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IS IT MORE VISIBLE FROM ABOVE? COMPARISON OF THE EFFECTIVENESS OF METHODS FOR LOCATING BOBAK MARMOT, MARMOTA BOBAK (RODENTIA, SCIURIDAE), BURROWS IN UKRAINE

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Is It More Visible from Above? Comparison of the Effectiveness of Methods for Locating the Bobak Marmot, *Marmota bobak* (Rodentia, Sciuridae), Burrows in Ukraine. Brusentsova, N. &Vasyliuk, O. — Burrow systems detection is a reliable method for the counting Bobak marmots. We compared the effectiveness and labour costs of three methods of burrow detection: ground survey, unmanned aerial vehicle survey and satellite survey. The research was conducted in 2021 (Kyiv Region). Ground surveys mapped 42 (12 main and 24 secondary) burrows, while UAV imagery identified 45 burrows. The proportion of burrows detected by satellite imagery was 48 % of the number of burrows mapped by the ground survey. Secondary burrows were more difficult to detect than main burrows. The largest area of marmot family group territories was calculated from UAV data (0.27 and 0.08 ha), the smallest from satellite imagery data (0.11 and 0.01 ha). To obtain complete information on marmot colonies, it is best to use either UAV surveys or traditional ground surveys. If it is necessary to find potential areas where animals may be living, or to make a preliminary estimate of their distribution, the best option for detecting burrows is to analyse satellite imagery. The most promising approach is to study colonial burrowing mammals using a combination of ground and remote sensing methods. This provides the opportunity to obtain different types of data.

Key words: burrowing mammals, remote sensing, spatial distribution, unmanned aerial vehicles, Ukraine.

Introduction

Traditional field studies of burrowing animals involve ground surveys of large areas of different potential habitats in order to identify burrows, describe their occupancy status, and estimate their numbers (Domnich & Lebedeva, 2000; van Apeldoorn et al., 2006; Tokarsky et al., 2011). This is time consuming, especially when working on potential sites where it is unknown whether the target species is present. In open biotopes, remote sensing methods can significantly increase the efficiency of work in such circumstances.

High-resolution satellite imagery is a reliable and efficient resource for detecting burrowing animals and estimating their distribution over large areas (Sidle et al., 2002; Velasco, 2009; Koshkina et al., 2020; Munteanu et al., 2020). The use of unmanned aerial vehicles (UAVs) further expands the possibilities of taking images at the right time and at the right height, which increases the probability of detecting animal burrows and their detailed mapping (Sun et al., 2018; Old et al., 2019; Du et al., 2020; Virtue et al., 2023). However, the reliability of remote methods is highly variable and has to be calibrated with ground surveying. In Ukraine, such studies have not previously been conducted.

All methods have advantages and disadvantages (Old et al., 2019; Wang et al., 2019). Comparing different approaches to burrowing animal detection can help researchers in the planning stage to select the most appropriate method for their specific conditions and the main objective of the study. In addition, the accumulation of researchers' experience in using and discussing the characteristics of remote sensing methods contributes to the further development of such approaches (Du et al., 2022; Łopucki et al., 2022).

The Bobak marmot *Marmota bobak* (Müller, 1776) is a species of large colonial rodents that live in various types of open grassland areas and, in some places, directly in agricultural landscapes (Tokarsky et al., 2011; Koshkina et al., 2020). Its burrows are easily detected during field studies in the area and using remote sensing of the Earth (Velasco, 2009; Koshkina et al., 2020; Munteanu et al., 2020). This species is disappearing due to the reduction of steppe habitats and the degradation of steppe ecosystems (Tokarsky et al., 2011; Ronkin et al., 2020). Today, the Bobak marmot is listed in the Red Book of Ukraine and is therefore protected in Ukraine at the state level (Order…, 2021). The aim of our work was to evaluate the effectiveness of different methods for detecting marmot burrows and determining their spatial distribution: ground survey, UAV survey, and satellite survey.

