METHODS OF MAINTENANCE AND PRESERVATION OF ECOSYSTEMS AND THEIR COMPONENTS

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NEW METHOD OF CAMERA TRAP USAGE TO EVALUATE DIVERSITY AND DETERMINE CHARACTERISTICS OF MAMMALS IN THE VARIOUS HABITATS BY THE EXAMPLE OF ZEYA NATURE RESERVE[1]

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In this article we studied a new method to evaluate the mammals' diversity, based on the analyzed data of 3 camera traps, placed in the various biotopes of Zeya Nature Reserve. They were set in the sub-alpine spruce forest (from March to November in 2018, from February to August in 2019), in the oak forest with black birch (from February to October in 2019), and in the willow complex near riverbed (from October to December in 2019). Unlike the well-known methods to evaluate population density with camera traps, this one does not require recalculation coefficients which represent mobility of the accounted species. We compared the collected data with the results of the standard methods of mammals' density evaluation, such as winter routing, multi-day census on a particular plot and census by the encounters on transects. We demonstrate the potential of the said method to evaluate quantitative characteristics of the seasonal dynamics of population, and local concentrations of brown bear, wild boar and Manchurian wapiti in the various biotopes of the Eastern part of the Tukuringra Ridge. We also listed the main advantages and limitations of the said method.
Keywords: camera trap, terrestrial animals, new methods of species richness evaluation, Zeya Nature Reserve.
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In the recent years the researches of the terrestrial animals' ecology that were carried out with the help of camera traps have become an important part of zoological field observations. At the beginning camera traps were mostly used to register and count the rare species. Back then data analysis was based on personal identification of research subjects and application of the methods of secondary registration (Koli, 1979). The said method is described in the research of K.U. Karanth (1995) by the example of tiger census. With camera traps becoming more and more available, some new methods were created to be used for diversity evaluation of background species of terrestrial vertebrates, personal identification of which is neither possible nor rational. We can emphasize 2 main ones:

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1) determination of relative diversity indices, 2) determination of population diversity.

When applying the first method and processing the data from camera traps, the index of "encounters amount" of each species is usually used (Zheltukhin, Ogurtsov, 2018). Despite its advantages such as simple data processing, it also has some limitations. The first one is to decide what exactly should be considered as an encounter? Even if we could answer this question definitively, the received data presents such indices of richness that cannot be compared to the results of the standard census methods, such as winter routing (Kuzyakin et al., 1990), multi-day census (Rusanov, 1986) and ungulates census by their excrements (Sorokina, 1977). Until recently population density, the data on which was obtained from the camera traps, was calculated according to the formula suggested by J.M. Rowcliffe et al. (2008):

$$D=(y/t)\bullet(\pi/vr(2+\theta)),$$

where D is population density, y/t – amount of photo-registrations per time unit, v – (average) speed of an animal, r – detection range, θ – detection angle (in radians).

In this case the difference between the formulas of Rowcliffe $D=(y/t)\bullet(\pi/vr(2+\theta))$ and Formozov-Malyshev-Pereleshin $D=(y/t)\bullet(\pi/vr2)$ is only in θ; so if we assume θ to be a zero, then the difference is leveled (Formozov, 1935, 1990; Pereleshin, 1956; Kuzyakin et al., 1990). Therefore, the mathematical basis of photo-census, carried out according to J.M. Rowcliffe et al. (2008), is identical to winter routing, and has a specific problem, too. The problem is that we have to know the parameters of the accounted species' mobility to evaluate their population density: the length of their daily route and their speed. For each species these parameters depend on many different factors: snow cover depth, food availability, air temperature, their sex, age, etc. Many of those factors significantly vary by seasons and years. The mentioned coefficients in Formozov's formula, applied to winter routing, can be obtained by tracking and plot censuses. Theoretically speaking, when using camera traps according to Rowcliffe's methodic, the mobility parameters for all seasons can be determined by radio-labeling. However, due to the difficulties with obtaining the said parameter, the average animal's speed (length of its daily route) is usually used, without taking into account its seasonal features and conditions of a particular year.

We created and tested a special method (Podolsky et al., 2019; Kastrikin et al., 2020) which requires only camera traps and no extra recalculations to obtain quantitative evaluations of average and large terrestrial animals' populations. These evaluations can be compared to the results of the generally accepted methods of mammals' population evaluation, such as winter routing (Kuzyakin et al., 1990), multi-day census (Rusanov, 1986), ungulates census by their excrements (Sorokina, 1977) and census by encounters on transects.

Materials and Methods

In our research we used two SG968 K-10M camera traps and one SG562-D, set in different biotopes of Zeya Nature Reserve in Amur Region. The obtained data was used to create a basis for testing of the said methodic. Zeya Nature Reserve covers 99.4 thousand hectares in the east part of the Tukuringra Ridge.

