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Faecal pellet count method: some evaluations of dropping detectability for *Capreolus capreolus* Linnaeus, 1758 (Mammalia: Cervidae), *Cervus elaphus* Linnaeus, 1758 (Mammalia: Cervidae) and *Lepus europaeus* Pallas, 1778 (Mammalia: Leporidae)

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Abstract

Faecal pellet count is an indirect census method used to estimate the density of an animal population. Factors that affect the accuracy and precision of this method are the defecation rate, the decay time and the detectability of the droppings. In this study, we analysed the influence of some variables on the detectability of droppings: (i) environmental variables, EV (vegetation type, grass height, meteorological conditions); (ii) subjective variables, SV (operator, subjective visibility); (iii) faeces–species related variables, SRV (*Capreolus capreolus* Linnaeus, 1758; *Cervus elaphus* Linnaeus, 1758 and *Lepus europaeus* Pallas, 1778). The average values of dropping detectability, expressed as percentage of observations from the minimum detectability (0) to the maximum (1), were: 0.99 (SD = 0.07) for red deer faeces; 0.93 (SD = 0.16) for roe deer faeces; 0.89 (SD = 0.21) for European brown hare faeces. The red deer detectability value was statistically higher than the roe deer and European brown hare values ($X^2 = 26.61$, df = 2, $p < 0.01$). A generalised linear model (GLM) analysis shows that the variables which negatively affect the dropping detectability are different for the three species: (i) vegetation type, especially deciduous forest, for the red deer; (ii) grass height for the European brown hare; (iii) subjective visibility, especially the category "none", for the roe deer. These results suggest that the characteristics of both the study area and the species considered could affect the detectability of droppings, and therefore also the entire estimation density. So, faecal pellet count monitoring programmes should carefully take into account the environmental characteristics and should be performed when detectability is maximised (e.g. short grass, fewer leaves, less undergrowth).

Keywords: *Faecal pellet count, visibility, dropping detectability, percentage of observation, GLM*

Introduction

Faecal pellet count (FPC) is an indirect method used to estimate the density of an animal population from droppings on the ground. From the number of observed droppings, in combination with their decay time and the defecation rate of the target animal species, it is possible to obtain an accurate and precise density estimation (Putman 1984). This method was developed by Bennett et al. (1940) for the census of white-tailed deer (*Odocoileus virginianus* Zimmermann, 1780), and has been modified by different authors to improve its accuracy and precision (e.g. Eberhardt & Van Etten 1956; Van Etten & Bennett 1965; Mayle et al. 1999; Krebs et al. 2001).

FPC methods can be divided in two main categories: clearance count (CC) and faecal standing crop count (FSCC) (Mayle et al. 1999). The differences between the two mainly concern (i) the number of visits to each sample area to obtain a density estimation: two visits with the CC and one with the FSCC, and (ii) the parameters taken into account for the estimation: just the defecation rate for the CC and both defecation rate and decay time for the FSCC (Mayle et al. 1999).

FPC can be used as a census method (in a strict sense) within the context of a plot sampling survey, if the detection probability of dung is 100% (Borchers et al. 2002). Otherwise, this assumption can be relaxed

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when adopting other sampling methods, such as distance sampling (Marques et al. 2001). Several studies have pointed out that the FPC accuracy and precision are affected by different factors, the most important ones being: (i) defecation rate, (ii) decay time and (iii) detectability of the droppings (e.g. Van Etten & Bennett 1965; Mayle et al. 1996; Theuerkauf et al. 2008). The defecation rate is the number of pellet groups produced in one day by an animal, and the decay time indicates the number of days that a pellet group takes to deteriorate (Mayle et al. 1999). A pellet group is defined as a cluster of six or more pellets produced at the same defecation (Mayle et al. 1999). These two factors may change depending on animal species, diet, climate conditions (rainfall and temperature), habitat, and presence of invertebrate fauna (e.g. Neff 1968; Massei et al. 1998; Mayle et al. 1999; Prugh & Krebs 2004). The detectability of the droppings depends on (i) the dimensions of the faeces and/or pellet group, (ii) the environmental characteristics (e.g. grass height, vegetation type) and (iii) the ability of the operator to detect the pellet groups (Theuerkauf et al. 2008). The literature dealing with defecation rate and decay time is quite abundant (e.g. Mayle et al. 1999; Laing et al. 2003), but there is still little information about the extent to which density estimations are influenced by variable levels of dropping detectability (Theuerkauf et al. 2008).