Material and Methods

The field studies were conducted in April and June 2021 in Obukhiv District, Kyiv Region, in the vicinity of the village of Dudari. Data were collected as part of the "Biodiversity of Rzhyshchiv city amalgamated territorial community (CATC)" research program (Brusentsova & Vasyliuk, 2023). The study territory (49.887 N, 31.247 E) is an open area with slopes (gully system) covered with meadow-steppe vegetation. The vegetation is dominated by: *Bromus inermis* Leyss., *Bothriochloa ischaemum* (L.) Keng., *Poa angustifolia* L., *Festuca valesiaca* Gaudin., *Stipa capillata* L. Some areas are overgrown with shrubs; the lowlands are swampy. In the study territory, livestock is either absent or is present in small numbers. It is highly probable that local residents previously pastured their livestock here in past years. A decrease in grazing may be associated with an increase in the area of the croplands surrounding the study area. The territory is periodically burned by local residents. The Bobak marmot were reintroduced in Kyiv Region from Kharkiv Region during the period 1986–2005 (Tokarsky et al., 2011). In 1989-1990, animals were released within the Rzhyshchiv CATC (Dudkin, 1995). Once released, the marmots dispersed and relocated to favourable sites.

The work was carried out on a one-hectare test plot using three methods: ground surveys, survey of the area from an unmanned aerial vehicle, and analysis of data from publicly available high-resolution satellite imagery. The test plot contained two family groups of marmots. To standardise the counting of marmot burrows using different methods, separate entrances (holes) were recorded as the underground structure of the burrows was not known.

The ground survey in April involved a visit to the selected territory and a search for all marmot burrows on the test plot by walking on transects at a distance of 4–6 m apart. Coordinates and use features were determined for each identified burrow. All burrows were divided into main or permanent (summer and winter) and secondary or temporary (foraging and protective) burrows based on evidence of nearby life activity (footprints, tracks, fresh mounds of soil, etc.) (Tokarsky et al., 2011; Borovyk, 2014). Coordinates were determined using a Xiaomi Redmi 8A mobile device using the coordinate averaging function (accuracy is 2–3 m).

Unmanned aerial vehicle surveying in June produced georeferenced images for further processing to provide visual detection of marmot burrows. The research was carried out using the DJI Mavic Pro drone and DJI GO software. All images included in the study were captured using the original 12-megapixel RGB camera that is included in the basic UAV package. Surveying was carried out at a height of 30 m. In addition, photos were taken at a height of 15–25 m from different angles due to the complexity of the terrain. Detection of marmot burrows in the UAV image was performed visually in the QGIS 3.28 software (QGIS.org, 2023). A burrow was considered to be a main burrow if a significant mound of bare soil without vegetation was visible near the entrance.

Free high-resolution satellite imagery was accessed through the QuickMapServices module in QGIS. Detection of marmot burrows was carried out visually on Google satellite imaging (acquisition date: 12.03.2020). The resolution of this imagery allows identification of individual entrance by the exposed soil nearby and some established trails between burrows. Main burrow locations were considered to be the plots largest in area and free of vegetation, identified on satellite images as bright light spots of conventional round or oval shape.

Visualization and analysis of the obtained data were prepared using QGIS. To calculate the area of a marmot family group territory, a minimum convex polygon (MCP) for each group of burrows was constructed. The area was calculated using the coordinate system WGS84/UTM zone 36N.

Selected methods for detecting marmot burrows were compared according to four criteria: type of primary data; work location (on site fieldwork and remote data collection); type of financial resources; detectability of burrows.

Results

A total of 42 marmot burrows were mapped on the test plot in the vicinity of the village of Dudari during a ground survey of the territory. Among these burrows, 12 were classified as main burrows and 24 as secondary burrows (table 1).

