How to improve the estimation of red deer (Cervus elaphus) population density in Serbia

Miroslav, Urošević[1,*,†], Jovan, Mirceta[2,†], Bojan Tubic[2,†], Dejan Beukovic[1,†] and Samantha Wisely[3,†]

[1]University of Novi Sad, Faculty of Agriculture, Dep. of Animal Science Novi Sad, Trg Dositeja Obradovica 8; Novi Sad, Serbia
[2]Public Enterprise Vojvodinasume, Preradovićeva 2, Petrovaradin-Novi Sad, Serbia
[3]University of Florida – Cervidae Health Research Initiative, 110 Newins-Ziegler Hall, Gainesville, FL, USA

Abstract

Spatial and temporal estimates of population abundance or density are essential to evaluate whether conservation efforts are having the desired effects on endangered species and to determine the impact of extrinsic effects such as climate change or land use change, or the intrinsic threats such as disease outbreaks. Precise estimates are challenging because red deer have a relatively large radius of movement between the place where they stay during the day and where they take food at night which can lead to counting errors of 10, 20 and even 50%.

To the author's best knowledge, there is a lack of available data about red deer (Cervus elaphus) counting methods in Serbia, as well as possible improvements of the current situation. This was the motivation to conduct a short analysis on the state-of-the-art use of UAV (Unmanned Aerial Vehicles) i.e. drones in the estimation of red deer population density in Europe as a possible solution for Serbia.

Keywords

Game animals, Counting, Drones, South East Europe

1. Introduction

Accurate, consistent, and effective estimation of the population abundance of wildlife species is crucial for adaptive management and conservation of natural ecosystems. Spatial and temporal estimates of population abundance or density are essential to evaluate whether conservation efforts are having the desired effects on endangered species and to determine the impact of extrinsic effects such as climate change or land use change, or the intrinsic threats such as disease outbreaks. Population and species monitoring are important elements in the management and conservation of species [1], and many methods are used to make realtvie or absolute estimtes of population size Hunter harvest statistics are often used as an estimate of the minimum number live which is an indirect measurement of population size; however, this approach only concerns game species that are not protected, and game bags may reflect hunters behaviour and tradition rather than changes in population size [2, 3, 4].

Direct counting methods include ground-based transect surveys, faecal density counts, and images from camera traps [5, 6, 7, 8]. These ground-based methods are time-consuming and can be subject to biases, especially for game species. In person transects in daylight limit the detection of nocturnal species and species with visual camouflage [9, 10], and thus to monitor nocturnal game species, e.g., red deer (Cervus elaphus), nightly spotlight surveys are widely used [11, 12]. More recently, genotyping faecal samples in a genetic mark-recapture framework has provided population size estimates that are more accurate than hunter-harvest statistics [13] but are costly [14].

In recent years, the use of drones in search and rescue operations has increased and have the promise of being effective in wildlife monitoring. Drone technology combined with deep learning and image processing techniques have made processing the large amount of data more efficient and effective. However, there are also challenges such as legal restrictions and weather conditions. Continuous

4th International Workshop on Camera Traps, AI, and Ecology, 2024
*Corresponding author.
†These authors contributed equally.
miroslav.urosevic@stocarstvo.edu.rs (M. Urošević)

development of these technologies enable drones to be used more effectively in search and rescue operations [15] and in wildlife monitoring.

