DIURNAL DEFECATION RATE OF MOOSE IN SOUTHWEST FINLAND

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ABSTRACT: An accurate measure of defecation rate is essential for application of pellet group counts in moose (*Alces alces*) population estimates. We measured the wintertime, diurnal defecation rate of moose by tracking 7 GPS-collared and 22 uncollared moose in southwest Finland. The mean defecation rate was 23.5 ± 4.2 pellet groups/d, one of the highest values reported. The mean defecation rate did not differ between the tracking methods (GPS vs. uncollared moose); limited sample size precluded conclusions about sex and age differences. The defecation rate was not correlated with calendar week, length of accumulation period, or number of diurnal beds. Our results are appropriate for use in southwest Finland when using the pellet group method to assess moose population density.

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Counting fecal pellet groups of moose (*Alces alces*) has been widely used to estimate habitat utilization, feeding behavior, and population trends and density (see Franzmann et al. 1976b, Forbes and Theberge 1993, Härkönen and Heikkilä 1999, Rönnegård et al. 2008, Månsson 2009, Månsson et al. 2011a, b). Reliable moose population estimates are not always realized from pellet group counts (Rönnegård et al. 2008), but the method's usefulness has been noted (Neff 1968, Lautenschlager and Jordan 1993, Månsson et al. 2011b), despite some uncertainty (Neff 1968). However, to successfully estimate moose population density using a pellet group count, it is critical to use an accurate defecation rate in the survey area and time period (Timmermann 1974).

Earlier studies have used 2 main methods to estimate the defecation rates of moose: 1) track moose in snow-covered terrain (Joyal and Ricard 1986, Andersen et al. 1992), and 2) estimate the number of pellet groups in a closed area or island where the number of moose is known (Jordan et al. 1993). Defecation rates have occasionally been estimated by comparing the aerial censuses and pellet group counts in specific areas (Rönnegård et al. 2008). Moose enclosures could also be utilized, but results from domestic moose can be affected by food quality and behaviour that are dissimilar to natural conditions. GPS radio-collars enable intensive and accurate tracking by identifying specific individuals and the beginning and end points of their specific tracks, providing ideal conditions to measure defecation rates of free-ranging moose.

Moose defecation rates vary by age, sex, habitat, food quality, season, and year (DesMeules 1968, Franzmann et al. 1976a, Oldemeyer and Franzmann 1981, Joyal and Ricard 1986, Andersen et al. 1992, Månsson et al. 2011b). Large variations in defecation rate have been reported in different areas; for example, in North America variation was 9.6–32.2 pellet groups/d (Timmermann 1974), and in northern Europe rates varied

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from 14–26.9 pellet groups/d (Andersen et al. 1992, Remm and Luud 2003, Rönnegård et al. 2008). These data emphasize the importance of using area-specific rates when using the pellet group method to estimate moose population density.

Our main objective was to formulate a general estimate of the wintertime, diurnal defecation rate of moose in southwest Finland by tracking both GPS-collared and uncollared moose in snowy terrain. We also compared these 2 tracking methods and looked for differences in defecation rates between sex and age.

STUDY AREA

Moose were tracked in 2 separate areas approximately 100 km apart in southwest Finland (Fig. 1). Uncollared moose were tracked in the Orivesi-Kangasala area (~WGS84 61°36′ N, 24°22′ E) and GPS-collared moose in the Loppi-Hyvinkää area (~WGS84 60°38′ N, 24°35′ E). Both areas are located in the southern boreal vegetation zone with Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*) as the dominant tree species. Forest cover was 78% of the total land area in Orivesi-Kangasala and 71% in Loppi-Hyvinkää (Metla 2012).