Table 1. Detecting marmot burrows (separate entrances) by three methods in a trial area in the vicinity of the village of Dudari

Method	Number of detected main burrows	Number of detected secondary burrows	Number of detected unused burrows	All burrows
Ground survey	12	24	6	42
UAV survey	13	29	3	45
Satellite survey	12	8	0	20

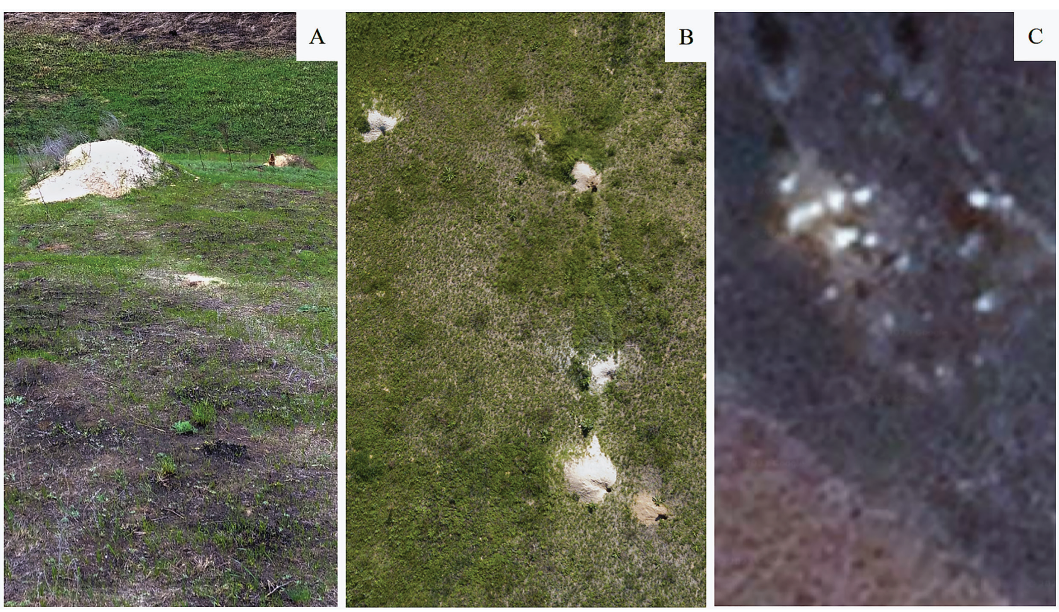

Fig. 1. View of the same burrow system during data collection using three methods: A — ground survey, B — UAV survey, C — satellite survey.

Satellite images mostly made it possible to identify the main primary burrows in active use by animals (fig. 1). The percentage of detected burrows by satellite survey was 48 % of the number of mapped burrows during the ground survey. Secondary burrows were more difficult to detect in satellite and UAV images because the entrances were obscured by vegetation and there were no visible mounds of bare soil.

The assessment of the spatial distribution of burrows also depended on the number and category of mapped burrows. The location of the main and secondary burrows facilitates understanding of the structure of marmot family group territories and the features of its use over a certain period of time. In the study area, we identified two family group territories on the basis of the locations of the main burrows (fig. 2).

The largest areas of marmot family group territories are calculated using UAV data — 0.27 and 0.08 ha, the smallest using data from satellite images — 0.11 and 0.01 ha. The area

