Use of pellet group counts in determining density and habitat use of moose Alces alces in Finland

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In Finland, monitoring of the moose *Alces alces* population has been based on moose sighting cards and on aerial or ground censuses. However, considerable criticism has been levelled at these techniques, and there is an increasing need for alternative census methods in monitoring and managing moose populations. In this study, pellet group counts were carried out to determine the density and habitat use of moose in a wintering area in central Finland. Pellet group counts were made using both strip and plot sampling procedures. Estimates of moose density depended significantly on the sampling procedures and on the parameters used. Moose density estimates based on plots were twice those based on strips. Different plot intervals in plot sampling gave similar results. Both sampling procedures gave similar results concerning the habitat use of moose. The highest pellet group densities were observed in young Scots pine *Pinus sylvestris* dominated thinning stands where winter food availability is considerably high. Because food is a limiting factor in winter, pellet group numbers should obviously well reflect moose habitat affinity, which can be classified in terms of forest stand characteristics. Pellet group counts could possibly be used to estimate population densities for moose management. However, it would appear that the plot method, which up to now is the widely used method, overestimates moose densities. Because of the great variation in the results, other possible sources of error in the parameters used should also be taken into account in order to improve the accuracy of the method to be applied.

Key words: Alces alces, habitat use, moose, pellet group counts, population density

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The successful management of game species at a sustainable level presupposes reliable estimates of different population parameters, such as population size and structure. Information about habitat use provides useful tools in combining forest and wildlife management. The numbers of moose *Alces alces* individuals have been estimated using aerial and ground censuses (Timmermann 1974). The pellet group count method is one way of performing a ground census.

The use of pellet group counts for big game was first reported by Bennett, English & McCain (1940). They suggested that this method can be used for determining approximate numbers of deer *Odocoileus* sp., as well as the movements and utilisation of for-

est types by deer. Neff (1968) reviewed the pellet group count technique and concluded that it can provide reliable data under most field conditions. Since then, the pellet group count method has been used for determining the habitat use of moose (e.g. Franzmann, Oldemeyer, Arneson & Seemel 1976b, Cairns & Telfer 1980, Forbes & Theberge 1993), deer (e.g. Stormer, Hoekstra, White & Kirkpatrick 1977, Cairns & Telfer 1980, Collins & Urness 1981, Bozzo, Beasom & Fulbright 1992), wapiti *Cervus canadensis* (Cairns & Telfer 1980), bison *Bison bison* (Cairns & Telfer 1980) and roe deer *Capreolus capreolus* (e.g. Papageorgiou 1978, Henry 1981, Aulak & Babinska-Werka 1990a, 1990b, Kay 1993). Pellet group counts have also been used for estimating the density of moose (e.g. Franzmann et al. 1976b, Jordan, Peterson, Campbell & McLaren 1993, Olsson, Wirtberg, Andersson & Wirtberg 1997), white-tailed deer *Odocoileus virginianus* (e.g. Eberhardt & van Etten 1956, Neff 1968, Fuller 1991), mule deer *O. hemionus* (Rogers, Julander & Robinette 1958, Freddy & Bowden 1983), fallow deer *Dama dama* (Bailey & Putman 1981) and roe deer (e.g. Lindström, Andrén, Angelstam, Cederlund, Hörnfeldt, Jäderberg, Lemnell, Martinsson, Sköld & Swenson 1994, Cederlund & Liberg 1995, McIntosh, Burlton & McReddie 1995, Olsson et al. 1997). The monitoring of cervid species by pellet group counts has, however, error sources that decrease the accuracy of the estimate. For instance, a variable individual defecation rate and observer bias should be taken into account when drawing conclusions (Neff 1968).

In Finland, managing and monitoring of the moose population has been based on questionnaires (i.e. moose sighting cards) and aerial and ground censuses (Nygrén & Pesonen 1993). Recently, there has been some controversy over the validity of questionnaires. There is, therefore, a need to develop alternative census methods for obtaining more reliable data about moose numbers that could be used to maintain a sustainable population level through hunting. It has been suggested (Tiainen 1998) that pellet group counts could be included in wildlife triangle censuses when determining roe deer and white-tailed deer densities. The same method should obviously be useful for moose as well.