2. Status of deer populations in Serbia and potential knowledge gaps

Currently, data necessary to estimate red deer population abundance are either not recorded or are not made available in a timely manner [16]. Data collected on hunting grounds in Serbia, as well as other data collected and processed by the Statistical Office of the Republic of Serbia [17], are published in two-year periodicals in the field of forestry, which does not meet the needs of modern hunting management and sustainable use of wildlife populations. Improvements could be implemented to make better use of this valuable data that has already been collected or could be collected with minimal additional effort. For example, the current information system of the Statistical Office of the Republic of Serbia [17] should enable all hunting ground users to directly enter data into a single database of the statistical office. In addition, these data should be harmonized with other databases and data sources in the field of hunting, such as the information system of the Hunting Association of Serbia and the Ministry of agriculture. According to the official statistical data, the estimated number of red deer populations in the spring of 2011 was about 4,200 individuals, and in the spring of 2019 about 6,300 individuals. However, the majority of assessment sheets do not contain information on the estimated age of individuals, nor is it requested on datasheets (Form T-11, Evaluation Sheet, Figure 1). Adding data on age class would allow better demographic estimations of populations to be made. Moreover, trophy value (Form E-4, Figure 2) is not recorded (The International Council for Game and Wildlife Conservation, "CIC" points) Changes to these forms would improve the amount of information about harvested animals which in turn would lead to better estimates of population size. Game laws should be adjusted to reflect this additional information for harvested animals.

3. The current procedure of estimation of red deer population in Serbia

Red deer are easier to count using visual surveys than roe deer because they have a different biological rhythm and way of behaving in nature. Red deer spend most of the year in herds, and they separate (individual movement) only during mating, while females are separated from the herd during calving. Thus, during certain times of the year, animals congregate in readily visible herds. However, there are numerous challenges when counting big game animals (red deer; fallow deer – Dama dama; roe deer – Capreouls capreolus; european mouflon - Ovis aries musimon and wild boar – Sus scrofa) that can lead to errors of 10, 20 and even 50% compared to the actual situation [18]. Precise estimates are challenging because red deer have a relatively large radius of movement between the place where they stay during the day and where they take food at night.

To mitigate biases in population estimation, the counting procedure itself should be carefully planned, considering that it is a complex process and requires teamwork with the coordination of a large number of participants, i.e."countersit is necessary to harmonize the methodologies for counting animals across all hunting grounds. Surveys should also be randomly stratified among suitable red deer habitats and given equal survey effort.

Образац Т - 11

ОЦЕЊИВАЧКИ ЛИСТ

Јелен / *Cervus elaphus L./*

_____

(Име и презиме ловца, место боравка, држава, регистарски број ловне карте)

Ловиште: _____

Место звано: _____

Датум лова: _____

Ред. број	Елементи мерења и оцењивања / *Measurements* /		Јед. мере	Мера	Средња мера	Константа ***	Утврђени бр. поена
1.	Дужина роговља / *Length of main beam* /	левог	cm				
		десног	cm			0,50	
2.	Дужина надочњака / *Length of brow tine* /	левог	cm				
		десног	cm			0,25	
3.	Дужина средњака / *Length of tray tine* /	левог	cm				
		десног	cm			0,25	
4.	Обим венца (руже) / *Circumference of coronet* /	левог	cm				
		десног	cm			1,00	
5.	Обим између надочњака и средњака / *Circumference of lower beam* /	левог	cm		xxxxxxx	1,00	
		десног	cm		xxxxxxx	1,00	
6.	Обим између средњака и круне / *Circumference of upper beam* /	левог	cm		xxxxxxx	1,00	
		десног	cm		xxxxxxx	1,00	
7.	Тежина свежег роговља умањена за 10 % односно _____ кг. / *Weight*		kg		xxxxxxx	2,00	
					xxxxxxx		
8.	Распон роговља / *Inside span*		cm		%	0 - 3	
9.	Број парожака на гранама роговља / *Number of tine ends* /	лева	ком.			1,00	
		десна	ком.				
	Збир поена од редног броја 1. до 9. / *Score* 1-9					∑ (1-9)	

Ред. број	Елементи оцењивања и лепоте роговља / *Beaty Points* /		Могући бр. поена	Утврђени бр. поена
10.	Боја роговља	/ *Colour*	0 - 2	
11.	Искричавост роговља	/ *Pearling*	0 - 2	
12.	Врхови (шиљци) парожака	/ *Tine ends*	0 - 2	
13.	Ледењаци	/ *Bay tines*	0 - 2	
14.	Круне	/ *Crown tines*	0 - 10	
	Збир поена од ред. бр. 10. до 14.		∑ (10-14)	
15.	Одузимање поена због недостатака	/ *Penalty points*	0 - 3	
	Образложење за одузимање поена:			
	Укупна оцена трофеја / *Final score*		∑ (1-15)	