The camera trap No. 1 was set near the east reserve border on the watershed of Kamenushka and Malaya Erakingra rivers (N 54° 09' 00.4", E 126° 47' 14.3), in the sub-alpine dark-bark spruce forest with patches of creeping pine, close to the upper forest border (1107 m above mean sea level), on the crossing of two animal trails. The trap was adjusted in parallel with horizon, the camera was pointing at the afforested gentle slope, fenced with patches of creeping pine. The area for animals' photo-registration was determined experimentally on spot and covered 34 m^2. The trap's exposition periods were as follows: from 03/15/2018 (10:30 am) to 12/01/2018 (00:00 am); from 02/22/2019 (16:07 pm) to 08/17/2019 (15:30 pm). The total exposition length was about 14.5 months (37,721,160 seconds). The camera was working in "photo mode". For every animal's encounter the following parameters were noted: date, time, duration of animal's staying in the registration area (in seconds), its species, amount of individuals, external features (sex, age, coat coloring) and behavior features of each animal. During the period of the camera trap functioning we registered 360 encounters of mammals of 7 species: mountain hare – 257 encounters (photo 1), squirrel − 3, Siberian musk deer – 15, Manchurian wapiti – 2, brown bear – 52 (photo 2), sable – 30, wolverine − 1.

Photo 1. A mountain hare with summer fur. Camera trap No. 1.

The camera trap No. 2 was set near the southeast reserve border (N 53° 51' 02.4", E 127° 22' 31.8"), near the bank of Zeya water reservoir, between the Tyoply and Razvedochny creeks, on the ridge of a low spur (423 m above mean sea level), covered with oak forest and black birch, with an animal trail along its top. The trap was adjusted in parallel with horizon. The camera was pointing at the clearing, fenced with Mongolian oak and black birch forest. The area of photo-registration was determined experimentally and covered 63 m^2. The trap's exposition periods were as follows: from 02/11/2019 (15:03 pm) to 03/05/2019 (13:05 pm); from 04/23/2019 (9:00 am) to 10/16/2019 (10:50 am). The total exposition length was about 6.5 months (17,085,480 seconds). The camera was working in "photo mode". During the period of its functioning we registered 60 encounters of mammals of 4 species: Siberian roe deer – 9 (photo 3), Manchurian wapiti – 5 (photo 4), wild boar − 29 (photo 5), brown bear – 17.

The camera trap No. 3 was set in the riverbed complex of the Garmakan River valley (upper flow), near the south reserve border (N 53° 59' 48.1", E 127° 05' 24.5"). The camera was pointing at the part of the side channel, willow bushes on the bank and permanent marking spot of lynxes and wolverines located near the butt of a dead inclined larch. The area of photo-registration was determined experimentally and covered 23 m^2. The trap's exposition period was as follows: from 10/21/2019 (13:03 pm) to 03/05/2019 (13:05 pm) − about 2 months. The camera was working in "photo + video (15 seconds) mode". In 2019 we registered 23 encounters of 4 species: Siberian musk deer − 1, Manchurian wapiti – 15 (photo 6), moose − 1, lynx – 1. Previously this camera trap had also registered wolverines (photo 7) and wolves (photo 8).

Photo 2. A bear walking to the creeping pine during its ripening period. Camera trap No. 1.

Photo 3. A male Siberian roe deer in the clearing of the oak forest. Camera trap No. 2.

Photo 4. A female wapiti in the clearing of the oak forest. Camera trap No. 2.

Photo 5. One-year-old boars in the clearing of the oak forest in spring. Camera trap No. 2.

Photo 6. A wapiti eating dry grass at the marking point of large predators. Camera trap No. 3.

Photo 7. A wolverine leaving its marking point. Camera trap No. 3.

The final quantitative index of the camera traps is the load of a particular species on the area of the photo/video-registration per time unit (month, decade, total exposition period, etc.), determined by the amount of individuals per area unit, e.g. individuals per 1000 ha. We mark it as "D". To obtain the required load index (D) we have to determine the main parameters: 1) area of registration zone, 2) duration of staying in registration area for each species, 3) duration of camera trap functioning (exposition). Below we are going to discuss the particularities of determination of these parameters.

1) Photo-registration area (Sr) or census area depends on the technical parameters of the camera trap (its angle of view, sensing range and distance of infrared backlight or flash), and on the way it was set (its horizontal incline, any obstacles in front of it, relief). It must be taken into account that sensing range of many camera traps usually is much lower than it is stated in their certificates. So, to avoid any mistakes even without the obstacles, partially blocking the camera's view, the photo-registration area of each trap has to be calculated right on the spot, experimentally. It can be marked by sticks to fix the angle and range of animals' registration.

Photo 8. An adult wolf on the ice of the upper Garmakan River. Camera trap No. 3.

2) Duration of animals' staying in the registration area (Tr) is the main richness index in our method. It is calculated in seconds, for each species and for a particular period (decade, month, total exposition period). If the camera trap registers more than one species at a time, then their staying duration (amount of seconds) has to be multiplied by their amount (if the group of animals entered and left the registration area simultaneously), or it can be calculated as a sum of time that all of the individuals from the said group spent in the registration area. The delay between the animal entering the area and the first photo being taken (or video being started) has to be added to the animal's staying duration. The delay period depends on the technical parameters of camera trap and the size and type of its storage and can be determined empirically, but it must be remembered that this period will change once the memory card is replaced with another one of different capacity. The total duration of animals' staying in the registration areas of the camera traps is listed by months in the tables 1-3.

3) Duration of exposition period (Tt) is calculated in seconds. Depending on the aim of the particular research, different time intervals of the camera trap's functioning can be used (day, decade, month, total exposition period). In our case to evaluate the population density we used the monthly periods of each camera's working as well as their total exposition periods (tables 1-3).