The aim of the present study is to compare two methods used in pellet group counts for determining moose winter density and habitat use, and to evaluate the reliability of the pellet group count method in monitoring moose populations.

Material and methods

Study area

The study area is situated at Lakomäki (62°54'N, 25°38'E) in central Finland. The forests are intensively managed and the dominant tree species is Scots pine *Pinus sylvestris*. In addition, there is an admixture of deciduous trees such as silver birch *Betula pendula*, white birch *B. pubescens*, aspen *Populus tremula*, rowan *Sorbus aucuparia* and willows *Salix* spp., which are important food for moose during winter. The study area is a well-known winter range area with a moose density of ca 2/km^2 in winter 1995/96 according to fixed-wing aircraft surveys. The survey in 1998/99 showed that the moose population had increased to ca 3/km^2 (J. Purhonen, unpubl. data). The moose density after the moose hunting season in December 1996 was 1/km^2 (J. Purhonen, unpubl. data). Winter ranges are considered to be suitable for pellet group counts (Neff 1968).

Pellet group counts and moose density

In the study area we inspected 45 4-metre-wide strips in spring and early summer 1997. The length of the strips averaged 772 m and varied between 300 and 1,440 m. In addition, the pellet groups were counted on circular plots (12.57 m^2, r = 2.0 m) at 20-metre intervals along each strip. The total number of plots inspected was 1,734.

The inspections were made by three observers. One of them made the compass line, marked the mid-line of the strip and counted the pellet groups. The other two counted the pellet groups along a 2-metre strip to the right and left of the mid-line. It was assumed that the number of missed pellet groups would be negligible using this procedure. Only the pellet groups lying on dead grass, hay or other dead plant material originating from late autumn to spring were counted. An edge group was counted if half or more of the pellets were lying within the strip or plot.

Moose density (moose/km^2) was calculated using the formula ((D/A)/(TxF)), where D is the number of pellet groups found, A the total area sampled (km^2), T the number of days the pellet groups had accumulated, and F the average number of defecations per day and individual (see Olsson et al. 1997). The variations of the moose density estimates were calculated among the strips (*cf.* Jordan et al. 1993). Thus, the number of pellet groups found on the plots along each strip was pooled in the plot sampling procedure. We calculated four different moose density values in order to investigate the effect of the parameters used

on the results. The number of days during which the pellet groups had accumulated was set as 210 days or 240 days, and the average number of defecations per day and individual was set as 14 (see Olsson et al. 1997) or 20.9 (Jordan et al. 1993).

Habitat classification and habitat use

Habitat classification was made on every strip and plot, and the strip length in each habitat type was measured. Forest compartments were classified according to the main categories used in forest management (1 = mineral soil forest, 2 = peatland forest), dominant tree species (1 = Scots pine, 2 = Norway spruce *Picea abies*, 3 = birch), forest site type (1 = *Myrtillus* type, 2 = *Vaccinium* type, 3 = *Calluna* type; Cajander 1909) and forest development class (1 = open stand or young stand, 2 = advanced young stand, 3 = young thinning stand, 4 = advanced thinning stand or mature stand). Habitat affinity was estimated according to the availability of acceptable food resources: areal coverage of 0-25% = poor, 26-50% = low, 51-75% = moderate, >75% = good. For winter, the estimates were made according to the edible tree species accessible at heights of over 50 cm. Dwarf shrubs are periodically available in winter and their availability was taken into account if the tree layer was in between the two classes. For summer, the accessible deciduous seedlings and saplings were ranked accordingly. An affinity index was used in ranking the habitat types, and was calculated as follows: index = (number of pellet groups in habitat x / total number of pellet groups)/(sampling area in habitat x / total sampling area) (*cf.* Cairns & Telfer 1980). An index value of 1.0 shows use of the habitat in the proportion that it occurs.

Statistical analyses

Chi-square goodness-of-fit analysis was used to test the hypothesis that the observed habitat use corresponded to the expected use based on habitat availability (Neu, Byers & Peek 1974). If the null hypothesis was rejected and a significant difference ($P < 0.05$) was detected in use versus availability, the Bonferroni Z-statistic with 95% confidence intervals (Neu et al. 1974) was used to determine which habitat types were used by moose in proportions higher or lower than their availability ($P < 0.05$).

