Influence of Selected Environmental Factors on the Value of Kidney Fat Index (KFI) and Carcass Weight of Roe Deer *Capreolus capreolus*

PIOTR CZYŻOWSKI[1], MIROSŁAW KARPIŃSKI[1], DAMIAN ZIELIŃSKI[1*], MAŁGORZATA GOLEMAN[1], KATARZYNA TAJCHMAN[1], BEATA RODZIK[2] AND LESZEK DROZD[1]

[1]*Department of Ethology and Animal Welfare, University of Life Sciences in Lublin, Akademicka 13, 20-950 Lublin, Poland*

[2]*Department of Mathematical Statistics, Institute of Mathematics, University of Maria Curie-Skłodowska, Pl. Curie-Skłodowskiej 1, 20-031 Lublin, Poland*

Corresponding author: Damian Zieliński, Department of Ethology and Animal Welfare, University of Life Sciences in Lublin, Akademicka 13, 20-950 Lublin, Poland, telephone: 48 081 4456889, e-mail: damian.zielinski@up.lublin.pl

Czyżowski, P., Karpiński, M., Zieliński, D., Goleman, M., Tajchman, K., Rodzik, B. and Drozd, L. 2017. Influence of Selected Environmental Factors on the Value of Kidney Fat Index (KFI) and Carcass Weight of Roe Deer *Capreolus capreolus*. *Baltic Forestry* 23(3): 691–697.

Abstract

The aim of this study was to determine the impact of environmental factors (index of agricultural production quality, forest cover rate, forest fragmentation index, the share of different habitat types, and selected meteorological factors) on the value of kidney fat index (KFI) and carcass weight of roe deer *Capreolus capreolus*. The research material consisted of 344 individuals of roe deer *C. capreolus* over the age of 3 years (296 bucks and 48 does). Roe deer for testing were obtained from 15 forest districts in the Lublin region, Poland. The KFI and carcass weight were measured. A multiple regression model was used to assess the impact of a number of environmental factors on the value of KFI in roe deer. The study showed no significant differences in KFI values between bucks and does. Indicators of the body condition of bucks were positively affected by the share of habitats occupied by fresh mixed deciduous forest and the index of agricultural production quality. The share of habitats with fresh coniferous forest and fresh mixed deciduous forest as well as the fragmentation of forests, had a positive influence on the KFI values and carcass weight of does. This study shows that the management of roe deer populations should take into account the impact of landscape structure and habitat quality.

Key words: Roe deer, KFI, carcass weight, individual condition, quality of habitat

Introduction

One of the parameters reflecting the appropriate density of wild ungulates in the hunting zone is the condition of individual animals expressed, among other things, by weight and body size, the quality of trophies, and body fat deposits (Bonino and Bustos 1998, Majzinger 2004, Janiszewski and Kolasa 2007, Karpiński et al. 2008). The measurement of fat reserves surrounding the kidneys in assessing the condition of wild ungulates has been used for more than half a century (Serrano et al. 2008). For the first time an assessment of kidney fat level was proposed by Riney (1955), based on the calculation of kidney fat index (KFI), which is easy to estimate after the death of the animal. Research on energy reserves of Cervidae in Poland has so far focused on red deer (Okarma 1984, Okarma 1991, Bobek et al. 1990, Dzięciołowski et al. 1996, Drozd and Piwniuk 2000), but there are still very few studies relating to the fat reserves of roe deer (Drozd and Gruszecki 2000, Czyżowski et al. 2015). The characteristics describing the condition of an individual can vary by season and depend on the deficiency of nutrients and the physiological state of the body, e.g. pregnancy or parasitic infection (Sams et al. 1998). Therefore, to describe the condition of roe deer, it is justified to use multiple parameters e.g. body weight and size, kidney fat index and femur marrow fat. The individual condition of wild ungulates is directly affected by environmental resources. The better the environmental conditions, the more food is available, which in turn has a positive effect on the quality of the individual's body condition (Gilot-Fromont et al. 2012). The functioning of the populations of large herbivores depends on many environmental factors, primarily on the availability of food, which in turn depends on the composition and structure of plant communities (Augustine and McNaughton 1998). Environmental factors produce a combined effect on the populations of animals, and it is difficult to analyse the impact of a single factor. For this reason, multiple regression analysis was used in this study to assess the impact of environmental factors on populations of roe deer. In the life sciences, multiple regression analysis is a research tool used for the identification of parameters with the strongest impact on the variability population characteristics (Mac Nally 2002). Environmentalists and conservation biologists heavily rely on multiple regression in formulating conclusions on the conditions of distributions or densities of species as a function of landscape elements or specific habitat types (predictor variables) (Loyn 1987, Mason 2013).

