Terrestrial Ecology and Behaviour
Research Article

ACTA ZOOLOGICA BULGARICA
Acta zool. bulg., 68 (3), 2016: 367-373

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

Federico Morimando[1]*, Stefano Focardi[2], Rossen Andreev[3], Simone Capriotti[4], Atidzhe Ahmed[5], Sonia Lombardi[2], Peter Genov[5]

[1] ATC 18 Siena 2, Via Massetana Romana 34, 53100 Siena, Italy; E-mail: morimando@proeco.it
[2] ISC-CNR, via Madonna del Piano 10, 50019 Sesto Fiorentino, Italy; E-mail: stefano.focardi@fi.isc.cnr.it; sonia.lombardi@ fi.isc.cnr.it
[3] Chepino State Hunting Station, Industrialen District, 4600 Velingrad, Bulgaria; E-mail: rosenandr@abv.bg
[4] Associazione Scientifico-Culturale UNIFAUNA, 50026 San Casciano V.P., Italy; E-mail: simonecapriotti@live.it
[5] Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, 2 Gagarin Street, 1113 Sofia; Bulgaria;
E-mails: atidje_dj@abv.bg; genov_bg@yahoo.it

Abstract: We performed an experimental survey of roe deer (*Capreolus capreolus*) in the Chepino Game Hunting Station (Southwestern Bulgaria) in spring 2014 using a camera-trap network. We established a network with a density of one camera per 2 ha of forest. Traps remained activated for five days in one sampling plot of 80 ha. Camera traps triggered by animal movements were set to take successive pictures with ten-second time lapses. Camera trap records were examined by three independent groups of researchers and allowed for a very high rate of individual recognition (up to 82% of individuals pictured were classified by sex and age class). We identified a minimum of 29 roe deer individuals corresponding to a density of 36 individuals/km^2, with a male/female ratio of 0.71, and a fawn/doe ratio of 1.33. This density was surprisingly high as compared to the known Bulgarian standards, and indicated a good conservative management of the roe deer population in the Chepino Region. Further, our estimates were confirmed by performing a capture-mark-recapture study of roe antlered bucks which were easy recognisable. We found a detection probability of 0.91 and a population density of 36.25 deer/km^2. Therefore, camera networks could be used as a reliable monitoring method to estimate roe deer population density and to get a reliable population structure in areas where alternative monitoring methods are not possible or are too expensive. We recommend this method to be adopted by game reserves in Bulgaria in order to improve knowledge about roe deer population demography and for improving the management of its populations.

Key words: Population estimate; camera-trapping; roe deer; reliability; capture-mark-recapture; Bulgaria

Introduction

Since Andersen's (1953) seminal experiment, wildlife biologists are aware that estimating roe deer abundance is a challenging task. Andersen (1953), Ueckermann (1964) and Pielowski & Bresinski (1982) have shown that the estimates provided by rangers and hunters may be strongly biased for lower counts and underestimate roe deer populations. This is because deer detectability is much lower than one expects (Focardi *et al.* 2002). Several methods have been developed which relax the assumption of perfect detectability, such as distance sampling, capture-mark-recapture, and pellet group counts (Borchers *et al.* 2002). Recent technical advances in digital camera-trapping and decreasing costs favour the application of this method to study, often with good accuracy, the presence and relative abundance of many

*Corresponding author

species of wildlife (Cutler & Swann 1999; Yasuda 2004; MacKenzie *et al.* 2005; O'Brien 2008; Tobler *et al.* 2008; Balme *et al.* 2009; Can & Togan 2009). Camera traps have proven very effective when applied to the estimation of population numbers for many species of carnivores, which are individually recognisable usually by fur markings (Barea-Azcón *et al.* 2007; Pettorelli *et al.* 2009; Guil *et al.* 2010). The effectiveness and reliability of camera trapping in estimating the demographic parameters of wildlife populations has already been demonstrated, even in the absence of individual recognition (Rowcliffe *et al.* 2008; Rovero & Marshall 2009). Photo-trapping is particularly useful when assessing population parameters for species in which sex and age classes can be easily distinguished (Wegge *et al.* 2004; Mendoza *et al.* 2011). Among ungulates, deer show easily distinguishable age/sex classes (Jacobson *et al.* 1997; McKinley 2006). Since bucks can be individually recognised using the branched-antler shape, a network of camera traps can estimate their detectability. This value can be extrapolated to other population segments (assuming identical detectability), and an overall population density can be obtained.