The primary aim of this work is to evaluate the influence of environmental variables (EV) and subjective variables (SV) on the detectability of droppings. Secondly, differences in dropping detectability among animal species (SRV) are also assessed, to evaluate how the FPC method could change according to the target animal species. From a practical point of view, these evaluations could be useful to improve the accuracy and precision of the FPC, and therefore should be taken into consideration in the survey design.

The animal species considered are those (i) more common in the study area and (ii) whose populations are commonly studied with FPC methods: roe deer (*Capreolus capreolus* Linnaeus, 1758), red deer (*Cervus elaphus* Linnaeus, 1758) and European brown hare (*Lepus europaeus* Pallas, 1778).

Materials and methods

Study area

The study was carried out in the Varaita valley, in the northwest of Italy, during autumn 2012 (Figure 1). The study area ranged from 600 m above sea level (asl) to 2300 m asl, characterised by a humid continental climate and an alpine climate at the higher elevations. The vegetation is typical of Alpine valleys: deciduous forest at lower altitudes, coniferous forest at intermediate altitudes and alpine pastures above the timberline.

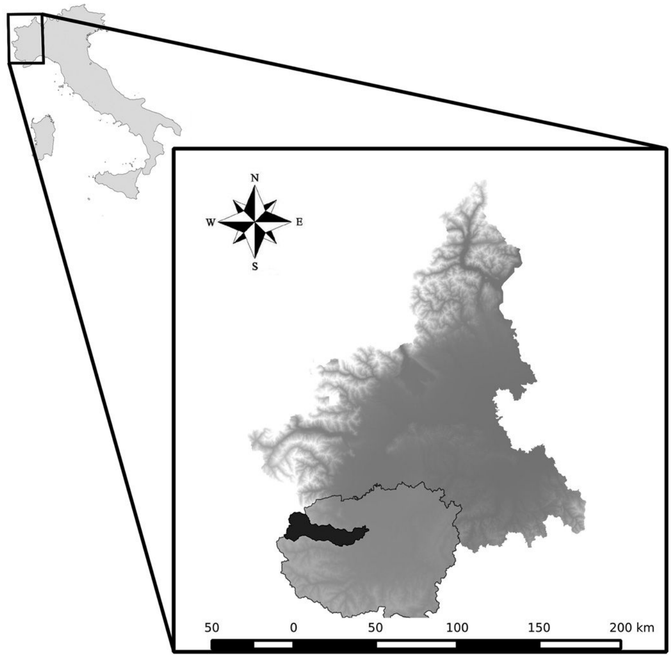

Figure 1. Location of the study area (dark grey): the *Varaita* valley, in Cuneo province and Piedmont region, in the northwest part of Italy.

Methodology

To test and verify how the detectability of droppings is affected by environmental, subjective and species-related variables, we checked its performance under controlled conditions, analysing how many droppings were found against the total number of droppings present.

The influence of five vegetation types was evaluated for the study, on the basis of the environments most frequently used by the three species: (1) mixed conifer forest, with silver fir (*Abies alba* Mill, 1768), Norway spruce (*Picea abies* Karst, 1881) and Swiss pine (*Pinus cembra* Linnaeus, 1753); (2) larch forest, with European larch (*Larix deciduas* Mill, 1768); (3) deciduous forest, with European beech (*Fagus sylvatica* Linnaeus, 1758), common hazel (*Corylus avellana* Linnaeus, 1753) and sweet chestnut (*Castanea sativa* Miller, 1754); (4) alpine pastures (grassland above the timberline); (5) field (grassland not cultivated beneath the timberline). A total of 90 sample areas were uniformly divided among the five vegetation types selected (18 sample areas for each vegetation type), as recommended by Mayle et al. (1999) for the stratified sampling method. The sample areas were geographically distributed with the Quantum GIS random point function (QGIS Development Team 2008) considering the stratification previously explained.

Since in natural conditions, it is not possible to know beforehand the total number of droppings present on the ground, we calculated the percentage of observation (*f*) using marked droppings positioned *ad hoc* on the sample areas. These droppings were previously marked with paint to distinguish them from droppings naturally present. White paint was used because it is a colour less detectable on the ground (Kufeld 1968). The mark was performed with a little white circular spot on one face of the pellet. Marked droppings were positioned in the sampled areas with the mark facing the ground. Under these conditions, the operator cannot see the mark and the census operations are therefore not affected by its presence. The operator in charge of depositing marked droppings was different from the one involved in the monitoring. The total number of droppings deposited in each sample area was a variable number (not a fixed one), to allow a blind evaluation (the average value for each sample area was: 3.6 ± 1.2 pellet groups for roe deer, 3.5 ± 1.4 pellet groups for red deer, 8.5 ± 4.4 pellets for European brown hare). The sample area corresponds to a 60-m^2 plot (3 × 20 m), and the marked droppings were positioned according to a random scheme in each sample area. The size and position of the pellet groups were also established with a random scheme for each sample area.

