^2; 3) random encounter model – 3.5 ind./km^2. This was twice as big as the officially reported data of 1.5 ind./km^2. Consequently, we can assume that applying more than one method would decrease the bias in the estimation. This is why we recommend that forestry and hunting officials should employ this approach for management purposes. Furthermore, the rapid technological advances might offer many other more costly but also more accurate options.

Key words: track counts, transect method, camera traps, REM, *Capreolus capreolus*

Introduction

The effective management of wild mammal populations requires accurate data regarding their abundance and population density. A large variety of methods exists in the literature and in practice but none of them is universally accepted. Some of these methods are more accurate but require large investments, e.g. the application of thermal cameras, telemetry studies and genetic surveys (Mayle et al. 1999, Pearse et al. 2001, Iannuzzo et al. 2010, Morelle et al. 2012, Wäber & Dolman 2015). Others are cheaper but provide questionable results, like the spring census applied in Bulgaria. Drive and pellet-group counts methods, on the other hand, require considerable field effort and the involvement of many staff members (Aulak & Babinska-Werka 1990, Campbell et al. 2004, Hemami & Dolman 2005, Borkowski et al. 2011).

The choice of method for estimation of game-species density depends on the scientific purposes and available funds (Chećko 2011, Morelle et al. 2012, Alves et al. 2013, Pellerin et al. 2017). The two most frequently utilised classical approaches which do not require extensive funding are the direct observations on transects (walked by foot) and track counts (snow /mud tracking). Camera trapping has been used increasingly in recent years among the hunting staff and hunting enterprise management in Bulgaria. They are cost-effective, relatively easy to operate and provide detailed data with wide applications. In many countries, camera traps have been used to constantly monitor the trends in the development of animal populations and even to estimate their abundance (O'Brien 2011). For these purposes in some European countries, data analysing the harvest in relation to the field effort (number of hunters and number of days) are used.

In Bulgaria, the officially accepted method for estimating population size for game species since 1962 has been the spring census (taxation) in March (Annex №28 to article 105, paragraph 2 in Regulation 18/07.10.2015). Specifically, regarding the ungulates, the staff of the State Hunting Enterprises is required to perform observations in their designated areas throughout the whole year. However, these observations are mainly conducted on supplementary feeding stations, i.e. points that specifically attract the animals. This limits the inference based on the resulting data. Part of the individuals does not visit such points due to various biological and behavioural characteristics of the species (territoriality, hierarchy, etc.) or due to abiotic factors (seasonal variation in activity, enough natural food base) and they are left undetected (Morellet et al. 2013). Due to these reasons, we believe that the application of more different methods will provide better results and possibly indicate population trends in the future.

As a case study, we used the roe deer (*Capreolus capreolus* L.), which is influenced by the presence of other species (red deer and the fallow deer, see Focardi et al. 2006) and has a more secretive lifestyle (Andersen 1961).

The aim of this study is applying three different methods (direct observations, track counts and camera traps) to estimate roe deer density in the State Hunting Enterprise „Shiroka polyana" in different parts of the year.

Materials and Methods

Study area

The State Hunting Enterprise (SHE) „Shiroka polyana" (Fig. 1) is located in the Western parts of the Rhodope Mountains with an area of 110 km^2, including three dams. Its relief is typically mountainous, with altitudes ranging from 1000 to 1790 m a.s.l. The climate in the region is characterised by late springs, short and cool summers, warm autumns and long cold winters with thick snow cover. The main habitats are formed by Scots pine (*Pinus sylvestris* L.), Norway spruce (*Picea abies* H. Karst.) and, to a lesser extent, by the European silver fir (*Abies alba* Mill.), European beech (*Fagus sylvatica* L.), common aspen (*Populus tremula* L.), sessile oak (*Quercus petraea* Liebl.), Balkan pine (*Pinus peuce* Griseb.), common alder (*Alnus glutinosa* Gaertn.), silver birch (*Betula pendula* Roth.). Part of the enterprise's territory is in the protected area "Dupkata" (4.5 km^2) – a Biosphere Reserve.