Table 1. Density of terrestrial mammals' population in the spot of the camera trap No. 1 (Sr=34 m^2).

Month, year	Duration of the camera trap's working (seconds)	Species											
		Hare		Siberian musk deer		Manchurian wapiti		Bear*		Sable		Wolverine	
		seconds	individuals/ 1000 ha	seconds	individuals/ 1000 ha	seconds	individuals/ 1000 ha	seconds	individuals/ 1000 ha	seconds	individuals/ 1000 ha	seconds	individuals/ 1000 ha
2018													
March	1,434,540	39	7.9	0	0	0	0	0	0	10	2.1	0	0
April	2,592,000	49	5.6	0	0	0	0	0	0	2	0.2	0	0
May	2,678,400	268	29.4	16	1.74	0	0	5	0.56	6	0.65	0	0
June	2,592,000	191	21.7	13	1.48	0	0	0	0	27	3.1	0	0
July	2,678,400	93	10.2	25	2.75	0	0	111	12.2	28	1.1	0	0
August	2,592,000	163	18.5	0	0	38	4.3	292	33.1	11	1.25	0	0
September	2,678,400	42	4.6	7	0.77	0	0	27	2.96	9	0.99	0	0
October	2,592,000	53	6.0	0	0	0	0	6	0.68	8	0.91	0	0
November	2,678,400	84	9.2	0	0	0	0	0	0	3	0.33	4	0.44
Total for 2018	22,516,140 (18,403,200)*	982	12.8	61	0.8	38	0.49	441	7.05*	104	1.36	4	0.05
2019													
February	547,620	0	0	0	0	0	0	0	0	0	0	0	0
March	2,678,400	62	6.8	0	0	0	0	0	0	0	0	0	0
April	2,592,000	111	12.6	0	0	0	0	31	3.5	0	0	0	0
May	2,678,400	132	14.5	11	1.24	0	0	0	0	0	0	0	0
June	2,592,000	255	28.9	11	1.25	0	0	6	0.68	10	1.14	0	0
July	2,678,400	61	6.7	30	3.3	0	0	0	0	11	1.2	0	0
August	1,438,200	41	8.4	0	0	0	0	95	19.4	9	1.8	0	0
Total for 2019	15,205,020 (11,979,000)*	662	12.8	52	1.0	0	0	126	3.1*	30	0.58	0	0
Total for 2018 and 2019	37,721,160 (30,382,200)*	1644	12.8	113	0.88	38	0.3	567	5.5*	134	1.04	4	0.03

Notes to tables 1, 2, 4 and 5: * − when estimating the average population density for the bear during the period of camera trap functioning, we took into account only the period of bear's activity outside the winter hibernation, from April to October.

Evaluating the population density. Once the source data was obtained, we calculated the richness indices for every species of terrestrial mammals for every month of the cameras functioning (tables 1, 2). Further below we will show it by the example of mountain hare, registered by the camera trap No. 1 in March 2018 (table 1).

Duration of the camera trap's functioning or exposition (Tt) for March was 23,909 minutes or 1,434,540 seconds. If the hare was staying in the registration area for the entire period, then the load on the area would be 1 individual per 34 m^2. The actual *registration time* (Tr) was 39 seconds. Using the ratio, we can determine the actual load or the hare's *population density in the registration area* (Dr), which is 0.000027 ind. per 34 m^2.

Table 2. Density of terrestrial mammals' population in the spot of the camera trap No. 2 (Sr=63 m^2).

Month of 2019	Duration of the camera trap's working (seconds)	Species: Roe deer		Manchurian wapiti		Wild boar		Brown bear	
		seconds	individuals/ 1000 ha	seconds	individuals/ 1000 ha	seconds	individuals/ 1000 ha	seconds	individuals/ 1000 ha
February	1,414,980	49	5.5	0	0	677	75.9	0	0
March	479,100	126	41.7	0	0	1454	481.7	0	0
April	637,200	0	0	0	0	0	0	0	0
May	2,678,400	6	0.4	34	2.0	26	1.54	203	12.0
June	2,592,000	0	0	0	0	116	7.1	363	22.2
July	2,678,400	0	0	0	0	0	0	50	2.9
August	2,592,000	0	0	0	0	0	0	7	0.43
September	2,678,400	0	0	0	0	26	1.54	7	0.41
October	1,335,000	11	1.3	31	3.7	0	0	0	0
Total	17,085,480 (15,191,400)*	192	1.8	65	0.6	2299	21.4	630*	6.6

Table 3. Density of terrestrial mammals' population in the spot of the camera trap No. 3 (Sr=23 m^2).

Month of 2019	Duration of the camera trap's working (seconds)	Species: Siberian musk deer		Manchurian wapiti		Moose		Sable		Lynx	
		seconds	individuals/ 1000 ha	seconds	individuals/ 1000 ha	seconds	individuals/ 1000 ha	seconds	individuals/ 1000 ha	seconds	individuals/ 1000 ha
October	817 305	0	0	196	104.3	0	0	0	0	0	0
November	2 678 400	12	1.9	716	116.2	0	0	31	5.0	0	0
December	1 016 846	0	0	865	369.8	413	176.6	18	7.7	15	6.4
Total	4 512 551	12	1.2	1777	171.2	413	39.9	49	4.7	15	1.4

Population density (D), recalculated in terms of the standard square measure, is 7.9 ind. per 1000 ha. Therefore:

$$D=((Tr/Tt)\bullet 10000000)/Sr,$$

where Tr is the total staying duration of the animals of the particular species in the registration area, in seconds, Tt – exposition period, in seconds, Sr – area of photo-registration, in square meters.