The aim of the study was to determine the correlation between the value of kidney fat index (KFI) and carcass weight in roe deer and selected environmental factors such as the index of agricultural production quality, forest cover rate, forest fragmentation index, the share of different habitat types, and selected meteorological factors.

Material and Methods

The research material consisted of 344 individuals of roe deer *Capreolus capreolus* over the age of 3 years (296 bucks and 48 does) harvested by hunters in 2012 to 2015 in accordance with the Rules on the Selection of Game Individuals and Populations in Poland (Annex to Resolution No. 57/2005 of 22 February 2005). Roe deer were harvested throughout the period of the hunting season, which in Poland runs from May 11th to September 30th for bucks and from October 1st to January 15th for does. Animals were eviscerated after the harvest. Every carcass (defined as residue obtained after the removal of internal organs, severed head and limbs in the joints) was weighed in game-handling cold room (with accurate to 0.1 kg), where the veterinarian (second co-author) has estimated age of females on the basis of evaluation of tooth wear (Lochman 1987). In turn, age of males was evaluated by game harvesting committee. Kidneys were dissected and weighed. Then, after the deduction of fat, the kidneys were re-weighed. The KFI was calculated as follows: KFI = weight of fat around the kidneys/weight of kidneys without fat (Riney 1955). Carcasses of roe deer (bucks without heads) were weighed with accuracy to the nearest 0.1 kg. For the purpose of further analysis, the age of individual animals was determined based on the assessed degree of tooth wear (Lochman 1987), which allowed the classification of animals as older than 3 years. Data from measurements were analysed using Statistica 10.0. Since the distributions of the analysed dependent variables (KFI and carcass weight) differed significantly from the normal distribution, the significance of differences between the distributions was assessed with non-parametric rank tests. The U Mann-Whitney rank test (*Z* statistics) was used for comparisons between the two groups. The normality of distributions of the analysed characteristics was evaluated with the Shapiro-Wilk test. The relationship between KFI and carcass weight was analysed based on the calculated Spearman rank correlation coefficient (rs). The effect of the independent variables (environmental factors) on the dependent variables (KFI and carcass weight) was determined using multiple regression analysis. The multiple regression model and a summary of the model are given in the description. Multiple regression analysis was conducted separately for bucks and does.

The following environmental factors for individual forest districts were considered:

- forest cover (%),
- forest fragmentation index (km / km^2) (Czyżowski et al. 2011),
- index of agricultural production quality (pt.): indicator of the quality of agricultural production was calculated by the Institute of Soil Science and Plant Cultivation in Pulawy on the basis of assigning points to the four elements of the natural environment. The sum of those points gives the indexation rate of agricultural production area. Soil, climate, topography and water are evaluated. The higher the total number of points for the assessed area, the higher the quality of agricultural production conditions (Witek et al. 1993),
- share of the main habitat types (12 types specified in management plans for individual Forest Districts: fresh coniferous forest, moist coniferous forest, boggy coniferous forest, fresh mixed coniferous forest, moist mixed coniferous forest, boggy mixed coniferous forest, fresh mixed deciduous forest, moist mixed deciduous forest, boggy mixed deciduous forest, fresh deciduous forest, moist deciduous forest, alder swamp forest),
- meteorological parameters: average monthly temperature in winter months prior to collection of the material, average monthly amount of precipitation (data from Hydrological and Meteorological Station in Radawiec, Lublin Region, Poland).

Roe deer were obtained from 15 forest districts from the Lublin region, Poland. The furthest extended points of the area are as follows: north 52°24'37.46" N, south 50°14'39.58" N, west 21°23'58.11" E and east 24°08'45.25" E. The distance of the study area is 2°009'57.88" from south to north, and 2°44'47.14" from west to east.

