LANDSCAPE FACTORS INFLUENCING ROE DEER ROADKILL FREQUENCIES ON THE M3 HIGHWAY OF HUNGARY

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ABSTRACT
Roe deer (*Capreolus capreolus*) is one of the most dangerous one for traveller's safety amongst the regularly occurring, conflicting wildlife species on the Hungarian highways. Severity of roe deer collisions might be minimized by manipulating its influencing factors, but these factors are firstly to identify and recognize. In this study we investigated the landscape features which remain totally or almost unaltered on a larger scale of time. Our purpose was to evaluate how the easily, and free-of charge-accessible spatial databases may be used to derive landscape factors by predicting spatial patterns of roe deer roadkills on the Hungarian M3 highway. The result of the generalized linear model suggested that, despite the fact that six of the implemented variables were considered to be highly significant, none of them had a remarkable impact on the roadkills' spatial pattern, since their coefficient (B-value) were in each cases almost equal to zero. We concluded that existing landscape databases which had been used in this work are not suitable to support roadecology-decisions alone, but may have a supplementary role. This consequence put the weight to the other possible predicting factors (such as traffic-, and human related factors), and emphasizes the importance of the proper mitigation measures, and well maintained protective fencing, taking into special account that temporary dysfunctions of the protective fencing may lead to occasional – and so unpredictable – wildlife occurrences on highways.

Keywords: roe deer-vehicle collision, roadkill patterns, Network Kernel Density Estimation, highway, road ecology

INTRODUCTION

Wildlife Vehicle Collisions (WVCs) cause annually more than 30 million forints damage to property in average on the Hungarian M3 highway, officially. This number in 2010 exceeded 54 million forints (according to police data on WVCs). These numbers are made worse by light, and serious personal injuries, and sometimes, deaths.

For practical point of view roe deer (Capreolus capreolus) is one of the most dangerous one for traveller's safety of the regularly occurring, conflicting wildlife species on the Hungarian highways. Its reason is, first of all, the relative big body mass. Additionally roe deer's long legs put most of its body to an almost equal level to most of the car's windscreens. Thus, in case of collision the probability for any kind of personal injury obviously increases.

Severity of roe deer collisions might be minimized by manipulating its influencing factors, so these factors are firstly to identify and recognize. In pursuit of this effort many scientific studies and synthesising work were done so far (PUTMAN, 1997; TROMBULAK AND FRISSELL, 2000; FORMAN, 2003; IUELL ET AL., 2003; IUELL, 2007; etc.). Influencing factors can be classified into different groups such as: temporal, traffic-related, landscape, weather, etc. (COLINO-RABANAL ET

AL., 2011; CARVALHO AND MIRA, 2010; GRILO ET AL., 2009; RAMP ET AL., 2005; SEILER, 2005).

Within this study we focus on the landscape features which remain totally or almost unaltered on a larger scale of time, too, such as settlements range, forested areas' range, hydrological features of the surface, etc.). Our purpose was to evaluate how the easily, and free-of charge-accessible spatial databases may be used to derive landscape factors by predicting spatial patterns of roe deer roadkills on the Hungarian M3 highway. Permanent wildlife-relevant features are expected to remarkably influence spatial patterns of roadkills.

MATERIAL AND METHOD

Study area

Our study area was the section between the 10+120[th] and the 174+700[th] kilometres of the Hungarian M3 highway *(Figure 1.)*. The M3 is one of the most important motorways of Hungary, a part of the so called "V[th]" or "Trieste – Venice – Ljubljana – Maribor – Budapest – Uzhhorod – Lviv - Kiev" Pan European transition corridor so it has a remarkable role in the East-West transportation. The first 70 kilometres of it was already built in 1983. The highway reached Füzesabony at the 114[th] kilometre in 1998 and Polgár at the 175[th] kilometre in the year 2002. The approximate daily traffic volume on this section exceeds 20000 vehicles per day. There are two traffic lanes, auxiliary lanes and one hard shoulder (emergency lane), as well; the speed limit is 130 km/hour.

The highway is located primarily along the frontier of the Great Hungarian Plain and the Northern Medium Mountains of Hungary. In the first part of the M3 hilly, whilst on the second part plain landscape dominates. Beside two forested area on the Eastern and the Western side of Gödöllő the adjacent of the road is mainly ruled by agricultural fields.