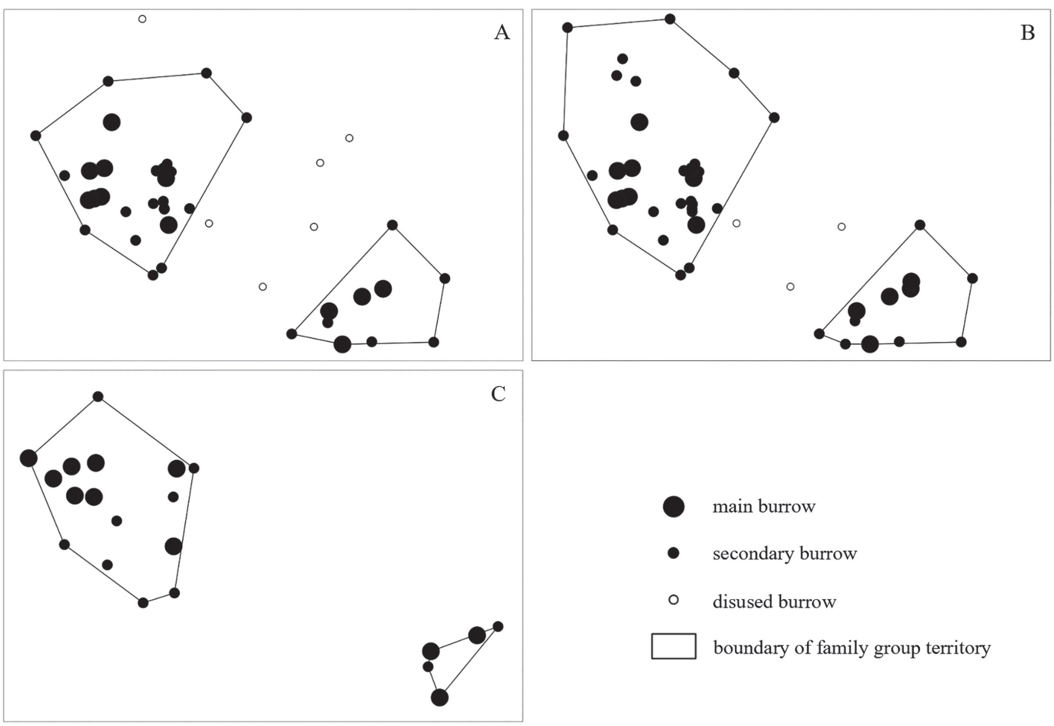

Fig. 2. Marmot family group territories schematics calculated based on the data of three methods: A — ground survey (2021), B — UAV survey (2021), C — satellite survey (2020).

Table 2. Comparison of methods for detecting marmot burrows (separate entrances)

Method	Primary data	Work location	Type of financial resources	Detectability of burrows
Ground survey	Database	Field	Time resources, transport and expeditionary equipment	All burrows are identified
UAV survey	Aerial image	Field and remote	Time resources, transport, expeditionary equipment and UAV	All burrows in use are identified
Satellite survey	High resolution satellite image	Remote	Time resources, satellite image	The main and some secondary burrows are identified

of marmot family group territories during the ground survey was 0.19 and 0.08 ha. Disused burrows were present between the two family group territories.

The total time required was similar for ground and UAV surveys, but the UAV method required the most time for remote data collection (table 2). Satellite image analysis does not require significant time in the field, only visual confirmation of marmots' presence.

Discussion

The main marmot burrows in open areas were easily identified during ground and remote surveys. Secondary burrows were less reliably distinguished using remote methods (especially for satellite images) due to less or no exposed soil and vegetation covering the entrance. Wombat researchers in Australia have noted similar challenges in recognizing different types of shelters when working with wombat burrows (Old et al., 2019). Summer counts may differ from spring burrow counts due to more developed vegetation and new burrows dug by marmots in summer months (Enkhbat et al., 2023). In our study, the greater number of burrow entrances identified using UAV images than during the ground survey (table 1) may stem from several reasons. Near two entrances, the exposed soil was of a different color than in the other burrows. This may indicate that these are new burrows that appeared between April and June, and the animals are still digging them. In other cases (when remote sensing is not verified by field work) it may be an observer's mistake when other objects in nature resemble burrows. We did not conduct any additional ground surveying while working with UAVs. The use of UAVs equipped with thermal images can improve the detection of burrows used by animals, especially in conditions of mature vegetation (Cox et al., 2021; Virtue et al., 2023).

Calculated on the basis of ground surveys (0.19 and 0.08 ha) and UAV surveys (0.27 and 0.08 ha) using the construction of a minimum convex polygon, the areas of marmot family group territories in the studied area near the village of Dudari correspond in size to areas of marmot family group territories, which are indicated for the Kharkiv region (Tokarsky et al., 2011) and Striltsiv Steppe in the Luhansk region (Borovyk, 2014). These calculations can be refined by constructing an MCP taking into account a buffer zone of 15 m (Borovyk, 2014) around burrows and trails. Satellite images are the least accurate for calculation of the area of marmot family group territories, as they do not account for a significant number of secondary burrows. The presence of abandoned burrows between marmot family group territories near Dudari may indicate that it used to be a single territory that was then divided.

