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Hunting Resource Management by Population Size Control by Remote Sensing Using an Unmanned Aerial Vehicle

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ABSTRACT

The study was carried out on the territory of the Kemerovo region-Kuzbass (Western Siberia, Russia). The purpose of the study was to obtain information on the species diversity and population of big-game animals. The monitoring was carried out on the forest territories of the region's administrative districts. In the course of remote sensing using an unmanned aerial vehicle, the presence of all types of animals under consideration, except for the bear, was recorded. The deviation of the population number determined using the traditional method of digital technologies varied up to 50%. It was established that environmental measures organized and carried out by the regional administration and hunting farms improved the situation and stabilized the population of the main group of game animals. It was found that when using a sufficiently high sensitivity of the thermal imager (the used thermal imager had a very high sensitivity class ≤ 60 mK at 300 K), long-haired animals, which are characterized by a lower intensity of thermal radiation (for example, wolves) are identified and recognized in the images. The larger the animal and the worse the thermal insulation layer (wool or feathers), the easier it is to identify it in infrared images and the lower the sensitivity requirements of thermal imagers. The ability to recognize and record smaller animals and birds requires additional research on existing technologies. Our research has confirmed the validity of digital remote monitoring methods for managing the wildlife of hunting farms and nature conservation areas of the Siberian Taiga territories.

INTRODUCTION

Conservation of biological diversity is an obligation to future generations. The problem is peculiar to all territories without exception. Siberia has amazing and diverse wildlife. Despite the remoteness of most of the Siberian region from civilization, it has experienced the harmful effects of human presence.

Kemerovo Region is located in the south of Western Siberia and covers an area of 95,725 km^2 (Fig. 1). Coal, chemical industries, and metallurgy are the key economic branches of the Kemerovo region (Prosekov 2021a).

Forest and taiga play a vital role in maintaining the Kuzbass ecosystem. The inhabitants of mountainous areas are directly dependent on forest resources in terms of food, firewood, fodder, and wood. The forest also plays an important role in providing habitat for wildlife. The climate of the Kemerovo region is sharply continental (winter is cold and long, summer is warm and short). Average temperatures in January vary from -17 to -20°C, and in July, from +17 to +18°C. The average annual precipitation ranges from 300 mm on the plains and in the foothill part to 1,000 mm or more in mountainous areas. The frost-free period lasts from 100 days in the north of the region to 120 days in the south of the Kuznetsk Basin.

The game resources of the Kemerovo region-Kuzbass are formed under the influence of sharply differentiated natural conditions of the region, as well as man-made impacts on the natural environment. The natural landscapes of the Kemerovo region-Kuzbass are extremely diverse, and many of them have been greatly changed by human influence. The variety of terrain and climate determines the diversity of vegetation. On the mountain peaks, there are plants of tundra and alpine meadows. The middle and low

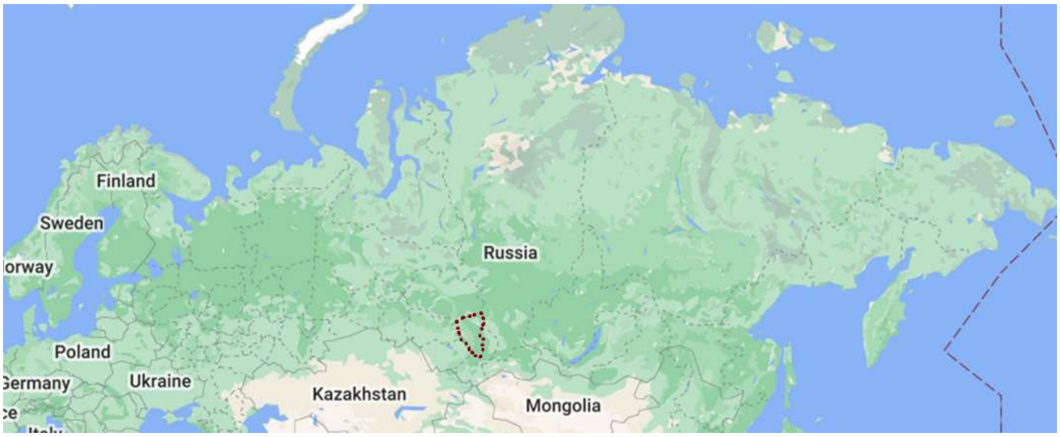

Fig. 1: Kemerovo Region-Kuzbass on the map of Russia.