On the section was built before 1983 there are not any wildlife passages. Between the 80[th] and the 175[th] kilometres 6 different wildlife underpasses are located, but not any overpasses. According to the current Hungarian standards the whole M3 is surrounded by protective fencing (MAGYAR ÚTÜGYI TÁRSASÁG, 2007).

Spatial road data are deriving from the National Road Databank and were provided by the Coordination Centre for Transport Development of Hungary.

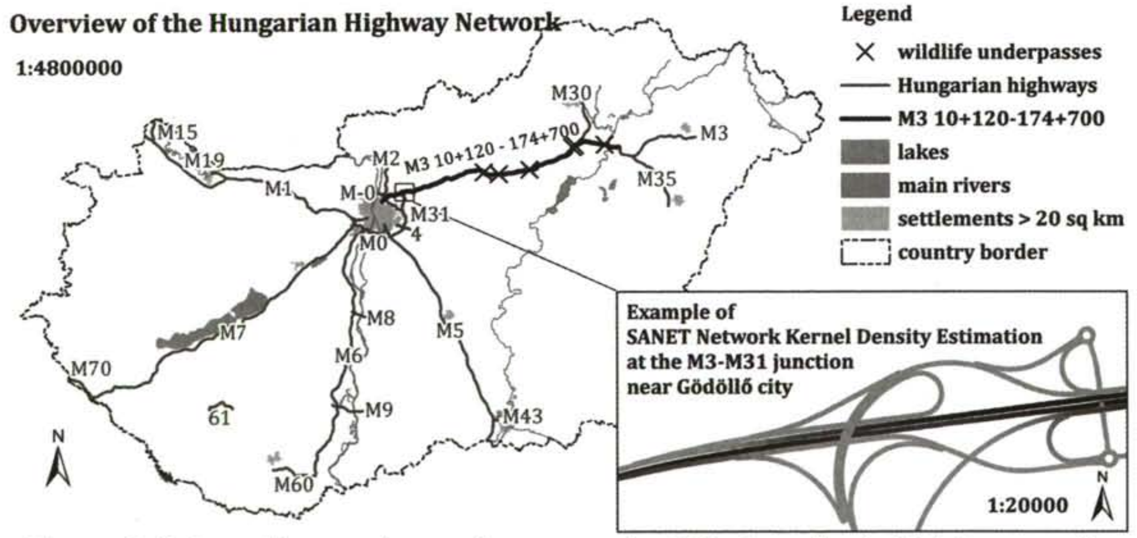

Figure 1. Schematic overview and an example of the investigated highway section

Data acquisition and analysis

Roe deer roadkill data from 2003 till 2011 for the respective highway section were taken from the State Motorway Management Ltd.'s database. Landscape data are derived from the Corinne Land Cover 2006 (CLC 2006), and the National GIS Database, (OTAB 1, 1:100000).
The common GIS environment for the data handling and analyses was an ArcGIS 9.3 platform. Statistical calculations along a network such as river line or transportation infrastructure need slightly different approach than 2-dimensional, planar calculations. OKABE ET AL. (2006) improved a statistical application called SANET which provides more appropriate outputs in a network environment than standard planar statistics would do so. We used the SANET version 4 for the following network-statistical tasks. To investigate the degree to which clustering occurs within the roadkill dataset the network K-function (OKABE AND YAMADA, 2001) – which is an adaptation of Ripley's K-function – was calculated with 99 times of Monte Carlo simulations in order to ensure the statistical significance of the observed distribution. Network Kernel Density Estimation with discontinuous equal split method was used to measure the average roadkill density for each 50 metres. Bandwidth was set to 750 metres (so NKDE values apply to 1.5 km) road length according to the fact that roe deer individuals may have the chance for certain migration in short time along the highway within the fences. SANET's distance between base points and non-base points' method were used several times, as well. 3000 points were placed randomly along the network with a minimum distance of 100m between each other (mean: 111±25.8 SD). On each of these sample points all of the following list's variables' values were calculated in order to get a representative sample for the whole range of the road network. The list of the investigated variables is shown in *Table 1.*

