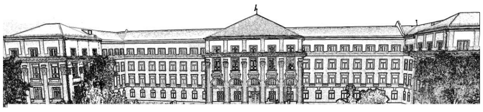

UDC 59.002
IRSTI 87.27.07
DOI 10.37238/2960-1371.2960-138X.2025.99(3).142

[1]Sergazinova Z.M., [2]Makarov A.V., [1]Magzamov A.E., [1]Vishnya B.I., [1]Kaliyeva A.B.

[1]Toraighyrov University, Pavlodar, Kazakhstan
[2]Institute of Systematics and Ecology of Animals SB RAS, Novosibirsk, Federation, Russia

E-mail: wwwszm@mail.ru

DIGITALIZATION OF ACCOUNTING OF GAME ANIMALS: LITERATURE REVIEW

Annotation. The article presents an analysis of the world experience in the use of digital technologies in the accounting of game animals. Key approaches are considered, such as the use of geographic information systems (GIS) to analyze the suitability of habitats and the potential number of mammals and birds, automated systems for monitoring and accounting of animals using unmanned aerial vehicles (UAVs) and camera traps. Examples from various countries are analyzed, where the digitalization of monitoring and accounting of animal communities has increased the accuracy of the data obtained, which has reduced the impact on ecosystems and improved the management of hunting resources. The possibility of adapting these technologies to the conditions of Kazakhstan is considered, with an emphasis on the need for an integrated approach to monitoring to ensure the sustainable development of the hunting industry and the preservation of natural heritage in the face of global environmental challenges. The presented results can be used to develop effective strategies for the digitalization of wildlife monitoring in Kazakhstan and other countries with similar natural and climatic conditions.

Keywords: digitalization of animal accounting; unmanned aerial vehicles (UAVs); geographic information systems (GIS); camera traps; remote sensing; Biodiversity monitoring.

Introduction

Kazakhstan, with its unique natural conditions and rich biodiversity, is faced with the need to introduce modern accounting methods to ensure the sustainable development of the hunting industry. Global experience in this area shows that digitalization contributes to environmental and economic efficiency, which is especially important in the face of global challenges such as climate change and biodiversity loss. Research show that the use of unmanned aerial vehicles (UAVs) significantly improves the effectiveness of monitoring wildlife, especially nocturnal species that live in hard-to-reach areas. They allow for accurate population counts and analysis of animal behavior, minimizing stress and impact on their natural habitat. Satellite monitoring is particularly useful for large-scale research and monitoring of anthropogenic impacts, and GIS is used for habitat analysis, modeling migration routes, and creating ecological corridors.

The problem of modern research is the need to improve the accuracy and efficiency of accounting for game and commercial animals to ensure sustainable management of natural resources. Traditional accounting methods are often accompanied by difficulties, such as high labor intensity, limited ability to process large amounts of data and insufficient efficiency in obtaining up-to-date information. In addition, many countries, including Kazakhstan, are facing problems of poaching, ecosystem degradation and changes in the number of animal populations. This requires the introduction of innovative approaches for accurate monitoring and rational management of hunting resources.

The objects of research in this article are modern methods of accounting for game and commercial animals using digital technologies.

The purpose of the article is to analyze and systematize the world experience of using digital technologies in the accounting of game animals, as well as to develop recommendations for adapting these technologies to the conditions of Kazakhstan. The research aims to identify the benefits of digitalization in the hunting industry, including improving monitoring accuracy, improving resource management and reducing the impact on ecosystems.

Materials and methods of research

A literature review was conducted using the scientific databases MDPI, Scopus and eLIBRARY to analyze digital technologies for recording game animals. Twenty-four sources were included in the review, covering studies from 2002 to 2025. The focus was on papers that examined the use of unmanned aerial vehicles (UAVs), camera traps, and geographic information systems (GIS) in wildlife monitoring. The analysis covered both methodological aspects of the technologies and practical results of their application in different natural and climatic conditions.

For comparative analysis of the effectiveness of the methods, a table was compiled, indicating the types of equipment, target animal groups and main results of the research. The following criteria were used as criteria for comparative assessment: accuracy of population counting, scale of territory coverage, impact of the method on animal behavior, cost and labor intensity of application.

As a result, the key advantages and limitations of each method were highlighted, which allowed to substantiate the prospects of their integrated application in Kazakhstan for monitoring of game species.

Research results

Use of UAVs with thermal imaging sensor

Traditional methods of counting game animals, such as winter route counting, counting in places of concentration of animals, questionnaire method, face a number of restrictions. These challenges include low accuracy, high labour intensity, data subjectivity and inability to cover large or hard-to-reach areas. Modern technologies, including thermographic surveying, the use of drones, geographic information systems (GIS) analysis and satellite monitoring, can significantly improve traditional methods, eliminate their key disadvantage and expand their capabilities.