Other methods for population estimates can be used but pros and cons should be carefully evaluated in a cost/benefit framework. For example, drive counts are often used by wildlife agencies (Apollonio *et al.* 2010). In forested habitat, drive counts are generally considered a cheap method, but it is time consuming and inefficient in terms of the area sampled (Meriggi *et al.* 2008). Further, Maillard *et al.* (2010) have reported that drive counts lead to an increased negative bias as a function of deer density. Nocturnal distance sampling is potentially effective (Gill *et al* 1997; La Morgia *et al.* 2015), but it needs expensive technology, well-trained personnel, and statistical expertise. Capture-Mark-Recapture (CMR) methods are quite precise, provided that many animals are marked and are known to be alive in the study area (Strandgaard 1967; Gaillard *et al.* 1986; Iannuzzo *et al.* 2010), but this methodology is rather costly.

In Bulgaria, little information is available for roe deer demography, albeit some earlier genetic (Markov 1985, 1998, Markov *et al.* 1987), ethological (Petrov *et al.* 1968), and ecological studies (Kolev 1966; Grigorov 1970; Kolev *et al.* 1976). Most of the demographic information is based on culled animals or on direct observations from feeding stations. Official statistics in Bulgaria show a decrease in roe deer numbers from over 140,000 roe deer in 1988 to almost 60,000 at the beginning of the 2000s, followed by a slow recovery (Official Annual Reports of Bulgarian Agriculture and Food Ministry, Executive Forest Agency, 2010-2015). The most recent estimate reports 99,758 individuals over an area of 110,994 km^2 (Russev 2014).

According to Kolev (1983), the mean roe deer density in the game reserves of Bulgaria is 1.9 individuals/km^2. Recently, Ahmed *et al.* (2015) collected more precise and reliable data in the Chepino Game Hunting Reserve, using camera traps at feeding stations. They studied the population structure in 2010-2014 and showed that the sex ratio was shifted in favour of females, due to trophy hunting.

Further, Ahmed *et al.* (2015) suggested that population numbers were strongly underestimated with respect to actual abundances. The main problem with counting deer at feeding stations was the bias introduced by the spatial distribution of feeding sites and by the presence of potentially dominant species (Bartoš *et al.* 2002). Moreover, hunting activity represented a severe source of disturbance. Ahmed *et al.* (2015) demonstrated that the attendance of roe deer in the feeding station is much higher during the non-territorial period (autumn and winter) than in the territorial season (spring and summer). They also estimated the carrying capacity of the area to 3.1-6 deer/km^2 and the reproductive success (0.8 fawns/female) appeared to be low.

The aim of the present paper is to extend the approach applied by Ahmed *et al.* (2015), by relaxing the constraints of working at feeding stations and monitoring a randomly selected area within the Chepino Game Hunting Station. We used a network of camera traps almost uniformly distributed within the sampling area. The purposes of the research were 1) to evaluate the minimal roe deer density, 2) to validate this estimate through using CMR methodology, and 3) to provide wildlife managers with guidelines for performing camera trap estimates for roe deer populations.

Materials and Methods

The research was carried out in the Chepino Game Hunting Station of the Ministry of Agriculture consisting of a game reserve (Fig. 1) with an area of 300 km^2 situated in the western part of Rhodope Mountains. The sampling site (41°56'16.15"N, 23°58'37.66"E) of 80 ha was a forested area located between 1200 and 1280 m a.s.l. The main habitat was beech forest (*Fagus silvatica*) and coniferous stands dominated by Scots pines (*Pinus silvestris*) and spruces (*Picea excelsa*). During May19-24, 2014, the area was monitored by a network of 40 camera traps (Scout Guard 565F digital incandescent with passive triggered flash). Cameras were fitted to trees (1 m high) with plastic strips in proximity to roe deer marking points,