Figure 1: Form T-11, Evaluation Sheet (Source: https://www.paragraf.rs/obrasci/Obrazac_T_-_14_-_Ocenjivacki_list.pdf)

Evidencija o izvršenim radovima i merama u lovištu

Lovište : "Rasina" **Lovna godina : _____ /_____**

E V I D E N C I J A
o investicijama u lovištu **Obrazac E - 1**

Red. broj	Naziv investicije - objekta	Mesto izgradnje	Izgradnja		Vrednost investicije
			započeta	završena	
1	2	3	4	5	6

Primedba : _____

_____

*** * * * ***

Figure 2: Form E-4, Records of completed works and measures in the hunting grounds (Source: https://www.lukrusevac.rs/data/uploads/obrasci/Evidencija-o-izvrsenim-radovima-i-merama-u-lovistu.doc)

At the end, the organizer of the entire counting process at one hunting ground invites all the counters or observers to jointly analyze the collected data and perform a recapitulation of the obtained figures or aggregated data.

From the described counting process, it is clear how demanding this activity is in every sense, as regards the number of people, time consumption and ultimately costs. Counting is best or most successfully done in the morning or early evening because that's when the deer are most active, i.e. they are looking for food, so they can be seen or observed more easily. Also, it is more successful to observe deer in winter or early spring when there is less vegetative cover and animals are congregated in herds. Days when meteorological conditions (temperature, pressure and air humidity) change suddenly are not suitable for game counting, as deer consequently change their day/night rhythm with an uncertain outcome in the future [18].

After taking all the mentioned factors into account, the counting organizer should determine the counting time and the direction of movement of the members of the counting team (usually 2 to 3 people in a group). As mentioned, observers should be placed at crossings (hunting towers, valleys, embankments, watercourses, roads) that record the direction of movement, the number of animals and the exact time (hour, minute) when it happened. In any case, they enter the data with all the details (place of capture, all categories of deer) in the appropriate forms as well as possible remarks, such as the joining of two groups from two directions.

4. Red deer estimation in the Public Enterprise "Vojvodinasume", Serbia

Hunting grounds in Public Enterprise (PE) 'Vojvodinasume' have been established and set up on an area of 108,988.00 ha. In this area, 17 hunting grounds have been established, set up and entrusted to PE "Vojvodinasume" (Figure 3). Total area of enclosed hunting grounds is 25,552.00 ha or 23.50% of the total area under hunting grounds established in PE "Vojvodinasume". The red deer habitats in the area managed by the PE Vojvodinasume are mainly the flat forest land, along the Sava and Danube rivers.

PE "Vojvodinasume" is a business entity conducting activities in the sector of hunting. It owns hunting grounds and game breeding farms with professional staff working on them. This makes it one of the key actors in planning the development of the hunting sector both in the Province of Vojvodina and the whole Republic of Serbia.

Enclosed hunting grounds are used for intensive, modern methods of breeding two autochthonous species (red deer and wild boar) and two allochthonous species (fallow deer and mouflon), generally kept and bred together on the same enclosed site. Intensive production and breeding of large game is intended mainly for foreign hunters-tourists (foreign market). However, over the past couple of years, local hunters-tourists have also been taken into consideration (domestic market).

Counting of red deer is done in the second half of March. To determine the estimated number of individuals, a combination of several methods is used: the number of harvested animals, observation of animals by game wardens from the tower, the presence of game footprints, camera traps, and counting of animals by simultaneously passing several people through the hunting ground. The breeding stock of red deer is evaluated by synthesis of all parameters. The final population size estimate refers to the population post-hunting season but before calves are born. The use of camera traps in game counting at PE Vojvodinasume is still relatively new and has not been validated.