The use of UAVs with a thermal imaging sensor can transform wildlife monitoring, contributing to the effective tracking of animal populations over large areas. UAVs have established themselves as a universal tool for observing animals in their natural environment, especially in hard-to-reach and remote regions. They are successfully used to observe large mammals, birds, reptiles and even small animals. For example, in the open landscapes of Canada, the use of drones with thermal imagers made it possible to count coyotes, foxes and skunks. The researchers conducted more than 200 flights at night, detecting the animals with to their heat signatures. This made it possible not only to confirm the presence of species, but also to assess their activity and population density [1, 2].

In waterfowl wetlands, the use of UAVs with high-resolution cameras has proven to be effective in counting populations. In one research, drones were used to monitor nesting birds, such as gulls and ducks, allowing for an accurate record of them without disturbing the animals. While traditional methods, including ground surveys or manned flights, often lead to stress in birds, which can skew data on their abundance and behavior. In contrast, the use of drones allows for aerial surveying, minimizing any negative impact on communities [3].

Some African countries and Sumatra are now using drones to monitor large mammals such as elephants and giraffes. This research helped to assess the state of their populations, determine the main routes of their migrations and habitats. Through the use of multispectral sensors mounted on drones, researchers have been able to analyze vegetation cover and water availability, which is critical for the survival of these animals in arid climates [4, 5].

Thermal imaging cameras integrated into UAVs provide unique capabilities for detecting animals in low-visibility conditions. They allow you to record thermal radiation, which is especially useful for working at night or in dense vegetation. This makes them indispensable for counting nocturnal species of animals or those that are invisible to observers. In Canada, such cameras have been successfully used to detect the heat signatures of medium-sized mammals such as coyotes and foxes, confirming their versatility. Thermal imaging cameras also find applications in agricultural areas, where they are used to identify animals in fields before harvesting to prevent them from dying [2].

Multispectral cameras allow not only to record animals, but also to analyze the state of their habitat. These sensors provide data on vegetation, soil conditions and water availability, which is particularly important for assessing the ecological health of an area. For example, in national parks in Africa, drones with multispectral cameras are successfully used to analyze the ecological environment of landscapes and identify areas with the most suitable habitats for large mammals.

One of the most significant advances in the accounting of game animals is associated with the automation of the analysis of data obtained from UAVs. Collecting a huge number of images creates the need for efficient processing, and this is where deep learning algorithms come in. For example, algorithms such as Faster R-CNN and YOLO demonstrate high accuracy in recognizing objects in images. Faster R-CNN provides accurate species recognition, whereas YOLO stands out for its speed of analysis, which is especially important when processing large amounts of data. In South

Korea, deep learning algorithms were used to analyze images collected from drones in order to take into account the number of birds. With the help of images taken from a height of 100 meters, databases were created, including thousands of images, which were then automatically processed. This approach not only improves the accuracy of accounting but also significantly reduces the analysis time compared to manual methods [3].

In Greenland, the use of UAVs has proven effective in monitoring species such as the white-fronted goose *Anser brachyrhynchus* and the ringed pin *Charadrius hiaticula*. Studies have shown that RGB cameras installed on drones are able to capture birds on glaciers and coastal areas, providing highly detailed images. These devices made it possible to identify hidden birds' nests, which were invisible due to their natural camouflage coloration. For example, the thermal radiation of the body of a nesting ringed plover against the background of the cold surface of stones allows it to be easily identified on thermograms. This made it possible not only to count the number of nesting birds, but also to study the distribution of their nesting territories, which is key for the conservation of these species [6].

Thermographic sensors are widely used in research not only in the Arctic, but also in other difficult climatic conditions. An important feature of thermal cameras is their ability to record the thermal radiation of the body of animals, which makes them indispensable for night monitoring or work in conditions of poor visibility. In Greenland, thermal cameras have been shown to be effective in studying bird nesting grounds, and in marine mammal studies, they have been able to determine the condition of animals, including the thickness of the fat layer, which is important for assessing the adaptation of species to environmental changes. This is especially true for species such as seals, whose survival is closely tied to changes in temperature and food availability. In Korea, the use of drones with thermal sensors made it possible to observe the lesser spoonbill (*Platalea minor*) in conditions where human presence was impossible. These observations confirmed the effectiveness of such technologies for working in difficult environmental conditions, allowing the protection of rare species without the need for their immediate concern [6, 7].

In Scotland, UAVs with high-resolution cameras have proven successful in the study of grey seals (*Halichoerus grypus*) and grey seals (*Phoca vitulina*). The survey from a height of 30–50 meters made it possible to identify individual individuals by patterns on the skin, as well as measure their size, which is critical for assessing the health of animals and their adaptation to climate change. These data were obtained without physical contact with the animals, which minimized stress for them. The studies also found that the reaction of seals to drone flights varied depending on their characteristics. Less noisy models, such as Cinestar 6, caused minor behavioral changes, even when approaching at a distance of about 30 meters, while noisier vehicles, such as Vulcan 8, sometimes caused the animals to go into the water [7].

