هشتمین کنفرانس ملی
نوآوری در کشاورزی، علوم دامی و دامپزشکی
8th National Conference on
Innovation in Agriculture, Animal Sciences and Veterinary Medicine
www.animal.bcnf.ir

An overview of the role of new technologies in wildlife disease monitoring and tracking

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ABSTRACT

The advent of new technologies has revolutionized the field of wildlife disease monitoring and tracking, providing unprecedented opportunities to enhance the understanding, prevention, and management of diseases affecting wildlife populations. This overview examines the significant impact of advanced tools such as satellite tracking, GPS collars, remote sensing, drones, and sophisticated diagnostic techniques in detecting and analyzing disease patterns. Additionally, it highlights the role of data analytics and artificial intelligence in processing vast datasets to predict outbreaks and model disease transmission dynamics. The integration of these innovative technologies has enabled more accurate, real-time monitoring, facilitating early intervention and informed decision-making. By leveraging these advancements, researchers and conservationists can better protect wildlife health, support biodiversity, and mitigate the risks of zoonotic diseases that threaten both animal and human populations. This comprehensive review underscores the transformative potential of new technologies in promoting effective wildlife disease surveillance and management strategies.

Keywords: *Wildlife, Monitoring, Review*

1. *INTRODUCTION*

New technologies have also paved the way for innovative approaches to wildlife disease management and conservation strategies. With the integration of machine learning algorithms and artificial intelligence, researchers can now analyze vast datasets to identify patterns, predict outbreaks, and model the spread of diseases across different ecosystems [1, 4]. These technologies provide a more efficient and accurate means of understanding the complex interactions between wildlife, pathogens, and their environments [26]. Moreover, drones and unmanned aerial vehicles (UAVs) have significantly enhanced surveillance capabilities. Drones equipped with thermal cameras and sensors can monitor wildlife populations in remote or inaccessible areas, detect signs of disease, and collect biological samples without disturbing the animals. This non-invasive approach is particularly valuable for studying endangered species and sensitive habitats [6, 20]. Advanced molecular techniques, such as next-generation sequencing and CRISPR-based diagnostics, have revolutionized pathogen detection and genetic analysis [41]. These tools enable scientists to identify pathogens at the molecular level, understand their genetic makeup, and track their evolution over time. Such insights are crucial for developing targeted vaccines and treatments, as well as for implementing effective biosecurity measures [7]. The collaboration between technology developers, conservationists, and public health officials is fostering a multidisciplinary approach to wildlife disease management. By leveraging the strengths of various fields, we can develop more comprehensive and sustainable strategies to protect both wildlife and human health [38]. Aim of this study is an overview of the role of new technologies in wildlife disease monitoring and tracking.

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2. *Method and Materials*

This study employs a comprehensive narrative review method to delve into the intricacies of wildlife disease monitoring and tracking. By systematically searching and analyzing keywords such as "wildlife disease," "monitoring," and "tracking," we have meticulously explored reputable databases, including GoogleScholar, ScienceDirect, PubMed, SID, Magiran, and Civilica. Additionally, free searches on Google have been conducted to ensure no relevant data is overlooked. This exhaustive approach has enabled the collection of a robust dataset, which forms the foundation for an in-depth examination of the current state of wildlife disease surveillance, highlighting critical trends, innovations, and research gaps in this vital field. The gathered data is instrumental in shaping a nuanced understanding of how modern monitoring and tracking technologies are deployed to manage and mitigate wildlife diseases effectively.

3. *Results*

new technologies are revolutionizing wildlife disease monitoring and tracking. These advancements enhance our ability to detect and respond to diseases, provide deeper insights into the ecological dynamics of disease transmission, and support the development of targeted conservation and public health strategies. As we continue to innovate and integrate these technologies, the potential for improving wildlife conservation and safeguarding human and animal health becomes increasingly promising [29, 44].

3.1 Satellite Tracking and GPS Collars

Satellite tracking and GPS collars have revolutionized wildlife disease monitoring and tracking, providing invaluable tools for researchers and conservationists. These technologies offer unprecedented insights into the movement patterns, behaviors, and health of wildlife populations [43]. By attaching GPS collars to animals, researchers can collect real-time data on their locations. This allows for precise tracking of their movements across large geographical areas. Monitoring these movement patterns helps identify potential hotspots for disease transmission and understand how diseases spread among wildlife populations [5].GPS collars provide data on the daily activities and behaviors of animals. For instance, changes in movement patterns or reduced activity levels can signal the onset of illness. This early detection of abnormal behavior can prompt timely interventions and prevent disease outbreaks from escalating [23]. Satellite tracking helps scientists study migration routes and habitat use. Understanding where animals go and the environments they interact with provides crucial information on how diseases might spread across different regions and ecosystems. It also aids in identifying critical habitats that need protection to reduce disease risks [3]. GPS data combined with environmental data (such as temperature, humidity, and vegetation) can reveal how environmental factors influence disease dynamics. For example, certain conditions may make animals more susceptible to infections, and this knowledge can inform conservation strategies to mitigate disease risks [8]. By tracking multiple species simultaneously, researchers can study interactions between different animal populations. This is particularly important for understanding zoonotic diseases that can jump between species, including humans. Identifying these interactions helps in predicting and managing potential cross-species disease transmission [42]. The data collected from satellite tracking and GPS collars support the development of targeted conservation and disease management plans. By knowing where and how diseases are likely to spread, wildlife managers can implement measures to protect vulnerable populations and prevent large-scale outbreaks [35]. Satellite tracking and GPS data can be shared globally, fostering collaboration among researchers and conservationists. This collective effort enhances our ability to monitor wildlife health on a larger scale and develop coordinated strategies for disease prevention and control [32].