Because of the different biology of the hare (fewer pellets produced and more scattered), a “single observation” was defined as the finding of one pellet (p) for European brown hare (Krebs et al. 2001) and one pellet group (pg) for red deer and roe deer (Mayle et al. 1999).

Each sample area was surveyed with the FPC method for the simultaneous study of the marked droppings of roe deer, red deer and European brown hare. Following the method of Mayle et al. (1999), droppings were searched for within the plot by systematically analysing the ground, and also moving part of the vegetation (grass and leaves).

The variables analysed in the study are reported in Table I and were recorded for each sample area.

Statistical analysis

For each sample area, we calculated the percentage of observation (*f*) as the fraction of found droppings with the total number of deposited droppings, considering the droppings as single pellets (p) for European brown hare and pellet groups (pg) for roe and red deer. The possible values of *f* range from 0 to 1, where 0 indicates non-detectability and 1 the maximum detectability for the droppings. The *f* parameter has then been analysed with a generalised linear model approach (GLM) to evaluate which are the most important variables that affects the detectability of the droppings. The *f* parameter has been normalised using its average and standard deviation.

The GLM analysis was elaborated with a stepwise selection with backward elimination. The best models

Table I. Factors evaluated in the study; all variables are considered categorical.

Vegetation type (Veg_type)	Grass height (Grass_height)	Meteorological conditions (Met_cond)	Operator (Operator)	Subjective visibility (Sub_visibility)	Species (Species)
Conifer forest	0	Sunny	1	Good	Roe deer
Larch forest	1–10 cm	Partially cloudy	2	Sufficient	Red deer
Deciduous forest	11–20 cm	Cloudy		Inadequate	European Brown hare
Alpine prairie	21–30 cm			None	
Field	31–40 cm				

were the ones with lower values of the Akaike Information Criterion (AIC) (Bozdogan 1987). The family distribution adopted in the GLM analysis was the "gaussian" family with the "identity" link function.

All statistical analyses were performed with the software RStudio 0.96.122 (RStudio 2012).

Results

The results of the average value of the parameter *f* for the total sampled areas, divided among animal species, are reported in Table II and Figure 2. From this analysis, we noted a slight difference among the averages of the *f* parameter for the three species (Table II). A Kruskal–Wallis test revealed a significant effect of the species on the *f* parameter (X^2 = 26.61, df = 2, p < 0.01). A post-hoc test using Mann–Whitney tests with Bonferroni correction showed significant differences between red deer and European brown hare (r = 0.38, p < 0.01) and between red deer and roe deer (r = 0.26, p < 0.01).

The results of the GLM analysis for each animal species are reported in Table III, together with the AIC values, the coefficients estimated for the significant variables and the statistical parameters for each GLM model. The variables which affect the parameter *f* are: subjective visibility in the roe deer model (R^2 = 0.59, F = 40.97, p < 0.01, AIC = 182.75), vegetation type in the red deer model (R^2 = 0.11, F = 2.54, p < 0.05, AIC = 233.72) and grass height in the European brown hare model (R^2 = 0.25, F = 7.13, p < 0.01, AIC = 238.46).

In the roe deer model, the only category of subjective visibility which has a statistically significant influence on *f* is the "none" visibility, which generates a negative trend in the detectability of the droppings (β = –3.10, t = –11.04, p < 0.01). In the red deer model, the only category of vegetation type that has a statistical significant influence on *f* is the "deciduous forest", which produces a slightly negative trend in the detectability of the droppings (β = –0.75, t = –2.60, p < 0.05). In the European brown hare model, there are two categories of grass height that have a statistical significant influence on *f*. The group "31–40 cm" is the one that has the most negative influence on the detectability (β = –2.21, t = –5.14, p < 0.01), while the group "11–20 cm" has a minor effect on *f* (β = –0.63, t = –2.12, p < 0.05).

Table II. Average value of *f* divided for the three animal species; we include, respectively, the average value of *f*, the standard deviation (SD) and the range of the 95% confidence interval (CI min and CI max).

