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Comparison of Methods for Counting Hoofed Animal Density in Sikhote-Alin

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ABSTRACT

During four months in the winter period of 2002–2003, a census of four species of hoofed animals (red deer, sika deer, roe deer, and musk deer) was conducted in the study areas of the Sikhote-Alin Reserve and the surrounding area, including the territory of the planned Reserve Tavayza. The census was conducted on a monthly basis at two sites in the pine and broadleaved forest (nature Reserve and surrounding area) and at three sites in the oak and broadleaved forest. A total of 40 counts were made. Five fieldworkers were working at each site for two days. During the first day, the fieldworkers counted daily hoof prints and removed them. During the second day, newly appearing hoof prints were counted. In addition to the usual counting of crossings of hoofed animals, the number of individual animals was counted, as well. Thus, the census was conducted by two methods: counting of hoof prints in the tracks and counting of individual animals in a certain area. The results of these surveys were organized into a database which shows the relative density of hoofed animals (number of individuals per km²). The analysis of absolute density of hoofed animals in different habitats and its correlation with the number of hoof prints per 10 km was performed.

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Introduction

To assess the state of the population of hoofed animals, it is first necessary to determine the spatial distribution and abundance of the species under study. Among the main parameters are population size and density. Determining the abundance of animals is an important issue.

The resulting information is essential for areas where wildlife is protected, as well as for hunting farms where the resources from hoofed animals are used. Winter route counting of hoof prints of large mammals are traditionally used in all protected areas and hunting farms in Russia. However, there are different methods of counting of hoof prints and different ways of calculating the density of a species. Because of this, the obtained density values vary significantly.

Materials and Methods

A census of hoofed animals with the purpose of determining the density of their populations was conducted in the Terney area of Primorsky Krai during the winter of 2002–2003. Five study areas were selected, two were in oak forests at an unprotected territory of

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the planned Reserve Tavayza (Vtoroy stream, tributary of Skrytaya River, Serebryanka River basin, Russkaya River which flows into the Sea of Japan). One site was selected in a valley forest at an unprotected territory of the same nature reserve (Signalnaya River, tributary of Zabolochennaya River), and another one was located in a pine forest at an unprotected territory along the Nechet stream (tributary of Tayozhnaya river). The final-territory was in a pine forest at the territory of the Sikhote-Alin Reserve also along the Nechet stream. The average size of the study area was 9 km² each. Five fieldworkers taking parallel routes were engaged in field work. Terrain was taken into account during route plotting. The census was conducted monthly in December through March for two consecutive days in each study area, and the number of animals was determined for each day of the counting. In addition to determining the number of animals in the study area, the fieldworkers counted all of the crossings of hoof prints in their routes, using the same method that is used during the traditional winter route counting.

On the first day, the fieldworkers counted daily hoof prints and removed them. On the second day, newly appearing hoof prints were counted. Each study area was divided into routes for five fieldworkers in such a way that the distance between the routes was approximately 250 m. The routes were plotted in parallel to each other where it was possible due to terrain. In other cases, circular routes were plotted in fan-shape fashion.

Each fieldworker was given a copy of the map at a scale of 1: 25,000 with the plotted route. The fieldworkers counted hoofed animals on the route by two methods: a) by counting all hoof print crossings as is performed during the winter route counting and b) by calculating the number of individuals by their hoof prints and indicating the direction of their movement as is done during areal counting. Additionally, during the first and the second days, the fieldworkers tracked small segments of the path to determine: a) the direction in which the animals left the path i.e., inside or outside of the area under study, and b) if different hoof prints belonged to a single individual. In addition to the records, the fieldworkers marked animal routes on the map. As a result, the entire area was divided into study corridors by study routes.