Table 1. List of the investigated variables with definitions and descriptive information

variable name	definition	descriptive
dependent variable		
NKDE750	NKDE [roadkill density per 1.5 km]	0.22±0.417; min: 0.000; max: 4.714
explanatory variables		
D_VEGTOL	distance to nearest access road joint [m]	2927±1955.3; min: 1; max: 9208
D_ALULJ	distance to nearest under-crossing structure [m]	1273±1119.3; min: 0; max: 6250
D_ FELULJ	distance to nearest over-crossing structure [m]	695±515.5; min: 0; max: 3036
D_VADATJ	distance to nearest wildlife underpass [m]	20348±21638.9; min: 9; max: 70875
D_ERDO	distance to nearest forest edge [m]	619±521.7; min: 0; max: 3022
D_TELEP	distance to nearest settlement's edge [m]	1345±817; min: 0; max: 4540
A_RI500	α-Richness*	min: 1; max: 6
SHAD500	Shannon's Diversity Index*	0.46+-0.415; min: 0; max: 1.544
%ERDO_500	proportion of forested areas* [%]	7.6+-20.98; min: 0; max: 100
%TERM_500	proportion of natural like areas* [%]	2.2+-6.52; min: 0; max: 43.2
%NYIT_500	proportion of opened areas* [%]	75.7+-32.41; min: 0; max: 100
VIZ_500	water presence/absence*	1:"yes" or 2: „no"
A_RI2500	α Richness**	min: 1; max: 12
SHAD2500	Shannon's Diversity Index**	0.97+-0.475; min: 0; max: 1.952
%ERDO_2500	proportion of forested areas ** [%]	6.8+-14.64; min: 0; max: 76.9
%TERM_2500	proportion of natural like areas** [%]	3.4+-3.31; min: 0; max: 14.9
%NYIT_2500	proportion of opened areas** [%]	72.2+-23; min: 6.7; max: 100
VIZ_2500	water presence/absence**	1:"yes" or 2: „no"

*within 500 m radius, **within 2500m radius

Distances were measured by Euclidean distance method. α-Richness and Shannon's Diversity Indices were calculated by using Diversity Calculator by (BUJA, 2009) based on each CLC categories.

The class "forested areas" (%ERDO_500; %ERDO_2500) contains CLC categories of 3.1.1: broad-leaved forest; 3.1.2: coniferous forest; 3.1.3: mixed forest. Into the class of "natural-like areas" (%TERM_500; %TERM_2500) belong CLC 2.4.3: land principally occupied by agriculture, with significant areas of natural vegetation; 3.2.1: natural grasslands; 3.2.4: transitional woodland-shrub; and 4.1.1: inland marshes. "Opened areas" contain CLC 2.3.1: pastures, and 2.1.1: non-irrigated arable land. Water may indicate watercourses and water bodies, equally.

The two distance threshold values (500m and 2500m) reveal two different background hypotheses: taking into account the landscape parameters within 500m would mean that we expect individuals that were roadkilled at their normal daily activity (500m radius derives from the area of an average spring-autumn home range size), since the landscape parameters within 2500m must be considered in case of supposition of long-distance moving, exploring, dispersing individuals (CSÁNYI ET AL., 2009). Spearman's nonparametric correlation was run to identify the correlations between any of the explanatory variables. Effects on explanatory variables on the response were evaluated by a generalized linear model with 1.5 parameter tweede distribution with "log" link function. Data management and the statistical analyses were carried out by the software PASW 18.0 (SPSS Inc.), the R statistical package, and Microsoft Office 2007.

RESULTS

Between 2003 and 2011 there were 115 roe deer carcasses found on the M3 highway from its beginning till the 175th kilometre. According to the Network K-function curves the distribution of these roadkills' locations along the road network show significantly clustered pattern below a distance of approximately 80km *(Figure 2.)*.