Figure 1. Study area

The study area varies in terms of climate, which is classified as moderate transitional in the northern part and sub montane in the southern plains and valleys. The annual amount of precipitation depending on the position of an area above sea level ranges from 500-600 mm in the north, up to 700-800 mm in the south. The average annual temperature for most of the area is about 7.5 °C. The growing period lasts from 208 to 220 days. Forests cover 23% of the area and are characterized by great diversity in terms of their size and species composition. The dominant forest habitats are fresh coniferous forest and fresh mixed deciduous forest (Trampler et al. 1990).

Results

The study revealed significant differences in carcass weight of does in comparison to bucks (Z = -2.060; p = 0.038). However, no significant differences were found in the kidney fat index for bucks in comparison to does (U Mann-Whitney test Z = -0.951; p = 0.342). The analysis of the relationship between the values of KFI and carcass weight demonstrated a significant positive correlation between these parameters in bucks (rs = 0.436; $p < 0.05$) and does (rs = 0.507; $p \leq 0.05$).

Table 1. Values of the parameters analysed for bucks and does (*Capreolus capreolus*) (median, Q25-Q75, n)

Trait	Measure	Bucks	Does	*p*-value
KFI	Median (Q25-Q75) n	1.205 (1.118-1.325) 296	1.200 (1.133-1.378) 48	0.342
Carcass weight (kg)	Median (Q25-Q75) n	18.0 (17.0-20.0) 296	19.0 (18.0-20.0) 48	0.038*

*significant at $p < 0.05$

A multiple regression model was used to evaluate the impact of environmental factors on the value of the KFI in roe deer. The regression model for KFI (Table 1) shows a positive effect of the share of fresh mixed deciduous forest and average winter temperatures on the KFI of males. In this model, another variable, i.e. forest fragmentation, had a negative effect on the value of the KFI. The obtained model explained 15% of the KFI variation (R^2 = 0.145), and gave a precise formula for the dependent variable because the relative error of the estimate was 13%. The regression equation for the KFI in bucks is:

Buck KFI = $0.005_{(\pm 0.001)}$ × Fresh mixed deciduous forest $-0.052_{(\pm 0.014)}$ × Forest fragmentation $+0.012_{(\pm 0.004)}$ × Average winter temperatures + $1.297_{(\pm 0.026)}$ (±0.164)

Table 2. Multiple regression analysis of KFI values in bucks

N=296	b*	SE of b*	b	SE of b	*t*(292)	*p*-value
Intercept			1.297	0.026	49.322	0.000
Fresh mixed deciduous forest	0.390	0.065	0.005	0.001	6.005	0.000
Forest fragmentation	-0.243	0.064	-0.052	0.014	-3.778	0.000
Average winter temperature	0.152	0.055	0.012	0.004	2.761	0.006

Analysis of the impact of environmental factors on the carcass weight of bucks by using the multiple regression model (Table 3) showed the strongest negative impact of the share of boggy mixed coniferous forest and forest fragmentation on the value of the carcass weight. However, the share of fresh mixed deciduous forest, the amount of precipitation in winter, and the index of agricultural production quality had a positive influence on this parameter. The obtained model explained 16% of variation in carcass weight (R^2 = 0.163), and gave a precise model for the dependent variable because the relative error of the estimate was 12%. The regression model for carcass weight in bucks is:

Carcass weight of bucks = $-0.680_{(\pm 0.115)}$ × Boggy mixed coniferous forest - $0.826_{(\pm 0.300)}$ × Forest fragmentation + $0.036_{(\pm 0.011)}$ × Fresh mixed deciduous forest + $2.698_{(\pm 0.669)}$ × Winter precipitation + $0.046_{(\pm 0.022)}$ × Index of agricultural production quality + $13.600_{(\pm 1.410)}$ (±2.204)

Table 3. Multiple regression analysis of the carcass weight of bucks

N=296	b*	*SE* of b*	b	*SE* of b	*t*(290)	*p*-value
Intercept			13.600	1.410	9.647	0.000
Boggy mixed coniferous forest	-0.339	0.057	-0.680	0.115	-5.939	0.000
Forest fragmentation	-0.287	0.104	-0.826	0.300	-2.748	0.006
Fresh mixed deciduous forest	0.228	0.070	0.036	0.011	3.240	0.001
Winter precipitation	0.224	0.056	2.698	0.669	4,030	0.000
Index of agricultural production quality	0.180	0.086	0.046	0.022	2.078	0.039