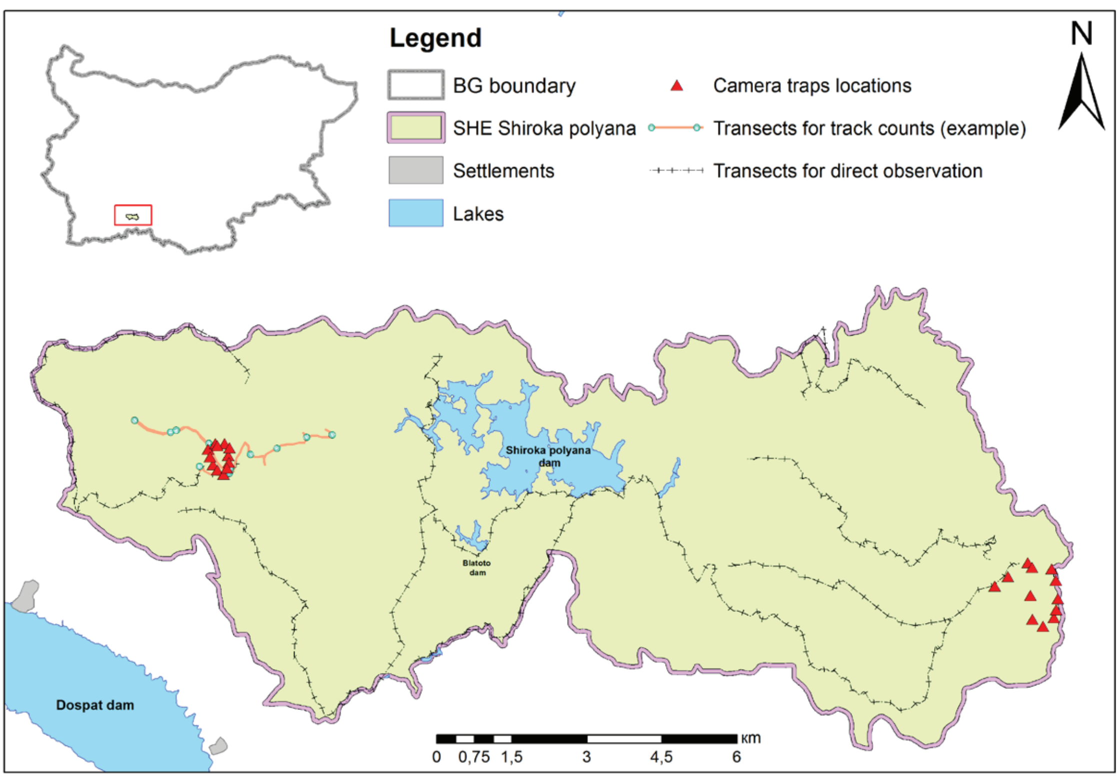

Fig. 1. Study area with camera-trap locations and transects for direct observations and track counts of roe deer.

Sampling methods

The three methods compared in the current study include two classical approaches (transect counts and track counts) and a recently developed method of estimating population density from camera trap data:

Direct observations on predefined transects. This method was applied in April 2016. Despite its apparent resemblance to the spring census, this approach is much more robust since it is based on: 1) observations conducted by a single person or team, eliminating the possibility of double detection of the same individual; 2) mathematical treatment of the results, whereas the spring census counts are based on the subjective judgement of the forestry/ hunting enterprise staff. The total length of the walked transects was 76.53 km within 3 days (**Fig. 1**). For each transect, two strips with a width of 20 m or 30 m (according to the visibility of the habitat) on the two sides of the transect were observed for roe deer individuals. The total covered area this way is estimated as 2.41 km^2. The minimal roe deer density was calculated as the number of observed individuals, divided by the size of the covered area (Mayle et al. 1999). The data were normalised to km2 for comparison with the other methods.

Track counts. Snow tracking was performed in two consecutive days in January 2017 on three transects with a total length of 10.4 km (**Fig. 1**). The mean number of recorded tracks was used for further estimation. The Formozov-Malyshev-Pereleshin formula (Acevedo et al. 2008) was used for population density estimation:

$$D = \frac{\pi}{2}\frac{x}{SM}$$

where D is population density (ind/km^2); x – total number of recorded tracks (on all transects); S – total length of all transects, km; M – mean distance moved by the species in a day, km. Internationally published studies in similar habitats were referred to determine the mobility of the roe deer (Hinge 1986).