Results

Moose density

There were considerable differences between the moose density estimates obtained using different parameters (Table 1). The difference in moose numbers was about 30% depending on the time used in calculating the defecation period. The density estimates obtained from plot counting were twice those obtained using the strips. The effect of sampling intensity on the density estimates was slight when different plot intervals were used.

Habitat use

In each comparison, the χ^2-goodness-of-fit tests revealed that pellet groups occurred in the habitats in proportions different from those expected on the basis of availability ($P < 0.05$). Mineral soil forests were used more ($P < 0.05$) and peatland forests less ($P < 0.05$) than expected (Table 2). Pine-dominated stands were used more ($P < 0.05$) than expected. Spruce-dominated and birch-dominated habitats were used less ($P < 0.05$) than expected from their availability. *Calluna*-type habitats were used more ($P < 0.05$) than expected. More fertile forest site types were used less ($P < 0.05$) than expected. Young thinning stands were used more ($P < 0.05$) than expected from their availability and advanced young stands were used in accordance with their availability, whereas open and young stands as well as advanced thinning stands and mature stands were used less ($P < 0.05$) than expected.

The number of pellet groups observed was significantly higher than the expected number ($P < 0.05$) in

Table 1. Effect of the parameters used in density estimates (moose/km^2) made on strips and plots. The parameters used include: T = the number of days during which the pellet groups had accumulated; F = the average number of defecations per day and individual. Density estimates are given for different plot intervals in the plot sampling procedure.

Parameters			Moose density estimate			
			Plot interval			
T	F	Strips	20 m	40 m	60 m	80 m
210	14	6.8	13.7	13.7	12.3	14.3
240	14	6.0	12.0	12.0	10.7	12.6
210	20.9	4.6	9.2	9.2	8.2	9.6
240	20.9	4.0	8.1	8.0	7.2	8.4

Table 2. Occurrence of pellet groups and affinity indices on strips in different habitat types. Pellet groups and affinity indices based on plots are presented in parentheses.

Habitat classification	Proportion of total area	Proportion of pellet groups (P_i)	Affinity index	Confidence interval on proportion of occurrence (P_i)
Main category				
Mineral soil forest	0.733	0.891* (0.897)	1.2 (1.2)	$0.877 \leq P_1 \leq 0.905$
Peatland forest	0.267	0.109* (0.103)	0.4 (0.4)	$0.095 \leq P_2 \leq 0.123$
Dominant tree species				
Scots pine	0.843	0.936* (0.950)	1.1 (1.1)	$0.924 \leq P_1 \leq 0.948$
Norway spruce	0.109	0.028* (0.025)	0.3 (0.2)	$0.020 \leq P_2 \leq 0.036$
Birch sp.	0.047	0.036* (0.025)	0.8 (0.5)	$0.027 \leq P_3 \leq 0.045$
Forest site type				
Myrtillus	0.533	0.318* (0.326)	0.6 (0.6)	$0.295 \leq P_1 \leq 0.341$
Vaccinium	0.308	0.248* (0.259)	0.8 (0.8)	$0.227 \leq P_2 \leq 0.269$
Calluna	0.159	0.434* (0.415)	2.7 (2.6)	$0.410 \leq P_3 \leq 0.458$
Forest development class				
Open + young stand	0.055	0.017* (0.022)	0.3 (0.4)	$0.010 \leq P_1 \leq 0.024$
Advanced young stand	0.031	0.036 (0.029)	1.1 (0.9)	$0.027 \leq P_2 \leq 0.045$
Young thinning stand	0.633	0.863* (0.873)	1.4 (1.4)	$0.846 \leq P_3 \leq 0.880$
Advanced thinning + mature stands	0.281	0.084* (0.076)	0.3 (0.3)	$0.070 \leq P_4 \leq 0.098$

* The observed pellet group distribution differed significantly from the expected distribution ($P < 0.05$).

habitats ranked moderate or good in winter with respect to accessible food (Table 3). Good summer habitats were used less than expected from their availability ($P < 0.05$). The proportions of observed pellet groups and affinity indices were rather similar in the respective habitat types when the pellet group count methods were compared (see Tables 2 and 3).