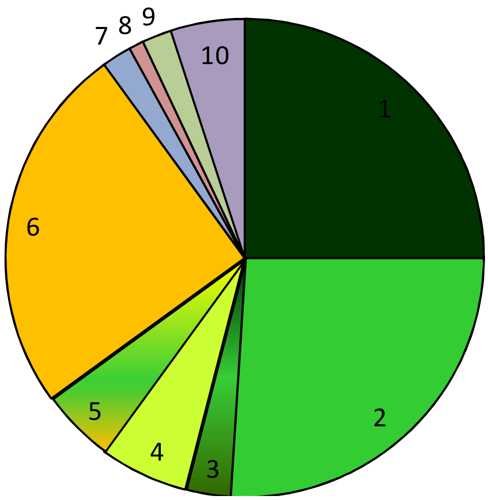

Fig. 2: The structure of the main habitat classes of game animals in the Kemerovo region –Kuzbass: 1 - coniferous forests, 2 - small-leaved forests, 3 - mixed forests, 4 - young forest growth, 5 - meadow-steppe complexes, 6 – farmland, 7 – floodplain complexes, 8 - transformed, damaged areas, 9 - unsuitable for hunting territories, 10 - other (swamps, tundra, etc.).

mountains are overgrown with fir and aspen forests with tall grass and relict plants. The foothills and intermountain basins feature the vegetation of steppes and forest steppes. The diversity of habitats of game animals in the Kemerovo region – Kuzbass is clearly shown by the data in Fig. 2. Coniferous, small-leaved forests, and farmland occupy almost equal shares (about 25%). Small-leaved mixed and meadow-steppe complexes are represented to a lesser extent. All this determines the conditions for the coexistence of forest and steppe flora in the region (Ilyashenko et al. 2019, Skalon et al. 2019).

The publicly accessible hunting grounds (Fig. 3) of the Kemerovo region-Kuzbass amount to 1992.9K hectares (26.2% of the total), including the assigned 5604.2K hectares (73.8%). Almost the entire assigned area (no more than 80% of the lands of the subject of the Federation) in the Kemerovo region – Kuzbass is distributed among hunting providers. There are no public lands in many districts of the region. First of all, these are the territories of the Kuznetsk Basin that are most unfavorable for big-game taiga animals (Leninsk-Kuznetsky, Topkinsky, Promyshlennovsky, Izhmorsky, Chebulinsky municipal districts). In the areas with less anthropogenic load, higher biodiversity, and yield class of hunting grounds, the share of publicly accessible land is higher (for example, in the Tashtagol district, it's more than 90%).

The diversity of climatic and phytocenotic conditions of the Kemerovo region-Kuzbass determines the wildlife diversity. On the territory of the region, there are about 450 species of vertebrates (about 325 species of birds and 75

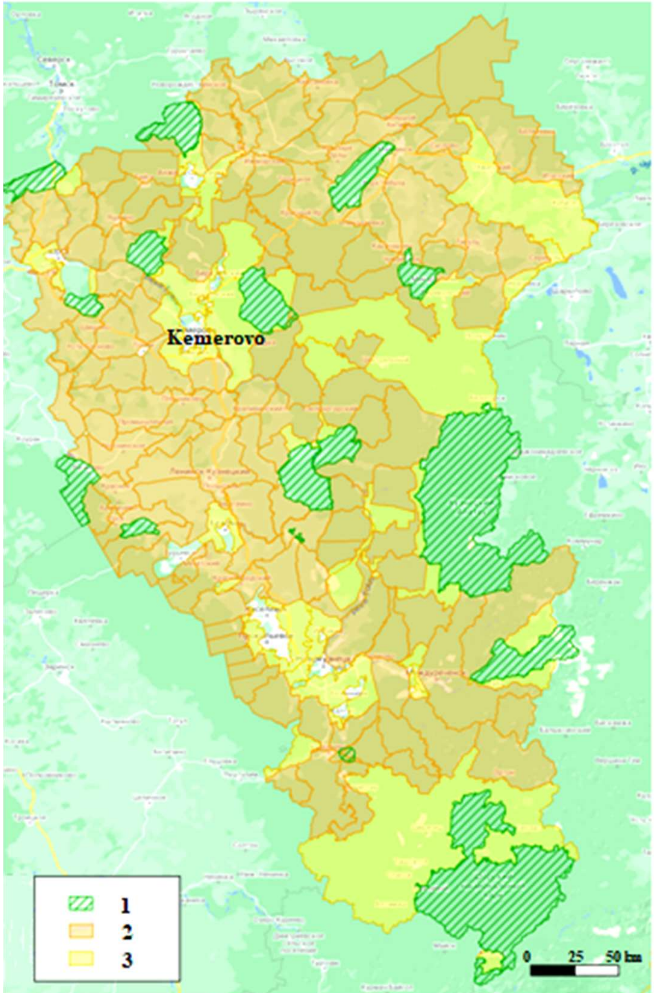

Fig. 3: Boundaries of protected territories and hunting grounds of the Kemerovo region: 1 - specially protected natural territories, 2 - assigned hunting grounds, 3 - publicly accessible hunting grounds.