For does the multiple regression model (Table 4) indicated a significant positive impact of the share of fresh coniferous forest, boggy mixed coniferous forest, moist mixed deciduous forest, and fresh mixed deciduous forest on the KFI value. A positive impact of the forest fragmentation index on the KFI in roe deer females was also noted. Forest cover rate was also considered in the multiple regression model, and it had a negative effect on the dependent variable. The obtained model explained 35% of the variation of KFI (R^2 = 0.351), and gave a precise formula for the dependent variable because the relative error of the estimate was 15%.

Doe KFI = $0.083_{(\pm 0.022)}$ × Fresh coniferous forest $-0.063_{(\pm 0.020)}$ × Forest cover + $0.995_{(\pm 0.278)}$ × Forest fragmentation $+0.536_{(\pm 0.168)}$ × Boggy mixed coniferous forest $+0.082_{(\pm 0.030)}$ × Moist mixed deciduous forest + $0.013_{(\pm 0.004)}$ × Fresh mixed deciduous forest $-1.454_{(\pm 0.787)}$ (±0.199)

Table 4. Multiple regression analysis of KFI values in does

N=48	b*	*SE* of b*	b	*SE* of b	*t*(41)	*p*-value
Intercept			-1.454	0.787	-1.847	0.072
Fresh coniferous forest	5.712	1.530	0.083	0.022	3.733	0.001
Forest cover	-3.908	1.245	-0.063	0.020	-3.139	0.003
Forest fragmentation	3.293	0.921	0.995	0.278	3.575	0.001
Boggy mixed coniferous forest	2.817	0.882	0.536	0.168	3.196	0.003
Wet mixed deciduous forest	1.187	0.437	0.082	0.030	2.718	0.010
Fresh mixed deciduous forest	0.933	0.275	0.013	0.004	3.396	0.002

The regression model for the carcass weight of does (Table 5) showed that the share of fresh coniferous forests, fresh mixed deciduous forest, and the index of agricultural production quality had the strongest positive impacts on the value of this parameter. Forest cover rate, also considered in the multiple regression model, had a negative impact on the dependent variable. The obtained model explained 53% of the variation of carcass weight (R^2 = 0.534), and the relative error of the estimate was 8%.

Carcass weight of does = $0.221_{(\pm 0.042)}$ × Fresh coniferous forest + $0.155_{(\pm 0.026)}$ × Fresh mixed deciduous forest - $0.096_{(\pm 0.040)}$ × Forest cover + $0.104_{(\pm 0.043)}$ × Index of agricultural production quality + $8.548_{(\pm 4.152)}$ (±1.504)

Table 5. Multiple regression analysis of carcass weight of does

N=48	b*	*SE* of b*	b	*SE* of b	*t*(43)	*p*-value
Intercept			8.548	4.152	2.059	0.046
Fresh coniferous forest	1.664	0.316	0.221	0.042	5.274	0.000
Fresh mixed deciduous forest	1.221	0.205	0.155	0.026	5.953	0.000
Forest cover	-0.654	0.274	-0.096	0.040	-2.385	0.022
Index of agricultural production quality	0.494	0.207	0.104	0.043	2.390	0.021