Fig. 1. Location of the study area in Bulgaria

such as to uniformly cover the sampling area. The size of the sampling area was calculated from aerial photos using GPS reference points collected during trap deployment and using tracks and paths through the woods and fields as borders for the sampling area itself. We used one camera per 2 ha of forested area. Such high density of camera traps has not been used yet in similar studies (Jacobson *et al.* 1997, McKinley *et al.* 2006) but pilot surveys (Morimando, personal observations) showed that it represents a good trade-off between the number of cameras and the surface area covered. In front of the camera on an opposite tree trunk, we spread some anise scent paste (Trophy Hunt Inc.) just before switching on the camera. The use of this bland attractant increases the chances of acquiring multiple photos of the same individual which is necessary for improving individual recognition. We did not use any baiting, scent, or attractants before the start of the camera trapping session to avoid changes in roe deer behaviour. We set cameras to record the date and time on each picture with a latency time of 10 seconds between consecutive snapshots.

At the end of the monitoring session (five consecutive days, 24 hours a day), photos were downloaded onto a PC using the software PICASA (Google Inc.), and the number of individuals belonging to each age and sex class (bucks, adult females, and yearlings of both sexes, i.e. animals being born the previous year) was assessed using several commonly used traits, such as the presence/absence of antlers, the shape of the rump-patch, and apparent size.

Three independent teams of researchers provided individual identification. The three outputs were compared to identify which animals were identified by at least two teams. Important clues for individual recognition were the state of the spring moult, pregnancy status in females, antler branching, eventual presence of antler malformations, the presence of velvet, and number of antler points (Jacobson *et al.* 1997). Moreover, in some cases, deer were individually recognisable owing to peculiar features, such as scars and body malformations.

The estimation of population densities assumed that during the territorial phase for roe deer in May bucks recorded during the five-day trapping session were mainly territorial residents. Annual home ranges vary from 20 to 60 ha, as reported for radio-collared animals (Pellerin *et al.* 2008, Said & Servanty 2005). The home ranges are generally smaller in spring and summer than during the rut (San José & Lovari 1998; Rossi *et al.* 2001; Lamberti *et al.* 2004). We calculated the sex-ratio (number of males / number of females) and the fawn/doe ratio (number of fawns / number of adult females).

Further, we employed the approach of Jacobson *et al.* (1997) and used closed population models following the full-likelihood model of Otis *et al.* (1978), where detection probability was kept constant through the whole experiment. This is realistic since trap-happiness and trap-shyness can be assumed negligible using camera traps. The used model was $\{\hat{p} = p(.) = c(.) == \text{constant}\}$, where $p(.)$ was the first detection probability and $c(.)$ was the probability of subsequent observations. The model was implemented using the software MARK (Cooch & White 2015). Two detections of the same indi-

Table 1. Results of the analysis of camera traps in the Chepino Game Hunting Station, Bulgaria

Team	Females		Males		Unidentified (U)	Sex ratio	Fawns/ doe	Total		Population density (deer/km²)
	Adult	Yearling	Adult	Yearling				U included	U excluded	
1	9*	12	12*	4*	3	0.76	1.78	40	37	46.25
2	7	8*	9*	4*	2	0.87	1.71	30	28	35.00
3	10*	9*	7	4*	4	0.58	1.30	34	30	37.50
n	**9**	**8**	**8**	**4**		**0.71**^	1.33^	**34.66**§	**29**§§	**36.25**

* Teams of researchers with the highest percentage of identification match**.**
^ Computed from *n* values.
§ Column mean
§§ Row sum of the values of *n*.

Table 2. For each buck (M) and yearling (MG) we report the day when it was observed at least by one camera trap

	Date of observation (May 2014)				
Animal identification	21	22	23	24	25
M1	0	0	1	0	0
M2	0	1	0	0	0
M3	1	0	1	0	0
M4	0	0	1	0	0
M5	0	0	1	1	0
M6	1	0	0	1	1
M7	1	0	1	1	0
MG1	0	1	1	0	0
MG2	0	1	0	1	1
MG3	1	0	1	1	0

vidual were considered independent when occurring (i) in different days or (ii) in the same day but the animal was recorded by different camera traps. Case (ii) occurred only for M6 on the 24/5/2014 and for MG3 on the 23/5/2014.

To compute global population abundance, we have to estimate correctly the number of sighted animals (n). Thus $\widehat{N} = \frac{n}{\widehat{p}}$ is an estimate of the population abundance, whose confidence limits were derived from the confidence limits of $\widehat{p}$ obtained from MARK.