Red deer abundance I estimated on the 17 hunting grounds (divided into 5 organizational units), (Figure 4). The majority of red deer habitat belongs to flat areas (105.805 ha) with only one in hilly or mountainous habitats (4.118 ha). According to the map on Figure 3 and statistical data (Figure 4), the largest number of red deer are located near the Danube river in the hunting grounds "Apatinski rit" (No 2) and "Kozara" (No 3) with total number of 1.734 animals, as well as "Deliblatska Peščara" (No 11) with 790 animals. The sum of these three hunting ground is 2.524 animals, which is more than two-thirds of the red deer population on PE Vojvodinasume properties. If the fourth most productive hunting ground in terms of the number of red deer (450 animals), which is the Bosutske Sume (No 13), is added , the

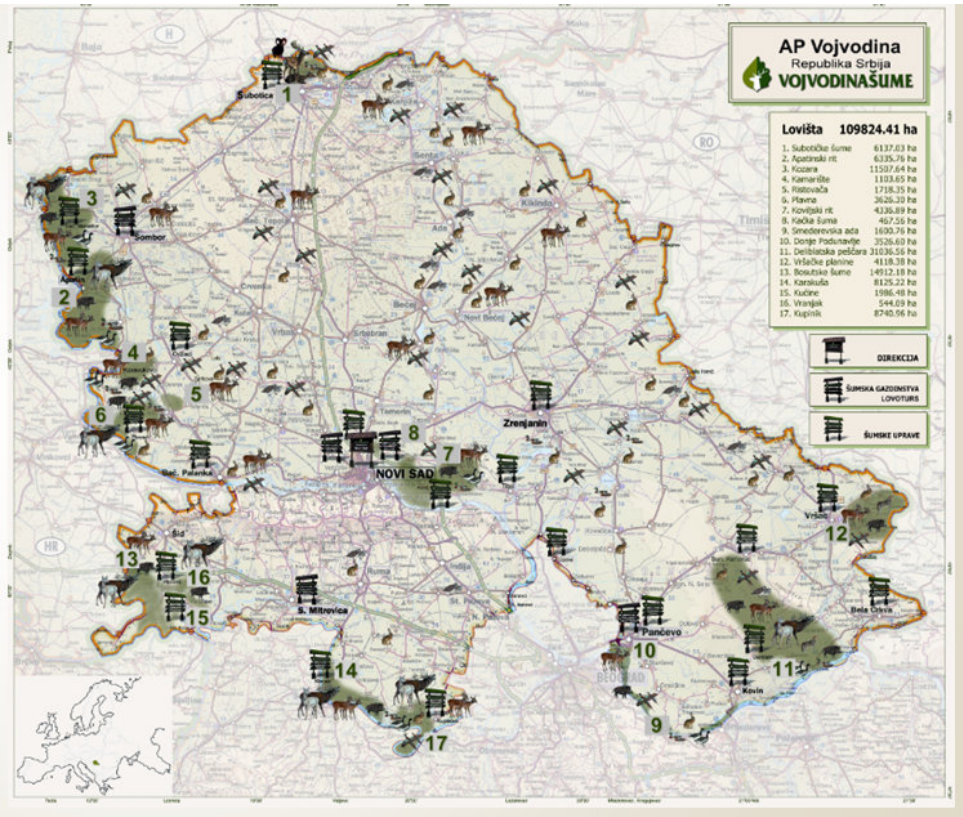

Figure 3: The map of hunting grounds PE "Vojvodinasume", Serbia (source: PE "Vojvodinasume")

number of deer on those four hunting grounds on the banks of the Danube and Sava rivers, it follows that this number (3974 animals) is more than four fifths of the red deer fund in PE Vojvodinasume.

5. The experiences of other researchers

Although there is not much research on the use of drones in deer population estimation, it appears that there are numerous challenges and technical details that need to be solved.

In their study in Germany, Zabel et al. [19] evaluated the accuracy of Unmanned Aerial Vehicles (UAVs) and thermal infrared cameras in counting red deer populations. The study revealed that factors such as season, flight altitude and temperature affect the accuracy of the UAV. These results suggest that UAVs have the potential to provide accurate population counts, but it is important to consider various factors.