Discussion and Conclusions

In Poland, the hunting season for bucks lasts from May 11th until September 30th and coincides with the period of reproduction (determination of the territory and its defence, rutting season) but does are harvested from October 1st to January 15th. Seasonal fluctuations in the body weight of animals are related to the quality and abundance of food on an annual basis as well as weather conditions, oestrus, pregnancy and the lactation period. Bucks reach the highest weight before the rutting season, i.e. in June and July, and does in late autumn (Janiszewski et al. 2009). The difference in the harvest date has an impact on the differences in carcass weight and fat reserves of the hunted game (Hewison et al. 1996, Czyżowski et al. 2015 Males only having been weighed without head, we don't compare the weights of the two sexes, but only the KFI. Our study found no differences in the rate of KFI between the sexes, which is consistent with findings by other authors (Finger et al. 1981, Holand 1992, Serrano et al. 2008), who indicated that the level of fat reserves does not depend on the reproductive cycle and, therefore, suggested that carcass weight is a more reliable indicator in assessing the condition of roe deer. According to other researchers, fat reserves in the body of roe deer compared to other wild ungulates are very low, therefore in this species body mass is a better determinant of the quality of individual animals (Andersen et al. 2000, Toïgo et al. 2006). As shown by the regression models, the share of fresh mixed deciduous forest has a positive impact on the indicators of the condition of male roe deer. These nutrient-rich habitats provide easily digestible and high-calorie feed in the form of herbaceous plants, which bucks need especially during the breeding season (Jackson 1980, Kałuziński 1982, Mysterud et al. 1999, Heinze et al. 2011). Another study (Pettorelli et al. 2001) found significantly greater differences in the body weight of roe deer in more fertile habitats. In a study of Krupka et al. (1986), the highest density of roe deer in the Lublin region was reported in the forests located on fertile soils with a predominance of deciduous trees. Barančekova (2004) also concluded that the optimal forest habitats for roe deer are deciduous forests. The preference of bucks for easily digestible and high-calorie feed in the summer is also partly reflected in the multiple regression model, which revealed a positive impact of the index of agricultural production quality on carcass weight (Table 4). It seems obvious that the bucks harvested from areas with higher agricultural productivity should have higher carcass weight, which is associated with a greater availability of more valuable feed (Kamieniarz 2013). In other studies (Janiszewski et al. 2009, Petelis and Brazaitis, 2003) bucks from agricultural ecosystems are characterized by higher carcass weight in comparison to bucks inhabiting typical forest areas. It is interesting that the present study revealed a negative impact of forest fragmentation on the value of KFI and the carcass weight of males because according to other authors this species prefers a mosaic of habitats which, due to its diversified food base, better covers the demand for nutrients (Tufto et al. 1996). In a previous study on the impact of forest fragmentation on roe deer carcass weight, Czyżowski et al. (2010) showed no effect of fragmentation on the average carcass weight of this species. These differences may result from different densities of roe deer in the study area. In our paper we did not take into account the influence of the density on body weight and fat level. According to Pettorelli et al. (2002), density is a key factor influencing indicators of the condition of ungulates. It is possible that the negative impact, shown in our study, of forest fragmentation on indicators of the condition of bucks is the result of higher density of roe deer in areas with fragmented forest complexes. This is confirmed by studies by Vincent et al. (1995) which demonstrated that with increased density weight of roe deer declined. The multiple regression model also demonstrated a positive impact of monthly average winter temperature on the value of KFI in bucks. Gaillard et al. (1993) reported that high temperatures during the winter may contribute to a faster growth rate of roe deer fawns, and at the same time promote less energy expenditure. In regression models for female roe deer, the share of coniferous forest habitats, primarily fresh coniferous forests, had a positive effect on the value of KFI and carcase weight. Does were harvested in the autumn and winter, and as reported by Bobek et al. (2016) as well as Janiszewski and Szczepański (2001), coniferous forest habitats are the main sanctuary of game during winter, where both food availability and weather protection at this time of year are much better than in mixed and deciduous forests. The sprouts and shoots of bilberries available in these habitats are an important part of the diet of roe deer in winter (Cederlund et al. 1980, Mysterud and Østbye 1995). In the presented model, the share of mixed forests, mainly fresh mixed deciduous forests, had a positive effect on the indicators of the individuals' condition. The preference of roe deer for these habitats in winter was also confirmed in other studies (Bobek et al. 2016, Heinze et al. 2011). In the multiple regression models for does the forest cover rate had a negative impact on the value of KFI and carcass weight. However, the effect of forest fragmentation was positive, which could mean that in winter the best living conditions for does are in small forests scattered in the agricultural landscape. This is confirmed by the regression model analysis, which revealed a positive effect of the index of agricultural production quality on the weight of females. Similar findings were reported by other authors (Gill et al. 1996, Jepsen and Topping 2004, Saïd and Servanty 2005), who concluded that of all ungulates the roe deer best adapts its behaviour to changes in habitat, which allows it to function well in fragmented forests. The differences of influence of forest fragmentation on carcass weight of males and females may result from the fact that the does were harvested in autumn and in winter and males in summer. According to Hewison et al (2009) positive impact of habitat fragmentation on the does (carcass weight and KFI) was the result of access to high quality food available in the fragmented agricultural landscape in autumn. The negative impact of forest fragmentation on buck carcass weight can be the result of previously mentioned increase in the density of roe deer in these areas.

