Balkan Journal of Wildlife Research

2015, vol.2, iss. 1, pp. 1-8
ISSN: 2335-0113

Original scientific paper UDC: 639.1.058

DOI: 10.15679/bjwr.v2i1.23

CAN THE SCOPE OF POACHING BE PREDICTED ON THE BASIS OF THE EXISTING PARAMETERS?

Lavadinović V.M. [1] *Popović Z.,* [2] *Ranković N.,*[1] *Radosavljević A.*[3]

Abstract: Serbia is characterized by favorable natural conditions for the management of game, whose abundance is unsatisfactory. One of the reasons for that is poaching as a harmful activity that directly affects the abundance of the main hunting game species. Although many domestic experts and researchers agree that poaching has a significant negative impact on the management of hunting game, to this detrimental effect is not given adequate attention. That is why the aim of this study is to draw the attention of stakeholders to this problem. The study tests the possibility of building a statistical model that can be used to predict the volume of poaching. On the basis of 13 variables analyzed in 129 hunting grounds, the results indicate that it is possible to predict the extent of poaching using the power regression model with three variables and a $R^2 = 0.23$ coefficient of determination.

Key words: poaching, hunting grounds, predictions, Serbia

Introduction

Thanks to favorable climatic and orographic factors, the Republic of Serbia is a habitat to over 39% of the species of plants, 51% of fish, 49% of reptiles and amphibians, 67% of mammals and 74% of bird species that can be found on the European continent (Biodiversity Strategy of the Republic of Serbia for the 2011-2018 period, 2011). The high biodiversity represents a great potential for game management, since the majority of major European game species are widespread in Serbia (Šelmić et al., 2001). Despite favorable natural resources the abundance of game is not at a satisfactory level. This statement can be corroborated by a comparison between the abundance of game in Austria and Serbia (Table 1). Both countries have approximately the same total area, population and hunting area. However, Austria is leading over Serbia in the number of hunters and forest cover (FACE, 2002, the Government of the Republic of Serbia, 2004), while Serbia has more favorable habitats for game management. The difference in game abundance is drastic, as a much larger number of individuals are shot in Austria than in Serbia. This comparison indicates an unsatisfactory abundance of game in Serbia, also agreed upon by Šelmić et al., (2001).

The current abundance of game is the result of the impact of several negative influences, including poaching. Although scholars and researchers, both from Serbia and the neighboring countries are aware of the negative effects of this phenomenon (Ranković & Popović, 2002, Popović et al., 2003; Popović et al., 2004; Vapa et al., 2006; Valchev et al. 2006; Papaioannou & Kati, 2007), this problem is not given adequate attention in the scientific community of Serbia. Poaching is not specific only to the area of the Balkan Peninsula and its hunting sector, but also occurs in other countries or industries (Byers & Noonburg, 2007; Zabel & Holm-Müller, 2008). Several studies devoted their attention to this issue in order to resolve it (Manel et al., 2002; Rowcliffe et al., 2004; Webb & Haines, 2012).

[1] Vukan Lavadinocvić, MSc, teaching assistant, Nenad Raknović, University of Belgrade, Faculty of Forestry Kneza Višeslava 1, 11030 Belgrade, Serbia
[2]Zoran Popović, PhD, full professor University of Belgrade, Faculty of Agriculture, Nemanjina 6, 11080 Belgrade, Serbia
[3] Aleksandar Radosavljević, Directorate of Forestry of Ministry of agriculture and environmental protection, Omladinskih brigada 1, 11070 Belgrade, Serbia

Table 1. Abundance and hunters' bag for several game species in Serbia and Austria (source: 1- FACE, 2002; 2-Zentralstelle Österreichischer Landesjagdverbände, 2003; 3- Statistical yearbook, 2010)