Larsen et al. [20] in their study in Denmark, investigated the use of a drone equipped with a thermal camera for recognizing wild mammal species in open areas and determining the sex and age of red deer (Cervus elaphus) and roe deer (Capreolus capreoulus), and these species could be distinguished from one another and from cattle They described many details about characteristics used for recognising species e.g. cattle and deer could be distinguished by their body shape. The width of the waist of cattle was more than twice their hip and shoulder width, whereas deer had an almost identical waist, shoulder, and hip width. Hence, deer looked more rectangular in shape than cattle in the thermal videos. Red deer and roe deer were also visually different and could be distinguished by head and antler shape. The snout of a red deer is relatively long compared to that of a roe deer. Furthermore, the movements of red deer were perceptibly slower compared to those of roe deer. Another important parameter for measuring the length of the mammals was the positioning of the individual. The standard measurements of mammals include tail length and total length [21]. For accurate measurements hereof, the individual should be standing and not lying curled up. More time spent recording individuals

The name of hunting ground	The type of hunting ground	The total surface (*ha*)	The breeding stock of wild game (No.) Red deer (Cervus elaphus)				
			March 2024	March 2023	March 2022	March 2021	March 2020
Kozara	flat land	11.508	1.259	1.416	1.463	1.456	1.443
Apatinski rit	flat land	6.336	475	483	506	530	525
Subotičke šume	flat land	6.137	0	0	0	0	0
Organizational unit "Sombor"		***23.981***	***1.734***	***1.899***	***1.969***	***1.986***	***1.968***
Plavna	flat land	3.626	130	130	130	124	124
Koviljski rit	flat land	4.456	0	0	0	0	0
ŠG "Novi Sad"		***8.082***	***130***	***130***	***130***	***124***	***124***
Bosutske šume	flat land	14.912	450	450	451	431	430
Karakuša	flat land	8.125	138	153	162	168	170
Kupinik	flat land	8.741	52	46	0	0	0
Kućine	flat land	1.965	84	84	84	81	81
Vranjak	flat land	544	0	0	0	0	0
Organizational unit "Sremska Mitrovica"		***34.287***	***724***	***733***	***697***	***680***	***681***
Vršačke planine	hilly-mountainous	4.118	127	86	50	72	51
Deliblatska Peščara	flat land	31.037	790	758	753	684	694
Donje Podunavlje	flat land	3.527	0	0	0	0	0
Smederevska ada	flat land	1.601	0	0	0	0	0
Organizational unit "Banat Pančevo"		***40.283***	***917***	***844***	***803***	***756***	***745***
Ristovača	flat land	1.718	0	0	0	0	0
Kamarište	flat land	1.104	24	0	0	0	0
Kaćka Šuma	flat land	468	0	0	0	0	0
Organizational unit "Lovoturs"		***3.290***	***24***	***0***	***0***	***0***	***0***
PE „Vojvodinasume“	**17 hunting grounds**	**109.923**	**3.529**	**3.606**	**3.599**	**3.546**	**3.518**

Figure 4: Statistic data about red deer population of PE “Vojvodinasume”

increases the possibility of obtaining exact measures. One of the challenges in monitoring red and roe deer is that they forage in the same areas, and therefore it is important to find ways to distinguish between species of deer from thermal drone images. The group structure of roe deer differs throughout the year. In the summer months, roe deer tend to live alone or in family groups, while in autumn and winter, they gather in groups of up to 60–70 individuals [22]. In this study, however, red deer and roe deer could be distinguished from each other by their very different body sizes, head forms and movement speeds. With sufficient data, the shapes of the heads could be measured and analyzed to show if there is a significant difference in the head shape between red deer and roe deer. In autumn, when the study was conducted, roe deer still moved around in small groups on the moor (13 km2), Lyngby Hede, managed by The Danish Nature Agency and the antlers of the stags were easily recognized by the thermal camera.