In the process of wildlife monitoring, the drone's customized flight path, which reflects the topographic features of the land cover, greatly improves the success rate of animal detection and maximizes the efficiency of the UAV use. Thermal imaging drones detect heat sources based on body temperature and offer superior operational flexibility and detection speed compared to drones with an RGB camera, as they can operate both during the day and at night. The use of thermal imaging drones to detect wildlife has significant potential to accurately assess animal populations over large areas in a relatively short period of time. UAVs with thermal imagers can detect the location of wildlife in real time, identify individual species and count their numbers, leading to more accurate estimates of their numbers [8].

Compared to the use of UAVs, ground-based surveys of both birds and mammals are time-consuming and can disrupt and affect the results of their spatial distribution, while visual monitoring and daylight counting limits the detection of nocturnal and visually difficult to detect species. The use of unmanned aerial vehicles makes it possible to simultaneously study several parameters, such as behavioral responses, accounting for the number and gender ratio in communities. In addition, UAVs have better detection capabilities for some species and are more efficient in terms of survey time compared to other methods. Several studies have found that the use of drones had more accurate and efficient results compared to traditional ground-based methods of counting birds [8–10].

Monitoring populations using UAVs with a thermal imaging camera is especially effective in recognizing and counting medium and large nocturnal mammals in open fields. In the study of colonies of the black-tailed prairie dog (*Cynomys ludovicianus*), remote sensing using UAVs was used together with AI. The paper demonstrated that deep-processed, high-resolution aerial imagery is a powerful potential tool not only for mapping colonies, but also for characterizing heterogeneity within and between colonies, providing detailed information on individual burrow locations [11].

In the hunting grounds of the Kemerovo region, the use of combined imagery using unmanned aerial vehicles (UAVs) with conventional and thermal imaging cameras was used to monitor the number of game animals. The results of the study showed that the use of digital counting methods makes it possible to identify deviations in the number of animals by 30–50 % compared to the traditional method of winter route counting. At the same time, long-haired animals, characterized by a lower intensity of thermal radiation, are identified and recognized in the images. The use of UAVs has proven to be particularly effective for large animals (elk, maral, roe deer), while the identification of small animals and birds requires further technological improvements [12].

Thus, it can be concluded that in environmental monitoring, the use of UAVs has a number of advantages over traditional methods. This method is more effective for counting the number of birds, terrestrial and marine mammals due to the possibility of its use in hard-to-reach places and at night, relatively silent operation of drones and covering large areas of the study area.

Use of GIS systems

In terrestrial ecosystem monitoring, GIS is most often used to analyze the suitability of habitats for different animal species based on the characteristics of vegetation cover, the presence of tree stands, water bodies, anthropogenic structures, and the area of settlements. An example of the use of GIS systems is the creation of "wildlife corridors". On the basis of high-resolution satellite images, it is possible to visualize the current state of ecosystems, the availability of suitable habitats for certain species of animals, the degree of degradation of natural landscapes as a result of anthropogenic activities. Based on this and the actual presence of wild animals, it is possible to predict their distribution and potential abundance in the study area [13–15]. At present, as a result of the use of high-resolution satellite images and topographic maps, it is possible to identify important ecological features in the habitats of rare and endangered species and to locate potential ecological "corridors" between animal communities. The creation of ecological "wildlife corridors" through GIS is becoming more common to allow different animal species to move more easily between their habitats. These "corridors" allow for increased genetic diversity between populations and reduced negative interactions between wildlife and humans [16].

Monitoring with camera traps

In recent years, the use of camera traps to monitor wildlife populations has become increasingly popular due to the cost-effectiveness of this approach, the wide range of species observed and the absence of negative effects on animal behavior. Camera trap imagery offers the ability to collect continuous time series of biodiversity data, allowing for real-time monitoring [17]. With the development and improvement of machine learning algorithms, especially in the field of image processing, automatic detection and identification of species from imagery has become accessible and widely used. When using camera traps, it is possible to collect time series of data on the presence of herbivores or predatory animals. When combined with satellite imagery of vegetation cover, it can create a scalable, cost-effective and replicable wildlife monitoring system [18].

The use of camera traps offers significant advantages over traditional monitoring methods. First, the real-time processing of such data allows for continuous monitoring of the presence of species in a particular habitat, which allows for highly adaptive management of animal resources. Secondly, this method is cost-effective and convenient for the researcher, reducing dependence on time-consuming and expensive aerial surveys. At the same time, local data processing also reduces the need to upload images, which is ideal for remote areas. Thirdly, the use of camera traps for monitoring the animal population is possible in any habitat, both with a limited water level and in places where there are permanent watercourses.

Modern research using camera traps is actively developing two key areas: biodiversity monitoring and estimation of animal population density.

