IMPROVING MOOSE POPULATION ESTIMATES IN RUSSIA: ACCOUNTING FOR DISTANCE BETWEEN RESIDENTIAL AREAS AND TRACK SIGHTINGS

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ABSTRACT: Moose (*Alces alces*) population density in the Kirov region of Russia is often overestimated when using the relationship between the distance between a residential area and the initial sighting of moose tracks. This paper presents a modified approach to provide better estimates when using this techinique. Statistically valid density estimation techniques, standardization of estimation points and routes, landscape characteristics, and time have been addressed in the new approach. Moose density is estimated once annually based on the distance to the first track, and annual surveys should maintain alike protocol. This improved method will provide more accurate population density estimates critical to prevent regional overharvest of moose.

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Key words: *Alces alces*, density, distribution, moose, population estimate, Russia, track surveys.

INTRODUCTION & BACKGROUND

Spatial distribution of individuals within a population is generally described as 3 types – equal, occasional, and grouped (Odum 1986) – that can be affected by regional and temporal influences (Naumov 1963). In Estonia, moose (*Alces alces*) distribution changes seasonally; moose in summer-autumn are evenly distributed but in winter their distribution is sporadic or a "focal type of distribution" (Ling 1977). Likewise, moose distribution differs between summer and winter in the northeast portion of European Russia (i.e., Kirov Region; Glushkov 1982). This seasonal difference is caused by November migration related to forage deficiency on summer range (Yazan 1972), as well as increased moose hunting that occurs after snow cover (Glushkov 1997, 2001).

The relationship between snow cover and increased harvest has not been considered previously relative to population density estimates (i.e., ecological density; Bubenik 1965) that are based upon the distance between a residential area and the initial sighting of moose tracks. The unique spatial distribution caused by this relationship is neglected in typical winter route censuses (WRC), creating error in abundance estimates (Glushkov 2004) and potential overharvest of moose that threatens population stability (Glushkov et al. 2012). This paper provides the rationale for a modified approach to account for this relationship when calculating a population estimate.

Previous studies provide baseline information about seasonal moose distribution in the Kirov region of Russia (Glushkov 1977). Group size is larger in winter (2.8 ± 0.9) than in summer (2.0 ± 0.6), and dispersion:density ratios of 2.4 in November versus 5.1 in March (measured from aerial surveys within 1 min flight range of 60 ha

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plots [n = 970]) confirms the more uneven winter distribution of moose. These early (November) and late winter (March) data (1976–1985) were used to construct a graph of sighting frequency in plots with varied moose density that described the character and variance of seasonal moose distribution in the Kirov region (Fig. 1). There were fewer unoccupied plots (0 moose) and plots occupied by ≥4 moose in November than in March when there were fewer plots with 2–3 moose. These seasonal differences are statistically different, and specific to both particular areas (χ^2 = 42.7–171.4) and the Kirov region as a whole (χ^2 = 118.1). These data made it possible to classify summer-autumn distribution of moose as "occasional" and winter distribution as "grouped with cluster formation" (Glushkov 2001).

The distance between human settlements and the initial observation of a moose track was measured during helicopter surveys; the area between was assumed absent of moose. This distance was compared to the sighting frequency of animals and tracks in occupied habitat. In the southern area of the region the correlation was not as strong ($r = -0.50$, $t_r = 2.15$) as in the north ($r = -0.65$, $t_r = 3.42$). Similar tests were conducted with data from 288 terrestrial straight-line survey routes in 27 regional districts (2595 km total length with 288–200 ha sample plots; November 1996); the distance to the initial moose track and the population estimate was inversely related (corr. coeff. = –0.35; p = 0.002). In 10 of 15 districts surveyed, the average distance to the sighting of the first track was >7 km, and in 2 districts it was ~9 km; tracks were first observed at a distance of 14, 16, and 25 km on the other 3 routes.

Because physical ability limits the intensity and extent of a terrestrial survey, an equation was developed (Glushkov 1999) to calculate the probable distance to the initial track encountered (L) from the length of the route travelled where no tracks were encountered (R_0):

$$L = 0.816R_0 + 2.98 \qquad (1)$$

The histogram depicting the distribution of theoretical frequencies of plots with various moose densities indicated that the proportion of plots with 2 animals was underestimated 4 times and that of unoccupied plots was overestimated 2 times. In general, the equation to estimate population density (P) from distance (X) had little practical value ($P = 9.17 - 0.54\ X$). The error in density estimates was presumably due to insufficient area in sample plots. A subsequent survey (1999) was carried out on 14 routes with larger sample plots (700–2200 ha) at the end of each route. The following describes this new survey approach that provides more reliable population density estimates.