METHODS

Tracking of Uncollared Moose

We actively searched for uncollared moose in their known habitats during fresh snow conditions between December and April, 1999–2003. The accumulation period for pellet counts began when moose were seen or flushed, enabling data collectors to accurately time their count by locating fresh resting places, pellet groups, or tracks in

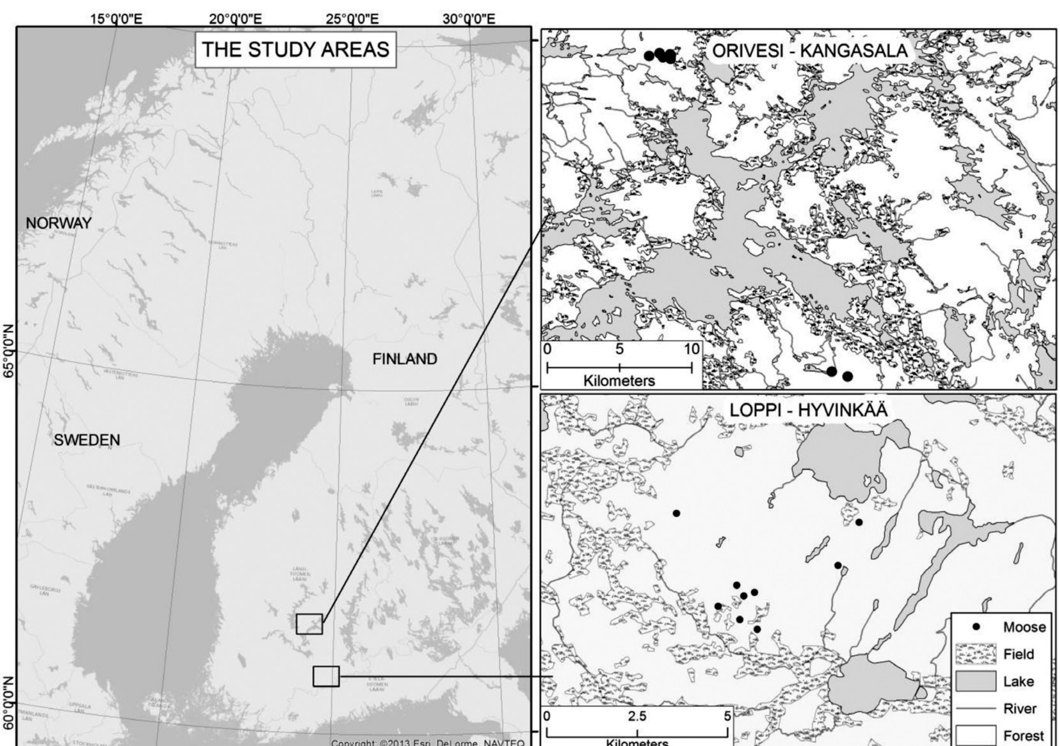

Fig. 1. Study area locations and starting points of moose tracking periods in southern Finland. In the Orivesi-Kangasala area some of the starting point coordinates of uncollared moose are rough estimates and overlap because they could not be separated at the map scale.

the snow. The pellet groups were counted the following day, until moose fled from the counter. The end of the accumulation period was determined in a similar manner as the starting point. The accumulation periods varied from 8–31 h.

Moose were classified as either adults or calves by visually observing them and their pellets, bedding places, and behavior. Their sex could be determined without visual contact by analyzing their urination methods, as bulls urinate in front of the hind hooves. We measured the diurnal defecation rate of 5 bulls, 3 cows, and 3 calves. Additionally we measured 3 cows with twin calves and 1 cow with a single calf, without separating the pellet groups of the cows and calves. In total, we were able to record the diurnal defecation rates of 22 uncollared moose and count the number of beds of 7 individuals.

Tracking of GPS-Collared Moose

The Finnish Game and Fisheries Research Institute (FGFRI) provided location data for the GPS-collared moose. The FGFRI implemented GPS-collaring procedures in accordance with Finnish legislation, with permission from the National Animal Experiment Board of Finland. An individual GPS-collared cow was tracked once and another on 5 separate occasions, while 1 cow with twin calves was tracked once, and one cow with a single calf twice; altogether, 7 individuals were tracked.