In the field of population estimation methods, a new approach was proposed based on the frequency of camera traps. It allows you to calculate the number without the need for individual identification of individuals. The method was tested on four tropical species: red-necked wallaby (*Macropus rufogriseus*), Chinese water deer (*Hydropotes inermis*), muntjac (*Muntiacus reevesi*) and mara (*Dolichotis patagonum*). The new approach demonstrated high accuracy in estimating population density depending on the frequency of camera traps and showed similar abundance values in comparison with the previously known abundance of these species [19]. Later, in the mountains of Tanzania, the effectiveness of using the frequency of camera traps as an index of population density was confirmed on the example of one model species - Harvey's duiker (*Cephalophus harveyi*). Using the number of camera traps as an indicator of abundance has been shown to be a promising and cost-effective way to quickly estimate the number of animals in remote areas [20]. In the Italian Apennines, a comparative analysis of three methods for estimating the population density of the European roe deer (*Capreolus capreolus*) was carried out. In this study, the method of analyzing camera trap actuations was compared with route counting and the method of counting fecal groups. The results showed relatively similar values of roe deer population density by these three methods, while counting with camera traps is characterized by an average level of accuracy and the least labor intensity. In general, the conclusions in this work confirmed the high accuracy of the use of camera traps with appropriate data calibration and noted the effectiveness of an integrated approach to improve the reliability of monitoring [21]. In Northern Sweden, studies were conducted to compare the methods of photographing and recording excrement in estimating the population density of roe deer and elk (*Alces alces*). The results showed that the use of camera traps could be a viable alternative compared to classical monitoring methods and could be particularly useful for monitoring multispecies communities [22].

As part of the monitoring of biodiversity in the Republic of Belarus, the effectiveness of using camera traps for the long-term study of badger (*Meles meles*) settlements was demonstrated on the territory of forestries. This made it possible to identify seasonal features of behavior and the structure of social groups without interfering with the natural environment [23]. In China, in the Guanyinshan Nature Reserve (Shaanxi Province), camera traps with infrared cameras were used to assess species diversity. In July 2009, 18 camera traps were installed in the reserve, which made it possible to collect 2115 images and identify 27 species of wild animals in the period from August 2009 to July 2011. Among the recorded species were such key representatives of the fauna as the red panda (*Ailurus fulgens*), Berezovsky's musk deer (*Moschus berezovskii*) and the Asiatic badger (*Meles leucurus*). The work demonstrated the high efficiency of using camera traps to monitor fauna in hard-to-reach mountain ecosystems and emphasized the importance of a long period of data collection to ensure the representativeness of the results [24].

Thus, the results of modern studies demonstrate the high prospects of digital accounting methods, especially camera traps and remote sensing, for improving the accuracy of monitoring the number, population structure and biodiversity of game and rare animal species.

Comparative characteristics of digital methods of animal counting

To generalize and systematize the world experience in the use of digital technologies in the monitoring of hunting and other animals, a comparative analysis of the studied literature was carried out. The table presents the key studies, which indicate the methods and equipment used, the animal species studied, as well as a brief summary of the main results of each of the studies carried out. This makes it possible to visually assess the variety of approaches, their effectiveness and applicability to different monitoring conditions.

Table - 1 – Comparative analysis of digital methods of animal counting

Authors	Method (equipment)	Species under study	Key findings
(Chabot & Bird, 2015)	UAV (review article)	Common wildlife groups (ungulates, birds, marine mammals)	UAVs are recognized as effective for monitoring wildlife in large and hard-to-reach areas
(Bushaw et al., 2019)	UAVs with thermal imaging cameras	Fox (*Vulpes vulpes*), raccoon (*Procyon lotor*), coyote (*Canis latrans*)	UAVs made it possible to accurately assess the location and abundance of mesopredators in the prairies of Canada
(Hong et al., 2019)	UAV with RGB cameras combined with a deep learning-based bird detection method	Black Mallard (*Anas poecilorhyncha*), Common Teal (*Anas Crecca*), Great White Egret (*Ardea alba*), Grey Heron (*Ardea cinerea*)	The use of deep-learning-based bird detection techniques in combination with aerial photography from UAVs is quite suitable for detecting birds in various conditions. The Faster R-CNN model is the most accurate, and the YOLO is the fastest model
(Lee et al., 2019)	UAVs with RGB and thermal imaging cameras	White-fronted Goose (*Anser brachyrhynchus*), Ringed Goose (*Charadrius hiaticula*), Little Spoonbill (*Platalea minor*)	The use of UAVs with thermal imaging cameras can be successfully used to observe animals in the extreme conditions of Greenland and in the protected area of the Republic of Korea, as well as to search for hidden nests of waders in coastal shoals
(Pomeroy et al., 2015)	UAV with video surveillance	Grey seal (*Halichoerus grypus*), grey seal (*Phoca vitulina*)	The use of UAVs caused different behavioral reactions in seals during breeding and molting. It is noted that the drone's flight altitude above 50 m minimizes the stress of seals during observations
(Burke et al., 2018)	UAV with thermal infrared cameras	River rabbit (*Bunolagus monticularis*)	Optimization of flight parameters has increased the efficiency of counting animals with thermal imagers. With the help of