RESULTS AND DISCUSSION

Figure 2 depicts the relationship between moose population density (D) and the distance (x) from a residential area to the initial (recent) track. The predictive equation was formulated with a logarithmic density

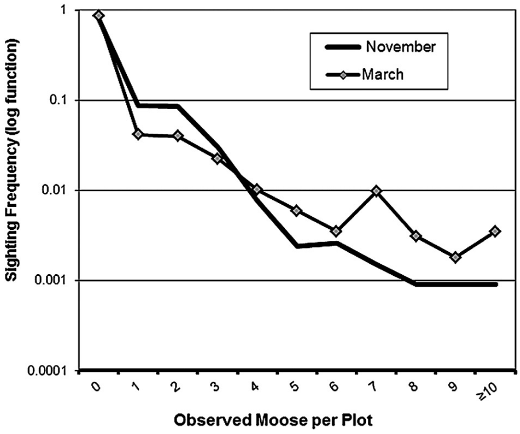

Fig. 1. The relationship between the sighting frequency and the number of observed moose per plot in early (November) and late (March) winter in the Kirov region, Russia.

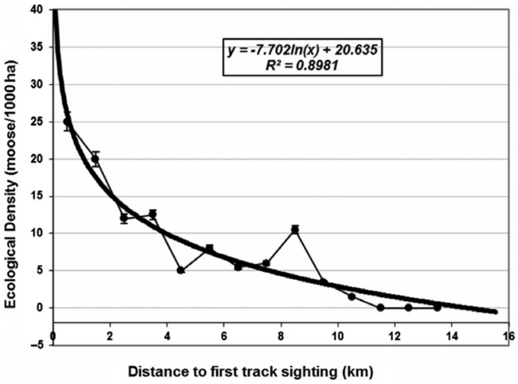

Fig. 2. The relationship between moose population density and the distance to the first track sighting in the Kirov region, Russia.

function that is considered reasonable and acceptable for sample estimates based on the inequality criterion of dispersion and the mean-square deviation of *P* (Draper and Smith 1986).

$$D = - 7.7023 \ln(x) + 20.635; \quad R^2 = 0.8981, P < 0.001 \qquad (2)$$

A verification of this equation was attempted in 2003–2004 within an experimental hunting farm (63,000 ha) by comparing the “known” moose population estimate with an estimate derived from survey routes and sample plots; the estimate was comparable and deemed satisfactory. However, this comparison is general at best because there was no differentiation between seasonal estimates (early and late winter), and no method to evaluate extrapolation across a larger area. In an attempt to verify the method in practice, and to achieve necessary reduction of the dispersion value, the number of paired observations would need to increase to 40 based on equation (2) and the value of coefficient of determination.

In general, the experimental estimates were not contradictory of the hypothesis that moose density is directly related to the distance from a residential area due to their anthropophobic behavior as a result of intensive hunting. This new method is more elementary and easier to implement at the beginning of winter to estimate moose density at both the district and regional scale. Its use is intended for determining abundance trends and setting seasonal harvest quotas (Glushkov and Buldakov 1997). Specification of the starting route point, radial direction, and reference to a sample plot at the end of the route removed some associated drawbacks of the traditional WRC method. The independence of the “distance” parameter from weather conditions increases not only accuracy but also comparability of estimates.

A relatively even population distribution in early winter predetermines reduction of the estimate error, and defines the “native population which inhabits a given area during summer, autumn, and early winter and is subject to hunting”, a definition critical to determine harvest level. The estimate makes it possible to determine, apart from ecological density, an area that is actually used by moose during early winter (extrapolation area), and animal numbers at the district and regional levels.

Comparability theory (Yurghenson 1970) can be used as the basis to extrapolate population density estimates provided that data are available in a particular region to estimate density in subsequent years. It is possible to use equation (2) initially while simultaneously measuring and calculating plot estimates to improve the population estimate. If necessary, a locally specific equation can be developed from a single estimate from the plots and sample routes; calculations of the average R value and extrapolation areas are provided in Glushkov (2001).

Application of this new method utilizes GIS technology and requires preparatory work to organize permanent estimation points and placement of routes and plots. The area unused by animals and the extrapolation area are determined with GIS technology. An estimation point can be any "standard" residential area – a village, a workers' settlement, or a farm enterprise with ≥30 people; all are recorded in reference books, marked on maps, and have a post office and permanent approach roads. The principle criteria for selecting these areas are that they are dead-end locations on a year-round motorway and representative of the surveyed lands within the district.