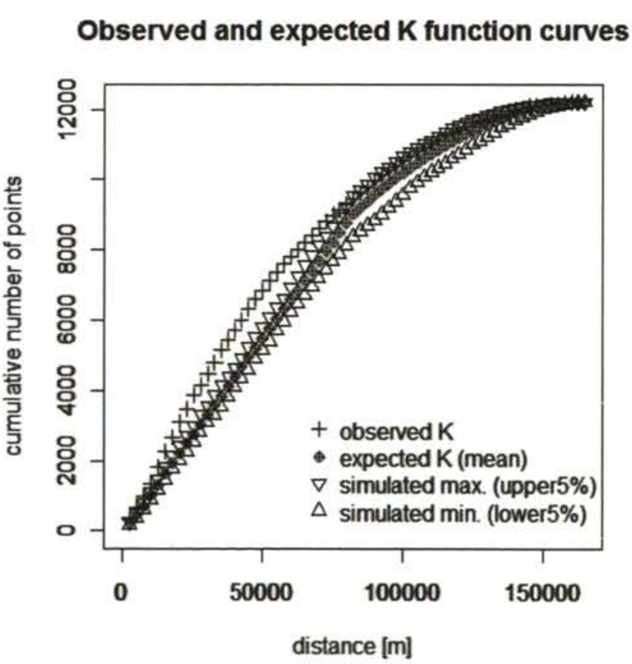

Figure 2. Network K-function curves showing clustered trend in the roadkill dataset

Table 2. Goodnes of fit

	value	value/df
Deviance*	5128.981	1.714
Scaled Deviance*	2506.165	
Pearson Chi-Sq.*	5830.408	1.948
Scaled Pearson Chi-Sq.*	2848.902	
Log Likelihood*	-2440.790	
Akaike's Information Criterion (AIC)*	4897.581	
Finite Sample Corr. AIC (AICC)*	4897.629	
Bayesian Inform. Criterion (BIC)*	4945.632	
Consistent AIC (CAIC)*	4953.632	

*df: 2993

Dependent Variable: NKDE750

Model: (Intercept), D_VEGTOL, D_VADATJ, D_TELEP, TERM_500, NYIT_500, ERDO_2500

The Spearman's Rho Nonparametric Correlation pointed out a few highly significant ($p<0.01$), strong (correlation coefficient > 0.71) correlation. In these cases, in order to reduce the autocorrelation we excluded one of the variables, respectively: A_RI500, A_RI2500, SHAD500, SHAD2500, %ERDO_500, %NYIT_2500. Furthermore the variable VIZ_500 found to be extremely unbalanced, consequently was not used longer in the model. We run the model with an iteration method, and step by step eliminated the following non-significant variables: %TERM_2500, D_FELULJ, D_ALULJ, D_ERDO, VIZ_2500. The final model is summarized in *Table 2*. The fitted model *(Table 3.)* was significantly differing from the intercept-only model by the Omnibus test (Likelihood Ratio Chi-Square: 139.435; df: 6; $p<0.001$).

Table 3. Parameter estimates

parameter	coefficient (B)	std. error	Wald	df	p
(Intercept)	-1.515	.1865	65.930	1	<0.001
D_VEGTOL	.000	.0000	8.275	1	0.004
D_VADATJ	.000	.0000	25.616	1	<0.001
D_TELEP	.000	.0001	61.583	1	<0.001
TERM_500	.022	.0056	15.949	1	<0.001
NYIT_500	-.008	.0019	19.393	1	<0.001
ERDO_2500	-.022	.0042	28.734	1	<0.001
(scale)	2,047[a]	.0492			

dependent Variable: NKDE750
modell: (Konstanter Term), D_VEGTOL, D_VADATJ, D_TELEP, TERM_500, NYIT_500, ERDO_2500

a. Maximum-Likelihood-Estimatior

CONCLUSIONS

The Network K-functions' curves showed the clustered trend along the road network in the roadkill dataset. The chosen landscape factors, however, found to be highly significant; do not have much predictive power to the spatial patterns of the roadkill hotspots; since their coefficient (B-value) are almost equal to zero. This consequence put the weight to the other factors (such as traffic-, and human related factors), and emphasizes the importance of the protective fencing and the mitigation measures.

In accordance to our study's aim we must conclude that the existing landscape databases which had been used in this work are not suitable to support roadecology-decisions alone, but may have a supplementary role. However, with additional data, existing information might be refined, and so with a synergist contribution to the result.

Results of this work are in line with our earlier suggestions in terms of the highway-management: protective fences, service gates, and crossing structures have always to be well maintained (MARKOLT ET AL., 2009). Temporary dysfunctions (open left service gate, cut fencing) of the fencing may lead to occasional roe deer and other animal's occurrences on the protected side of the highway, and may threat the traffic safety. Accidents and roadkills which are resulted by this reason are not predictable by landscape factors.

Finally an interesting result is that the assumed impact of the 6 existing underpass (as permanent wildlife-relevant features) was not observable. One of its explanations could be that these passes are not functioning well, but this hypothesis needs further investigations.

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