			UAVs, for the first time in the study area, a rare, endangered species was discovered - the river rabbit
(Burke et al., 2019)	UAVs with thermal imaging cameras	Borneo orangutan (*Pongo pygmaeus*)	With the help of UAVs, 41 orangutans and a group of proboscis monkeys were successfully detected in the rainforest. The potential advantages and limitations of UAVs with thermal imagers in comparison with other methods are discussed
(Dunstan et al., 2020)	Combining UAVs and underwater photography	Green sea turtle (*Chelonia mydas*)	A comparison of three methods for observing green turtles on the Rhine Island (Australia) is given. The results showed that the use of UAVs is more efficient in terms of time spent, personnel engagement and weather resilience
(Kearney et al., 2023)	UAV with deep learning algorithm	Black-tailed prairie dog (*Cynomys ludovicianus*)	Using UAVs together with a deep learning algorithm can accurately detect the burrows of prairie dogs. At the same time, scaling from individual burrows to entire colonies is possible, but requires further research
(Ivanova & Prosekov, 2024)	UAV with conventional and thermal imaging cameras	Elk (*Alces alces*), red deer (*Cervus elaphus sibiricus*), roe deer (*Capreolus pygargus*) and other species	The use of a combined approach (with conventional and thermal imaging cameras) effectively registers all species of game animals. Such remote monitoring makes it possible to formulate algorithm conditions for automatic species detection
(Danks & Klein, 2002)	GIS modeling	Musk ox (*Ovibos moschatus*)	GIS Models Successfully Used in Study to Predict Suitable Habitat for Musk Oxen in Alaska

(Gibson et al., 2004)	GIS modeling	Red-headed bristlebill (*Dasyornis broadbenti*)	Based on GIS, a predictive spatial model of the habitat of the red-headed bristlebill was developed. Correlations were found between the presence of the species and altitude above sea level, distance to the stream, distance to the coast and the level of development of shrub vegetation
(Dwyer et al., 2015)	OzTrack online platform for sharing GPS data on animal location tracking	Koala (*Phascolarctos cinereus*), southern cassowary (*Casuarius casuarius*), saltwater crocodile (*Crocodylus porosus*)	The OzTrack online platform offers a set of reliable and affordable tools for processing, visualizing and analyzing data on the location of animals. OzTrack uses free and open-source software available online
(Rathore et al., 2012)	GIS modeling	Tiger (*Panthera tigris*)	GIS modeled the likely routes of tigers between Kanha and Pench National Parks and identified potential migration corridors
(Hartig et al., 2023)	Overview of new approaches to data processing	Different types	New databases (GPS, camera traps) open up new prospects for ecological and spatial analysis
(Weber et al., 2025)	Camera traps and satellite images of vegetation cover	Different Species of Herbivores	With the help of the spatio-temporal animal monitoring system, accurate data on the population density of herbivores were obtained in real time, which allows for targeted population management and promotion of savannah recovery
(Rowcliffe et al., 2008)	Camera traps	Red-necked wallaby (*Macropus rufogriseus*), Chinese water deer (*Hydropotes inermis*), muntjac (*Muntiacus reevesi*), mara (*Dolichotis patagonum*)	An approach is proposed that makes it possible to estimate the density of the population of animals based on the frequency of images with camera traps, without the need for individual recognition of individuals

(Rovero & Marshall, 2009)	Camera traps	Blue Duiker (*Philantomba monticola*), Suni (*Neotragus moschatus*), Bushbuck (*Tragelaphus scriptus*), Harvey's Duiker (*Cephalophus harveyi*)	It is shown that the frequency of camera trap shooting (the number of photographs per unit of time) can be a reliable indicator of the population density of the species under study. This method has great potential for standardizing monitoring programmes, especially in remote, hard-to-reach areas
(Marcon et al., 2019)	Camera traps	Roe deer (*Capreolus capreolus*)	The results showed that the camera trap method is applicable to estimating the population density of roe deer. At the same time, it has an average level of accuracy and requires the least effort from the counters
(Pfeffer et al., 2017)	Camera traps and excrement accounting	Moose (*Alces alces*), roe deer (*Capreolus capreolus*)	Using camera traps, a model of random encounters was tested, without the need to recognize individual individuals. The results showed that when monitoring ungulate communities, camera traps can be a reliable addition to traditional counting methods
(Smolyarko & Yushkevich, 2025)	Camera traps	Badger (*Meles meles*)	On the example of a local settlement of badgers, the sex and age structure, reproduction, daily activity and interaction with other species were studied
(Liu et al., 2013)	Camera traps with infrared cameras	Takin (*Budorcas taxicolor*), common goral (*Naemorhedus goral*), crested deer (*Elaphodus cephalophus*), golden pheasant (*Chrysolophus pictus*), wild boar (*Sus scrofa*), Sumatran buffalo (*Capricornis sumatraensis*)	With the help of camera traps and population indices in the Guanyinshan Nature Reserve (China), data on the number of species, their dynamics and daily activity were obtained

Analysis of the presented data shows that each of the digital methods of accounting has its own advantages and limitations in monitoring game animals. UAVs with thermal imaging and RGB cameras have demonstrated high efficiency in the operational accounting of medium and large mammals, especially at night and in hard-to-reach regions. GIS technologies make it possible to carry out spatial modeling of the habitat and design ecological corridors, which is important for the preservation of migration routes and support for populations of rare species. Camera traps have proven their value as a cost-effective tool for long-term monitoring of biodiversity and estimation of community numbers with minimal interference with animal habitats. The most effective for sustainable management of hunting resources is the combined use of all three approaches: UAV counting, spatial modeling using GIS and constant monitoring of the number using camera traps.