The GPS-collared moose were tracked a few days after fresh snowfall in December–March 2010. The counter went to the most recent location of moose tracks which were usually ~12 h old. The pellet groups were counted along the moose track by following it against the original course of the moose; the coordinates of the pellet groups, beds, and urination sites were located with hand-held GPS devices. The accumulation period finished when an individual track became mixed with others or sunset precluded tracking. The duration of the accumulation period was determined by identifying the time associated with the closest location of the tracks with GPS collar data. The accumulation periods ranged from 6–47 h.

Data Analysis

At least 20 pellets were required to make a pellet group. We processed the pellet group data of 29 moose (7 GPS-collared, 22 uncollared) to calculate the diurnal defecation rate (number of pellet groups produced per individual in 24 h) from the accumulation periods of individual bulls, cows, and calves. Mean values were calculated for the group of cows and calves when it was impossible to identify calf from cow pellet groups; analyses of 25 separate cases were used to calculate the diurnal defecation rate.

For comparison, we sampled the mean values of diurnal defecation rates of 3 sex and age classes: 1) bulls, 2) cows, and 3) calves and cow-calves. The last class was required because we were only able to track 3 individual calves, which was insufficient for any reasonable analysis. We also compared the mean defecation rates of the uncollared and GPS-collared moose. Due to limitations in the linearity and homogeneity of variances in the data, we used the Kruskal-Wallis test for multiple samples and the Mann-Whitney test for paired sample comparisons. Furthermore, we searched for possible correlations between the diurnal defecation rate and 1) the calendar week of the accumulation period, 2) the duration of the accumulation period, and 3) the number of diurnal beds for part of the samples. All statistical calculations were performed using the Statistical Package for the Social Sciences (SPSS) 17.0 software.

Data relating to home range of moose during the accumulation period (calculated using the Home Range Tools for ArcGIS® version 1.1 with the Minimum Convex Polygon method), length of the moose track during the accumulation period, and the number of diurnal urinations were also collected from the GPS-collared moose, but insufficient sample sizes precluded their utilization in the analysis.

RESULTS

The diurnal defecation rate ranged from 12.2–32 pellet groups with an overall mean of 23.5 ± 4.2 (SD; Table 1, Fig. 2). The mean values of bull, cow, and calf/cow-calf groups were different (Kruskal-Wallis test: $\chi^2 = 9.9$, df = 2, $P = 0.007$; Table 1). The calf and cow-calf group had the highest mean rate, but was statistically different only from the cow group (Table 1). The bull group had the lowest mean rate, but also the lowest and highest absolute values (i.e., the widest range; Table 1). The cow and bull group rates and the rates of the uncollared and GPS-collared moose were not different (Table 1).

The diurnal defecation rate was not related to the calendar week of the accumulation period (Fig. 2, Table 2). The GPS-collared individual which was tracked 5 times between 17 January and 23 February 2010 showed no trends during this period. The defecation rate did not correlate to the duration of the accumulation period or to the number of diurnal beds (Table 2). The mean values for the other variables were: diurnal number of beds = 8.0 ± 4.2 (SD, n = 15), the diurnal urination rate = 1.0 ± 1.0 (SD, n = 9), the area of home range during the accumulation period = 95,267 m^2 ± 122,399 (SD, n = 9), and length of track during the accumulation period = 955 m ± 832 (SD, n = 6).

DISCUSSION

The mean defecation rate was considered high (23.5 ± 4.2 pellet groups/d) but similar to the average rate measured in relatively good moose habitat in southern Norway (22.9 pellet groups/d; Andersen et al. 1992). Lower defecation rates were measured in southern Sweden (14 pellet groups/d; Rönneberg et al. 2008) and on Isle Royale, North America (20.9; Jordan et al. 1993). Many studies have reported lower defecation rates in Alaska and Canada (see DesMeules 1968, Franzmann et al. 1976a, Oldemeyer and Franzmann 1981, Joyal and Ricard 1986).