Our research and studies by other authors (Hevison et al. 2001, Pettorelli et al. 2001, Morellet et al. 2011, Kamieniarz 2013) show that the management of roe deer populations should take into account the impact of landscape structure and habitat quality. This justifies the establishment of hunting areas for breeding by merging several neighbouring Forest Districts with similar natural and physiographic conditions that allow for similar wildlife management. The breeding areas have been established based on the assumption that the existing hunting ranges used as basic units for game management are too small and do not cover the natural habitats of game populations. One of the primary tasks of breeding areas is the rational management of populations, including reduced damage to forests and agricultural crops, while maintaining appropriate densities of game populations, as well as sustaining species biodiversity and diversity of forest habitats.

References

Andersen, R., Gaillard, J.M., Linnell, J.D.C. and Duncan, P. 2000. Factors affecting maternal care in an income breeder, the European roe deer. *Journal of Animal Ecology* 69(4): 672–682.

Augustine, D.J. and McNaughton, S.J. 1998. Ungulate effects on the functional species composition of plant communities: herbivore selectivity and plant tolerance. *The Journal of Wildlife Management* 1165-1183.

Barančekova, M. 2004. The roe deer diet: Is floodplain forest optimal habitat? *Folia Zoologica* 53(3): 285-292.

Bobek, B., Merta, D. and Furtek, J. 2016. Winter food and cover refuges of large ungulates in lowland forests of south-western Poland. *Forest Ecology and Management* 359: 247-255.

Bobek, B., Perzanowski, K. and Weiner, J. 1990. Energy expenditure for reproduction in male red deer. *Journal of Mammalogy* 71(2): 230-232.

Bonino, N. and Bustos, J.C. 1998. Kidney mass and kidney fat index in the European Hare inhabiting northwestern Patagonia. *Mastozoologia Neotropical* 5(2): 81-85.

Cederlund, G., Lundqvist, H., Markgren, G. and Stålfelt, F. 1980. Foods of moose and roe deer at Grimsö in central Sweden: results of rumen content analyses *Svenska Jägareförbundet* 11: 167–247.

Czyżowski, P., Karpiński, M. and Rachfałowski, R. 2010. Evaluating the environmental factors influences on body mass of wild ungulates obtained in Lublin region. *Annales Universitatis Mariae Curie-Skłodowska. Sectio EE Zootechnica* 28(2): 1-7.

Czyżowski, P., Karpiński, M. and Rachfałowski, R. 2011. Influence of forest fragmentation on the game species population. *Annales Universitatis Mariae Curie-Skłodowska. Sectio EE Zootechnica* 29(1): 1-9.

Czyżowski, P., Karpiński, M., Goleman, M. and Drozd, L. 2015. Quality of individual roe deer males (*Capreolus capreolus*) during the 5-month-long hunting season: possible impact on the reproduction rate. *Polish Journal of Ecology* 63: 291-296.

Drozd, L. and Gruszecki, T. 2000. Content of fatty acids in reserve and tissue fat of red-deer (*Cervus elaphus*) and roe-deer (*Capreolus capreolus*) obtained in central-eastern Poland. *Annales Universitatis Mariae Curie-Skłodowska. Sectio EE Zootechnica* 18: 303-307.

Drozd, L. and Piwniuk, J. 2000. Estimation of red deer (*Cervus elaphus*) condition from central-eastern Poland on the basis of the thickness of external fat layer and kidney fat index. *Annales Universitatis Mariae Curie-Skłodowska. Sectio EE Zootechnica* 18: 297-301.

Dzięciołowski, R., Babińska-Werka, J., Wasilewski, M. and Goszczyński, J. 1996. Physical condition of red deer in a high-density population. *Acta Theriologica* 41(1): 93-105.

Finger, S., Brisbin, I., Smith, M. and Urbston, D. 1981. Kidney fat as a predictor of body condition in white-tailed deer. *The Journal of Wildlife Management* 45(4), 964-968.