Our results showed that the advantage of the ground survey method is its simplicity of implementation and completeness of obtained data. Satellite imagery analysis can be quite inexpensive if publicly available data are used. But such images, as a rule, can be subject to time delay and provide only a part of the necessary information about burrow locations. It is necessary to have skills in working with UAVs, geographic information systems, and image processing in order to conduct research using remote methods.

The UAV survey method produces high-resolution images, is convenient from the point of view of planning, and provides the opportunity to conduct surveys where it is difficult or undesirable to perform them by ground survey (Whitehead et al., 2014; Wang et al., 2019; Virtue et al., 2023). A significant advantage of this method is the availability of material confirmation of observations (aerial images), which can be reviewed over time and possible errors can be detected. Additional parameters (for example, vegetation) can be analyzed from the images or researchers can track the state of the research target over time.

Prices for drones, cameras, sensors, and batteries are also likely to decrease in the future, while potential accuracy through increased resolution and battery life will increase, making drones an important piece of field equipment (Old et al., 2019).

Satellite imagery is a source of immediately-available data covering large areas and is useful primarily in planning field research. Conclusions about the presence or absence of burrows can only be with regard to the moment that the satellite imagery was captured. Extrapolation to other dates and especially years can lead to errors (Velasco, 2009). In our study additional errors could be introduced due to the fact that satellite data were obtained one year prior to the date of field research using other methods. The number and location of secondary burrows may change over the years. When obtaining data using satellite imagery, errors may also occur due to the misidentification of other objects (bare soil, stones, gravel roads) as marmot burrows (Velasco, 2009). Satellite research using publicly available data does not require significant material or technical costs, is safe, and does not disturb target animals. The use of commercial satellite images can provide data covering the desired time period, but will significantly increase the cost of research (Wang et al., 2019).

Climatic conditions can also be limiting factors for remote methods. Dry years or seasons may increase the number of false positive burrow identifications due to an increase in the number of objects that appear to resemble burrows in satellite and UAV images (Velasco, 2009). Clouds can create a shadowing effect and affect burrow visibility in the resulting images. Additionally, unlike ground surveys, which can be conducted in a variety of weather conditions, drones cannot be flown in rainy or windy conditions (Old et al., 2019).

Visual searches for burrows on satellite and UAV images is time-consuming and subjective. Today, a number of approaches for the automatic detection and counting of such objects are being developed, but they are not yet perfected (Du et al., 2022; Virtue et al., 2023). UAV and satellite images can be easily used with GIS software, enabling different types of analysis such as habitat use assessment (Assal & Lockwood, 2007; Old et al., 2019).

Conclusions

Each of the methods for detecting marmot burrows has its advantages and disadvantages, and researchers need to decide their priorities on a case-by-case basis. The main burrows of marmots are easily identified by both ground and remote sensing. The accuracy of detecting this category of burrow is similar for all methods tested. Secondary burrows are less reliable with remote sensing methods, especially on satellite imagery. Assessment of the spatial structure of marmot family group territories depends on the number and category of burrows detected by different methods. The least accurate is the calculation of the area of individual marmot family group territories based on satellite imagery, as it is unable to account for a significant number of secondary burrows.

The best way to obtain complete information on individual marmot colonies is to use unmanned aerial vehicles or traditional ground surveys. If it is necessary to find potential areas where these animals may be present, or to make a preliminary estimate of their distribution, then the best option for detecting burrows is to analyze satellite imagery.

In our opinion, the most promising approach is the study of colonial burrowing mammals using a combination of ground and remote sensing methods, which allow different types of data to be collected. Their use makes it possible to study the temporal and spatial distribution dynamics of the Bobak marmot and to compare the structure of marmot family group territories and populations. Such studies will help to draw conclusions about the state of the population or the success of the reintroduction of this rare species in Ukraine.

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