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Red deer density in the air-polluted area of forest ecosystems in the Krušné hory Mts. – Klášterec nad Ohří Forest District

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ABSTRACT: The density of red deer in the area of forest ecosystems disturbed by air pollution in the Krušné hory Mts. – Klášterec nad Ohří Forest District was determined in two model hunting districts Jelení hora and Černý potok. To determine the density of red deer two methods were used, namely the clearance plot method and a method without the clearance of transects – faecal standing crop. Based on the repeated counting of faecal pellet groups on 16 marked plots (No. 1 to 16) in the research area, mean values of the estimate of the red deer population density were determined in the Jelení hora hunting district in 2007 and 2008 using the FSC method, viz 24 ± 23 individuals·km^{-2} (95% CI) and the CPM method, viz 105 ± 88 individuals·km^{-2} (95% CI) and in the Černý potok hunting district using the FSC method, viz 8 ± 5 individuals·km^{-2} (95% CI) or 77 ± 50 individuals·km^{-2} (95% CI) by the CPM method. No statistically significant differences were found out between the density of game and particular groups of similar biotopes.

Keywords: deer count; pellet group; red deer

The density of game is estimated in forest stands by means of indirect methods, most often by counting faecal pellets (Putman 1984). Accurate and precise estimates of abundance are required for the development and management of game populations (Marques et al. 2001). Methods of counting faecal pellets are relatively cheap and quick. However, the knowledge of a defecation rate and a period of the faecal pellet persistence in the environment is necessary for the estimate (Mayle 1999).

The faecal standing crop and the clearance plot method sometimes referred to as faecal accumulation rate (Staines, Ratcliffe 1987; Smart et al. 2004; Daniels 2006) rank among the most frequently used indirect methods of counting pellet groups (FPG – Faecal Pellet Group). The FSC (Faecal Standing Crop) method is aimed at counting pellet groups on randomly selected plots normally distributed in the environment. Based on these data it is possible to estimate a population density. To determine game densities it is necessary to know daily defecation rates and a period of the pellet group persistence in the environment (Smart et al. 2004).

The CPM method (Clearance Plot Method) is based on the repeated clearing of the same plots from all faecal pellets and subsequent counting pellet groups on the plot after a certain time period. Using this method the period of faecal pellet persistence on a plot is given by a time period between particular visits. The number of defecation rates is different in particular species of game (Mayle, Staines 1998), in particular seasons and in each individual (Mitchell et al. 1985).

Using these methods is possible because red deer defecate at a certain place and time without the need of special latrines or the use of faecal pellets as a means to mark the territory (Mitchell et al. 1985).

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All plots are cleared and used at other visits to determine game density by the clearance plot method (Smart et al. 2004). The omission of a pellet group or counting an old pellet group often resulted in inaccuracies (Staines, Ratcliffe 1987).

Smart et al. (2004) reported the persistence of pellets determined on randomly selected plots in all age classes using the rectal faecal pellets within the limits of 150 to 295 days according to the type of environment. The persistence of roe-deer and fallow-deer pellets reaching 180 days for both species was given in the paper of Mayle et al. (2000).

The amount of daily defecation rates for red deer was reported in papers of Dobiáš et al. (1996), namely 19 pellet groups/deer/day, and of Mitchell and McCowan (1984), who mentioned 25 pellet groups/deer/day.

MATERIAL AND METHODS

Two hunting districts were selected as model localities (Jelení hora and Černý potok) in the Krušné hory Mts., Klášterec nad Ohří Forest District. Both monitored areas are situated in the southwestern part of the Krušné hory Mts., i.e. in the northwestern part of the Czech Republic. The altitude of the area ranges between 680 and 994 m a.s.l., mean annual temperature is 4.8°C and total annual precipitation is 800–850 mm.

The total area of the Jelení hora hunting district is 2,420 ha, viz forest 2,137 ha, pasture land 280 ha and other areas 3 ha. About 20% of the total hunting ground areas are occupied by waterlogged sites, which represent the sufficient supply of water. The following forest vegetation zones (FVZ) are represented: 7 FVZ (52%), 8 FVZ (31%) and 6 FVZ (17%).