Prospects for the implementation of digitalization in Kazakhstan for the accounting of hunting and commercial species

The territory of the north-east of Kazakhstan, in particular the Pavlodar region, has significant potential for the development of digital technologies for monitoring hunting and commercial species. At present, there is an acute lack of comprehensive information on the number, distribution and dynamics of wildlife populations, which limits the possibilities for effective management of hunting resources. Existing scientific research on medium and large mammals is fragmentary and does not cover the territory of the north-east of Kazakhstan in full.

The introduction of modern digital methods, such as aerial photography using unmanned aerial vehicles (UAVs), automatic monitoring using camera traps and spatial data analysis in geographic information systems (GIS), will qualitatively change the approach to the accounting of hunting species. The use of thermal imaging and multispectral sensors on UAVs will ensure high-precision recording of animals even in hard-to-reach and poorly studied areas, and camera traps will provide continuous data on seasonal activity and the sex-age structure of communities.

The introduction of digital technologies will make it possible to improve the accuracy of accounting, reduce labor costs, minimize the stress impact on animals and allow you to quickly respond to changes in the number of game species. In addition, the creation of integrated databases and models of the spatial distribution of communities will contribute to the development of science-based recommendations for the regulation of hunting, biodiversity conservation and sustainable nature management.

Conclusion

Based on the analysis of literature sources in the field of application of modern methods of accounting for hunting and commercial species of animals, the following conclusion can be made. The use of UAVs makes it possible to carry out an absolute count of the number of mainly large and medium-sized animals, to identify the features of biotopic distribution, nesting, behavior, aggregation of waterfowl in molting sites, and also allows you to assess the ecological state of habitats and migration routes. When using camera traps, it is possible to assess not only the species composition, but also the population density of game animals based on the frequency of camera operation, to identify daily activity, sex and age composition of populations, behavioral characteristics and interaction with individuals of other species. In addition, unlike the use of UAVs, camera traps are less expensive and allow long-term monitoring over large areas. GIS technologies based on geoinformation mapping and modeling make it possible to visualize the spatial distribution of animals in the areas under study, as well as to predict changes in their ranges as a result of remote monitoring data. These methods of counting can be recognized as an alternative to traditional ground-based methods of counting, they allow for accurate, prompt and minimally invasive monitoring of populations, which is especially important in the context of growing anthropogenic pressure. However, the use of digital technologies in monitoring the animal population does not exclude ground-based methods of counting, and their integrated use makes it possible to obtain more accurate data on the number and population parameters of hunting and commercial mammals and birds. International experience confirms that the integrated use of digital technologies and ground-based accounting methods contributes to optimizing the management of animal resources and reducing the risks of loss of biological species. For Kazakhstan, the digitalization of accounting is a strategically important area that ensures scientifically based regulation of hunting, the restoration of natural ecosystems and integration into global biodiversity conservation programs.

REFERENCES

[1] Chabot, D., & Bird, D. M. (2015). Wildlife research and management methods in the 21st century: Where do unmanned aircraft fit in? *Journal of Unmanned Vehicle Systems, 3*(4), 137–155. https://doi.org/10.1139/juvs-2015-0021

[2] Bushaw, J. D., Ringelman, K. M., & Rohwer, F. C. (2019). Applications of Unmanned Aerial Vehicles to Survey Mesocarnivores. *Drones*, *3*(1), 28. https://doi.org/10.3390/drones3010028

[3] Hong, S. J., Han,Yu., Kim, S. Y., Lee, A.Y., & Kim, G. (2019). Application of Deep-Learning Methods to Bird Detection Using Unmanned Aerial Vehicle Imagery. *Sensors*, *19*(7), 1651. https://doi.org/10.3390/s19071651

[4] Vermeulen, C., Lejeune, Ph., Lisein, J., Sawadogo, P., & Bouché, Ph. (2013). Unmanned Aerial Survey of Elephants. *PLOS One, 8*(2), e54700. https://doi.org/10.1371/journal.pone.0054700

[5] Koh, L. P., & Wich, S. (2012). Dawn of Drone Ecology: Low-Cost Autonomous Aerial Vehicles for Conservation. *Tropical Conservation Science, 5*(2), 121–132. https://doi.org/10.5167/uzh-72781

[6] Lee, W. Y., Park, M., & Hyun, C. U. (2019). Detection of two Arctic birds in Greenland and an endangered bird in Korea using RGB and thermal cameras with an unmanned aerial vehicle (UAV). *PLOS One, 14*(9), 1–16. https://doi.org/10.1371/journal.pone.0222088

[7] Pomeroy, P., O'Connor, L., & Davies, P. (2015). Assessing use of and reaction to unmanned aerial systems in gray and harbor seals during breeding and molt in the UK. *Journal of Unmanned Vehicle Systems, 3*(3), 102–113. https://doi.org/10.1139/juvs-2015-0013