These statistical methods are described by V.A. Kastrikin et al. in their future and not yet published article about using the camera traps in the territory of Khinganskiy Nature Reserve. The article also describes the formula to calculate the standard deviation, which can be used to obtain the required dispersion measures (standard error of mean), and an example of bootstrap method applying to construct a confidence interval of the grand mean.

Results and Discussion

Let's compare the indices, obtained by different evaluation methods of mammals' richness, and the features of the animals' population for the various parts of Zeya Nature Reserve, captured by the camera traps.

West part of the nature reserve. We compared the data, received in 2018 and 2019 from the camera trap No. 1 which was set in the mid-mountain sub-alpine dark-bark spruce forest, and the census results, obtained by the multi-day censuses which were carried out on the "Kamenushka" plot during the same years. It is the closest census plot of the reserve, located 1-6 km from the camera trap No. 1. Most of the "Kamenushka" station is formed by the flatlands, and the mid-mountain spruce forests cover only 1/4 of the entire plot.

Despite the differences of the habitats conditions, the population indices of Siberian roe deer, Manchurian wapiti, mountain hare and wolverine, collected in the photo-registration area, can be compared to the ones collected from the "Kamenushka" plot where the multi-day census was performed (table 4). The higher richness of the most species can be related to the fact that the camera was aiming at the crossroad of the animals' trails. Moreover, the mountain hare's population density is at its maximum in the sub-alpine zone where the trap was set. The absence of roe deer can be explained by the fact that it tends to the low-mountain relief and avoids the sub-alpine spruce forests and mid-mountain biotopes in general. The absence of moose can be explained by the relative rarity of the species.

Population indices of brown bear were obtained in August 2018 (33.1 ind./1000 ha) and can be compared to the ones from the alpine tundra during the high fruiting of the creeping pine (11.1 ind./1000 ha), registered in 2000 during the visual census on the plots with a clear view (Podolsky, Krasikova, 2003). The fruiting was above the average in 2018 but did not reach its maximum. The high population indices in the photo-registration area were due to the camera pointing at the trail crossing, actively used by bears during their seasonal migrations.

The average population indices of sable (0.6-1.4 ind./1000 ha) were much lower than the ones on the multi-day census plot (9.3-16.3 ind./1000 ha). Perhaps, it is due to the fact that the SG968 K-10M camera usually cannot capture a fast-moving sable. Its reaction time is relatively high, about 1.5 seconds, which is enough for the sable to leave the photo-registration area. Therefore, we can conclude that the indices of sable's population density, obtained with the said camera trap type, are not comparable to the results of the standard census methods, such as multi-day census and winter routing. The camera trap was not able to catch stoats and weasels, inhabiting the researched territory. They move too fast and usually jump deep into snow, as if "mining" it, and therefore not registered by the trap. The tree-living species, such as squirrels and flying squirrels, are also almost impossible to capture with camera traps; however the squirrel was registered 3 times, while the flying squirrel − never.

Unlike the most of the other census methods which can estimate animals' richness for a short period of time (winter routing and multi-day census) or for the entire season (ungulates census by their excrements), the suggested method allows to track the changes of population indices for the entire year. This in its turn makes it possible to analyze the seasonal changes of animals' population (fig. 1, 2).

Seasonal migrations of animals between altitudinal belts are very common for the mountainous territories, caused by their food and protection conditions, as well as the depth of snow cover. In the early January the depth of snow in the dark-bark spruce forests of the sub-alpine zone of the Tukuringra Ridge is usually more than 50-60 cm, growing up to 1 m in March. Siberian roe deer is well-adapted to the deep snow, however when the cover is higher than 50 cm the roe becomes severely vulnerable to predators (Podolsky et al., 2006) and is usually hunted by sable. Thus, in the early winter the roe deer moves from the sub-alpine spruce forests down to the low-mountain relief.

Table 4. Results of evaluation of mammals' richness in the west part of the nature reserve, carried out by different methods.

Methods	**Species (individuals/1000 ha)**											
	Mountain hare	**Squirrel**	**Flying squirrel**	**Siberian musk deer**	**Manchurian wapiti**	**Roe deer**	**Moose**	**Sable**	**Stoat**	**Weasel**	**Wolverine**	**Brown bear**
Photo-registration in the sub-alpine spruce forest (camera trap No. 1), maximal average monthly indices for: 2018 2019	29.4 28.9	0.32 1.2	0 0	2.75 3.3	4.3 0	0 0	0 0	3.1 1.8	0 0	0 0	0.44 0	33.1 19.4
Photo-registration in the sub-alpine spruce forest (camera trap No. 1), average indices for the census periods of: March-November 2018 February-August 2019	12.8 12.8	0.05 0.11	0 0	0.8 1.0	0.49 0	0 0	0 0	1.36 0.58	0 0	0 0	0.05 0	7.05 3.1
Photo-registration in the sub-alpine spruce forest (camera trap No. 1), maximal average monthly indices for 2018 and 2019	12.8	0.08	0	0.88	0.3	0	0	1.04	0	0	0.03	5.5*
Multi-day census on the "Kamenushka" plot in March 2018 March 2019	2.2 2.8	4.8 10.8	2.6 4.3	0.4 0.3	0 0.5	0 1.8	0 1.0	16.3 9.3	3.9 1.8	5.2 1.3	0.13 0.16	no data
Visual census of brown bears in the alpine tundra in the year rich with creeping pine (August 2000)	–	–	–	–	–	–	–	–	–	–	–	11.1
Census of brown bears in the alpine tundra by their excrement in the lean year (August 2002)	–	–	–	–	–	–	–	–	–	–	–	1.4