Stands of substitute tree species composed of blue spruce (*Picea pungens*) and Serbian spruce (*Picea omorica*), larch and birch predominate. Roughly 500 ha of the hunting ground area are covered by peat soils where mountain pine (*Pinus mugo*), (*Pinus uncinata)* and white birch (*Betula pubescens*) are dominant species.

Outside the Jelení hora massif where the proportion of European beech (*Fagus sylvatica*) aged 90–130 years prevails, the 1st and the 3rd age class predominate and, compared to the normal forest, the 5th to the 8th age class are missing.

The total area of the Černý potok hunting district is 1,878 ha. It is composed of two forest stands. Forest vegetation zones FVZ 6 (70%) and FVZ 7 (30%) predominate there. They consist particularly of stands of substitute tree species, namely blue spruce, Serbian spruce and Norway spruce. Compared to the normal forest, the proportion of the 5th to the 8th age class is minimal and the 1st to the 3rd age class are dominant there.

To determine the red deer density two methods were used, namely a method with clearing the transects (CPM – Clearance Plot Method) and a method without clearing the transects (FSC – Faecal Standing Crop). The monitoring was carried out in two neighbouring hunting grounds Jelení hora and Černý potok, Klášterec nad Ohří Forest District.

According to the shape of hunting districts, depending on their location, predominance of particular biotopes and age of stands, 16 transects were uniformly established (No. 1–16), namely 8 in the Jelení hora hunting district (No. 1–8) and 8 in the Černý potok hunting district (No. 9–16). Their location was most often selected in forest stands and on unpaved roads (former boundary zones) with vegetation or on machine-prepared mounds intended for reforestation. The transects were marked by wooden stakes painted in orange colour. The width of the transects was 2–4 m (forest stands, unpaved roads, former boundary zones) or 10 m (mounds prepared by machines and intended for reforestation) and their length was 50–720 m at places allowing the easy counting of faecal pellet groups (FPG). The group of faecal pellets with more than 6 cylindrical pellets was regarded as an FPG.

Groups of pellets lying on the transect boundary were alternatively included or ignored. The pellet group monitoring was carried out by two workers moving simultaneously along the transect. Their position in terms of coordinates was recorded by means of a portable GPS Garmin eTrex Vista device and the area of each of the transects was determined. At the first visit (FSC method), after the evaluation of the count of faecal pellet groups, all plots were cleared and used for monitoring the red deer density by the clearance plot method. Data on particular visits are shown in Table 1. The working procedure mentioned above was repeated after every other visit of the marked plots. In the next year, the same working procedure was used. In the Jelení hora hunting district, 8 transects of the total length of 2,744 m and area 10,176 m^2 were established. In the Černý potok hunting district, 8 transects were also established, their total length being 2,290 m and area 9,880 m^2.

To estimate the red deer population density by the clearance plot method and FSC method the formula D (individuals·km^{-2}) = $n \times 10^6/(S \times t \times f)$ (Prokešová et al. 2006) was used where n was the number of determined pellet groups in a transect, S the size of the area in m^2, t the period of the tran-

sect exposition (in days) between particular visits (clearance plot method). The mean period of 160 days of the pellet group persistence in the environment using the FSC method was derived from the paper of Smart et al. (2004) and *f* was the amount of daily defecation rates of the respective animal species. For red deer, the daily defecation rate 19 pellet groups/deer/day was used (Dobiáš et al. 1996).

In the Jelení hora hunting district, plots No. 1 to 8 were laid out. Plots No. 1 and 2 were laid out in stands of substitute tree species, particularly of blue spruce (*Picea pungens*), Serbian spruce (*Picea omorica*) and white birch (*Betula pubescens*). Plots No. 3, 4 and 5 were laid out in the resting area of game, namely in peat bogs. Plots No. 6–8 were laid out in beech stands aged 60–70 years.

In the Černý potok hunting district, plots No. 9 to 16 were laid out. Plots No. 9 and 11 were laid out in stands of substitute tree species, particularly of blue spruce (*Picea pungens*), Serbian spruce (*Picea omorica*) and white birch (*Betula pubescens*). Plots No. 12, 13, 14 and 15 were laid out on the area of spread mounds prepared for reforestation and partly already reforested by the target species Norway spruce (*Picea abies*). Plots No. 10 and 16 were laid out in a mature spruce stand.