During data analysis, the number of animals that were inside each study strip was counted separately, and then the data were summarized for the entire study area. As a result, we had all of the animals' paths mapped out. Analysing the direction of the paths, we determined the number of individuals in the study strip. When determining the number of individuals, the following was taken into account: a) the path of a hoof print tracked by the fieldworker, b) the number of individuals and the freshness of the hoof print, c) the location of hoof prints of this animal on the next day, and d) the distance of oppositely directed paths from one another (at a distance smaller than the diameter of the daily hoof print these prints were considered as belonging to the same animal). The hoof print of a startled animal was equivalent to a visual contact and counted as an animal inside the study area at the time of registration.

The differences of this method from that used for animal census in the study areas at hunting farms are as follows: a) hoof print crossings are calculated as during the winter route counting, b) a differentiated approach to calculation of the animals with an equal number of incoming and outgoing hoof prints, and c) taking into account the daily print path determined by additional tracking during the first or the second day of the study. Thus, two indicators of animal abundance were obtained for each study area.

- 1. The number of hoof print crossings per 10 km of the route (winter route counting indicator): $\frac{S \times 10}{m}$.
- S being the total number of crossings on the route, m length of the route in kilometres.
- 2. The number of individuals in a given area: N.

A total of 40 surveys were conducted in the study areas, with the total length of the route taken into account being 1314.4 km. Calculations of the density of animals in the study areas were performed by three methods: a) by the method adopted at hunting farms in which the difference of the incoming and outgoing hoof prints is calculated (Rusanov, 1973) by the differential method used by our group, which is based on the method of double-checking and tracking of hoof prints of individual animals to determine the paths of incoming and outgoing prints, taking into consideration the location of the animals on the second day of the study, and c) traditional winter route counting method, using the well-known Formozov's formula (1932), with corrections from Malyshev (1936) and Pereleshin (1950) to convert the relative indicator of the winter route accounting the absolute density:

 $Z = \frac{1,57 \cdot S}{d m}.$

Z – being the total density per 1 km², S – the number of hoof prints, m – route length in km, d – the length of the daily path in km. The data were analysed using standard statistical methods (Rokitsky, 1973). The computer program STATISTICA for Windows 5.0 (StatSoft, Inc., 1999, Tulsa, Oklahoma, USA) was also used.

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Comparison of Two Methods of Calculation of Hoofed Animals

Five species of hoofed animals were registered in the following study areas: roe deer *Capreolus pygargus* Pallas, 1771; red deer *Cervus elaphus* L., 1758; sika deer *Cervus nippon* Temminck, 1838; musk deer *Moschus moschiferus* L., 1758; and boar *Sus scrofa* L., 1758. Hoof prints of boar were spotted only in two study areas in the pine forest due to low abundance of the animal during this winter. Therefore, the results concerning boar were excluded from the analysis.



Fig. 1. Correlation of density of hoofed animals calculated by different methods on the 1st and 2nd days (n = 40 counts).

Winter tracking of the daily paths of hoofed animals was performed by fieldworkers during this winter at the territory of the reserve and in adjacent areas. Average daily path were 1323.2 m (n = 60) for the roe deer, 1479.7 m (n = 89) for the red deer, and 3033 m (n = 10) for the sika deer.

Comparing the results obtained by different methods of counting in the study areas, one can observe that the hunting method reveals low animal densities comparing the counting data of just the first day, the difference is on average two times for the number of roe deer, 1.7 times for the number of red deer, four times for the number of sika deer, and 2.7 times for the number of musk deer (Fig. 1). The difference between the results of counting in the first and second days was insignificant. The principle of the hunting method is that it is assumed that the animal is absent from the study area or study corridor if the number of incoming and outgoing hoof prints is equal. Values obtained using the hunting method on the second day were sometimes higher and sometimes lower than those obtained on the first day of the study. The principle of the differential method is that it takes into account the paths of incoming and outgoing hoof prints, taking into consideration the location of the animals on the second day of the study. Values obtained using this method on the second day of the study. Values obtained using this method on the second day of the study. Values obtained using this method on the second day of the study. Values obtained using this method on the second day were usually lower than those of the first day, on average by 16.5% for red deer, 14.7% for musk deer, 10% for sika deer, and for roe deer the results of the first and second day of study were similar. We suggest using average values for two days obtained using the differential method as the final result for the study area.