Species	Average	SD	CI min	CI max
Roe deer	0.93	0.16	0.90	0.97
Red deer	0.99	0.07	0.97	1.00
European brown hare	0.89	0.21	0.85	0.94

Discussion

Many studies have been performed to evaluate the FPC method and to assess the influence of defecation rate and decay time on density estimations (e.g. Putman 1984; Harestad & Bunnell 1987; Lehmkuhl et al. 1994; Mayle et al. 1996; Massei et al. 1998; Krebs et al. 2001; Laing et al. 2003; Prugh & Krebs 2004), but only a few of these have dealt with the detectability of droppings (Lehmkuhl et al. 1994; Persson 2003; Theuerkauf et al. 2008). Theuerkauf et al. (2008) carried out one of the first studies in this direction, but there is still work to be done to fill this gap and to be able to evaluate the detectability of droppings on a larger scale. Our work is a step in this direction and is an important starting point for the evaluation of dropping detectability, and

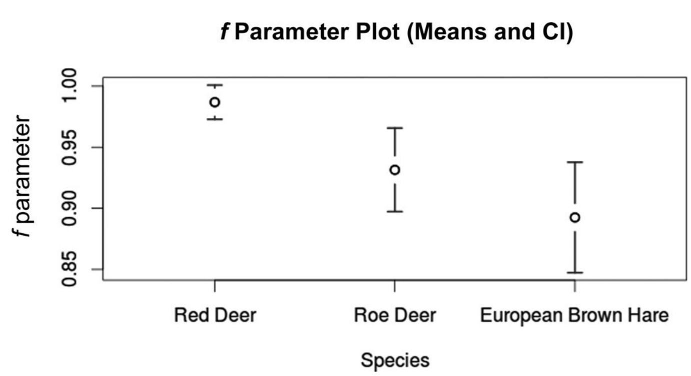

Figure 2. Plot of the global percentage of observation *f* grouped by animal species: the dots indicate the average value and the vertical bars indicate the confidence intervals (CI).

Table III. GLM results divided respectively among roe deer, red deer and European brown hare. For each species we include the formula of the best model with the corresponding AIC value, then the coefficients of the model where *B* is the estimated coefficient, SE the standard error, *t* the value of the test and *p* the *p*-value of each coefficient, then the GLM model and the related statistics. GLM: Generalised Linear Model; AIC: Akaike Information Criterion; SE: Standard Error; Sub_visibility: Subjective visibility; d.f.: degrees of freedom; Veg_type: Vegetation type.

	Formula: ***f* = Sub_visibility**				
	Minimum AIC value: AIC = 182,75				
	Coefficients:	*B*	SE	*t*	*p*
Roe deer	Intercept	0.256	0.088	2.904	0.005
	None	**−3.103**	**0.281**	**−11.043**	**< 0.01**
	Inadequate	−0.224	0.247	−0.904	0.369
	Sufficient	−0.141	0.171	−0.826	0.411
	Model: *y* = 0.256–3.103*("none_visibility")				
	GLM statistics: $\boldsymbol{R = 0.77}$ $\boldsymbol{R^2 = 0.59}$ $\boldsymbol{F = 40.97}$ **d.f. = 85** $\boldsymbol{p < 0.01}$				
	Formula: ***f* = Veg_type**				
	Minimum AIC value: AIC = 233,72				
Red deer	Intercept	0.225	0.204	1.103	0.273
	Larch forest	−4,790E–16	0.293	0.000	1.000
	Deciduous forest	**−0.750**	**0.289**	**−2.598**	**< 0.05**
	Alpine prairie	3,525E–16	0.289	0.000	1.000
	Field	−0.125	0.289	−0.433	0.666
	Model: *y* = 0.225–0.750*("deciduous_forest")				
	GLM statistics: $\boldsymbol{R = 0.33}$ $\boldsymbol{R^2 = 0.11}$ $\boldsymbol{F = 2.54}$ **d.f. = 84** $\boldsymbol{p < 0.05}$				
	Formula: ***f* = Grass_height**				
	Minimum AIC value: AIC = 238.46				
European brown hare	Intercept	0.332	0.165	2.009	< 0.05
	1–10_cm	−0.220	0.219	−1.003	0.319
	11–20_cm	**−0.630**	**0.297**	**−2.123**	**< 0.05**
	21–30_cm	−0.411	0.474	−0.866	0.389
	31–40_cm	**−2.213**	**0.430**	**−5.141**	**< 0.01**
	Model: *y* = 0.332–2.213*("31–40_cm") – 0.630*("11–20_cm")				
	GLM statistics: $\boldsymbol{R = 0.50}$ $\boldsymbol{R^2 = 0.25}$ $\boldsymbol{F = 7.13}$ **d.f. = 84** $\boldsymbol{p < 0.01}$				

Note: The text in bold highlights, respectively, the most important variable for the model of each species, the statistically significant coefficients and the relevant GLM statistics.

consequently improves the accuracy and precision of the FPC method.