In order to compute n, for each sex and age class, we selected the two teams with the highest matching rate. For instance, if team 1 and team 3 exhibited the highest match and recognised 9 and 10 adult females, respectively, we calculated the minimum number of deer common to the two teams, i.e. 9, which represented the minimum number of adult females. The sum of these values for all classes represented the global value of n. In this procedure, we implicitly assumed that all unidentified deer were counted and identified during at least one sighting occasion.

Results

We collected 588 pictures including a number of non-target species (wild boar *Sus scrofa*, red deer *Cervus elaphus*, pine marten *Martes martes* and red squirrel *Sciurus vulgaris*), as well as a number of empty shots probably triggered by flying birds. The three independent groups of researchers carefully examined the 58 photos (10% of the total sample) in which roe deer were recorded and were able to recognise 40, 30, and 34 different individuals, respectively (Table 1). We crisscrossed the three different analyses in order to calculate the overlap percentage among the three groups in recognising the same deer, i.e., we computed the matches of different individuals recognised by each team. Across the total 58 snapshots, in 10 cases (17%) the three groups did not agree on identification, in 28 cases (48%) at least two groups agreed on the same identification, and in 20 cases (34%) the three teams agreed. Finally, we got n=29, corresponding to a density of 36.25 roe deer/km² (Table 1). We found a sex- ratio of 0.71, which was a bit low with respect to documented sex ratios for roe deer. The number of fawns per adult female was on average 1.3 (Table 1) with some difference among teams probably linked to the difficulty in discriminating 1-year old fawns from adults.

The capture history file of the male deer is reported in Table 2. The studied model $\{\widehat{p} = p(.) = c(.) == \text{constant}\}$ had a non-significant residual distribution (χ^2_{28}=26.1, P 0.43) but the fit was not completely satisfactory since $\hat{c} = 3.95$ $\hat{c} = 3.95$, as compared to $\hat{c} \leq 3.0$ $\hat{c} \leq 3.0$, suggested in the literature (Lebreton *et al.* 1992). From the capture-history file, we computed a detection probability per day of 0.387 (0.23-0.56). Hence, the probability of not being detected during one day was (1-0.387)= 0.765, and the probability of non-detection during the whole survey was 0.765^5= 0.087, which yielded a probability of being detected at least once $\widehat{p} = (1 - 0.087) = 0.91$

$\hat{p} = (1 - 0.087) = 0.91$ with a confidence interval (0.73-0.98). Therefore, the estimated population was 39.68 with confidence limits 36.8-49.1 deer/km^2.

Discussion

Our results indicated that the performance of the proposed design of the camera trapping network in assessing the abundance and sex-ratio of the roe deer population was quite good. We found that at least at small spatial scales, roe deer density might be higher than previously reported for Bulgaria (Kolev 1983; Russev 2014; Ahmed *et al.* 2015). Our results indicated a successful conservative management of the roe deer population in Chepino. According to Ahmed et al (2015) harvesting in the Reserve ranges from 30 to 40 roe bucks per year, which is quite low considering the density found, even if we cannot extrapolate our results to the whole Reserve without a wider survey. This high density of roe deer population in Chepino was probably due to the use of foraging stations, which are a crucial element for deer survival, especially during winter due to harsh and persistent snowy conditions, and the resultant artificial feeding which strongly reduces starvation in roe deer (Ossi *et al.* 2015). The low level of the male/female ratio can be explained with the fact that only adult males are shot for trophy hunting. The fawn/doe ratio reported in this study differed from the one reported by Ahmed *et al.* (2015) for the same area. The value found in this study was medium-high considering that the fawns we observed were able to survive the winter and, thus, were recruited into the population. In order to verify whether the differences among teams were linked to the difficulties in attributing the correct age-class, it might be better to conduct the survey to the end of winter.