At other times of the year, when antlers are not present, it is not possible to differentiate between

male and female red deer [23]. Jarnemo et al. [24] found that female and male red deer are normally sexually segregated outside of the rut. When the rutting season begins in early September, the male red deer form large harems and the elder stags can be recognized by their roaring, fights, and urination, while the hinds can be determined by whether or not they nurse a calf. However, a young male deer without antlers or with smaller antlers may be confused with a hind due to its size, and because young males sometimes stay with the herd [25].

6. Conclusion and future challenges to be addressed in Serbia

According to previous reports, it has been demonstrated that UAV-based thermal imaging surveys can offer a non-invasive but potentially very accurate and precise surveying approach to estimate red deer population numbers, sex ratios and possibly breeding success in northern Europe. Unfortunately, there are no reports about the use of UAVs for red deer in South East Europe. Therefore, future research activities for the most accurate counts of stags should include flights in early summer, corresponding to when vegetation growth is still reduced and antler growth is developed. Additionally, camera traps and other methodsshould be used to validate the data obtained on the number of game species by UAV. The application of this method to large, free-ranging populations of red deer in West Balkan countries needs to be validated , and hunting managers would need to consider aspects such as sampling design, species identification, counting biases and also cost implications. UAVs technology should be tested in the West Balkans and a first stept would be drafting a guide for the estimation of red deer population density with detailed instructions. All these activities require time, persistence and of course the unity of all stakeholders, which currently is not easy to manage.

The diverse geographical areas of red deer habitats in PE Vojvodinasume should be kept in mind [19, 20]. Generally, the average elevation in Province Vojvodina is 110 m, with minimum elevation of 66 m and where the Gudurica peak on the Vršac Mountains, is the highest peak in Vojvodina, at an altitude of 641 m above sea level. But the main challenge for use of UAV is how to see, recognise and record red deer animals through the dense tree tops (mainly penduculate oak forests as well as black poplar and willow varieties) on the banks of Danube and Sava rivers. In order to solve these problem, we would plan to count game during the vegetation period when the leaves fall from the trees, that is, during the period of the first frosts (from beginning of November) until the end of March of the following year. UAV pilot studies should coincide with the prescribed terms for counting game in March.

Acknowledgments

This research was funded by the Ministry of Education, Science and Technological development of Serbia on the basis of the contracts for the realization and financing of scientific research work in 2024 (The Contract No. 451-03-65/2024-03/ 200117).

References

[1] J. P. Jones, G. P. Asner, S. H. Butchart, K. U. Karanth, The 'why','what'and 'how'of monitoring for conservation, Key topics in conservation biology 2 (2013) 327–343.

[2] C. Mitchell, A. D. Fox, J. Harradine, I. Clausager, Measures of annual breeding success amongst eurasian wigeon anas penelope, Bird Study 55 (2008) 43–51.

[3] J. Kahlert, A. D. Fox, H. Heldbjerg, T. Asferg, P. Sunde, Functional responses of human hunters to their prey—why harvest statistics may not always reflect changes in prey population abundance, Wildlife biology 21 (2015) 294–302.

[4] T. Christensen, L. Haugaard, DÅvildt i danmark – status for bestand og udbytte 2017, https://dce.au.dk/fileadmin/dce.au.dk/Udgivelser/Notater_2017/DAAVILDT_I_DANMARK.pdf, 2017.

[5] C. C. Webbon, P. J. Baker, S. Harris, Faecal density counts for monitoring changes in red fox numbers in rural britain, Journal of Applied Ecology 41 (2004) 768–779.