Density of Hoofed Animals in Sikhote-Alin

There is not enough data to characterize the density of hoofed animals at the territory of the reserve because the census was performed in a single area (n = 8 counts in the pine-broadleaf forest, Nechet). The remaining counts were performed in unprotected areas where furred and hoofed animals are hunted. The density of deer in broadleaved and coniferous-broadleaved forests was approximately 0.60 individuals/km², with the following densities for the individual species: red deer - 0.65 individuals/km², sika deer - 0.19 individuals/km², and musk deer - 0.08 individuals/km² (Table 1) on average for the entire winter period (n = 32 records, Fig. 2).

 Table 1

 Density of hoofed animals in Sikhote-Alin determined by differential method.

Species	Density, individuals/km ²								
	Unprotected territory		Reserve	On average*					
	Broadleaved forests ($n = 24$ counts)	Pine-broadleaved forests ($n = 8$ counts)	Pine-broadleaved forests ($n = 8$ counts)	(n = 40 counts)					
Roe deer	0.4	0.7	0.6	0.5					
Red deer	0.4	1.1	1.1	0.6					
Sika deer	0.2	-	-	0.2					
Musk deer	0.1	0.03	2.5	0.6					
Total	1.1	1.8	4.2	1.9					

* Calculated by the method of "weighted" average.



Fig. 2. Average density of hoofed animals in Sikhote-Alin at unprotected territory (n = 32 counts).

If we compare the density of the hoofed animals in the broadleaved forests and coniferous-broadleaved forests, it appears that the density of the populations of musk deer, roe deer and red deer is higher in the second type of forest. This is because mixed forests were previously the sites of logging, and the feeding capacity of this habitat is higher than in broadleaved forests in winters with a shortage of acorns. Accordingly, the density of roe deer and red deer is also higher in mixed forests. For these two species, the mode of mixed forests (whether they are protected or unprotected) is less important than the fact whether they previously were the site of logging. Outside of the reserve at the adjacent territory in the same pine-broadleaved forests, the density of roe deer and red deer was even slightly higher than in the reserve (Fig. 3). The situation is quite different for musk deer. Its density in the unguarded area was 80 times lower than in the reserve (Fig. 4, Table 1).

Comparison of the Results of Plot and Route Counting Methods

We have collected data for 40 counts in the study areas and at the same time, 1314.4 km of route surveys from the same area. Therefore, it is possible to analyse density values defined using three methods: hunting method, differential method, and calculation by Formozov's formula.



Fig. 3. Density of hoofed animals in broadleaved forests (BLF, three study areas, n = 24 counts) and pine-broadleaved forests (CBLF, two study areas, n = 16 counts) of Sikhote-Alin, determined using the differential method.



Fig. 4. Density of hoofed animals in pine-broadleaved forests of the reserve (1 study area, n = 8 counts) and unprotected territory (1 study area, n = 8 counts), determined using the differential method.

The results of the counts of roe deer are shown in Fig. 5. The data obtained using the hunting method were in most cases lower than those calculated according to the formula, at select sites by 27–56%, at one site higher by 7%, and on average for all study areas lower by 40%. Values obtained using the differential method were higher than those calculated using the formula by 3–40%, or 7% on average. The changes of values during the winter are shown in Fig. 6.

The results of the census of red deer are presented in Fig. 7. The values obtained using the hunting method were lower at most sites by 7–60%, in one case they were higher by 17%, and on average, they were lower by 23%. The values obtained using the differential method were generally higher by 15–53%, in one case lower by 17%, and on average, they were higher by 27%.

Changes in the values during the winter of 2002–2003 are shown in Fig. 8. The results of the counts of the sika deer are shown in Fig. 9. Values obtained using the hunting method, in one case, were lower by 44%, in another case, higher by 50%, and average values almost coincided. Data obtained with differential method in both cases were higher by 64% and 50%, and on average, they were higher by 57%.