Gaillard, J.M., Delorme, D. and Jullien, J.M. 1993. Effects of cohort, sex, and birth date on body development of roe deer (*Capreolus capreolus*) fawns. *Oecologia* 94(1): 57-61.

Gill, R.M.A., Johnson, A.L., Francis, A., Hiscocks, K. and Peace, A.J. 1996. Changes in roe deer (*Capreolus capreolus* L.) population density in response to forest habitat succession. *Forest Ecology and Management* 88(1): 31-41.

Gilot-Fromont, E., Jégo, M., Bonenfant, C., Gibert, P., Rannou, B., Klein, F. and Gaillard, J.M. 2012. Immune phenotype and body condition in roe deer: individuals with high body condition have different, not stronger immunity. *PloS One* 7(9): e45576. Available online at: https://doi.org/10.1371/journal.pone.0045576

Heinze, E., Boch, S., Fischer, M., Hessenmöller, D., Klenka, B., Müllerd, J., Pratib, D., Schulzec, E.D., Seelec, C., Socherb, S. and Hallea, S. 2011. Habitat use of large ungulates in northeastern Germany in relation to forest management. *Forest Ecology and Management* 261: 288–296.

Hewison, A.J.M., Angibault, J.M., Bideau, E., Vincent, J.P., Boutin, J. and Sempere, A. 1996. Annual variation in body composition of roe deer (*Capreolus capreolus*) in moderate environmental conditions. *Canadian Journal of Zoology* 74(2): 245-253.

Holand, Ø. 1992. Fat indices versus ingesta-free body fat in European roe deer. *The Journal of Wildlife Management* 56(2): 241–245.

Jackson, J. 1980. The annual diet of the roe deer (*Capreolus capreolus*) in the New Forest, Hampshire, as determined by rumen content analysis. *Journal of Zoology* 192(1): 71-83.

Janiszewski, P., Daszkiewicz, T. and Hanzal, V. 2009. Wpływ czynników przyrodniczych i terminu odstrzału na masę tuszy sarny europejskiej (*Capreolus capreolus* L.) [Effect of environmental factors and time of shooting on carcass weight of European roe deer (*Capreolus capreolus* L.)]. *Forest Research Papers* 70(2): 123-130, (in Polish with English abstract).

Janiszewski, P. and Szczepański, W. 2001. Analysis of autumn-winter diet of stags, hinds and calves of reed deer (*Cervus elaphus* L.) based on rumen content. *Folia Forestalia Polonica Ser. A - Forestry* 43: 69-83.

Janiszewski, P. and Kolasa, S. 2007. Comparison of carcass and weight of antlers of roebuck (*Capreolus capreolus*) harvested in forest and field habitats. *Baltic Forestry* 13(2), 215-220.

Jepsen, J.U. and Topping C.J. 2004. Modelling roe deer (*Capreolus capreolus*) in a gradient of forest fragmentation: behavioural plasticity and choice of cover. *Canadian Journal of Zoology* 82(9): 1528-1541.

Kałuziński, J. 1982. Composition of the food of roe deer living in fields and the effects of their feeding on plant production. *Acta Theriologica* 27(31): 457-470.

Kamieniarz, R. 2013. Struktura krajobrazu rolniczego a funkcjonowanie populacji sarny polnej [The structure of agricultural landscape and functioning of the field roe deer population]. *Doctoral dissertation,* Rozprawy Naukowe. Uniwersytet Przyrodniczy w Poznaniu, 71 pp. (in Polish with English abstract).

Karpiński, M., Czyżowski, P. and Drozd, L. 2008. Wskaźnik tłuszczu około nerkowego (KFI) u kozłów (*Capreolus capreolus*) [Roebuck's (*Capreolus capreolus*) kidney factor index (KFI)]. *Acta Scientiarum Polonorum Zootechnica* 7(1): 33-37 (in Polish with English abstract).

Lochman, J. 1987. Określanie wieku zwierzyny [Determination of the age of game]. Państwowe Wydawnictwo Rolnicze i Leśne, Warszawa, 268 pp. (in Polish).

Loyn, R.H. 1987. Effects of patch area and habitat on bird abundances, species numbers and tree health in fragmented Victorian forests. In: Saunders, D.A., Arnold G.W., Burbidge, A.A. and Hopkins, A.J.M. (Eds.): Nature Conservation: the role of remnants of native vegetation. Surrey Beatty and Sons, Chipping Norton, Australia, p. 65-77.