The high values reported in our study area are not unreasonable when comparing the status of the moose population in Finland to other Nordic countries. The Finnish moose population is lower and of a higher productive state compared to those in

Table 1. Mean values of the wintertime, diurnal defecation rate and comparisons between moose groups in southern Finland.

	Pellet groups (#/ind/24 h)					Mann-Whitney Test		
	Mean	Min	Max	n	SD	Test against	*U*-value	*P*
Grouping by moose type:								
Bulls	20.1	12.2	32.0	5	7.3	Cow	12	0.152
Cows	22.3	18.9	24.0	9	2.2	Calf + groups	10	0.002
Calf and Cow-calf groups	25.9	23.0	31.3	11	2.2	Bull	11	0.061
Grouping by tracking method:								
GPS-collared	23.5	20	26.7	9	1.8	Uncollared	64	0.647
Uncollared	23.4	12.2	32.0	16	5.2			
All moose	23.5	12.2	32.0	25	4.2			

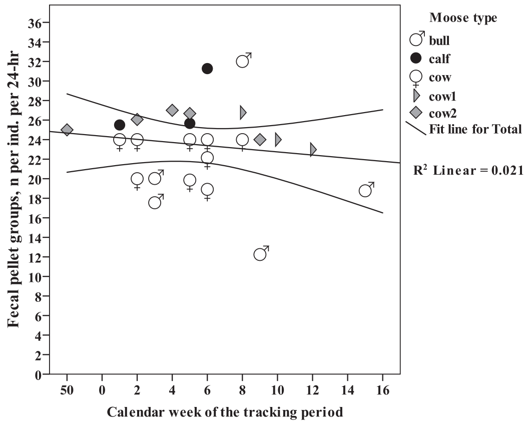

Fig. 2. The diurnal defecation rate of moose in southern Finland relative to the time of the tracking period (calendar weeks). Moose types are classified as: 1) individual bulls, calves, and cows, and 2) cow-calf groups (when individuals could not be separated during tracking); cow1 = cow with single calf, cow2 = cow with 2 calves.

Table 2. Pearson correlations between the diurnal defecation rate (pellet groups/moose/24 h) and temporal variables in southern Finland; no differences were found.

	Calendar week	Accumulation period (h)	Beds/ moose/ 24 h
Coefficient	−0.144	−0.086	−0.403
P-value	0.492	0.682	0.136
n	25	25	15

Sweden and Norway (Lavsund et al. 2003, Tiilikainen et al. 2012). These differences presumably imply better foraging habitat, higher nutritional condition, and a resultant higher defecation rate in Finland. Because defecation rates are influenced by food quality and availability and show large variation (Andersen et al. 1992), it follows that area-specific defecation rates should be measured when using pellet group counts to estimate population density.

The extremes in defecation rate varied largely in our study, but most observations, especially of the GPS-collared individuals, were similar to the mean indicating the general reliability of these data and their application to estimate population density. The extreme values could result from local foraging conditions or from longer movements associated with unintended disturbances while tracking the uncollared moose.

Because the defecation rate can correlate with age and sex, these relationships should be taken into account if a change in population structure occurs (Franzmann et al. 1976a). Our data indicate that the calf and cow-calf group had slightly higher defecation rates than individual cows as also reported by DesMeules (1968), but opposite that of Joyal and Ricard (1986). Bulls and cows were not different in our analyses; however, general conclusions about sex and age differences cannot be made due to the limited sample size.

Using an accurate defecation rate is critical when applying pellet group counts in moose population density estimates. Defecation rates have not been published previously in Finland, and given the considerable variation in similar data from northern Europe, we consider our results the best available for local use. Furthermore, similar defecation rates were obtained for both regions in our study, making the mean values applicable to all of southern Finland. The lack of correlation between calendar week and defecation rate indicates a stable accumulation rate throughout winter, suggesting that these rates might be applicable for springtime pellet group counts. Variations in the absolute data and means should be taken into account when calculating confidence limits for the final moose density estimate.