Camera traps and density estimation without the need for individual recognition (REM model) (Rowcliffe et al. 2008). This study took place between the 1st and the 7th of June, 2017. Twenty=four camera traps (Bestguarder DTC-880V) were randomly placed at a distance of approximately 500 m from each other (**Fig. 1**). Thus, the minimum number of camera traps required by the model was exceeded. The devices were set up at the chosen distance from each other in order to cover the area effectively. The devices were separated in two model areas, representative of the area (12 camera traps each). The camera traps were set up to take three consecutive pictures (5 seconds apart) and a 10-sec video upon activation. The time period between consecutive triggering was set to be one minute (i.e. new series of photos and a video could be taken one minute after the previous triggering). For each location, a standard form was filled, containing information about the habitat characteristics. The resulting data were imported and analysed through CameraBase 1.6 (Tobler 2013), adapted (by adding additional input and analytical options) and translated in Bulgarian (Zlatanova, unpublished). Photos showing the prolonged stay of an individual in front of the camera trap were considered as one individual registration to avoid overrepresentation of the species. The population density was estimated using the following formula:

$$D = \frac{y}{t}\frac{\pi}{vr\,(2+\theta)}$$

where D is population density (ind./km^2); y – total number of independent registrations; t – total number of camera trap days; r – radius of the detection zone of the camera trap, km; θ – angle of the detection zone of the camera trap, radians; v – mobility of the species (distance moved in a day, km). Due to malfunctioning of some of the camera traps, the total number of studied camera trap days was 110 (t). A total of 11 independent registrations of roe deer were recorded (y). A study in similar habitats in Scotland indicates that the mean travelled distance for the roe deer is 1.25 km/24 h (v) (Hinge 1986). Using such data from Bulgaria or the near parts of Europe would certainly decrease the bias in this estimation, but it is currently lacking. The information about radius and angle of the detection zone was acquired through the technical specifications of the camera traps: radius (r) = 0.025 km; angle (θ) = 1.13 rad.

Results

A total of 25 tracks with an average of 7.7 individuals per transect, were recorded (min = 2, max = 15 per transect). The estimated population numbers and densities are presented in Table 1.

The G-test of goodness-of-fit showed no statistically significant differences between the derived number of individuals from the three methods ($G = 0.2$, d.f = 2, $P = 0.905$). The officially reported data from the census in the State Hunting Enterprise are for 164 individuals (1.5 ind./km^2) in spring 2017. There was a statistically significant difference between this value and the estimated population density from the three methods (exact binomial test of goodness-of-fit, $p < 0.01$).

Table 1. Estimated population density derived from the three methods, compared with the official census data.

Method	Direct observations	Track counts	Camera traps	**Official census**
Density (ind./km²)	3.2	3.0	3.5	1.5

Table 2. Comparison of the different methods based on their characteristics. Each method was rated on a scale from 1 to 3 for each characteristic, (1 being the worst and 3 being the best score). Duration/ required field effort = time consumption of the method; Precision = accuracy of the obtained results; Seasonal/ visibility independence = possibility of application throughout the year and whether the method depends on the presence/absence of foliage; Ease of learning/ needed training to apply the method = time required for untrained staff to acquire the method.

Characteristics	**Methods**			
	Direct observations	**Track counts**	**Camera traps**	**Official census**
Duration/ required field effort	2/3 (whole-day observations on multiple transects)	2/3 (whole-day observations on multiple transects)	3/3 (quick set up, does not require direct observations and large field effort)	1/3 (year-round observations and intensive census in the spring)
Precision	3/3	3/3	3/3	1/3
Seasonal/ visibility independence	2/3 (difficult in the periods with foliage)	1/3 (only in winter)	3/3 (independent of season)	1/3 (year-round and in spring, difficult in the periods with foliage)
Ease of learning/ needed training to apply the method	3/3	2/3	2/3	3/3
Total	**10/12**	**8/12**	**11/12**	**6/12**