Then in May, when most of the snow melts away, the roe deer returns to the spruce forests. During the snowless periods the Manchurian wapiti can be found there as well, but rarely. Unlike the ungulates, the mountain hare and sable are the constant inhabitants of the upper forest border. These patterns of dynamics and structure of the animals' population of the sub-alpine forests of Zeya Nature Reserve are registered per annum (fig. 1).

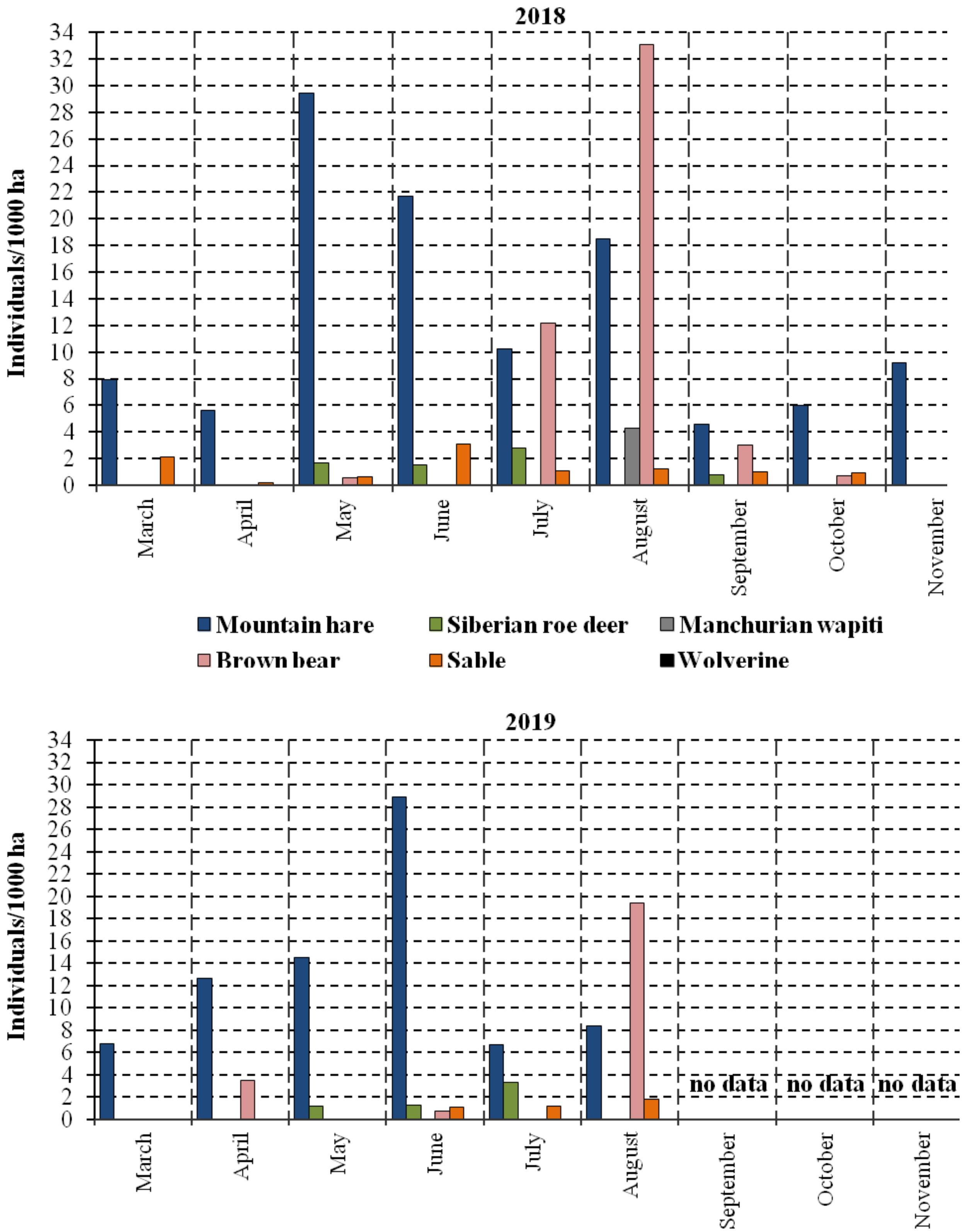


Fig. 1. Dynamics of animals' population in the Ayansky spruce forest at the upper forest edge, west part of Zeya Nature Reserve (according to the camera trap No. 1).