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REFERENCES

Andersen, R., O. Hjeljord, and B-E. Saether. 1992. Moose defecation rates in relation to habitat quality. Alces 28: 95–100.

DesMeules, P. 1968. Détermination du nombre de tas de crottins rejetés et du nombre de reposées établies, par jour, par l'original (*Alces alces*), en hiver. Le Naturaliste Canadien 95: 1153–1157. (In French with English abstract).

Franzmann, A. W., P. D. Arneson, and J. L. Oldemeyer. 1976a. Daily winter pellet groups and beds of Alaskan moose. Journal of Wildlife Management 40: 374–375.

———, J. L. Oldemeyer, P. D. Arneson, and R. K. Seemel. 1976b. Pellet-group count evaluation for census and habitat use of Alaskan moose. Proceedings of North American Moose Conference Workshop 12: 127–142.

Forbes, G. J., and J. B. Theberge. 1993. Multiple Landscape Scales and Winter Distribution of Moose, *Alces alces*, in a Forest Ecotone. Canadian Field-Naturalist 107: 201–207.

Härkönen, S., and R. Heikkilä. 1999. Use of pellet-group counts in determining density and habitat use of moose *Alces alces* in Finland. Wildlife Biology 5: 233–239.

Jordan, P. A., R. O. Peterson, P. Campbell, and B. McLaren. 1993. Comparison of pellet-group counts and aerial counts for estimating density of moose at Isle Royale: a progress report. Alces 29: 267–278.

Joyal, R., and J-G. Ricard. 1986. Winter defecation output and bedding frequency of wild, free ranging moose. Journal of Wildlife Management 50: 734–736.

Lautenschlager, R. A., and P. A. Jordan. 1993. Potential use of track-pellet group counts for moose censusing. Alces 29: 175–179.

Lavsund, S., T. Nygrén, and E. J. Solberg. 2003. Status of moose populations and challenges to moose management in Scandinavia. Alces 39: 109–130.

Månsson, J. 2009. Environmental variation and moose *Alces alces* density as determinants of spatio-temporal heterogeneity in browsing. Ecography 32: 601–612.

———, H. Andrén, and H. Sand. 2011a. Can pellet counts be used to accurately describe winter habitat selection by moose *Alces alces*. European Journal of Wildlife Research 57: 1017–1023.

———, C. E. Hauser, H. Andrén, and H. P. Possingham. 2011b. Survey method choice for wildlife management: the case of moose *Alces alces* in Sweden. Wildlife Biology 17: 176–190.

Metla. 2012. Finnish Forest Research Institute, National Forest Inventory. http://www.metla.fi/metinfo/vmi/ <accessed November 2012>.

Neff, D. J. 1968. The pellet-group count technique for big game trend, census, and distribution: a review. Journal of Wildlife Management 32: 597–614.

Oldemeyer, J. L., and A. W. Franzmann. 1981. Estimating winter defecation rates of moose, *Alces alces*. Canadian Field-Naturalist 95: 208–209.

Remm, K., and A. Luud. 2003. Regression and point pattern models of moose distribution in relation to habitat distribution and human influence in Ida-Viru county, Estonia. Journal for Nature Conservation 11: 197–211.

Rönnegård, L., H. Sand, H. Andrén, J. Månsson, and Å. Pehrson. 2008. Evaluation of four methods used to estimate population density of moose *Alces alces*. Wildlife Biology 14: 358–371.

Tiilikainen, R., E. J. Solberg, T. Nygrén, and J. Pusenius. 2012. Spatio-temporal relationship between calf body mass and population productivity in Fennoscandian moose *Alces alces*. Wildlife Biology 18: 304–317.

Timmermann, H. R. 1974. Moose inventory methods: a review. Naturaliste Canadien 101: 615–629.