Data obtained using hunting method were lower than the data calculated according to Formosov's formula by 40%, on average. Values obtained using the differential method were always higher than data calculated using this formula by 7%, on average.

Values of red deer quantity obtained by using the hunting method were lower on average by 23%, and differential method data were higher on average by 27%. Sika deer counts indicate that the hunting method data were, in one case, lower by 44%, in another



Fig. 5. Correlation of roe deer density obtained using three methods in the study areas (n = 40 counts, routes length = 1314.4 km).



Fig. 6. Correlation of roe deer density during winter (n = 40 counts, routes length = 1314.4 km).



Fig. 7. Correlation of red deer density obtained using three methods in the study areas (n = 40 counts, routes length = 1314.4 km).



Fig. 8. Correlation of red deer density during winter (n = 40 counts, routes length = 1314.4 km).



Fig. 9. Correlation of sika deer density obtained using three methods in the study areas (n = 40 counts, routes length = 1314.4 km).



Fig. 10. Correlation of density of three species of hoofed animals in Sikhote-Alin obtained using three methods (n = 40 counts, routes length = 1314.4 km).

case, higher by 50%, and on average, almost coincided. Differential method values on average, are lower by 57%. We believe that the greatest difference between the methods of calculation, observed in sika deer quantity, is associated with insufficient tracking of daily paths of this species during this season (n = 10), compared to roe deer (n = 60) and red deer (n = 89) (Fig. 10).

Correlation between the Density of Hoofed Animals and the Number of their Hoof Prints

Conducting a simultaneous (complex) census with different methods in a single study area makes it possible to study the correlation between the animal population density and the number of traces of their hoof prints in a given area. Correlation of regression coefficients (R) separately obtained by hunting and differential methods for four species is presented in Table 2.

Comparative correlation of coefficients for four species of hoofed animals is presented in Fig. 11. Evidently, the greatest variation of obtained regression coefficients between the above two methods is observed for musk deer, the smallest variation was obtained for sika deer.

Analysis of regression correlation between the density of animals and the number of hoof prints gave the following results for roe deer and red deer. The hunting method gave a squared regression coefficient (R^2) = 0.287 for roe deer and 0.57 for red deer; the differential method resulted in 0.621, and 0.771, respectively. Therefore, to calculate the density we use the results obtained by the latter method. The regression formula for roe deer is: density (individuals/km2) = 0.21221 + 0.08193 × number of tracks per 10 km. The regression formula for the red deer density (individuals/km2) = $-0.0191 + 0.14475 \times number of tracks per 10 km$.

8

Table 2

Regression coefficient for three species of hoofed animals.

Area	Roe deer		Red deer		Musk deer		Sika deer		Total	
	Hunt. method	Diff. method								
Nechet-reserve	0.297	0.105	0.675	0.886	0.026	0.813	-	-	0.327	0.887
Nechet-outside reserve	0.400	0.489	0.74	0.868	0	0.986	-	-	0.486	0.668
Signalnaya	0.751	0.867	0.531	0.699	0.905	0.856	-	-	0.449	0.754
Russkaya	0.009	0.690	0.051	0.560	0.440	0.900	0.680	0.730	0.085	0.750
Vtoroy stream	0.809	0.902	0.150	0.530	-	-	0.059	0.970	0.820	0.899



Fig. 11. Regression coefficient (R) between the number of individuals and the number of their hoof prints for four species of hoofed animals.

Conclusion

Comparison of three methods used for the census of the number of hoofed animals has shown that the best results are obtained by using the differential method. Low regression coefficient values obtained using the hunting method suggests inadequacy or unreliability of the hunting method.

It is possible to determine the density of hoofed animals by Formozov's formula using the results of winter route counting, with a route length of at least 200 km. The number of trackings of daily paths of each species of hoofed animals performed during the same winter must be at least 30.

Comparing the costs for winter route counting with tracking of daily paths and two-day counting in study areas, it can be concluded that the latter requires much less funds and can be recommended as the primary method for calculating the density of hoofed animals.

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