Discussion

The biological and ecological characteristics of the roe deer suggest that the detection probabilities throughout the year are different. In the climatic conditions of Bulgaria, the best possibilities for observing roe deer in mountainous areas are April-May, and a bit earlier in the year in the plains. During this period, the animals venture into open areas to forage on crocus (*Crocus* sp.) and rarely visit supplementary feeding sites. During the summer, they keep to closed and shady areas due to the hot weather and the insects which pester them, and visit feeding sites at night, when they are difficult to observe. In autumn, the availability of a sufficient natural food base is the reason why the deer remain in more sheltered areas, and only in areas with poorer habitats, the deer begin to frequent feeding sites. These visits increase everywhere with the first snowfall and longer-lasting snow cover. Due to the cold weather in winter, the deer are more active during the day and, therefore, the possibility of observation improves. Taking into consideration these peculiarities in the activity of the deer, we chose to apply these three methods in the aforementioned months. The obtained similar results (average of 3 ind./km^2) from all three methods imply relatively good accuracy. Of course, no known method has so far been able to count all individuals in a given population but this is not necessary. For the good management of wild species, it is more important to know what is the trend in the size of the population – whether it increases or decreases. Observations at feeding sites can also be used for discerning such a trend, but as already mentioned, the inference will cover only part of the population of the species. This monitoring approach is also applied in other European countries (Meriggi et al. 2008). The roe deer density reported in the literature varies widely: in the Chizé Reserve (France) – 6-22 ind./km^2 (Pettorelli et al. 2002); in the floodplain forests along the Morava River (Czech Republic) – 7 ind./km^2 (Prokešová et al. 2006); in the Białowieża Primeval Forest (Poland) – 1.2 ind./km^2 (Sönnichsen et al. 2017). Flajšman et al. (2018) review data from 14 countries, mainly in Western Europe, and report roe deer densities between 4.5 and 73.5 ind./km^2.

In Bulgaria, previous studies indicate that the suitable area for the roe deer in the country is approximately 40,000 km^2, which has the capacity to support 120,000 individuals, or a density of 3 ind./km^2 (Kolev 2007), which is very close to the results from our study. The recommended maximal population density is 12 ind./km^2 (Kolev 2007). The highest estimated population has been reported for SHE "Chepino" (29-36 ind./km^2), also located in the Rhodope Mountains (Morimando et al. 2016). Damyanov et al. (2010) have estimated a density of 2.5 ind./km^2 for the hunting enterprise "Vitoshko-Studena" in 2008. These results indicate that population densities of roe deer vary widely within the country. This is why we recommend game managers to use more than one scientifically sound approach to assess the populations, which will result in results that are more accurate. Following Acevedo et al. (2008), we have compared the tested methods on a three-step scale (

Table 2) and propose that the hunting units should assess their capabilities regarding the methods and their key characteristics and choose and apply the one which suits their needs best. Based on the comparison, we recommend camera trapping as the most cost-effective and least time-consuming tool.

Conclusions

The estimated population density of the roe deer in the study area is on average 3 ind./km^2 based on the three tested methods. This is twice as big as the officially reported data of 1.5 ind./km^2. Consequently, we can assume that applying more than one method would decrease the bias in the estimation. This is why we recommend that forestry and hunting officials should employ this approach for management purposes. Furthermore, the rapid technological advances might offer many other more costly, but also more accurate options.

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References

Acevedo P., Ruiz-Fons F., Vicente J., Reyes-García A. R., Alzaga V. & Gortázar C. 2008. Estimating red deer abundance in a wide range of management situations in Mediterranean habitats. Journal of Zoology 276 (1): 37–47.

Alves J., Alves da Silva A., Soares A. M. V. M. & Fonseca C. 2013. Pellet group count methods to estimate red deer densities: Precision, potential accuracy and efficiency. Mammalian Biology 78 (2): 134–141.

Andersen J. 1961. Biology and management of roe-deer in Denmark. La Terre et La Vie 1: 41–53.

Aulak W. & Babinska-Werka J. 1990. Estimation of roe deer density based on the abundance and rate of disappearance of their faeces from the forest. Acta Theriologica 35 (1–2): 111–120.

Borkowski J., Palmer S. C. F. & Borowski Z. 2011. Drive counts as a method of estimating ungulate density in forests: Mission impossible? Acta Theriologica 56 (3): 239–253.

Campbell D., Swanson G. M. & Sales J. 2004. Comparing the precision and cost-effectiveness of faecal pellet group count methods. Journal of Applied Ecology 41 (6): 1185–1196.

Chećko E. 2011. Estimating forest ungulate populations: a review of methods. Forest Research Papers 72 (3): 253–265.

Damyanov D., Vasileva G., Georgiev G., Genov P.& Ahmed A. 2010. Management of game populations in State Game Enterprise 'Vitoshko -Studena ' II. *Capreolus capreolus* L. Forest Science 4: 69–80. (In Bulgarian)

Flajšman K., Borowik T., Pokorny B. & Jędrzejewska B. 2018. Effects of population density and female body mass on litter size in European roe deer at a continental scale. Mammal Research 63 (1): 91-98.