[6] P. Aubry, D. Pontier, J. Aubineau, F. Berger, Y. Léonard, B. Mauvy, S. Marchandeau, Monitoring population size of mammals using a spotlight-count-based abundance index: How to relate the number of counts to the precision?, Ecological indicators 18 (2012) 599–607.
[7] F. P. Princee, Exploring studbooks for wildlife management and conservation, volume 17, Springer, 2016.
[8] Z. J. Delisle, E. A. Flaherty, M. R. Nobbe, C. M. Wzientek, R. K. Swihart, Next-generation camera trapping: systematic review of historic trends suggests keys to expanded research applications in ecology and conservation, Frontiers in Ecology and Evolution 9 (2021) 617996.
[9] B. Ingberman, R. Fusco-Costa, E. L. de Araujo Monteiro-Filho, Population survey and demographic features of a coastal island population of alouatta clamitans in atlantic forest, southeastern brazil, International journal of primatology 30 (2009) 1–14.
[10] R. Kays, J. Sheppard, K. Mclean, C. Welch, C. Paunescu, V. Wang, G. Kravit, M. Crofoot, Hot monkey, cold reality: surveying rainforest canopy mammals using drone-mounted thermal infrared sensors, International journal of remote sensing 40 (2019) 407–419.
[11] M. Garel, C. Bonenfant, J.-L. Hamann, F. Klein, J.-M. Gaillard, Are abundance indices derived from spotlight counts reliable to monitor red deer cervus elaphus populations?, Wildlife Biology 16 (2010) 77–84.
[12] L. Corlatti, A. Gugiatti, L. Pedrotti, Spring spotlight counts provide reliable indices to track changes in population size of mountain-dwelling red deer cervus elaphus, Wildlife Biology 22 (2016) 268–276.
[13] C. Ebert, J. Sandrini, B. Welter, B. Thiele, U. Hohmann, Estimating red deer (cervus elaphus) population size based on non-invasive genetic sampling, European Journal of Wildlife Research 67 (2021) 27.
[14] S. P. Davis, Evaluating the use of drones to estimate deer density and count wildlife trails in bath nature preserve, Ohio, Master's thesis, University of Akron, 2021.
[15] S. M. S. M. Daud, M. Y. P. M. Yusof, C. C. Heo, L. S. Khoo, M. K. C. Singh, M. S. Mahmood, H. Nawawi, Applications of drone in disaster management: A scoping review, Science & Justice 62 (2022) 30–42.
[16] S. Mladenović, Sistem monitoringa populacija jelenske divljači u Srbiji, Ph.D. thesis, University of Belgrad, 2022.
[17] Statistical Office of the Republic of Serbia, Bulletin forestry in the republic of serbia, belgrade, no. 660 (2024).
[18] R. Z., Hunting for 3rd and 4th grade forestry school (in Serbian), Institute for textbook publishing and teaching aids, 2006.
[19] F. Zabel, M. A. Findlay, P. J. White, Assessment of the accuracy of counting large ungulate species (red deer cervus elaphus) with uav-mounted thermal infrared cameras during night flights, Wildlife Biology 2023 (2023) e01071.
[20] H. L. Larsen, K. Møller-Lassesen, E. M. E. Enevoldsen, S. B. Madsen, M. T. Obsen, P. Povlsen, D. Bruhn, C. Pertoldi, S. Pagh, Drone with mounted thermal infrared cameras for monitoring terrestrial mammals, Drones 7 (2023) 680.
[21] W. Ansell, Standardisation of field data on mammals, African Zoology 1 (1965) 97–113.
[22] W. Bresiński, Grouping tendencies in roe deer under agrocenosis conditions, Acta theriologica 27 (1982) 427–447.
[23] T. Y. Ito, A. Miyazaki, L. A. Koyama, K. Kamada, D. Nagamatsu, Antler detection from the sky: deer sex ratio monitoring using drone-mounted thermal infrared sensors, Wildlife Biology 2022 (2022) e01034.
[24] A. Jarnemo, G. Jansson, J. Månsson, Temporal variations in activity patterns during rut–implications for survey techniques of red deer, cervus elaphus, Wildlife Research 44 (2017) 106–113.
[25] E. Bennitt, H. L. Bartlam-Brooks, T. Y. Hubel, A. M. Wilson, Terrestrial mammalian wildlife responses to unmanned aerial systems approaches, Scientific reports 9 (2019) 2142.