In current management, estimates of demographic parameters are often biased owing to the subjective opinions of rangers, hunters and managers. To move to fact-based management, it is necessary to use objective, sound methodologies that are difficult to apply due to a limited availability of resources and lack of statistical skill. We showed that the use of a survey based on camera traps can aid managers to obtain reliable demographic estimates without the use of complex statistical analyses. Indeed, in this work we used CMR methodologies to validate the results obtained by the independent teams. The use of at least three different teams of experts makes individual recognition somewhat objective. For roe deer, the identification success is high (in our study we achieved 82% of cumulative matching in individual recognition). We suggest that using at least one camera for 2 ha of forest with the help of a bland attractant or lure can lead to a better balance between cost-effectiveness, labour efficiency, and objective rigour in determining roe deer density and population parameters as compared to other empirical methods, such as drive counts or observation from vantage points.

Usually researchers tend to use infrared-trigged cameras to monitor wildlife in order to reduce disturbance. We think that camera-traps supplied with white flash are more suitable for individual recognition and for assessing population structure than infrared-triggered cameras; this makes it easier for the observers to use colour-related information during night sessions which provides very important clues for individual recognition.

Further, use of a CMR estimate of the detection probability showed that the design used allowed us to observe a large portion of the population. However, the correction for detectability demonstrated that the local roe deer population attained a high value of about 40 deer/km^2. Despite relevant differences in habitat with the Italian landscape where this methodology was initially developed for roe deer (Morimando, unpublished data in ATC 18 internal report, 2011), the density level found in Italy (over 50 deer/km^2) appears to be in similar range, once again confirming the strong ecological plasticity of this species. These figures are consistent with the findings of Focardi *et al.* (2002) for a population in the Northern Apennines. Carnevali *et al.* (2009) showed that the roe deer density might exceed 10 deer/km^2 all over the Northern Apennines and attain values as high as 40 deer/km^2.

In conclusion, we suggest experimenting with our camera trap methodology in game reserves spread across Bulgaria could aid to obtain quantitative and reliable data on roe deer population density and structure.

Acknowledgments: We would like to thank the Commission Board of ATC 18 Siena 2 for help and funding part of the equipment. The Italian CNR and the Bulgarian Academy of Science funded the project. The administration of the Chepino Game Hunting Reserve provided research facilities and accommodation. Dr Horvath kindly revised the English.

References

Ahmed A., A. Vlasseva, R. Andreev & P. Genov 2015. Roe deer (*Capreolus capreolus* L.), (nobody's) whose hunting species. Challenges, Bulgarian Hunting and Fishing Union, – *Bulgarian bookstore*, First Edition, Sofia **2**: 27-32. (In Bulgarian).

Andersen J. 1953. Analysis of a Danish roe deer population (*Capreolus capreolus* L.) based upon the extermination of the total stock. – *Danish Review of Game Biology,* **2**: 127-155.

Apollonio M., S. Ciuti, L. Pedrotti & P. Banti 2010. Ungulates and their management in Italy. – In: Apollonio M., R. Andersen, R. Putman (Eds.): European Ungulates and their Management in the 21st Century. Cambridge University Press, Cambridge, 475-506.

Balme G.A., L.T.B. Hunter & R. Slotow 2009. Evaluating methods for counting cryptic carnivores. – *Journal of Wildlife Management*, **73**: 433-441.

Barea-Azcón J.M., E. Virgós, E. Ballesteros-Duperón, M. Moleón & M. Chirosa 2007. Surveying carnivores at large spatial scales: a comparison of four broad-applied methods. – *Biodiversity Conservation*, **16**: 1213-1230.

Bartoš, L, D. Vankova, K.V. Miller & J. Šiler. 2002. Interspecific competition between white-tailed, fallow, red, and roe deer. – *Journal of Wildlife Management*, **66**: 522-527.

Borchers D.L., S.T. Buckland & W. Zucchini 2002. Estimating animal abundance. Closed populations, Springer-V., Berlin.

Can Ö.E., İ. Togan 2009. Camera-trapping of large mammals in Yenice Forest, Turkey: local information versus camera traps. – *Oryx*, **43**: 427-430.

Carnevali, L. Pedrotti, F. Riga & S. Toso 2009. Banca Dati Ungulati: Status, distribuzione, consistenza, gestione e prelievo venatorio delle popolazioni di Ungulati in Italia. Rapporto 2001-2005. – *Biol. Cons. Fauna*, **117**: 1-168. (In Italian and English summary).

Cooch E.G. & G.C. White 2015. Program MARK: A Gentle Introduction (edition 14). Colorado State University. http://www.phidot.org/software/mark/. Accessed: 2015 Sep 20.