In our analysis, there is a notable difference among the visibility of the droppings related to the animal species: the red deer pellet groups have a higher detectability than the roe deer and European brown hare droppings (Table II and Figure 2). This difference is similar to the results obtained by Theuerkauf et al. (2008) in their study: they estimated a detectability of 99% for red deer pellet groups and 47% for roe deer pellet groups. Moreover, our percentage of observation *f* for the red deer (*f* = 0.99, SD = 0.07) is exactly the same as that obtained by Theuerkauf et al. (2008). This first result suggests that the FPC method, a technique that requires finding all of the faeces present in each sample area for an accurate estimation density (Mayle et al. 1999), is suitable for studying red deer populations, because almost all the droppings are detected. However, our percentage of observation *f* for the roe deer (*f* = 0.93, S.D. = 0.16), although lower than the value for the red deer, is very different from the value of 47% of Theuerkauf et al. (2008), suggesting that the detectability of roe deer droppings may fluctuate on the basis of some type of variables, such as environmental characteristics or seasonal trends, as noted by other authors (Harestad & Bunnell 1987; Lehmkuhl et al. 1994). It is important, then, to study, at a local level and in different seasons of the year, the detectability of roe deer droppings before performing a FPC study, because these fluctuations could affect the accuracy of the method. A way to correct and control these fluctuations could be achieved by adopting a correction factor for dropping detectability, as suggested by Theuerkauf et al. (2008).

For the European brown hare, there are no data concerning dropping detectability, so a comparison of our percentage of observation *f* with other studies could not be carried out.

Considering the GLM analysis, we can see that there is no common variable that affects *f* for the three animal species, but every model is affected by a different one (Table III), probably due to the different size and shape of the pellets.

Both Lehmkuhl et al. (1994) and Persson (2003) state that the detectability of droppings is generally affected by environmental characteristics and by the season of the year. The latter factor has not been evaluated in our study, but we can agree on the environmental characteristics. For both red deer and European brown hare droppings, some environmental variables play an important role in decreasing the detectability: deciduous forest slightly affects red deer detectability while grass height is an important variable for the European brown hare. The influence of the deciduous forest is predictable, especially in autumn when we made the FPC, because falling leaves have a similar colour to the faeces and they can easily cover the pellet groups. If the FPC method had been carried out in winter or spring, perhaps this problem would be solved and the variable "vegetation type" would not affect detectability, as reported by Theuerkauf et al. (2008). Grass height is also a predictable affecting variable, because it was difficult to sample areas in which the grass was higher than 30 cm. Harestad and Bunnell (1987) also confirm that the detectability of pellet groups is lower in moist and vegetated environments than in dry and bare ones. The influence of grass height on dropping detectability is probably more evident for European brown hare (single pellets) than for roe and red deer (pellet groups). This difference is due to the fact that long grass could more easily cover a single, small pellet than a group of numerous pellets, so more precautions must be taken when monitoring animal species that deposit single pellets, like the European brown hare.

Regarding the variable affecting roe deer detectability, we should analyse the results with some consideration. Subjective visibility is a variable realised by the operator for evaluating beforehand the detectability expected from an environment. In other words, it is a variable that evaluates the judgement expressed by the operator. This variable seems to be an important predictor for roe deer detectability, because it predicts 59% of the variance of *f* ($R^2 = 0.59$, $p < 0.01$). Given the lack of other studies on this aspect, and the fact that it is a variable that does not help to increase detectability, we are unable to draw any conclusions or make any suggestions on this aspect.

Finally, the operator involved in the monitoring and the meteorological conditions does not seem to be important for the decrease in dropping detectability, but again in this case, the lack of literature on this aspect did not allow us to make comparisons with other studies.

These results could potentially be used by other FPC studies to correct the total number of observed pellet groups, considering the dropping detectability, and then to increase the FPC accuracy, but further studies would be needed in different environments and seasons to obtain appropriate correction factors applicable in different regions.