[8] Burke, C., Rashman, M. F., Wich, S. A., Symons, A., Theron, C., & Longmore, S. N. (2018). Optimizing Observing Strategies for Monitoring Animals

Using Drone-Mounted Thermal Infrared Cameras. *International Journal of Remote Sensing, 40*(2), 439–467. https://doi.org/10.1080/01431161.2018.1558372

[9] Burke, C., Rashman, M. F., Longmore, S. N., McAree, O., Glover-Kapfer, P., Ancrenaz, M., & Wich, S. A. (2019). Successful observation of orangutans in the wild with thermal-equipped drones. *Journal of Unmanned Vehicle Systems, 7*(3), 235–257. https://doi.org/10.1139/juvs-2018-0035

[10] Dunstan, A., Robertson, K., Fitzpatrick, R., Pickford, J., & Meager, J. J. (2020). Use of unmanned aerial vehicles (UAVs) for mark-resight nesting population estimation of adult female green sea turtles at Raine Island. *PLOS One, 15*(6), e0228524. https://doi.org/10.1371/journal.pone.0228524

[11] Kearney, S. P., Porensky, L. M., Augustine, D. J., & Pellatz, D. W. (2023). Toward broad-scale mapping and characterization of prairie dog colonies from airborne imagery using deep learning. *Ecological indicators, 154,* 110684. https://doi.org/10.1016/j.ecolind.2023.110684

[12] Ivanova, S. & Prosekov, A. (2024). Hunting Resource Management by Population Size Control by Remote Sensing Using an Unmanned Aerial Vehicle. *Nature Environment and Pollution Technology, 23*(1), 391–399. https://doi.org/10.46488/NEPT.2024.v23i01.033

[13] Danks, F. S., & Klein, D. R. (2002). Using GIS to Predict Potential Wildlife Habitat: A Case Study of Muskoxen in Northern Alaska. *International Journal of Remote Sensing, 23*(21), 4611–4632. https://doi.org/10.1080/01431160110113890

[14] Gibson, L. A., Wilson, B. A., Cahill, D. M., & Hill, J. (2004). Spatial Prediction of Rufous Bristlebird Habitat in a Coastal Heathland: A GIS-Based Approach. *Journal of Applied Ecology, 41*(2), 213–223. https://doi.org/10.1111/j.0021-8901.2004.00896.x

[15] Dwyer, R. G., Brooking, Ch., Brimblecombe, W., Campbell, H. A., Hunter, J., Watts, M. E., & Franklin, C. E. (2015). An open Web-based system for the analysis and sharing of animal tracking data. *Animal Biotelemetry, 3*(1), 1–11. https://doi.org/10.1186/s40317-014-0021-8

[16] Rathore, Ch. S., Dubey, Y., Shrivastava, A., Pathak, P., & Patil, V. K. (2012). Opportunities of Habitat Connectivity for Tiger (Panthera Tigris) between Kanha and Pench National Parks in Madhya Pradesh, India. *PLOS One, 7*(7), e39996. https://doi.org/10.1371/journal.pone.0039996

[17] Hartig, F., Abrego, N., Bush, A., Chase, J. M., Guillera-Arroita, G., Leibold, M. A. Ovaskainen, O., Pellissier, L., Pichler, M., Poggiato, G., Pollock, L., Si-Moussi, S., Thuiller, W., Viana, D. S., Warton, D. I., Zurell, D., & Yu, D. W. (2023). Novel community data in ecology-properties and prospects. *Trends in Ecology & Evolution, 39*(3), 280–293. https://doi.org/ 10.1016/j.tree.2023.09.017

[18] Weber, M., Strijbis, J., Osner, N., Périquet-Pearce, S., Crowther, T. W., & Werden, L. K. (2025). An open-source method for spatially and temporally explicit herbivory monitoring in semi-arid savannas. *Journal of Environmental Management, 377*(1), 124690. https://doi.org/10.1016/j.jenvman.2025.124690

[19] Rowcliffe, M., Field, J., Turvey, S., & Carbone, C. (2008). Estimating Animal Density Using Camera traps Without the Need for Individual Recognition.

Journal of Applied Ecology, 45(4), 1228–1236. https://doi.org/10.1111/j.1365-2664.2008.01473.x

[20] Rovero, F., & Marshall, A. R. (2009). Camera Trapping Photographic Rate as an Index of Density in Forest Ungulates. *Journal of Applied Ecology, 46*(5), 1011–1017. https://doi.org/10.1111/j.1365-2664.2009.01705.x

[21] Marcon, A., Battocchio, D., Apollonio, M., & Grignolio, S. (2019). Assessing Precision and Requirements of Three Methods to Estimate Roe Deer Density. *PLOS One*, *14*(10), e0222349. https://doi.org/10.1371/journal.pone.0222349