The number of estimation points in a district depends on the total area, % forest cover, land cover diversity, and the number of settlements and their distribution. Ideally, 4 radial routes with plots at the end must cover the study area completely (see Fig. 3); the inner circle corresponds to the anthropogenic zone with zero moose density. Moose population density within the ring with sample plots is equal to the density over the whole habitation area (outer ring, Fig. 3). In districts with large forest area and lack of human settlements, the width of the ring and the area of land used by animals (extrapolation area) can be correspondingly large. In districts with small fragmented forests and densely populated settlements, the habitation area around proximate human settlements decreases by the value of the overlapping anthropogenic area; i.e., the extrapolation declines.

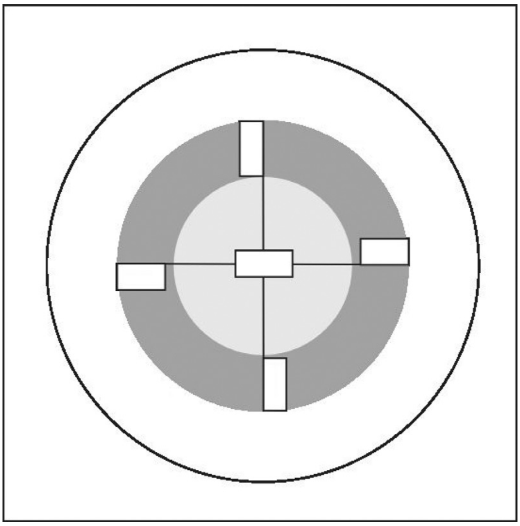

Fig. 3. The principle scheme for establishing 4 radial survey routes with sample plots to estimate moose density in the Kirov region, Russia. The center typically represents human settlement with zero moose density; density is extrapolated for the area of concentric rings.

The area standards for one estimation point are 100,000 ha for districts with forest cover >65%, and 60,000 ha otherwise. However, these standards may require a design compromise due to conflict with statistical requirements and the predetermined error value of the estimation data. For example, in densely populated districts with little forest cover, fragmented forests are often isolated by farming lands, settlements, and other man-made features. In this case, an estimation point can be a settlement which is located near a relatively big forest. The width of the forest along the line to the nearest settlement should be ≥2x the average distance to the first moose track; smaller forests and forests located in anthropogenic zones are not subject to estimation. The routes from such estimation points should be oriented into the forest not the cardinal directions (Fig. 4). Reducing the number of routes and plots to 1–2 per estimation point requires an adequate increase in the number of estimation points.

Standard route lengths are necessary to carry out the first estimate that is used for further corrections (Table 1). The route length is subsequently corrected from the distances to the first track in the experimental estimates. A route is travelled one-fold, once a year, preferably by vehicle. Choosing the size and the shape of sample plots is particular to the size of compartments, configuration of forests, and availability of access routes. It is best to use rectangular plots of

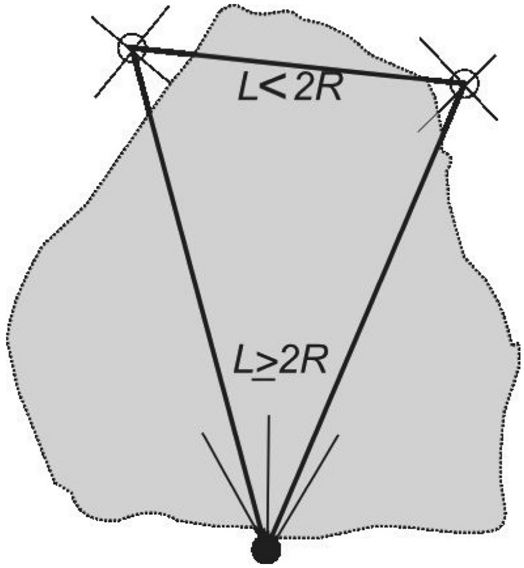

Fig. 4. A depiction of how survey routes are distributed in irregular fragmented forests; forest width to the nearest settlement should be >2x the average distance to the first moose track. Multiple estimation points may be required to achieve a sufficient number of survey routes in an area.

Table 1. The stand and length of radial routes required in varying proportions of forest cover to estimate moose population density in the Kirov region, Russia.

% Forest Cover	Route Length (km)
80–100	12
70–79	10
55–69	8
40–54	7
25–39	5
<25	4

2x4 dimension or plots of other shapes in areas >800 ha (Agafonov et al. 1988).

The new method of field data collection and subsequent calculation of moose population estimations described here will provide more reliable population estimates than with previous approaches. This is critical in the Kirov region of Russia that has experienced population overestimates and subsequent overharvest of moose. A coordinated strategy of using better population estimates, and measuring calf survival and non-harvest mortality, including poaching, will benefit regional moose management in Russia (Glushkov 2009).

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