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Source: Folia Zoologica, 65(1) : 52-58

Published By: Institute of Vertebrate Biology, Czech Academy of Sciences

URL: https://doi.org/10.25225/fozo.v65.i1.a8.2016

Folia Zool. – 65 (1): 52–58 (2016)

Population dynamics and structure of roe deer (*Capreolus capreolus*) inhabiting small-size forests in north-western Poland

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Received 14 January 2015; Accepted 21 August 2015

Abstract. According to hunting statistics in the last two decades, both the population numbers and harvesting of roe deer in Poland have been on the increase from 597000 to 876000 animals and from 158000 to 172000 harvested individuals, respectively. The number of roe deer reported by hunters are mainly based on guesswork, therefore the objective of the study was to verify the inventory of roe deer conducted by hunting clubs in the Myślibórz Forest District (north-western Poland) and to determine the sex ratio and age structure this species. The study area is including 86 small size forest complexes and covers 12990 ha. Roe deer number were determined over four years from 2002 to 2006. In sampling plots (February 2002) data from snow tracking and driving census showed significant correlation (r = 0.663, p = 0.003) between the relative population density (N/km) – independent variable and population density (N/1000 ha) – dependent variable. Roe deer snow tracks were counted during five days each year on 16 line transects (length 66.4 km) and the relative population densities (animal per km*day^{-1}) for the whole study area were calculated. These indices were inserted into the regression formula that was obtained from sampling plots. It allowed to calculate the population density (N/1000 ha) and then roe deer numbers inhabiting the study area. Population density ranged from 300.1-319.0 individuals/1000 hectares of forest, and the differences between the four years of study were statistically insignificant. In summer, the sex ratio of the population was 1:1.4 in favour of females, and the autumn increment of young animals amounted to 70.2 fawns/100 does. The average population number of roe deer assessed for these four years was 3568 individuals and was more than two times higher than the average population size (n = 1670) given by hunters.

Key words: line transects, snow tracking, population density, sex ratio, age structure, driving census

Introduction

The roe deer (*Capreolus capreolus* L.) is the most numerous representative of wild ungulates in Poland, and lives in forest environments and large areas of cultivated landscape (Kałuziński 1982a, Pielowski 1984, Budna et al. 2013). It is an important species from the viewpoint of game management but it is also a burdensome species for silviculture because of the damage it inflicts on forest plantations. In the last two decades, both the population numbers and harvesting of roe deer in Poland have been on the increase. According to data from the Central Statistical Office (Budna et al. 2013), there were 597000 roe deer in Poland in 2000, whereas in 2013 their number amounted to 876000. In the same period, the harvest of the species increased from 158000 individuals to 172000.

Taking inventories of game species is obligatory in all hunting districts throughout Poland. Each year, the hunting clubs leasing hunting districts report the population numbers for each game species, between the end of February and the beginning of March. No objective methods are applied in the inventorying process, and the numbers are based on guesswork; namely estimates prepared by each hunting club.

To determine the population numbers of roe deer and other ungulates is very important because of the growing costs of protecting forests against damage exerted by deer populations, as well as harm caused by ungulates in farmlands. In the last decade, the cost of protecting forests against moose, red deer, and roe deer increased from 14.6 million to 35.1 million Euro, whereas the compensation for damaged farm crops rose from 6.8 million to 18.3 million Euro (Grzybowska et al. 2014, Frąckowiak & Mikos 2015).

In the Myślibórz Forest District, roe deer are an essential component in local game management, though it is also a species that causes significant

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damage. It is the cause of 57.9 % of significant browsing of beech seedlings in reforestation areas (Rembacz 2007).
For this reason, the objective of the presented study was to verify the results of inventories performed by hunters, using a driving census in sampling plots and snow tracking on line transects. This method is often applied when assessing population numbers of ungulates living in forest habitats (Bobek et al. 2005, Pellikka et al. 2005, Fonseca et al. 2007, Sitnikova 2012).