An important feature of Zeya reserve is its seasonal concentrations of brown bears, gathering at the creeping pines thickets and in the alpine tundra (Podolsky, Krasikova, 2003). The eastern part of the Tukuringra Ridge lies between the Zeya-Bureya Plain and the Upper Zeya Lowland, where the creeping pine massifs are almost absent. Every 3-5 years when cedar is rich with nuts, in the upper mountain belts (alpine tundra with patches of creeping pine and solid pines massifs), the total area of which is about 3.2 thousand ha, the brown bears gather from the area 2-3 times bigger than the entire territory of the nature reserve (about 100 thousands ha). Moving between the feeding sites and their permanent habitats, the bears pass through the sub-alpine spruce forests. We set a camera trap in that biotope and determined bears' population indices, as well as objectively characterized the dynamics of their seasonal feeding concentration for every decade during the years of different fruiting intensity of the creeping pine (fig. 2). After the bears leave their dens (from mid-April to early May) and before the creeping pines start ripening (in the late July − early August), the bears could be seen quite rarely. In the relatively fruitful 2018 a significant concentration of bears (32.8 ind./1000 ha) was already gathering in the sub-alpine zone in the last decade of July, even before the cones fully ripened. In June of lean 2019 the bears were registered by the camera trap No. 1. In both years the maximal population indices were registered in the second decade of August, with 42.8 and 17.7 ind. per 1000 ha, respectively. In 2018 a significant concentration of bears in the upper mountain belts was registered until the last decade of August (35.5 ind./1000 ha), and single individuals were encountered regularly until early October. It means that the bears' presence in the upper belts during the summer-autumn period of fruitful 2018 was lasting more than 2 months, and, on the contrary, it was limited by the first and second decades of August in lean 2019 (fig. 2).

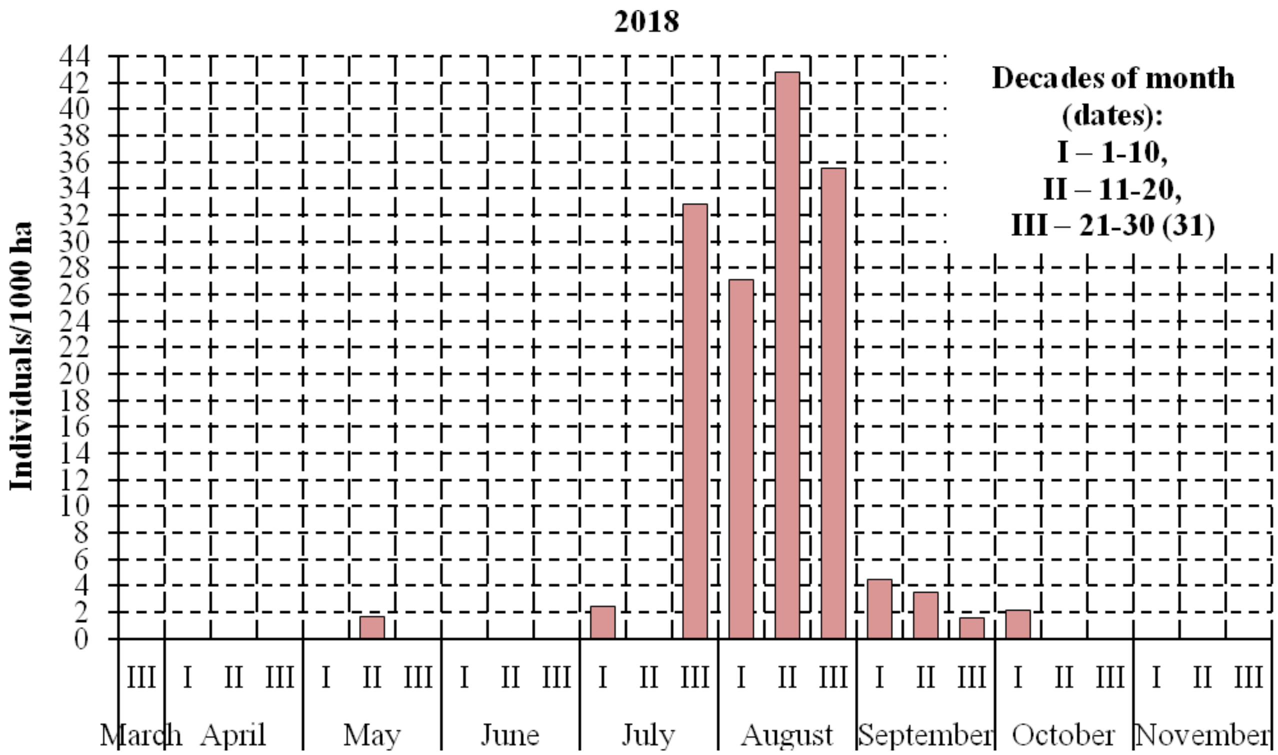
Southeast part of the nature reserve. We compared the data, received in 2019 from the camera trap No. 2 which was set in the oak forest, and the census results, obtained by the winter routing and multi-day censuses which were carried out on the "Tyoply" plot. The trap was located in the southeast past of that plot, adjoining the bank area of Zeya water reservoir. The "Tyoply" Station is formed by the low mountains. The oak and oak with black birch forests are spread over the slopes of south and east expositions on the forelands and peninsulas between the bays of Zeya reservoir. Those biotopes cover about 1/3 of the entire territory of the plot for multi-day census.