Discussion

The estimates of the moose population density obtained using pellet group counts varied much. The number of days in the counting period can be standardised for between-year comparisons, and the use of permanent sampling areas will minimise this type of error. It is a well-known fact that the large variability in the daily defecation output limits the use of pellet group counts for accurate censuses of moose (Timmermann 1974, Franzmann, Arneson & Oldemeyer 1976a, Franzmann et al. 1976b, Oldemeyer & Franzmann 1981, Joyal & Ricard 1986). On the other hand, Jordan et al. (1993) demonstrated that moose pellet group counts can also give reliable results. They suggest that each local moose population should be calibrated separately in order to use defecation rates that correspond to the food resources. However, this is difficult to perform, and it would be more feasible to compare the pellet group method with e.g. aerial counts (Jordan et al. 1993).

The size and shape of the sample plots affect the results obtained by pellet surveys. With large plots the number of missed pellet groups may increase because of the higher observer error (Neff 1968). Jordan et al. (1993) concluded that a circular plot is optimal for counting moose pellet groups. They used

Table 3. Occurrence of pellet groups and affinity indices on strips in different habitat types during winter and summer. Pellet groups and affinity indices based on plots are presented in parentheses.

Habitat classification	Proportion of total area	Proportion of pellet groups (P_i)	Affinity index	Confidence interval on total proportion of occurrence (P_i)
Habitat affinity in winter				
Poor	0.372	0.093* (0.097)	0.3 (0.3)	$0.078 \leq P_1 \leq 0.108$
Low	0.293	0.190* (0.207)	0.7 (0.7)	$0.170 \leq P_2 \leq 0.210$
Moderate	0.294	0.609* (0.588)	2.1 (2.0)	$0.584 \leq P_3 \leq 0.634$
Good	0.041	0.107* (0.109)	2.6 (2.8)	$0.091 \leq P_4 \leq 0.123$
Habitat affinity in summer				
Poor	0.528	0.619* (0.603)	1.2 (1.1)	$0.594 \leq P_1 \leq 0.644$
Low	0.278	0.196* (0.203)	0.7 (0.7)	$0.176 \leq P_2 \leq 0.216$
Moderate	0.142	0.154 (0.162)	1.1 (1.2)	$0.136 \leq P_3 \leq 0.172$
Good	0.053	0.031* (0.031)	0.6 (0.6)	$0.022 \leq P_4 \leq 0.040$

* The observed pellet group distribution differed significantly from the expected distribution ($P < 0.05$).

circular plots of 65.74 m^2, and Olsson et al. (1997) used 25 m^2 circular plots for moose and 10 m^2 for roe deer. In the case of roe deer, the smaller plot size obviously decreases the number of missed pellet groups (*cf.* Smith 1968) just because they are relatively small. In this respect, Cederlund & Liberg (1995) also recommended a size of 10 m^2 for roe deer.

According to Franzmann et al. (1976b), there is a risk of overestimating moose numbers in pellet group counts. In our study, there was a twofold difference in the moose density estimates given by strips and plots. A similar trend was also observed in the roe deer density estimates in southern Finland (R. Heikkilä & S. Härkönen, pers. obs.). Based on other information available about the area, the strip method evidently gave moose numbers closer to the actual ones whereas the densities from plot sampling were overestimates. Both methods may, however, include considerable sources of error, despite the fact that the observations were made by three experienced observers and that moose pellets are relatively large. The lower density on the strips could be due to uncounted pellet groups lying on the border line. This is probably one reason for low density estimates in counting relatively small pellet groups of white-tailed deer in Pennsylvania (D. deCalesta, pers. comm.). In the case of moose, one possible source of error is that the observers may include more groups lying on the border lines of plots than when using the strip method. The sampling intensity was relatively high on the strips, obviously increasing the accuracy of the estimates. However, strip counting is time-consuming compared to plot sampling. In addition, it appears that plot sampling gives rather similar estimates even at relatively long plot intervals.

The moose densities obtained in the present study were considerably higher than those estimated by hunters after the moose hunting season in December 1996. This difference could be due to moose movements. The study area is a well-known wintering area where moose density can be relatively high in mid-winter due to migration from summer ranges.