species of mammals), 70% of which live here permanently. Hunting is in demand almost throughout the region. The most important game mammals are elk, Siberian roe deer, red deer (maral), brown bear, badger, sable, fox, and Arctic hare.

Anthropogenic gradients made the system unsuitable for various wild animals, which led to the loss of both diversity and population size. The population size dynamics are shown in Table 1 (Department NRE of KR 2020, Prosekov 2021b).

A decrease in the population of natural enemies (wolf, lynx), an increase in the area of farmland and the length of power lines, an increase in the area of secondary biotopes, stabilization of the number of maral due to the activities of the Kuznetsky Alatau Nature Reserve and wildlife sanctuaries, the fight against poaching led to fluctuations in the population of animals in both directions.

At the same time, in the Kemerovo region-Kuzbass, the harvest of those species that have practically disappeared or have their population reduced has stopped (Table 2). In particular, Siberian weasel, lynx, wolverine, and wolf, hunting for which is either prohibited or there are no hunting resources, are no longer harvested. Along with this, the harvest of squirrels in the region has almost halved due to a reduction in their population.

The main purpose of the organization of a hunting farm is to determine the position of hunting providers in the general economic system of the projected territory, as well as the choice of the ownership form and its organizational structure. Kemerovo region – Kuzbass has quite considerable hunting potential. The fauna of the region is diverse, but significant anthropogenic impact drastically reduces the yield class of hunting grounds. In general, with a high differentiation of the

Table 1: Dynamics of the population size of game animals in the Kemerovo region – Kuzbass (2001–2019).

Object of the study	Population, specimen					
	2001	2006	2011	2017	2018	2019
Elk	4130	2230	2728	4804	5010	5112
Maral	860	810	410	905	962	985
Siberian roe deer	5020	4740	3848	6858	7086	7436
Wild boar	-	-	228	1096	361	321
Brown bear	2000	2000	2274	3125	3086	3036
Wolf	230	60	6	-	-	7
Red fox	3000	2380	3525	4587	4449	4562
Wolverine	80	80	87	67	71	69
Badger	12500	13000	10292	10786	14370	12046
Sable	7500	9000	7713	14329	14066	12778
Otter	300	300	417	629	689	706
American mink	7300	11000	10006	11067	10850	10778
Siberian weasel	6000	4100	3370	1643	1462	1378
Steppe polecat	1400	940	1047	198	339	193
Stoat	2800	1700	2125	379	377	476
Eurasian beaver	6500	11100	18037	17829	18131	18738
Squirrel	53400	40800	20232	22990	23778	22898
Arctic hare	30800	34700	28129	38108	29653	32275
European hare	900	610	378	352	271	401
Muskrat	28000	30000	28476	17155	17109	16451
Groundhog	3350	4500	3755	4133	4130	4435
Lynx	400	370	242	128	151	111
Capercaillie	13600	7600	7870	13194	11281	6863
Grouse	351000	222300	296213	396436	313471	233116
Black grouse	128000	70500	73856	185509	138957	132452
Waterfowl	64500	83300	74513	49150	50284	52630
Moorfowl	28600	26900	33593	-	-	-

Table 2: Game harvesting dynamics in the Kemerovo region – Kuzbass (2001–2019).

Object of the study	Population, specimen					Harvest,
	2005	2006	2011	2018	2019	%**
Maral	5	3	4	10	15	300.0
Roe deer	115	143	111	207	239	207.8
Elk	–	–	41	96	118	–
Lynx	3	2	2	–	–	–
Wolverine	–	–	–	–	–	–
Sable	928	1256	1612	3142	3163	340.8
Brown bear	59	52	79	219	249	422.0
Wolf	19	12	–	–	–	–
Badger	–	–	155	481	467	–
Wild boar	–	–	5	137	55	–

Table Cont....