Study Area

The Myślibórz Forest District is situated in north-western Poland, in an area administered by the Regional State Forest Directorate in Szczecin. The territorial scope of the study area covers 68266 ha, including 12987 ha of forests. The forests occur in the form of 86 complexes, of which the largest has an area of 7003 hectares, four complexes have areas from 500 hectares to 2000 hectares, three complexes – from 100 hectares to 500 hectares, whereas 78 complexes cover areas under 100 hectares. The solid forest complexes are surrounded by cultivated fields with maize (*Zea mays*) and rape (*Brassica napus*) being the predominant crops.
Within the Forest District concerned in the study, eight habitat types of forests occur, among which the mesic and hygric deciduous forest – *Tillio carpinetum* covering 64.7 % of the Forest District's area predominates. The highest proportions of tree species are those of Scots pine *Pinus silvestris* (32.5 %), oak *Quercus* sp. (23.1 %), and beech *Fagus sylvatica* (17.2 %). The proportions of birch *Betula* sp., and common alder *Alnus glutinosa* amount to 8.2 % and 7.8 %, respectively. Timber harvest system is based upon small size of clear cuts and selective cut of single trees or group of trees species. After the timber harvest is completed, the ground is planted by sampling of pine, oak, beech and other species. Timber rotation for pine is 100 years, and for oak and beech 160 years and 110 year, respectively.
The described area is a lowland landscape with low hills in the range 45.9-106.8 m a.s.l. accompanied by numerous lakes. The climate has a preponderance of the maritime climate features. The average annual temperature is 8.4 °C, the average annual sum of precipitation reaches 555 mm.
The area of the Myślibórz Forest District is also inhabited by a red deer population and a numerous wild boar population. The red deer number totals 470 individuals (36.2 N/1000 hectares) whereas the number of wild boars is 1124 individuals (97.3 N/1000 hectares) (Rembacz & Orłowska 2011). Population of mesopredators include red fox (*Vulpes vulpes*), otter (*Lutra lutra*), badger (*Meles meles*), pine marten (*Martes martes*), stone marten (*Martes foina*) and raccon dog (*Nyctereutes procyonoides*).
The Forest District supervises game management in seven hunting districts. Hunting season for bucks at the beginning of May and ends last day of September. Females and fawns are harvested from October till mid of January. Males are harvested selectively regarding age and shape of antlers. Females and fawns are hunted randomly. Harvest of roe deer in the study area is slightly female biased.
In the Myślibórz Forest, number of roe deer harvested during four years (2002-2006) ranged from 623 to 643 individuals. On average during hunting season 275 males, 291 females and 67 fawns is harvested.

Material and Methods

The four studies on the assessment of roe deer population numbers were conducted in February of 2002, 2003, 2005, and 2006. They consisted of two stages: (1) in 13 sampling plots (February 2002), by counting number of roe deer based on recording their snow tracks on line transects, the relative population density index (N/km) was obtained. Then, using driving census population density (N/1000 hectares) was calculated. The relationships between 13 pairs of variables were estimated using regression analysis, where the N/km was an independent variable and population density (N/1000 ha) was the dependent variable. (2) in the forested areas of seven hunting districts (11600 hectares), 16 uniformly distributed line transects were delineated. Based on recording number of snow tracks on line transects, the relative population density of roe deer (N/km) was calculated. Using the relationship between N/km and N/1000 ha that was derived from sampling plots data, the relative population density index (N/km) obtained from snow tracking on 16 line transects, was converted into population density (N/1000 ha) which was then used from estimating the numbers of roe deer living within the Myślibórz Forest District. Snow depth during population census was 10-15 cm and did not reduce mobility of roe deer.
Sampling plots (n = 13) with a total area of 1258 hectares were situated in areas where a considerable diversification of the relative population density index of roe deer was found during earlier pilot studies (Rembacz & Orłowska 2011). The areas of sampling plots ranged between 88.2-99.5 hectares.

Each sampling plot covered 4-5 forest compartments adjacent to each other with their longer sides. The limits of sampling plots consisted of lines between forest compartments, 4-5 m wide, providing good visibility. In each sampling plot, two line transects were marked on which roe deer snow tracks crossing the transect lines had been erased one day before the population census. The following day, each of the sampling plots was surrounded by 40-50 people, divided into groups in line with the methodology for assessing the population numbers using a driving census; namely, drivers, flankers, and stationary observers (Bobek et al. 2009). In the sampling plots so prepared, the relative population density index (N/km) was reached by the roe deer, which crossed the transects during the previous 24 hours. Then, the population density (N/1000 hectares) on the sampling plot was assessed using the driving census method. A "U" shape line of drivers (about 35 persons) and flankers (about five plus five persons) moved slowly towards the stationary observers. All roe deer which left the sampling plots were counted, and the number of animals was then converted into a population density measurement (N/1000 hectares).