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References

Bennett LJ, English PF, McCain R. 1940. A study of deer populations by use of pellet-group counts. The Journal of Wildlife Management 4:398–403. doi:10.2307/3796010.

Borchers DL, Buckland ST, Zucchini W. 2002. Estimating animal abundance: Closed populations. London, UK: Springer-Verlag. 314 pp.

Bozdogan H. 1987. Model selection and Akaike's Information Criterion (AIC): The general theory and its analytical extensions. Psychometrika 52:345–370. doi:10.1007/BF02294361.

Eberhardt L, Van Etten RC. 1956. Evaluation of the pellet group count as a deer census method. The Journal of Wildlife Management 20:70–74. doi:10.2307/3797250.

Harestad AS, Bunnell FL. 1987. Persistence of black-tailed deer fecal pellets in coastal habitats. The Journal of Wildlife Management 51:33–37. doi:10.2307/3801624.

Krebs CJ, Boonstra R, Nams V, O'Donoghue M, Hodges KE, Boutin S. 2001. Estimating snowshoe hare population density from pellet plots: A further evaluation. Canadian Journal of Zoology 79:1–4. doi:10.1139/z00-177.

Kufeld RC. 1968. Use of paint for marking deer pellet groups. The Journal of Wildlife Management 32:592–596. doi:10.2307/3798940.

Laing SE, Buckland ST, Burn RW, Lambie D, Amphlett A. 2003. Dung and nest surveys: Estimating decay rates. Journal of Applied Ecology 40:1102–1111. doi:10.1111/j.1365-2664.2003.00861.x.

Lehmkuhl JF, Hansen CA, Sloan K. 1994. Elk pellet-group decomposition and detectability in coastal forests of Washington. The Journal of Wildlife Management 58:664–669. doi:10.2307/3809679.

Marques FFC, Buckland ST, Goffin D, Dixon CE, Borchers DL, Mayle BA, Peace AJ. 2001. Estimating deer abundance from line transect surveys of dung: Sika deer in southern Scotland. Journal of Applied Ecology 38:349–363. doi:10.1046/j.1365-2664.2001.00584.x.

Massei G, Bacon P, Genov PV. 1998. Fallow deer and wild boar pellet group disappearance in a Mediterranean area. The Journal of Wildlife Management 62:1086–1094. doi:10.2307/3802561.

Mayle BA, Doney J, Lazarus G, Peace AJ, Smith DE. 1996. Fallow deer (*Dama dama* L.) defecation rate and its use in determining population size. In: Resources utilization in Fallow Deer. Supplemento alle Ricerche di Biologia della Selvaggina. XXV, 20–22 June 1995. Florence. pp. 63–78.

Mayle BA, Peace AJ, Gill RMA. 1999. How many deer? A field guide to estimating deer population size. Forestry Commission Field book 18, Forestry Commission, Edinburgh. 96 pp.

Neff DJ. 1968. The pellet-group count technique for big game trend, census, and distribution: A review. The Journal of Wildlife Management 32:597–614. doi:10.2307/3798941.

Persson IL. 2003. Moose population density and habitat productivity as drivers of ecosystem processes in northern boreal forests. Ph.D. thesis. Umeå, Sweden: Swedish University of Agricultural Sciences.

Prugh LR, Krebs CJ. 2004. Snowshoe hare pellet-decay rates and aging in different habitats. Wildlife Society Bulletin 32:386–393. doi:10.2193/0091-7648(2004)32[386:SHPRAA]2.0.CO;2.

Putman RJ. 1984. Facts from faeces. Mammal Review 14:79–97. doi:10.1111/j.1365-2907.1984.tb00341.x.

QGIS Development Team. 2008. QGIS Geographic Information System. Open source geospatial foundation project. Available: http://qgis.osgeo.org. Accessed May 2013 14.

RStudio. 2012. RStudio: Integrated development environment for R (Version 0.96.122). Boston, MA. Available: http://www.rstudio.org. Accessed May 2013 14.

Theuerkauf J, Rouys S, Jędrzejewski W. 2008. Detectability and disappearance of ungulate and hare faeces in a European temperate forest. Annales Zoologici Fennici 45:73–80. doi:10.5735/086.045.0107.

Van Etten RC, Bennett CL. 1965. Some sources of error in using pellet-group counts for censusing deer. The Journal of Wildlife Management 29:723–729. doi:10.2307/3798548.