[22] Pfeffer, S. E., Spitzer, R., Allen, A. M., Hofmeester, T. R., Ericsson, G., Widemo, F., Singh, N. J., & Cromsigt, J. (2017). Pictures or Pellets? Comparing Camera Trapping and Dung Counts as Methods for Estimating Population Densities of Ungulates. *Remote Sensing in Ecology and Conservation, 4*(9), 173–183. https://doi.org/10.1002/rse2.67

[23] Smolyarko, E. O., & Yushkevich, N. T. (2025). Opyt ispol'zovaniya fotolovushek v tselyakh monitoringa zhivotnogo mira na primere lokal'noi populyatsii barsuka (*Meles meles*) [The experience of using camera traps to monitor wildlife using the example of a local population of badgers (*Meles meles*)]. *Trudy Belorusskogo gosudarstvennogo tekhnologicheskogo universiteta* [Proceedings of the Belarusian State Technological University], *1*(288), 59–68. https://doi.org/ 10.52065/2519-402X-2025-288-6

[24] Liu, X., Wu, P., Songer, M., Cai, Q., He, X., Zhu, Y., & Shao, X. (2013). Monitoring wildlife abundance and diversity with infra-red camera traps in Guanyinshan Nature Reserve of Shaanxi Province, China. *Ecological indicators, 33*, 121–128. https://doi.org/10.1016/j.ecolind.2012.09.022

Сергазинова З.М., Макаров А.В., Магзамов А. Е., Вишня Б.И., Калиева А. Б.

АҢШЫЛЫҚ-КӘСІПШІЛІК ЖАНУАРЛАРДЫ ЕСЕПКЕ АЛУДЫ ЦИФРЛАНДЫРУ: ӘДЕБИ ШОЛУ

Аннотация. Мақалада аңшылық-кәсіпшілік жануарларды есепке алуда цифрлық технологияларды пайдаланудың әлемдік тәжірибесіне талдау ұсынылған. Тіршілік ету ортасының жарамдылығын және сүтқоректілер мен құстардың ықтимал санын талдау үшін геоақпараттық жүйелерді (ГАЖ), ұшқышсыз ұшу аппараттары (ұшқышсыз ұшу аппараттары) мен фототұзақтарды пайдалана отырып, жануарларды бақылау мен есепке алудың автоматтандырылған жүйелерін қолдану сияқты негізгі тәсілдер қарастырылады. Жануарлар қауымдастығының мониторингі мен есебін цифрландыру алынған деректердің дәлдігін арттырып, экожүйелерге әсерін азайтуға және аңшылық ресурстарды басқаруды жақсартуға мүмкіндік берген әртүрлі елдердің мысалдары талданды. Аңшылық саласының орнықты дамуын қамтамасыз ету және жаһандық экологиялық сын-қатерлер жағдайында табиғи мұраны сақтау үшін мониторингке кешенді көзқарас қажеттілігіне баса назар аудара отырып, осы технологияларды Қазақстан жағдайларына бейімдеу мүмкіндігі қаралды. Ұсынылған нәтижелер Қазақстанда және табиғи-климаттық жағдайлары ұқсас басқа елдерде жабайы

фаунаның мониторингін цифрландырудың тиімді стратегияларын әзірлеу үшін пайдаланылуы мүмкін.

Кілт сөздер: жануарларды есепке алуды цифрландыру; ұшқышсыз ұшу аппараттары (ұшқышсыз ұшу аппараттары); геоақпараттық жүйелер (ГАЖ); фототұзақ; қашықтықтан зондтау; биоалуантүрлілік мониторингі.

Сергазинова З.М., Макаров А.В., Магзамов А. Е., Вишня Б.И., Калиева А. Б.

ЦИФРОВИЗАЦИЯ УЧЕТА ОХОТНИЧЬЕ-ПРОМЫСЛОВЫХ ЖИВОТНЫХ: ЛИТЕРАТУРНЫЙ ОБЗОР

Аннотация. В статье представлен анализ мирового опыта использования цифровых технологий в учете охотничье-промысловых животных. Рассматриваются ключевые подходы, такие как применение геоинформационных систем (ГИС) для анализа пригодности местообитаний и потенциальной численности млекопитающих и птиц, автоматизированных систем мониторинга и учета животных с использованием беспилотных летательных аппаратов (БПЛА) и фотоловушек. Проанализированы примеры из различных стран, где цифровизация мониторинга и учета животных сообществ повысила точность полученных данных, что позволило снизить воздействие на экосистемы и улучшить управление охотничьими ресурсами. Рассмотрена возможность адаптации данных технологий к условиям Казахстана, с акцентом на необходимость комплексного подхода к мониторингу для обеспечения устойчивого развития охотничьей отрасли и сохранения природного наследия в условиях глобальных экологических вызовов. Представленные результаты могут быть использованы для разработки эффективных стратегий цифровизации мониторинга дикой фауны в Казахстане и других странах с аналогичными природно-климатическими условиями.

Ключевые слова: цифровизация учета животных; беспилотные летательные аппараты (БПЛА); геоинформационные системы (ГИС); фотоловушки; дистанционное зондирование; мониторинг биоразнообразия.