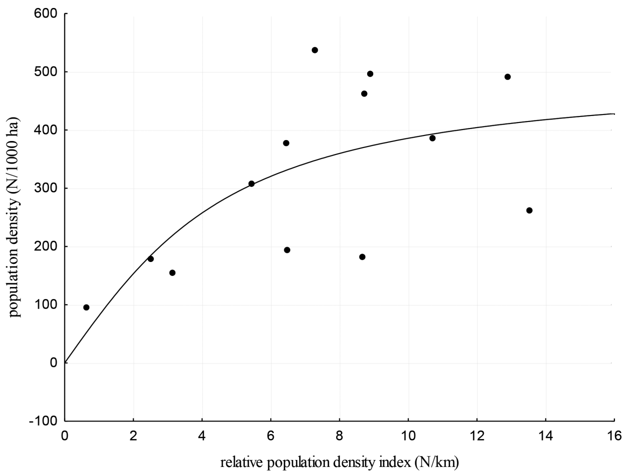

Fig. 1. Relationship between the relative population density index (N/km of transect) and the population density (N/1000 hectares). Both these variables were determined on 13 sampling sites in the Myślibórz Forest District in February 2002. Y = (321.0)*arctan [(0.259)*X]; r = 0.663, p = 0.003.

Depending on the snow conditions 16 line transects in the study area were tracked over a length of 64.9-68.1 km. Over the four year study period, the average length of line transects tracked in each year amounted 66.4 km per day. Each year the tracking of roe deer lasted six consecutive days. In the first day, all-terrain vehicles (n = 4) drove through all the transects and all the roe deer tracks encountered were erased. Over the next five consecutive days, the number of roe deer crossing the line transects was recorded, and their tracks erased again. In order to avoid multiple records of the same animals, on each day of tracking and on each transect only one crossing by a given individual or group of roe deer differing in numbers was considered in the calculations, and 1 km intervals of line transects were applied. The calculated daily relative population density indices (N/km*day) were treated as independent variables and inserted into a regression equation which had been developed earlier, thereby

Table 1. Estimated population numbers of roe deer obtained via snow tracking on line transects in the Myślibórz Forest District (north-western Poland). The data was collected from a forest area covering 11600 hectares.

Variables		Years			
		2002	2003	2005	2006
Number of roe deer in line transects (N/day)	mean	359.8	396.6	336.6	340.4
	SE	±38.3	±16.7	±9.7	±17.5
	V(%)	23.8	9.4	6.5	11.5
Roe deer per 1 km of line transects $*day^{-1}$	mean	5.7	5.9	5.2	5.3
	SE	±0.5	±0.2	±0.2	±0.3
	V(%)	19.3	6.7	6.8	12.5
Population density (N/1000 ha)	mean	309	319	300	302
	SE	±13.1	±4.5	±4.7	±8.5
	V(%)	9.5	3.2	3.5	6.3
Population size (N)	mean	3583	3701	3481	3508
	SE	±152.3	±52.5	±54.3	±98.8
	V(%)	9.5	3.2	3.5	6.3
Accuracy (±%) of mean population size at 95 % confidence level		±11.8 %	±3.9 %	±4.3 %	±7.8 %

Table 2. Comparison of roe deer population densities (N/1000 hectares of forest) in various regions of Poland. Data in parenthesis refers to population density reported by hunters.

Location	Population density	Environmental characteristics	Methodology	Author
central Poland Zielonka	302	coniferous forests and mixed deciduous woods (area 8000 ha)	driving census	Fruziński & Łabudzki 1982b
southern Poland Niepołomicka Forest	280	deciduous forests (area 1300 ha)	driving census	Bobek 1984
central Poland Rogów	540	complex of mixed coniferous forests and mixed deciduous woods (area 200 ha)	pellets count	Aulak & Babińska-Werka 1990
northern Poland Elbląg Hills	274 (245)	deciduous forests (area 10200 ha)	analysis of bags from collective hunts	Cwieluch & Tretowska 2011
southern Poland Rudziniec Forest District	205 (189)	complexes of coniferous forests and mixed deciduous woods (area 18600 ha)	analysis of bags from collective hunts	Kopec 2012
south-western Poland Bory Dolnośląskie Forest	57 (39)	coniferous and mixed coniferous forests (area 65300 ha)	snow tracking	Furtek 2014
southern Poland Niepołomicka Forest	391 (117)	deciduous forests (area 2000 ha)	snow tracking, pellets count	Ziobrowski 2014
southern Poland Niepołomicka Forest	104 (42)	coniferous forests and mixed deciduous woods (area 8800 ha)	snow tracking, belt transects	Ziobrowski 2014
north-western Poland Myślibórz Forest District	308 (mean over four years)	small deciduous woods (area 11600 ha)	snow tracking	this paper

obtaining a population density (N/1000 hectares), used later to calculate the population number.

Observations pertaining to the sex structure of population, and the age structure of roe deer bucks were conducted over a 30 day period starting at the end of July and the beginning of August. Again, in 30 days at the end of September and the beginning of October the observations were conducted on numbers of does and fawns. The data was collected by foresters during forest maintenance operations, by hunters during individual hunts, as well as by the authors conducting observations of their own. In each hunting district, the observations were carried out by three persons.