Object of the study	Population, specimen					Harvest,
	2005	2006	2011	2018	2019	%**
Squirrel	1108	697	2	827	618	55.8
Beaver	162	163	518	1128	1285	793.2
Fox	674	1245	361	1189	763	113.2
Arctic hare	3699	5570	3700	5565	4594	124.2
Siberian weasel	91	42	–	–	–	–
Grouse	6968	5270	3088	9201	7759	111.4
Black grouse	594	602	829	2602	2312	389.2
Capercaillie	46	40	78	163	204	443.5
Ducks (of all kinds)	618	9085	15855	10176	11029	1784.6

* % of the population size in 2019 compared to 2005.

game animals' habitats in the Kemerovo region-Kuzbass, the habitat conditions improve from the center to the periphery. So, it is important to correctly record the number of animals and birds in lands that differ by quality. It is possible to understand the lands and their yield only in dynamics since they change from year to year due to natural climatic and anthropogenic factors (logging, fires, agricultural activities, etc.) (Albery et al. 2021, Cayuela et al. 2018, Prosekov et al. 2020, Thulin & Rocklinsberg, 2020, van de Walle et al. 2018).

The study aimed to explore the possibility of using digital technologies (remote monitoring with unmanned aerial vehicles) for the control and management of wild game populations.

MATERIALS AND METHODS

Objectives of the Study

The objects of the study were the main game animals of the Kemerovo region – Kuzbass: elk (*Alces Alces*), maral (Cervus elaphus), Siberian roe deer (*Capeiolus pygargus*), wild boar (*Sus scrofa*), brown bear (*Ursus arctos*), wolf (*Canis lupus*), sable (*Martes zibellina*), badger (*Meles Meles*), European beaver (*Castor fiber*), fox (*Vulpes Vulpes*), Arctic hare (*Lepus timidus*).

Area of the Study

The remote monitoring of animals was carried out in the Muryukskoye Hunting Society (I), the Taidonskoye

Fig. 4: Map of Kemerovo region-Kuzbass: 1 - Krapivinsky district, 2 - Chebulinsky district.

hunting farm (II), and the Shestakovskoye hunting farm (III) located in the Chebulinsky and Krapivinsky districts of the Kemerovo region-Kuzbass (Fig. 4) during the winter periods of 2019 and 2020.

Research Methods

To record the wildlife population, the original technology of combined shooting (conventional photo, video, and thermal imaging in the infrared spectrum) was used (Prosekov et al. 2020). When assessing the scale of under-counting errors, there is no fundamental difference between shooting or visual observation using traditional or unmanned aircraft. Thermal imaging is reliable enough to determine the very fact of the presence of an animal by its thermal signature without omissions, provided that there is a significant difference in the temperature of the animal's body and the environment (up to 30-40°C). Still, it does not allow us to distinguish species with similar mass and geometric dimensions (for example, a wolf and a boar).

An unmanned aerial vehicle of the aircraft type "Supercam S250" (LLC "Unmanned Systems," Izhevsk, Russia) with a wingspan of 2.53 m (Fig. 5) was the physical carrier of the shooting and other equipment for the study. The model has the following operational characteristics: flight time – up to 3 h; flight range – up to 180 km; speed – from 65 to 120 km.h^{-1}; permissible distance from the operator (radio line range of action) – 50-70 km; flying height – from 50 to 500 m; permissible wind speed up to 15 m.s^{-1}, air temperature from -50 °C to +45 °C, moderate precipitation (rain, snowfall) is possible. There is a receiver of the global satellite navigation system on board for the most accurate coordinate control.

The specifications of the Sony RX1R II camera (Sony, Japan) and the ATOM500 thermal imager (Sun Creative Zhejiang Technologies Inc, Zhejiang, China) are given in Tables 3 and 4, respectively.

The shooting results were processed using a specialized software product (a PC app in Python), "Thermal Infrared Object Finder" (TIOF), developed at KemSU (Prosekov et al. 2020). The application records "thermal anomalies," i.e., areas in the images that have a higher temperature than the environment, which indicates the presence of an animal. Easy to install and use. The program works with data from any thermal imaging cameras. The program can process different file formats - jpeg, png, avi, mp4. The processing speed depends mainly on the number of streams. Thus, materials

Fig. 5: General view of the UAV used in the study.

Table 3: Key specifications of the camera used.