Cutler T.L., D.E. Swann 1999. Using remote photography in wildlife ecology: a review. – *Wildlife Society Bulletin*, **27**: 571-581. Focardi S., Raganella Pelliccioni E., Petrucco R. & Toso S. 2002. Spatial patterns and density-dependence in the dynamics of a roe deer (*Capreolus capreolus*) population in Central Italy. – Oecologia, **130**: 411-419

Gaillard J.-M., B. Boisaubert, J.-M. Boutin, J. Clobert 1986. Estimation of population numbers from capture-mark-recapture data application to roe deer. – *Gibier Faune Sauvage*, **3**:143-158.

Grigorov G. 1970. On the issue of determining the grading in the habitat of roe deer (*Capreolus capreolus* L.) and red deer (*Cervus elaphus* L.). Coll. Botev N., P. Petrov, B. Marinov, G. Stenin, B. Popov (Eds.): Symposium with international participation "Problems of hunting and fishing in the People's Republic of Bulgaria", Varna, 123-131. (In Bulgarian).

Guil F., S. Agudín, N. El-Khadir, M. Fernandez-Olalla, J. Figueredo, F. Domínguez, P. Garzon, G. Gonzalez, J. Muñoz-Igualada, J. Oria & F. Silvestre 2010. Factors conditioning the camera-trapping efficiency for the Iberian lynx (*Lynx pardinus*). – *European Journal of Wildlife Research*, **56**: 633-640.

Gill R.M.A, M.L. Thomas, D. Stocker 1997. The use of portable thermal imaging for estimating deer population density in forest habitats. – *Journal of Applied Ecology* **34**: 1273-1286.

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**: 1-9.

Jacobson H. A., J. C. Kroll, R. W. Browning, B. H. Koerth & M. H. Conway 1997. Infrared-Triggered Cameras for Censusing White-Tailed Deer. – *Wildlife Society Bulletin*, **25** (2): 547-556.

Kolev I. 1966. Study on the distribution and biology of roe deer in "Chepino" region – Rhodopes. Thesis, Sofia, 113 pp. (In Bulgarian).

Kolev I. 1983. Research and development on roe deer populations into Bulgaria in relation to environmental changes. Habilitation (Higher Institute of Forestry), Sofia, 214 pp. (In Bulgarian).

Kolev I., N. Botev & S. Manolov 1976. Contributions to study the habitats of roe deer in the Rhodopes, Rila and Pirin and usability. *Higher Institute of Forestry, Jubilee scientific session "50 years of higher forestry education"* (*Section Environmental Protection*), 210-217. (In Bulgarian).

Lamberti P., L. Mauri & M. Apollonio 2004. Two distinct patterns of spatial behaviour of female roe deer (*Capreolus capreolus*) in a mountainous habitat. – *Ethology, Ecology and Evolution*, **16**: 41-53.

Lebreton J.-D., K.P. Burnham, J. Clobert, D.R. Anderson 1992. Modeling survival and testing biological hypotheses using marked animals. A unified approach with case studies. – *Ecological Monographs*, **62**: 67-118

La Morgia V., Calmanti R., Calabrese A. & Focardi S. 2015. Cost-effective nocturnal distance sampling for landscape monitoring of ungulate populations. – *European Journal of Wildlife Research*, 61: 285-298

MacKenzie D.I., J.D. Nichols, N. Sutton, K. Kawanishi & L.L. Bailey 2005. Improving inferences in population studies of rare species that are detected imperfectly. – *Ecology,* **86**: 1101-1113.

Maillard D., J. M. Gaillard, M. Hewison, P. Ballon, P. Duncan, A. Loison, C. Toïgo, E. Baubet, C. Bonenfant, M. Garel & C. Saint-Andrieux 2010. Ungulates and their management in France. In: Apollonio M, R. Andersen, R. Putman (eds). European Ungulates and their Management in the 21st Century. Cambridge University Press, Cambridge, 441-474.

Markov G. 1985. Comparative population morphological and genetic analysis of the *genus Capreolus* Gray, 1821. Dissertation for the scientific degree "Candidate of biological sciences." Institute of Zoology, Sofia.