Moose density estimates from pellet surveys are based on a longer time period than aerial surveys where the estimates are made during a relatively short period of time. Thus moose movements, in particular, may affect the accuracy of aerial surveys. In this respect, we believe that pellet surveys may provide results sufficiently reliable for management purposes. Pellet group counts can be combined with aerial surveys (Forbes & Theberge 1993) to obtain more comparative information. Aerial surveys have, however, many sources of error that are difficult to quantify (Timmermann 1974). If the density estimates are considered to be uncertain, between-year trends can be used to improve the situation. In central Newfoundland, for instance, pellet group counts, aerial censuses and hunter observations were compared, and each method indicated a decline in the moose population (Bergerud, Manuel & Whalen 1968).

Franzmann et al. (1976b) concluded that the distribution of pellet groups corresponded to the reported and observed habitat use of moose in their study area in Alaska. According to Cairns & Telfer (1980), moose select forest habitats more evenly in relation to availability than white-tailed deer, which are more dependent on the shelter provided by larger trees. In addition, the bedding and feeding habitats of smaller cervids may differ considerably, and the suitability of pellet group counts in estimating the habitat use of deer has been questioned (Collins & Urness 1981). They noticed that the defecation rates were highest when the deer were most active, and especially immediately after resting, because deer defecated soon after leaving their beds. On the other hand, roe deer have been reported to bed often at feeding sites during summer (Mysterud 1996), i.e. pellet groups should be in the most used habitats. Similarly, the highest number of roe deer beds was relatively close to the feeding habitats during winter (Mysterud & Østbye 1995). Risenhoover (1986) reported that bedding, feeding, ruminating and food searching constituted 99% of moose winter time budgets in Alaska. He also suggested that moose have short food-searching distances in areas with high food availability. This means that pellet groups should be found near the feeding areas. According to browse surveys, pellet group density correlates positively with browsing intensity (Heikkilä & Härkönen 1993, 1998). In our study, the highest pellet group densities were observed in young Scots pine-dominated thinning stands, that provide good winter feeding habitats in our study area. Lateral twig accessibility is high and moose browse heavily in these stands (Heikkilä & Härkönen 1998). More fertile forest site types with spruce dominance are less favourable for moose, because food availability is low in these closed middle aged or older stands. Thus, we believe that the pellet group distribution gave a good indication of moose activity patterns and can be used to estimate the habitat use of moose.

Lautenschlager & Jordan (1993) suggested that a combined winter track/pellet group count method

would be suitable for censusing moose in easily accessible areas. In this respect, it might be reasonable to include pellet group counts in Finnish wildlife triangle censuses, as suggested by Tiainen (1998). Another important aspect is that pellet group counting is a considerably cheaper method than aerial surveys made from a helicopter (S. Härkönen, pers. obs.). Wildlife triangle censuses are performed in Finland using triangles of 12 km in length. The counting line has been marked out in the terrain and remains the same over the years. Triangle censuses are performed in late summer for Tetraonid species and in mid-winter for mammalian game species. If pellet group counts are included in triangle censuses, a third count is needed in spring. This means that the pellet group counts should be started as soon as possible after snow melt, and completed before spring growth becomes too dense because dense vegetation lowers the visibility of the pellet groups and increases the time used on counting. In addition, this count should include as many game species as possible, because it does not make economical sense if moose is the only species included. For instance, Lindström et al. (1994) counted mountain hare *Lepus timidus*, woodland grouse and roe deer in their pellet surveys. McIntosh et al. (1995) concluded that monitoring pellet groups is a useful method for tracking changes in roe deer density, because the rate of defecation is relatively constant within a given habitat type (Mitchell, Rowe, Ratcliffe & Hinge 1985). According to Fuller (1991), pellet group counts are of limited value in estimating white-tailed deer density. Fuller's conclusion was, however, immediately questioned by White (1992). In this respect, pellet group counts would possibly be suitable for monitoring the white-tailed deer and roe deer populations in southern Finland. If pellet group counts are conducted using triangle census routes, the sampling plots should be permanent and the centre point of the plot should be marked. The old pellet groups should be removed from the plots during the late summer census. Thus, the exact number of days during which the pellet groups have accumulated in spring countings will be known, and one of the major sources of error in this method will thereby have been minimised.

In conclusion, it is suggested that pellet group counts can be useful in monitoring habitat use and density of moose, and likely other cervid species as well. However, considerable attention should be paid to the sampling procedure and parameters used in the calculations because they may have significant effects on the results. The problems involved in calculating exact population density values should be taken into account, and it would obviously be better to compare only between-year trends.

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