In order to know the sex ratio and age structure of the population, the place of observation (the numerical designation of forest compartment, traditional name of hunting ground) were noted, together with the sex and age of adult individuals observed. In the observations, the following categories were distinguished: young animals (fawns) and adults, in which the bucks were classified as those of an estimated age of 1 to 3 years, and older. To exclude multiple records of the same animals, an analysis based on weekly space-time intervals was used. If a given individual (or group) was observed in the same place in a time interval shorter than seven days, then such an observation was dropped from the materials used for the final assessment of sex ratio and age structure of the population.

Results

Scaling the relationship between the relative population density index and the population density

The number of roe deer estimated by the driving census method on 13 sampling plot was 390 individuals. The population densities in particular sampling plots fell into the range from 95.2-537.2 individuals/1000 hectares, and its mean value was 316.9 ± 41.8 individuals/1000 hectares ($\bar{x}$ ± SE). The relative population density index estimated for the examined sampling plots ranged from 0.6 to 13.5 roe deer/km, with its mean value at 7.3 ± 1.1 individuals/km ($\bar{x}$ ± SE). Both variables were significantly correlated, and this correlation is presented in the regression equation given below. The equation is also presented in the form of a graph (Fig. 1). $Y = (321.0)*\arctan[(0.259)*X]$; $r = 0.663$, $p = 0.003$ where Y is the population density (N/1000 hectares), while X denotes the relative population density index (N/km). The high value of the correlation coefficient ($r^2 = 0.439$) means that nearly half of the diversification of roe deer density within sampling plots was explained by the relative population density index.

Dynamics of population numbers

The number of roe deer used for calculating the dynamics of population numbers ranged from 1683 individuals in 2005 to 1983 individuals in 2003. In particular years, the calculated daily mean numbers of roe deer which crossed line transects had relatively low variation coefficients (V), and fell within a 6.5-23.8 % range (Table 1). The mean value of the relative population density index (N/km) in the studied period, fluctuated between 5.2 individuals/km*day^{-1} in 2005 and 5.9 individuals/km*day^{-1} in 2003 (Table 1).

Using the regression equation in the calculations, where index N/km was the independent variable, whereas population density (N/1000 hectares) – the dependent variable, resulted in a marked reduction in the diversification of population density and number, from 3.2 % in 2003 to 9.5 % in 2002. Over the four years of study, the mean population density amounted to 307.6 individuals/1000 hectares, and was only slightly different in subsequent years (300.1-319.0 individuals/1000 hectares). The mean population number of roe deer inhabiting the study area reached up to 3568 individuals and did not differ significantly between the four years (F = 0.999, p = 0.418). During that time, the accuracy of the mean assessed for the 95 % confidence level was high and fell within the interval from ±3.9 % to ±11.8 % of the mean (Table 1).

Age structure and sex ratio in the population

The age structure and sex ratio in the studied population were assessed on the basis of 1816 observations of roe deer over four years of research. The materials collected in July and August (n = 590) i.e. in the rutting season, covered adult males (bucks) (n = 250), and adult females (does) (n = 340). In summer observations, the proportion of male individuals reached 42.4 % which indicates a sex ratio of 1:1.4 in favour of females. Among adult males, the proportion of animals aged 1-3 years amounted to 35.2 %. In autumn observations, conducted in September and October, 720 adult females and 506 fawns were noted. Thus it means that the autumn increment in the number of young was 70.2 fawns/100 does.

Discussion

There are several methods for estimating population number of roe deer (Strangaard 1967, Aulak & Babińska-Werka 1990, Mayle et al. 1999, Prokešová et al. 2006), but because of their costs and complex methodology, the majority of them are suitable mainly for research. Only a limited number of these methods can be used for population management. It refers to driving census and counting roe deer snow tracks on line transects (Fruzińki & Łabudzki 1982b, Bobek 1984, Nasiadka 1994, Furtek 2014). The last method was documented in the present work. Obtained results are reliable as the accuracy of the average roe deer population number evaluated in particular years ranged from ±3.9 % to ±11.8 % of the average at 95 % confidence level.