Game	**Serbia (2009)** [3]		**Austria**[1,2]	
	Population abundance	**Hunters bag**	**Hunters bag (1998)**[1]	**Hunters bag (no date)**[2]
Red deer (*Cervus elaphus*)	6,216	757	45,000	40,000
Roe deer (*Capreolus capreolus*)	111,000	8,000	260,000	240,000
Chamois (*Rupicapra rupicapra*)	832	35	25,000	25,000
Wild boar (*Sus scrofa*)	17,475	5,811	25,000	25,000
Brown hare (*Lepus europaeus*)	606,000	103,000	200,000	180,000
Pheasant (*Phasianus colchicus*)	403,000	173,000	200,000	200,000

This research deals with defining the factors affecting the presence of illegal activities in the hunting sector of Serbia, as an incentive to intensify work on the solving of this problem. The aim of this research is to identify the number and intensity of factors affecting the amount of reported cases of poaching that could serve as the basis for predicting the extent of illegal activities in the hunting area.

Material and Methods

This paper builds on a research of a group of authors (Lavadinović et al., 2012), whose statistical sample was enriched with 34 hunting grounds. A total of 129 hunting grounds, accounting for about 36% of the total number of hunting grounds in the Republic of Serbia, were analyzed in this study for the hunting year 2011/12. All the data used were obtained from charges submitted by the hunting grounds to the competent ministry in accordance with the legal obligation of forming the central database. The data were collected in central Serbia, while the state of the hunting grounds in the autonomous provinces of Vojvodina and Kosovo and Metohija is not included in this survey.

Hunters' fellowships manage about 110 hunting grounds, accounting for the majority of users in the analyzed hunting grounds. The State Enterprise "Srbijašume" is the second most important user managing 17 hunting grounds, while the State Enterprises "Borjak" and National Park "Tara" manage one hunting ground each (Figure 1).

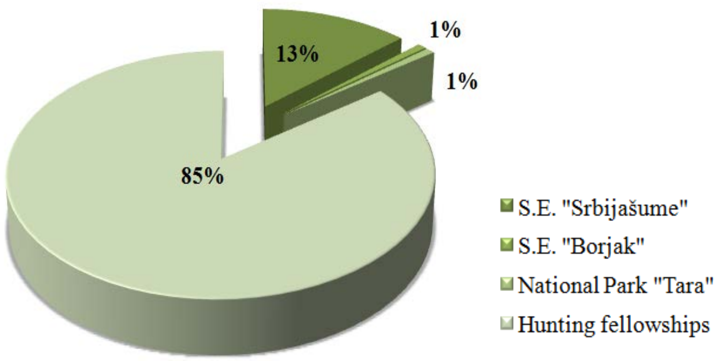

Figure 1. Structure of analyzed hunting grounds by users

The total areas of the analyzed hunting grounds range from 117 ha for the fenced hunting ground "Trešnja" to 105.856 hectares for the hunting ground "Caričin grad", while the average area of a hunting ground reaches 32.489 ha. The total area of these hunting grounds is 4,191,116 ha, of which hunting areas occupy 3,576,804 ha, i.e. 85%. Most of the hunting grounds are open and belong to the hilly-mountainous type.

For the purpose of this study fourteen parameters were identified and analyzed in each hunting ground. The number of all charges per hunting ground for the five-year period from the hunting year 2006/07 to 2011/12 was used as a dependent variable. The number of charges per hunting ground served as an indicator of the scope of poaching. The other 13 parameters were examined as independent variables, and their impact on the number of charges per hunting ground was analyzed.

The following parameters were used as independent variables: 1. total area of a hunting ground; 2. hunting area of a hunting ground; 3. non-hunting area of a hunting ground; 4. the number of professional staff employed; 5.the number of gamekeepers employed; 6. total number of employees; 7. the number of hunting fellowships' members per hunting ground; 8. roebuck abundance; 9. roe deer abundance; 10.wild boar abundance; 11. total wild boar population abundance; 12. brown hare abundance and 13. pheasant abundance. For the species of large game the abundance of males as trophy individuals was also taken into account. The data collected were used for modeling using regression and correlation analyses. Linear, exponential and power functional forms were used as part of these analyses, while the assessment of the obtained regressions included coefficients of determination, correlation, t -statistical parameters and the F-test for the correlation coefficient.