Acquired data were evaluated by Statistica 9.0 (StatSoft, Inc. 2009) and Microsoft Office Excel statistical software. Differences in the red deer density between particular years and methods of counting the faecal pellet groups were analysed by the Wilcoxon Matched Pairs Test. Evaluation of the red deer count depending on the environment was carried out using Friedman ANOVA and Kendall's Concordance. For the purposes of calculations, the plots were divided into 5 groups according to biotope similarity: (A) Stands of substitute tree species represented by plots No. 1, 2, 9 and 11, (B) Peat bogs represented by plots No. 3 to 5, (C) Beech stands represented by plots No. 6 to 8, (D) Spread mounds prepared for reforestation including plots No. 12 to 15, (E) Commercial forest including plots No. 10 and 16.

RESULTS

Based on the repeated counting of faecal pellet groups on 16 marked plots (No. 1 to 16) in the research area, the mean values of the estimate of red deer population density were determined in the Jelení hora hunting district in 2007 and 2008. The FSC and CPM method was used giving 24 ± 23 individuals·km^{-2} (95%

Table 1. The density of red deer (individuals·km^{-2}) determined on particular plots in the Jelení hora (No. 1–8) and Černý potok (No. 9–16) hunting districts

	Monitoring plots								
Jelení hora	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	Mean
FSC 13. 6. 2007	101.2	16.3	19.4	56.1	11.0	9.9	38.7	58.1	38.8
CPM 7. 8. 2007	157.7	13.6	26.3	105.7	0.0	19.1	65.7	36.2	53.0
CPM 10. 9. 2007	935.6	76.9	145.9	0.0	247.7	0.0	273.2	117.1	224.5
CPM 15. 10. 2007	330.5	74.7	147.7	0.0	150.4	0.0	368.6	227.6	162.4
FSC 3. 7. 2008	72.3	4.7	7.8	0.0	6.6	0.0	16.1	12.4	15.0
CPM 4. 8. 2008	180.7	11.7	77.5	0.0	32.9	0.0	48.4	83.0	54.3
CPM 20. 9. 2008	24.6	7.9	92.4	0.0	89.6	0.0	11.0	113.0	42.3
Area of transects in m^2	910	1,410	2,546	996	1,500	1,001	1,020	793	10,176
Černý potok	No. 9	No. 10	No. 11	No. 12	No. 13	No. 14	No. 15	No. 16	Mean
FSC 13. 6. 2007	1.3	0.0	2.5	0.0	21.3	8.8	12.0	24.0	8.7
CPM 7. 8. 2007	0.0	18.4	0.0	32.9	31.0	42.5	34.9	34.9	24.3
CPM 10. 9. 2007	12.3	29.8	12.0	426.4	384.5	110.0	282.4	169.4	178.3
CPM 15. 10. 2007	11.9	28.9	0.0	129.4	194.9	133.6	219.4	109.7	103.5
FSC 3. 7. 2008	0.0	6.3	2.5	17.0	3.6	5.8	12.0	12.0	7.4
CPM 4. 8. 2008	6.5	31.6	0.0	28.3	53.3	43.8	60.0	90.0	39.2
CPM 20. 9. 2008	13.3	21.5	0.0	19.3	60.5	19.9	122.6	40.9	37.2
Area of transects in m^2	2,517	2,344	1,290	581	926	1,126	548	548	9,880

FSC – Faecal standing crop, CPM – clearance plot method

CI) and 105 ± 88 individuals·km^{-2} (95% CI), respectively. In the Černý potok hunting district, the FSC and CPM method resulted in 8 ± 5 individuals·km^{-2} (95% CI) and 77 ± 50 individuals·km^{-2} (95 % CI), respectively. The mean values of red deer density on the particular plots and dates of particular visits are shown in Table 1.

In the Jelení hora hunting district in 2007, we found out a statistically significant difference in the values of red deer abundance determined by FSC and CPM methods (t = 3; P = 0.036) using the Wilcoxon Matched Pairs Test.

In 2008, a statistically significant difference in the red deer abundance determined by both methods was also proved (t = 0; P = 0.012).

In the Černý potok hunting district in 2007, a statistically significant difference was detected in the values of red deer abundance determined by FSC and CPM methods (t = 0; P = 0.012). In 2008, a significant difference in the abundance of game determined by both methods (t = 1; P = 0.017) was also demonstrated.