The population indices of Siberian roe deer, Manchurian wapiti and wild boar, collected in the registration area, can be compared to the ones obtained from the "Tyoply" plot by the multi-day census and winter routing through the oak forests (table 5).

The abnormally high maximal richness index of the wild boars (481.7 ind./1000 ha) can be related to the fact that a group of 4 young animals was staying around the trap in from February to March in 2019. In the autumn of 2018 the amount of acorns from the Mongolian oaks was very high, so they accumulated on the clearing in the registration area which was covering the part of the ridge near its top. While falling from the trees around the clearing, many acorns rolled down the slope for dozens of centimeters and sometimes for several meters. Being a valuable feeding resource in the end of the winter, those acorns caused an abnormally high population density of the wild boar in the photo-registration area.

After leaving their dens in spring (May) and in the early summer (June), the bears were actively looking for the last year's acorns, therefore intensely concentrating during the said period (12.2-22.2 ind./1000 ha). From the late June they stopped gathering in the oak forests. In the autumn of 2019 the amount of acorns was minimal, therefore no significant increases in the bears' population were registered (table 2).

South part of the nature reserve. We compared the data, received in 2019 from the camera trap No. 3 which was set in the riverbed complex of the Garmakan River (upper flow), and the results, obtained by the multi-day census which was carried out on the "34^{th} km" plot in 2019 and 2020. The camera was pointing at the part of the side channel, willow bushes on the bank and permanent marking spot of lynxes and wolverines located near the butt of a dead inclined larch. These results, obtained by different methods and compared afterwards, can be seen in the table 6.



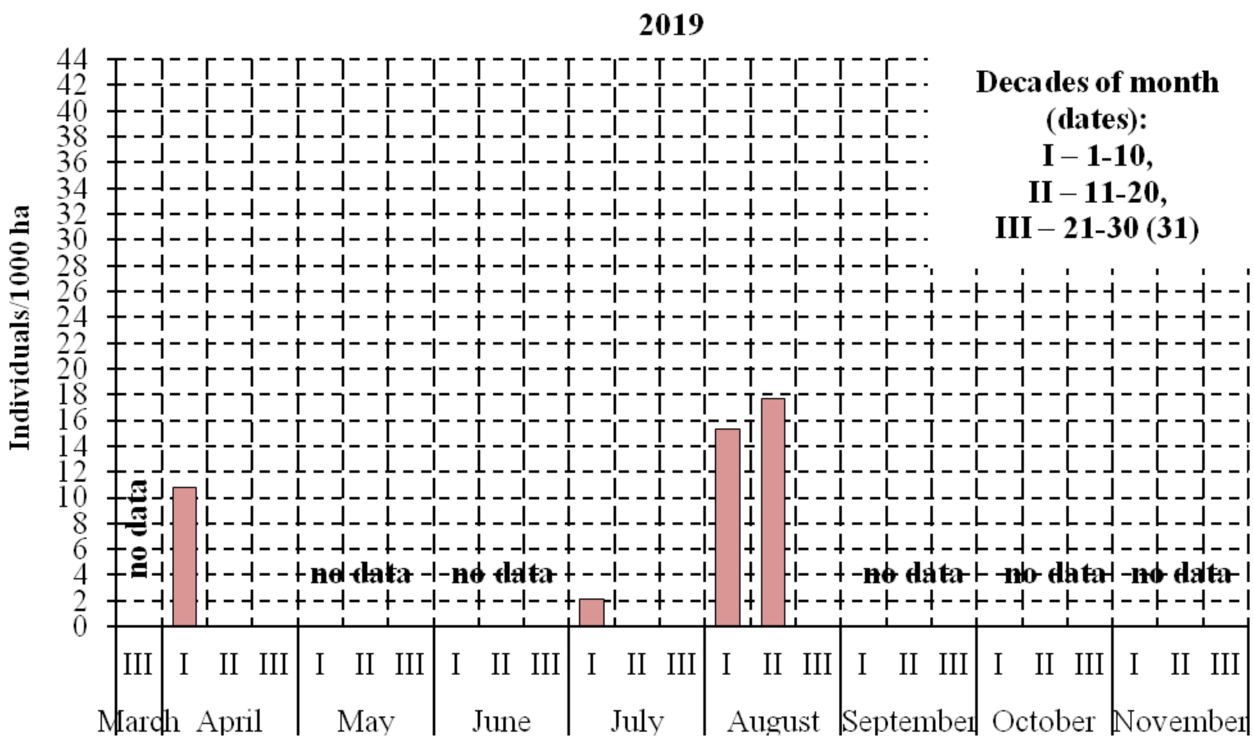


Fig. 2. Bear population dynamics by decades in the Ayansky spruce forest at the upper forest edge, west part of Zeya Nature Reserve (according to the camera trap No. 1).

During the period of the camera trap's functioning in October-December 2019 the lynx was registered only once, although the population density in the photo-registration area was significantly higher than on the plot of multi-day census. Obviously, the data received from the camera, pointing at that marking spot, was insufficient to make any conclusions about population density of the large predators that were using the spot.