Mac Nally, R. 2002. Multiple regression and inference in ecology and conservation biology: further comments on identifying important predictor variables. *Biodiversity & Conservation* 11(8): 1397-1401.

Majzinger, I. 2004. Examination of reproductive performance of Roe Deer (*Capreolus capreolus*) in Hungary. *Journal of Agricultural Science* 15: 33-38.

Morellet, N., Van Moorter, B., Cargnelutti, B., Angibault, J.M., Lourtet, B., Merlet, J. and Hewison, A.M. 2011 Landscape composition influences roe deer habitat selection at both home range and landscape scales. *Landscape Ecology* 26(7): 999-1010.

Mysterud, A., Larsen, P.K., Ims, R. A. and, Østbye, E. 1999. Habitat selection by roe deer and sheep: does habitat ranking reflect resource availability? *Canadian Journal of Zoology* 77(5): 776-783.

Mysterud, A. and Østbye, E. 1995. Roe deer *Capreolus capreolus* feeding on yew *Taxus baccata* in relation to bilberry *Vaccinium myrtillus* density and snow depth. *Wildlife Biology* 1: 249-253.

Okarma, H. 1984. The physical condition of red deer falling a prey to the wolf and lynx and harvested in the Carpathian Mountains. *Acta Theriologica* 29(23): 283-290.

Okarma, H. 1991. Marrow fat content, sex and age of red deer killed by wolves in winter in the Carpathian Mountains. *Ecography* 14(3): 169-172.

Petelis, K. and Brazaitis, G. 2003. Morphometric data on the field ecotype roe deer in southwest Lithuania. *Acta Zoologica Lituanica* 13(1): 61-64.

Pettorelli, N., Gaillard, J.M., Duncan, P., Ouellet, J.P. and Van Laere, G. 2001. Population density and smallscale variation in habitat quality affect phenotypic quality in roe deer. *Oecologi*a 128(3): 400-405.

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

Riney, T. 1955. Evaluation condition of free-ranging Red Deer (*Cervus elaphus*), with special references to New Zealand. *New Zealand Journal of Science and Technology* Section B 36(5): 429-463.

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

Sams, M.G., Lochmiller, R.L., Qualls, C.W. and Leslie, D.M. 1998. Sensitivity of condition indices to changing density in a white-tailed deer population. *Journal of Wildlife Diseases* 34(1): 110-125.

Serrano, E., Alpizar-Jara., R, Morellet, N. and Hewison, A.J.M. 2008. A half a century of measuring ungulate body condition using indices: is it time for a change? *European Journal of Wildlife Research* 54(4): 675-680.

Toïgo, C., Gaillard, J.M., Van Laere, G., Hewison, M. and Morellet, N. 2006. How does environmental variation influence body mass, body size, and body condition? Roe deer as a case study. *Ecography* 29(3): 301-308.

Trampler, T., Kliczkowska, A., Dmyterko, E. and Sierpińska, A. 1990. Regionalizacja przyrodniczo-leśna. Na podstawach ekologiczno-fizjograficznych [Regionalization of natural-forest. On the basis of ecological and physiographic]. Państwowe Wydawnictwa Rolnicze i Leśne, Warszawa, 157 pp. (in Polish).

Tufto, J., Andersen, R. and Linnell, J. 1996. Habitat use and ecological correlates of home range size in a small cervid: the roe deer. *Journal of Animal Ecology:* 715-724.

Vincent, J. P., Bideau, E., Hewison, A. J. M. and Angibault, J. M. 1995. The influence of increasing density on body weight, kid production, home range and winter grouping in roe deer (*Capreolus capreolus*). *Journal of Zoology*, *236*(3): 371-382.

Witek, T., Górski, T., Kern H., Żukowski, B., Budzyńska, K., Filipiak, K., Fiuk, M. and Strzelec, J. 1993. Waloryzacja rolniczej przestrzeni produkcyjnej Polski wg gmin [Valorisation of the agricultural production by Polish municipalities]. IUNG Puławy 248 pp. (in Polish).

Received 18 July 2016
Accepted 02 October 2017