Specification	Description
Matrix	Exmor R® full-frame CMOS matrix (35.9×24.0 mm), 3:2 screen format; number of effective pixels ~42.4 MP; total number of pixels ~43.6 MP
Lens	ZEISS® Sonnar T*, 8 elements in 7 groups (3 aspherical elements, including advanced AA aspherical elements), focal length f = 35 mm
Camera	Image processor: BIONZ™ X; ISO sensitivity (photography, recommended exposure index): ISO 100–25600 (in 1/3 EV increments) (expandable to ISO 50/64/80/32000/40000/51200/64000/80000/102400), AUTO (ISO 100–102400, with upper/lower limit selection); multi-frame noise reduction: ISO 100-102400 (in 1 EV increments), AUTO (ISO 100–102400, with upper/lower limit selection)

Table 4: Key specifications of the thermal imaging camera used.

Specification	Description
Parameters	Weight without lens 32 g, dimensions without lens 28×28×24 mm
Receiver	Infrared wave receiver on an uncooled microbolometric matrix made of amorphous silicon, resolution 640×480, pixel size 17 microns. Temperature sensitivity ≤ 60 mK at 300 K, 50 Hz. Spectral range 8–14 μm
Image processing	No shutting calibrating technology (NST) Start time less than 5 seconds. Noise reduction through a digital filter. Image resolution 768 × 576/640 × 480 pix. (NTSC resolution and frequency presets). Image frame rate 50 Hz (PAL) and 60 Hz (NTSC). Lens 25 mm.
Image settings	Image color (palette) – shades of gray. Polarity: hot white or hot black. Horizontal and vertical mirror reflection is possible. Digital zoom – x2, x4 and x8. Automatic contrast adjustment.
Power supply system	Power consumption is less than 0.8 watts. Standard supply voltage 3.6 V; possible voltage range 2.5-5.5 V.
Operating conditions	Operating temperature from -40°C to +60°C, storage temperature from -45°C to +65°C. Relative humidity from 5% to 95% (conditions without condensation of moisture). Vibration resistance meets the GJB 150-16 2.3.1 standard; impact resistance meets the GJB 150-8 standard. Resistance to temperature changes up to 5°C.min^{-1}.
Interface	Power connector; RS-232 serial control interface. Analog video output, dual-channel video output support. For navigation and geo-positioning, there is a ground-based geodetic “Javad Triumph 2” GNSS receiver.
Other significant characteristics	Supports geo-positioning in GPS systems,GLONASS, SBAS L1 differential correction systems using the Kalman algorithm to determine the camera location. Data refresh rate 100 Hz. Internal memory 2 GB. Receiver Autonomous Integrity Monitoring, RAIM for correct recording of navigation signals received from the satellite. Lift&Tilt shooting mode with automatic correction of the vertical position. USB connector, Bluetooth and Wi-Fi interface. Antenna, inclinometers (tilt angle meters), compass, lithium-ion batteries.

Table 5: Comparison of the results of winter route census and counting using digital technologies in the “Muryukskoye” hunting society (I), “Taidonskoye” (II) and “Shestakovskoye” (III) hunting farms

Study object	Population, specimen								
	I			II			III		
	1	2		1	2		1	2	
	2019	2019	2020	2019	2019	2020	2019	2019	2020
Maral	3	7	11	2	5	9	85	93	98
Roe deer	48	69	74	25	42	51	220	245	254
Elk	42	57	59	103	99	101	59	57	58
Wild boar	36	42	40	0	0	0	150	172	191
Sable	187	243	260	634	691	734	190	223	256
Badger	36	34	40	131	159	168	140	130	141
Fox	18	22	21	49	41	44	25	21	24
Arctic hare	89	74	69	400	398	395	180	233	225

1 – according to the winter route census data, 2 – according to the data of remote monitoring using UAVs.

from one standard UAV flight with a duration of 100-150 min can be processed in 25-50 s.

RESULTS

The results of remote monitoring of big-game animals (except for brown bears that are not available for registration in winter) using UAVs are presented in Table 5.

The recorded number of animals in the lands is mainly proportional to their share in the area of Chebulinsky (I, III) and Krapivinsky districts (II) (about 10% and 20% of the district area, respectively). At the same time, for most animal species, the ratio of harvesting to population is slightly higher than the regional average, which is due to the dependence of harvesting standards on density, low economic activity, and inaccessibility of hunting grounds.