Results

The paper Lavadinović et al. (2012) identified the normal distribution of a hunting ground, fulfilling this as a condition for further statistical analysis. The first phase of this research is based on the analysis of individual variables and their impact on the number of charges per hunting ground. In total, 13 variables were identified and their impacts were observed through regression curves which have linear, exponential and power forms.

In the case of linear regression out of the 13 variables analyzed, only 4 regression models stand out as statistically significant. Parameters such as 1. total area of a hunting ground, 2. hunting area of a hunting ground, 3. non-hunting area of a hunting ground and 4. brown hare abundance, have an impact on the volume of charges per hunting ground (Table 2).

The equation that used the total area of a hunting ground as a variable proved to be the most accurate of all linear models with one variable for predicting the number of charges per hunting ground, since it has the highest values of the coefficients of correlation (R) and determination (R^2), and the lowest statistical error of below 1%. However, analyses of the exponential and regression models with one variable were conducted due to the low values of R and R^2.

Table 2. Results of linear models with one variable

Parameter	Formula	R	R^2	F	F sig.
Up*	y=3.583+0.000178*x (1.51) (2.96)	0.254	0.065	8.762	0.004
Lp**	y=4.289+0.000183*x (1.87) (2.73)	0.236	0.056	7.477	0.007
Np***	y=6.157+0.000675*x (3.16) (2.30)	0.200	0.040	5.295	0.023
Z****	y=4.802+0.002795*x (2.14) (2.55)	0.221	0.049	6.507	0.012

* - Total area of a hunting ground; ** - Hunting area of a hunting ground;
*** - Non-hunting area of a hunting ground; **** - Hare abundance

Table 3. Results of the exponential models with one variable
(numbers in brackets are t-statistics of parameters)

Parameter	Formula	R	R^2	F	F sig.
Total area	$y=2.859 * 1.000024^x$ (5.02) (4.35)	0.407	0.166	18.920	0.000
Hunting area	$y=3.053 * 1.000026^x$ (5.50) (4.18)	0.394	0.155	17.439	0.000
Non-hunting area	$y=4.442 * 1.000064^x$ (8.43) (2.49)	0.248	0.061	6.213	0.014
Number of gamekeepers	$y=3.131 * 1.567^x$ (4.19) (2.74)	0.271	0.073	7.521	0.007
Number of employees	$y=2.799 * 1.342^x$ (2.78) (2.23)	0.223	0.050	4.988	0.028
Roe buck abundance	$y=4.792 * 1.002^x$ (8.91) (1.94)	0.195	0.038	3.769	0.055
Roe deer abundance	$y=4.676 * 1.0001^x$ (8.83) (2.16)	0.216	0.047	4.662	0.033
Wild boar abundance	$y=4.438 * 1.014^x$ (8.74) (2.68)	0.265	0.070	7.168	0.009
Total wild boar abundance	$y=4.358 * 1.0047^x$ (7.88) (2.39)	0.239	0.057	5.736	0.019
Brown hare abundance	$y=3.886 * 1.000264^x$ (6.47) (2.65)	0.262	0.069	7.018	0.009

The exponential models with one unknown proved to be better than the linear ones, as 10 out of 13 are statistically reliable (Table 3). Despite the difference in the number of statistically reliable models, both exponential regression and the linear one were used to identify the total area of a hunting ground as the most reliable parameter for predicting the number of charges per hunting ground

Table 4. Results of the power regression with a single variable
(numbers in brackets are t-statistics of parameters)

Parameter	Formula	R	R^2	F	F sig.
Total area	$y=0.0211*x^{0.561}$ (-2.96) (4.36)	0.408	0.167	19.004	0.000
Hunting area	$y=0.0246*x^{0.556}$ (-2.86) (4.27)	0.417	0.161	18.248	0.000
Non-hunting area	$y=0.3403*x^{0.359}$ (-1.28) (3.46)	0.334	0.112	11.964	0.000
Number of gamekeepers	$y=4.615*x^{0.939}$ (10.34) (3.26)	0.317	0.100	10.600	0.002
Number of employees	$y=2.362*x^{1.027}$ (2.18) (2.53)	0.251	0.063	6.385	0.013
Number of hunting fellowships' members	$y=2.243*x^{0.199}$ (2.37) (3.13)	0.306	0.094	9.831	0.002
Wild boar abundance	$y=3.816*x^{0.185}$ (4.99) (1.97)	0.198	0.039	3.881	0.052
Brown hare abundance	$y=2.659*x^{0.122}$ (2.12) (1.87)	0.189	0.036	3.505	0.064