The analysis of the animals' behavior, carried out on the basis of the photo/video-materials of the camera trap No. 3, showed that Manchurian wapiti and moose frequently approached and smelled the marking spot of lynxes and wolverines, and the wapiti ate dry grass previously stained with predators' urine. While being so attractive to the large ungulates, the spot had the highest local population density of wapiti (171.2 ind./1000 ha) and moose (39.9 ind./1000 ha) in the photo-registration area; it was 1-2 times higher than the standard census methods showed (table 6).

The Siberian roe deer was not interested in the marking spot. Its population indices, obtained by the photo-registration, were identical to the ones of the multi-day census.

Table 5. Results of evaluation of mammals' richness in the southeast part of the nature reserve, carried out by different methods.

Methods	**Species (individuals/1000 ha)**									
	Mountain hare	**Squirrel**	**Siberian musk deer**	**Roe deer**	**Manchurian wapiti**	**Wild boar**	**Weasel**	**Sable**	**Wolf**	**Brown bear**
Photo-registration in the oak forest (camera trap No. 2), maximal average monthly indices for 2019	0	0	0	41.7	3.7	481.7	0	0	0	22.2
Photo-registration in the oak forest (camera trap No. 2), average indices for the census period from February to October 2019	0	0	0	1.8	0.6	21.4	0	0	0	6.6*
Multi-day census on the "Tyoply" plot in February 2019	0	7.4	0.8	10.7	4.6	12.2	1.4	9.3	3.1	no data
Winter routing in the oak and black birch forests in January-February 2019	0	5.9	0	31.0	2.7	46.4	0	0	5.6	no data

Conclusion

The main advantage of the said method is the possibility to compare the obtained results with the data of the standard methods of population evaluation, such as winter routing, multi-day census and census of ungulates by their excrements. Moreover, unlike Rowcliffe's method (2008) and winter routing, this one does not require any recalculations to determine animals' mobility.

The indices obtained with our method show the population density (amount of individual per area unit) and the amount of time the animal spent in the photo-registration area. The similar principle is used in the census of ungulates by their excrements (Sorokina, 1977), when the load on the census zone in determined for the entire winter season. Our method allows researchers to permanently track the changes of population indices and therefore use it to obtain data about the yearly dynamics of animals' population and features of seasonal concentrations and migrations of some species (fig. 1, 2). Moreover, this method provides an objective quantitative data which characterizes the population changes in the various altitudinal belts of mountainous territories.

Table 6. Results of evaluation of mammals' richness in the south part of the nature reserve, carried out by different methods.

Methods	Species (individuals/1000 ha)							
	Mountain hare	**Squirrel**	**Siberian musk deer**	**Roe deer**	**Manchurian wapiti**	**Moose**	**Sable**	**Lynx**
Photo-registration in the valley complex (camera trap No. 3), maximal average monthly indices for 2019	0	0	1.9	0	369.8	176.6	7.7	6.4
Photo-registration in the valley complex (camera trap No. 3), average indices for the census period from October to December 2019	0	0	1.2	0	171.2	39.9	4.7	1.4
Multi-day census on the "34th km" plot in March, 2019	0.36	7.9	1.79	3.93	1.8	0.71	14.3	0.7
Multi-day census on the "34th km" plot in March, 2020	0	0	0	0	1	1.25	11.0	0
Winter routing in the valley biotopes in March 2019	0.4	11.9	0	5.6	1.46	2.1	12.5	2.8
Winter routing in the valley biotopes in March 2020	0	0	0	0	0.5	0	6.2	0

The suggested method is optimal to estimate the dynamical density of the large and average mammals' population in the spots of their seasonal concentrations, near the main migration trails and around the most important bounded habitats. It is very promising to determine the quantitative richness indices of those species with winter hibernation that cannot be found during winter routing, which is especially significant for the close biotopes. For instance, the data on the bears' population density was obtained during their concentration in the oak forests only with the help to the said method. The visual monitoring, performed for bear census in the alpine tundra (Podolsky, Krasikova, 2003), is not possible in such situations.

Comparing our results with the ones of the standard census methods (multi-day census, winter routing, visual monitoring), applied around the camera traps locations in the similar habitats, we were able to find a spectrum of species, the population indices of which can be correctly determined with our method (tables 3, 4). Those were the ungulates and large predators, as well as the mountain hare.

However, there were exceptions, since some of the traps were aiming at the marking points of lynxes and wolverines. Aside from large predators, those points also attract Manchurian wapiti and moose, so their population density in the photo-registration area can be 1-2 times higher that their background density.

The camera traps we used in our research were not able to determine the population density of the average and small Mustelids, such as sable, stoat, weasel and others. These animals move too quickly to be caught on the camera. Besides, some of them usually jump deep into snow, as if "mining" it, without coming into the camera's field of view. Some of the tree-living species, such as squirrels and flying squirrels, are also very hard to register with the camera traps.

The most significant limitation of our method is in the difficulties of the correct extrapolation of the final results, which is determined by the small area of photo-registration zone. We can be sure only about the load of particular species in the registration area, registered during the exposition period, and can only assume that similar biotopes had the similar population indices at the same time. However, a significant amount of camera traps can solve this problem, but even so our method cannot replace the traditional ones, such as winter routing, multi-day census and others, although it can significantly complement them.

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