No statistically significant differences were found out between the game density and the particular groups of similar biotopes in 2007 (ANOVA χ^2 = 3.6; P = 0.463), in 2008 (ANOVA χ^2 = 8; P = 0.938) and on average for both years 2007/2008 (ANOVA χ^2 = 3.2; P = 0.525). Evaluation of both groups is shown in Table 2.

Table 2. Mean values of the red deer density (individuals·km^{-2}) in 2007, 2008 and a version 2007/2008 as compared to particular groups of similar biotopes. Differences are evaluated using Friedman ANOVA and Kendall Concordance

Density/group of plots	2007	2008	Mean 07/08
A	68.9	23.5	46.2
B	46.5	26.7	36.6
C	81.8	26.1	53.9
D	89.5	30.3	59.9
E	64.4	38.7	51.5
ANOVA χ^2	3.6	8	3.2
P	0.463	0.938	0.525

P – probability

DISCUSSION

It is very problematic to obtain objective data on the actual abundance of free-living animals in a certain area. Methods of direct counting are hardly utilizable in forest areas (Bailey, Putman 1981). In our research, we found out the relatively high mean abundance of red deer using both indirect FSC and CPM methods in the Jelení hora and Černý potok hunting districts in 2007–2008. A significant difference in the values of the estimate of red deer mean density using FSC and CPM methods was determined in all cases.

Generally, it is possible to state that several times higher density of red deer was determined in both hunting districts using the CPM method compared to values determined by the FSC method. We assume that it can be caused by a number of factors affecting the abundance of game in the region as well as by the inaccurate (estimated) input data used for the calculation of red deer density by the FSC method (particularly the faecal pellet persistence on the plots and the amount of daily defecation rates, which are different in particular seasons and in each individual (Mitchell et al. 1985).

The accuracy of both methods is also markedly affected by the number of faecal pellet groups in monitored transects (Buckland 1992). The omission of pellet groups or counting older groups can also often result in inaccuracies (Staines, Ratcliffe 1987). Under the same conditions Campbell et al. (2004) considered the FSC method to be generally more accurate than the CPM method. It is possible to assent to this statement only if the measurement is carried out on the sufficient area of research plots.

Laing et al. (2003) noted that the FSC method measures the number of existing faecal pellet groups being related to the rate of decomposition. Thus, it takes into account only really present pellets on the given plot during a certain period.

Nevertheless, the problem can consist in the proper determination of the time of faecal pellet decomposition, which can fundamentally affect the final result. By reason of the very variable time of pellet group decomposition in actual experiments in the area we determined the time of pellet decomposition by estimation from papers of Mayle et al. (2000) and Smart et al. (2004).

While using the FSC method, faecal pellets accumulate during a longer time period than when using the CPM method (Mayle 1996). This fact can also often result in inaccuracies. Buckland (1992) reported a higher probability of the occurrence of zero values per unit area in using faecal accumulation rate (FAR) techniques compared to the FSC method, which can result in the lower accuracy under comparable conditions. This prediction was also demonstrated on several research plots of ours.

The FSC method is considered by many authors as potentially less accurate on the ground of the time estimate of pellet group decomposition (Mitch-

ell, McCowan 1984). Mayle (1996) stated that for data collection the FSC method is more advantageous than the FAR method when minimally 2 visits/transect are necessary. However, it was not demonstrated in our research.

The actual monitoring of particular transects was carried out from June to October in 2007 and 2008. Prokešová et al. (2006) reported March as the period of counting faecal pellet groups on plots. However, continuous or partial snow cover lies in the monitored area at that time. The snow would make monitoring impossible on these plots.

The width of particular transects was selected according to a locality within the limits 2–10 m. The monitoring of particular plots was carried out by 2 workers who moved along the transect at the same time. In papers of other authors, the width of transects was different, e.g. 1.5 m (Campbell et al. 2004) or 1 m (Mayle et al. 2000).

The position of particular plots was selected in such a way that they would be evenly distributed throughout the district and would cover all main biotopes. However, it is not possible to exclude an error in the distribution of particular transects which may be caused by the preference of a certain environment, e.g. in connection with the attractive supply of food for game. It can finally result in the overvaluation or undervaluation of red deer abundance in the area. Prokešová et al. (2006) also came to similar conclusions. In our research, no significant differences were demonstrated between groups (similar biotopes) and the density of game in these areas.

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