Morellet et al. (2011) indicated that in Poland population census is based upon drive counts and capture-mark recapture methods. These techniques were not used for management purposes but during research projects. The average roe deer population number assessed over a four-year period of study amounted to 3568 individuals and exceeded more than twice the mean number of this species (n = 1670) given by hunters in 1999-2001. Based on hunting statistics, the average harvest figure in that period (n = 663) was 39.7 % of the population estimated by hunters at the end of the hunting season. Had the numbers given by hunters been correct, the level of harvesting applied in 2002-2006 would have resulted in a dramatic reduction in the numbers of roe deer, since the annual net increment of this species evaluated in this study on the basis of demographic parameters (population number, sex ratio, harvest figure, autumn increment in numbers of young animals), and natural mortality (Fruziński & Łabudzki 1982b) was – during that period – 27.1 % of the number at the end of the hunting season (Bobek B., unpublished data).

In the hunting season, the harvest quota stabilising the population number should be 964 roe deer, which is therefore more than 300 individuals higher than the official harvest of the population.

The lack of significant differences in numbers of roe deer in the years 2002-2006 indicates that the difference between the net increment and the harvest of the population represents the losses caused by the dispersion of individuals (Strandgaard 1972, Wahlström & Liberg 1995), and poaching.

The sex ratio of roe deer populations living in forest and field-forest environments is greatly diversified. In the large complexes of coniferous forest habitats, it ranges from 1:1.2 to 1:1.4 (Kobielski et al. 2007) whereas in deciduous woods it further shifted in favour of females and ranges from 1:1.6 to 1:2.0 (Kopec 2012). These differences stem from territorial behaviour prevailing among roe deer, as well as the availability of deciduous browse and herbs. The sex ratio in the adult fraction of the population in late spring and summer is a result of the area inhabited by females, and the area inhabited by males. The latter tries to monopolise the possibly high number of females within its territory. The possibility to mark and defend large-size territories by males is limited, therefore the proportions between sexes should be markedly shifted in favour of females in the area where females occupy small areas. These prerequisites are met in deciduous woods because the number of resident females in the vegetation season is positively correlated with the amount of deciduous browse and herbs (Bobek 1977).

The sex ratio among roe deer in the Myślibórz Forest District is not markedly shifted in favour of females despite the fact that the forest environment is predominately deciduous. It is likely associated with the large sizes of combined forest-field areas inhabited by some females.

Compared with other regions, the autumn increment of young roe deer in the Myślibórz Forest District (70.3 fawns/100 does) is relatively low. Markedly higher increments of up to 87.8 fawns/100 does were found in a large complex of the Bory Dolnośląskie Forest (Kobielski et al. 2007), as well as in the medium-size "Zielonka" forest complex in central Poland (Fruziński & Łabudzki 1982b). These figures are similar to the autumn increment of young animals at 115 fawns/100 does reported from small forest complexes in Denmark (Strandgaard 1972). In Poland, only the estimated increments of the number of fawns recorded in the Gliwicko-Raciborskie Forest, and in the Silesian Lowland (50.6-58.3 fawns/100 does) (Dzięcielski et al. 2007, Kopec 2012) were lower than the figures calculated in our study.

Such a high diversification of the autumn increment in young roe deer probably results from predation by foxes on newly born fawns (Andersen & Linnell 1998, Jarnemo et al. 2004, Jaremo & Liberg 2005). Although the potential increment in young roe deer measured by the number of born offspring is usually higher in field-forest environment than in pure forests, the high density of foxes in fields means that the autumn increment in the number of young animals is higher in the forest environment (Panzacchi et al. 2009). The population density of roe deer inhabiting the lowland forests of Poland is highly diversified. In accordance with the data presented in Table 2, it ranges from 57 to 540 individuals/1000 hectares of forest. Such a wide gradient of density results from the combined effect of both environmental factors e.g. habitat type of forest, the size of a forest complex, particularly the length of forest-field boundary line, and the amount of animals harvested. The population densities in deciduous forest habitats are markedly higher than those in coniferous forest habitats because the number of resident roe deer is proportional to the supply of deciduous browse and herbs (Bobek 1977). The data on population densities compiled in Table 2 pertains to the winter season when roe deer cease to be territorial animals. The individuals whose territories included field sites adjacent to the forest, in autumn-winter time inhabit forest habitats, increasing the population density. This process occurs chiefly in small forest complexes which have long field-forest boundaries.

Concluding, the present harvest rate in the Myślibórz Forest District is only 18.1 % of roe deer population numbers in February (mean for four years). However, analysis of recruitment rate of roe deer population studied i.e. number of fawns per 100 females in autumn, it seem reasonable to increase the harvest rate to 30 % of population size estimated in March. Probably this higher hunting pressure will eliminate from our study area spring migratory losses of yearling animals. Additionally the drive counts or snow track counts in line transects are recommended as objective methods of population census. This new adaptive management strategy have to be established as cooperation between the local hunting clubs and team of wildlife biologists.

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