. In addition to the total area of a hunting ground, hunting area proved to be the second most reliable parameter in the exponential models. An analysis using power regression was used to identify 8 statistically significant models of the 13 parameters analyzed.

Out of 6 parameters related to game abundance in a hunting ground, only two have a statistically significant impact on the number of charges in a hunting ground, and those are the ones referring to hare abundance and wild boar abundance. On the other hand, all three parameters related to the area of a hunting ground have proved to be statistically significant (Table 4).
As in previous cases, the total area of a hunting ground proved to be the most reliable indicator in power regression models. Taking into account the results of all linear, exponential and level regressions with one variable that were conducted, it was discovered that in the power regression the parameter total area of a hunting ground provides the best results (Table 4). Correlation coefficient is 0.41 in this case, while the coefficient of determination reaches the value of 0.17.
In order to obtain a regression model of the highest quality for predicting the extent of poaching at a sufficiently exact level, regression models with more variables were also analyzed. Equations with a number of different parameters were developed within linear, exponential and power regressions in order to find a suitable model, which would provide the highest values of the coefficients of correlation and determination. The model which proved to be the best among the models of linear regression under this criterion was the one using the parameters: total area of a hunting ground (x_1) wild boar population abundance (x_2), hare abundance (x_3) and roe buck abundance (x_4). The equation for this model is as follows:

$$y=4.008+0.000262*x_1+-0.03685*x_2+-0.02011*x_3+0.001643*x_4$$
$$(2.37) \quad (-1.26) \quad (-1.79) \quad (1.00)$$

$$R = 0.37 \qquad R^2 = 0.11 \qquad F = 3.971^{+0.0046}$$

Nevertheless, this model cannot be considered reliable, because the coefficients of parameters referring to game abundance (x_1, x_2, x_3 and x_4) are not statistically significant. In the case of exponential regression the best model which was singled out is the one based on four parameters, including total area of a hunting ground (x_1), the number of gamekeepers employed in a hunting ground (x_2), roe deer abundance(x_3) and wild boar population abundance (x_4). This model is presented below:

$$\ln y=a+b*x_1+c*x_2+d*x_3+e*x_4$$
$$(2.43) \quad (0.85) \quad (0.67) \quad (-0.25)$$

$$y=2.40*1.00^{x1}*1.17^{x2}*1.00^{x3}*0.99^{x4}$$

$$R = 0.42 \qquad R^2 = 0.18 \qquad F = 4.981^{+0.0011}$$

The eexponential regression model revealed better results than the linear one, but cannot be considered reliable, because none of the parameters except total area of a hunting ground were statistically significant. The best model among power regression models uses four parameters, including total area of a hunting ground (x_1), the number of gamekeepers employed in the hunting ground (x_2), the number of members in the local hunting fellowship (x_3) and roe deer abundance (x_4). This equation is as follows:

$$In\ y= In\ a+b*In\ x_1+c*In\ x_2+d*In\ x_3+e\ In\ x_4$$
$$(2.17) \quad (2.15) \quad (1.70) \quad (-0.94)$$

$$y=0.086*x_1^{1.459}*x_2^{1.903}+x_3^{1.133}\ x_4^{0.929}$$

$$R = 0.48 \qquad R^2 = 0.23 \qquad F = 6.825^{+0.0000}$$

In this equation, the first two parameters are statistically significant. The third parameter can be tolerated, while roe deer abundance tends to be an unreliable variable.