Focardi S., Aragno P., Montanaro P. & Riga F. 2006. Interspecific competition from fallow deer *Dama dama* reduces habitat quality for the Italian roe deer *Capreolus capreolus italicus*. Ecography 29 (3): 407–417.

Hemami M. R. & Dolman P. M. 2005. The disappearance of muntjac (*Muntiacus reevesi*) and roe deer (*Capreolus capreolus*) pellet groups in a pine forest of lowland England. European Journal of Wildlife Research 51 (1): 19–24.

Hinge M. 1986. Ecology of red and roe deer in a mixed-age conifer plantation: Comparative studies on habitat selection, ranging behaviour and feeding strategies. PhD Thesis. Aberdeen University.

Iannuzzo D., Focardi S., Raganella-Pelliccioni E. & Toso S. 2010. A method to estimate roe deer *Capreolus capreolus* density at various spatial scales in a fragmented landscape. Wildlife Biology 16 (3): 283–291.

Kolev V. 2007. The Roe deer. Nasluka 79. (In Bulgarian)

Mayle B. A., Peace A. J. & Gill R. M. A. 1999. How many deer? A field guide to estimating deer population size. Forestry Commission, Edinburgh, 96 pp.

Meriggi A., Sotti F., Lamberti P. & Gilio N. 2008. A review of the methods for monitoring roe deer european populations with particular reference to Italy. Hystrix 19 (2): 103–120.

Morelle K., Bouche P., Lehaire F., Leeman V. & Lejeune P. 2012. Game species monitoring using road-based distance sampling in association with thermal imagers: a covariate analysis. Animal Biodiversity and Conservation 35 (2): 253–265.

Morellet N., Bonenfant C., Börger L., Ossi F., Cagnacci F., Heurich M., Kjellander P., Linnell J. D. C., Nicoloso S., Sustr P., Urbano F. & Mysterud A. 2013. Seasonality, weather and climate affect home range size in roe deer across a wide latitudinal gradient within Europe. Journal of Animal Ecology 82: 1326–1339.

Morimando F., Focardi S., Andreev R., Capriotti S., Ahmed A., Lombardi S. & Genov P. 2016. A method for evaluating density of roe deer, *Capreolus capreolus* (Linnaeus , 1758), in a forested area in Bulgaria based on camera trapping and independent photo screening. Acta Zoologica Bulgarica 68 (3): 367–373.

O'Brien T.G. 2011. Abundance, Density and Relative Abundance: A Conceptual Framework. In: O'Connell A. F., Nichols J. D., Ullas Karanth K. (Eds): Camera Traps in Animal Ecology. Chapter 6, Springer, Tokyo, New York 71-96.

Pearse D. E., Eckerman M., Janzen J. & Avise J. 2001. A genetic analogue of 'mark-recapture' methods for estimating population size: an approach based on molecular parentage assessments. Molecular Ecology 10: 2711–2718.

Pellerin M., Bessière A., Maillard D., Capron G., Gaillard J.-M., Michallet J. & Bonenfant C. 2017. Saving time and money by using diurnal vehicle counts to monitor roe deer abundance. Wildlife Biology 1: wlb.00274.

Pettorelli N., Gaillard J.-M., Van Laere G., Duncan P., Kjellander P., Liberg O. & Maillard D. 2002. Variations in adult body mass in roe deer: the effects of population density at birth and of habitat quality. Proceedings of the Royal Society B: Biological Sciences 269 (1492): 747–753.

Prokešová J., Barančeková M. & Homolka M. 2006. Density of red and roe deer and their distribution in relation to different habitat characteristics in a floodplain forest. Folia Zoologica 55 (1): 1–14.

Rowcliffe J. M., Field J., Turvey S. T. & Carbone C. 2008. Estimating animal desnsity using camera traps without the need for individual recognition. Journal of Applied Ecology 45: 1228–1236.

Sönnichsen L., Borowik T., Podgórski T., Plis K., Berger A. & Jędrzejewska B. 2017. Survival rates and causes of mortality of roe deer *Capreolus capreolus* in a rural landscape, eastern Poland. Mammal Research 62 (2): 141–147.

Tobler M. W. 2013. Camera Base 1.6. http://www.atrium-biodiversity.org/tools/camerabase/ (accessed 11 April 2016).

Wäber K. & Dolman P. M. 2015. Deer abundance estimation at landscape-scales in heterogeneous forests. Basic and Applied Ecology 16 (7): 610–620.

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