DISCUSSION

In the studied hunting grounds, the number of most species of game animals was underestimated. In some cases, such deviations reached 30-50% or more (Table 5). Perhaps the reason is the incorrectness of the scaling factors determined at the level of the subject of the Russian Federation in the conditions of small territories or a significant heterogeneity in the density of game populations within the studied hunting grounds. There was a significant underestimation of ungulate populations (maral, roe deer, and elk) using the winter route census method, which made it possible to identify continuous counting using digital technologies. The large population size of roe deer is explained by its spatial distribution and the difficulty of adequately covering unified routes with the winter route census.

In general, the game population density on the grounds of the Shestakovskoye hunting farm is naturally higher than the average in the Chebulinsky district, which is explained by the breeding and semi-free conditions for a number of species. In particular, the hunting farm has maral, wild boar, and roe deer. The farm did not issue quotas for maral harvesting, due to which the population is steadily increasing. Roe deer population density is quite large. The accuracy of ungulate records in the Shestakovskoye hunting farm is high. At the same time, the ratio of hares and foxes (1:7) is not quite typical for high-yielding lands and may require clarification. As for the wild boar, its population density in the game reserve conditions may be higher.

Differences in the actual number of elk are associated with the movement of the animal to the feeding grounds of hunting farms, during which it isn't easy to differentiate animal tracks by traditional methods. The inflated data on the elk number could be affected by the weather conditions of the corresponding periods, which forced the animals to move more actively (Koetke et al. 2020, Skalon et al. 2019, Jones et al. 2021). Close to the average, the snow cover minimized errors in the counting of wild boars (de Assis Morais et al. 2020, Lemel et al. 2003). In a snowy year, the discrepancies between the winter route census data and the digital survey data would be more significant. The sable population undercount reached almost 30%. The route does not cover part of the taiga zone with a high concentration of sable (Guo et al. 2017, Lavergne et al. 2021 Safronov 2016). The updated fox and hare data allow us to assert that in the lands of the Chebulinsky district, fox exerts strong pressure on the hare population. The predator-prey ratio is even more critical than according to traditional counting methods. Therefore, in the absence of fox hunting, the number of the hare is significantly reduced. In the "Taidonskoe" hunting farm, the number of foxes is lower than the record data, which keeps the hare population stable (Peers et al. 2020, van Beest et al. 2021).

The results of continuous counting using digital technologies for identifying each specimen show that the ungulate and wild boar (bred by the farm) figures have fairly high accuracy. Deviations here do not exceed 15%. In particular, maral and roe deer populations are calculated quite accurately. For species on which the hunting farm does not specialize, the counting accuracy is lower than the actual number.

CONCLUSION

Within the framework of existing approaches, the use of digital technologies for game animal counting usually involves the use of photo cameras. At the same time, the traditional problem of identifying animals in areas with dense vegetation remains. In most cases, when processing photo materials, there will be an undercounting, although somewhat less than with visual observation of animals by a counter. When using infrared imaging, it isn't easy to differentiate animals with similar sizes of the heat-emitting surface. There are also restrictions on the size of the animal. It was found that when using a sufficiently high sensitivity of the thermal imager (the used thermal imager had a very high sensitivity class $\leq$ 60 mK at 300 K), long-haired animals, which are characterized by a lower intensity of thermal radiation (for example, wolves) are identified and recognized in the images. The larger the animal and the worse the thermal insulation layer (wool or feathers), the easier it is to identify it in infrared images and the lower the sensitivity requirements of thermal imagers. For identification by thermal signature, the minimum required length is at least 45-50 cm (hare, sable). Smaller animals and birds are not identified even in an open area and, accordingly, are not recognized during counting. The ability to recognize and record smaller animals and birds requires additional research on existing technologies.

To increase the accuracy of the approach, it is necessary to take into account both the environmental parameters and the operating conditions of the UAV (season, vegetation cover, temperature of various surfaces, time of day, weather conditions, etc.). The influence of most of these factors on the use of digital technologies for recording game animals has not been fully studied. As a rule, such parameters are considered limitations for recording in accordance with the technical characteristics of the equipment used. The significance of the nature and density of vegetation, the presence of snow cover as a contrast for animal recognition also requires study.

The thermal imaging camera reliably detects any large animal, but it is impossible to establish its appearance based on a thermal image. A regular photo is needed for this. The study confirmed the effectiveness of the combined approach (conventional and thermal imaging). However, only the accumulation of the database of animal identifications during remote monitoring will allow us to formulate the conditions of the algorithm that automatically identifies species. The elimination of these features will make it possible to identify the presence of any animal as fully as possible, to carry out data processing automatically, and, therefore, minimize labor costs.

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