Markov G. 1998. Population and genetic differentiation and systematics of species representative of all deer (Cervidae) in Palearctic. Dissertation for scientific degree of "Doctor of biological sciences." Institute of Zoology, Sofia.

Markov G., S. Gerasimov & V. Nikolov 1987. Morphometric similarity of the hunting trophies of deer and comparative analysis of craniometrical signs and morphometric parameters of the antlers of the European roe deer (*Capreolus capreolus* L., 1758). Contemporary achievements of the Institute of Zoology–BAS, 56-59.

McKinley W. T., S. Demarais, K.L. Gee & H.A. Jacobson 2006. Accuracy of the camera technique for estimating white-tailed deer population characteristics. – *Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies*, **60**: 83-88.

Mendoza E., P.R. Martineau, E. Brenner & R. Dirzo 2011. A novel method to improve individual animal identification based on camera-trapping data. – *Journal of Wildlife Management*, **75** (4): 973-979.

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

Morimando F. 2011. Piano di gestione del Capriolo (*Capreolus capreolus*) nell'ATC 18 Siena 2. Internal Report of Ambito Territoriale di Caccia n° 18, Provincia di Siena, Regione Toscana.

O'Brien T.G. 2008. On the use of automated cameras to estimate species richness for large- and medium-sized rainforest mammals. – *Animal Conservation*, **11**: 179-181.

Ossi F. Gaillard J-M, Hebblewhite M. & Cagnacci F. 2015. Snow sinking depth and forest canopy drive winter resource selection more than supplemental feeding in an alpine population of roe deer. – *European Journal of Wildlife Research*, **61**: 111-124.

Pellerin M., S. Saïd & J-M. Gaillard 2008. Roe deer (*Capreolus capreolus*) home-range sizes estimated from VHF and GPS data. – *Wildlife Biology*, **14**: 101-110.

Petrov M., I. Kolev & P. Dragoev 1968. The roe deer in Bulgaria. Zemizdat, Sofia, 215 p. (In Bulgarian).

Pettorelli N., A.L. Lobora, M.J. Msuha, C. Foley & S.M. Durant 2009. Carnivore biodiversity in Tanzania: revealing the distribution patterns of secretive mammals using camera traps. – *Animal Conservation*, **13**: 131-139.

Pielowski Z. & W. Bresinski 1982. Population characteristics of the roe deer inhabiting a small forest. – *Acta theriologica*, **27** (28): 409-425.

Rossi I., P. Lamberti, L. Mauri & M. Apollonio 2001. Male and female spatial behaviour of roe deer in a mountainous habitat during the pre-rutting and rutting period. – *Ibex – Journal of Mountain Ecology,* **6**: 1-6.

Rovero F. & A.R. Marshall 2009. Camera trapping photographic rate as an index of density in forest ungulates. – *Journal of Applied Ecology,* **46**: 1011-1017.

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

Russev Ju. 2014. An overview of the state of census of hunting species in Bulgaria. – *Magazine of Forestry*, Report of Ministry of Agriculture, **6**: 18-20. (In Bulgarian).

Saïd S. & S. Servanty 2005. The influence of landscape structure on female roe deer home-range size. – *Landscape Ecology,* **20** (8): 1003-1012.

San José C. & S. Lovari 1998. Ranging movements of female roe deer: do home-loving does roam to mate? – *Ethology*, **104** (9): 721-728.

Strandgaard, H. 1967. Reliability of the Petersen method tested on a roe-deer population. – *Journal of Wildlife Management*, 643-651.

Tobler M.W., S.E. Carrillo-Percastegui, R.L. Pitman, R. Mares & G. Powell 2008. An evaluation of camera traps for inventorying large and medium-sized terrestrial rainforest mammals. – *Animal Conservation*, **11**: 169-178.

Ueckermann E. 1964. Der Rehwildabschuss. Verlag Pail Parey. Namburg und Berlin.

Wegge P., C.P. Pokheral & S.R. Jnawali 2004. Effects of trapping effort and trap shyness on estimates of tiger abundance from camera trap studies. – *Animal Conservation,* **7**: 251-256.

Yasuda M. 2004. Monitoring diversity and abundance of mammals with camera traps: a case study on Mount Tsukuba, Central Japan. – *Mammal Study*, **29**: 37-46.

Received: 06.11.2015
Accepted: 23.08.2016