Discussion

Although it is not the only cause for low game abundance, poaching is a serious problem in the hunting sector of Serbia. Therefore, the aim of this study was to examine the possibility of predicting its volume using the parameters that can easily be traced in a hunting ground. The number of charges per hunting ground used to be employed as an indicator of the scale poaching. However, this method is certainly not reliable, because it includes only an analysis of the extent of poaching registered through charges. There are probably examples of poaching that are not observed or registered by the competent authorities and the hunting guard service, which directly affects the reliability of this model. However, this risk was taken into account at the beginning of this research aimed highlighting the problem of poaching in the Republic of Serbia. This paper represents a preliminary research on a sample of 129 hunting grounds selected on the basis of data availability and testing of models, and not as a sample that is statistically significant for Serbia. On the basis of the coefficients of correlation and determination, the power regression model with 3 variables proved to be the best of all the analyzed models with one or more variables. Models with a larger number of variables are characterized by an increased multicollinearity error and therefore the variables that interfere with the multiregression model with this kind of errors were eliminated. The research results identified total area of a hunting ground, the number of gamekeepers and the number of members of the hunters' association as the most reliable parameters to predict the extent of poaching in a hunting ground. These findings are consistent with the study results of Lavadinović et al., (2012), which served as the basis for this research.

The parameter total area of a hunting ground proved to be the most important factor, both in the individual and multiparametric models. A greater hunting area leads to more extensive poaching, which is probably due to a greater area based on a smaller scale of activities that would deter poachers from approaching the hunting ground. Another reason could be the fact that larger hunting grounds border with more settlements, which makes the control of poachers' activities more difficult. With an increasing number of gamekeepers, there is also an increase in the number of charges, which is not associated with an increase in the scope of poaching, but with a more efficient control of the hunting ground and the prevention of illegal hunting activities. The number of members of the hunters' association is the third parameter that affects an increase in charges.

A larger number of members results in more charges, because members of these associations probably help gamekeepers in the revealing of illegal activities in a hunting ground. In addition to the parameters used by Lavadinović et al., (2012), this study also included the abundance of different game species in the analysis, as well as the abundance of the males of trophy species. The analyses have shown that these parameters play no role, indicating that the extent of poaching does not depend on the type of game managed in a hunting ground. Hence, it was concluded that poachers in Serbia are opportunistic and that trophies are of no special importance to them, i.e. that they have a major interest in the game meat. Game meat improves the nutrition of poachers and their families thus supporting the family budget threatened by the poor financial circumstances in the country. Similar observations were recorded by Ndibalema and Songorwa (2008) in their research on African poachers. This reason for poaching differs from the reasons for poaching in other European countries, where this activity is focused on large carnivores representing competition to people (Sindičić, 2009; Caniglia et al., 2010).

The best regression model in this paper has a 0.23 coefficient of determination. The results of this study also indicate the presence of factors unidentified by this research, whose impact has a far greater significance for the prediction of the volume of poaching than the ones used in this study. For this reason, that limit has to be taken into account when using this model. It must also be noted that the precision of this model is based on a reliable keeping of poaching records in a hunting ground. However, this model has to be used in accordance with its restrictive options.

This study represents the initial step in the analysis of the phenomenon of poaching in Serbia which causes severe damage to its hunting sector. Surprisingly, the scientific literature on this illegal activity is rare and unfocused on finding a solution that could solve this problem. To this end, more has to be done to motivate the scientific community to take an interest in this problem. At the same time, more accurate and elaborate research has to be conducted as a contribution to a better understanding of this problem.

Acknowledgments

This paper was realized as a part of the project Establishment of Wood Plantations Intended for Afforestation of Serbia (31041) financed by the Ministry of Education and Science of the Republic of Serbia within the framework Technological development for the period 2011-2014.

Data analysis would not be possible without a contribution of Marko Kelember, who helped with the data input.

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Received: 30.06.2015.
Accepted: 18.09.2015.

Lavadinović V.M. Popović Z., 2 Ranković N., Radosavljević A. (2015) Can the scope of poaching be predicted on the basis of the existing parameters?, *Balkan Journal of Wildlife Research*, 2(2), pp. 1-8.