satellite tracking and GPS collars are pivotal in advancing our understanding of wildlife diseases. They provide critical data that inform conservation practices, enhance disease surveillance, and ultimately contribute to the health and preservation of wildlife populations [31].

3.2 Remote Sensing and Drones

Remote sensing and drones have become indispensable tools in wildlife disease monitoring and tracking, offering innovative ways to gather data and observe wildlife in their natural habitats. These technologies provide a non-invasive means to monitor wildlife health, behavior, and environmental conditions, significantly enhancing our understanding and management of wildlife diseases [30]. This technology involves the use of satellites and aerial imagery to collect data on wildlife populations and their habitats. Remote sensing can detect changes in land use, vegetation cover, and environmental conditions that might influence disease dynamics. By analyzing these changes, researchers can identify areas at risk for disease outbreaks and monitor the spread of diseases across large landscapes [22]. Drones, or unmanned aerial vehicles (UAVs), have revolutionized wildlife monitoring by providing a flexible and cost-effective means to survey large and remote areas. Equipped with high-resolution cameras and sensors, drones can capture detailed images and videos of wildlife and their habitats. This data can help identify signs of disease, such as unusual behavior or physical symptoms in animals, without the need for direct human interaction [17]. Drones equipped with thermal cameras can detect heat signatures of animals, which is particularly useful for spotting wildlife in dense vegetation or during nighttime. Thermal imaging can help identify animals that are exhibiting signs of fever or other disease-related symptoms [11]. Drones can also monitor environmental factors such as temperature, humidity, and vegetation health. These parameters are crucial for understanding how environmental conditions affect disease transmission and outbreaks. For instance, changes in vegetation might indicate altered habitats that could influence the spread of vector-borne diseases [24]. In the event of a disease outbreak, drones can quickly survey affected areas to assess the extent of the outbreak and monitor the health of wildlife populations. This rapid response capability is vital for implementing timely interventions and preventing the spread of diseases [36]. Drones can be equipped with specialized tools to collect biological samples, such as water or soil samples, from areas that are difficult to access. These samples can then be analyzed for pathogens, providing insights into the presence and spread of diseases [9]. One of the significant advantages of using drones is their ability to monitor wildlife without causing disturbance. This non-invasive approach is crucial for studying sensitive or endangered species, ensuring that their natural behaviors and habitats remain unaffected [17].

Remote sensing and drones are transformative technologies in the realm of wildlife disease monitoring and tracking. They provide detailed, real-time data that enhances our ability to detect, understand, and manage wildlife diseases. By integrating these technologies into conservation practices, we can better protect wildlife populations and mitigate the impacts of diseases on ecosystems.

3.3 Advanced Diagnostic Tools

Advanced diagnostic tools have become a cornerstone in the monitoring and tracking of wildlife diseases, offering unprecedented accuracy and speed in detecting pathogens and understanding disease dynamics. These cutting-edge technologies enable researchers and conservationists to take proactive measures in managing and controlling wildlife health issues, ultimately benefiting both animal populations and ecosystems [16].

One of the most transformative advancements, NGS allows for the comprehensive analysis of genetic material from pathogens. This technology can identify and characterize viruses, bacteria, and other microorganisms with high precision, even in complex environmental samples. By sequencing entire genomes, researchers can track the evolution and spread of diseases, identify new and emerging pathogens, and develop targeted vaccines and treatments [39]. CRISPR technology, widely known for its gene-editing capabilities, is now being adapted for rapid and accurate disease diagnostics. CRISPR-based tools can detect specific genetic sequences associated with pathogens, providing a quick and reliable method for identifying infections. These diagnostics are particularly valuable in field settings, where rapid results can inform immediate management decisions [45]. Polymerase Chain Reaction (PCR) remains a gold standard for pathogen detection. Portable PCR devices have brought this technology out of the laboratory and into the field, allowing for on-site testing and faster diagnostics. These devices amplify pathogen DNA or RNA, making it possible to detect even low levels of infectious agents in wildlife samples [27]. This approach involves sequencing the collective genome of microorganisms within a given sample. Metagenomics can reveal the presence of multiple pathogens simultaneously and provide insights into the microbial community structure. This comprehensive view is crucial for understanding complex interactions between hosts, pathogens, and their environments [40]. These *miniaturized devices integrate multiple laboratory functions onto a single chip, enabling rapid and sensitive detection of pathogens. Biosensors can detect specific molecules or biomarkers associated with diseases, offering near-instant results. Lab-on-a-chip technologies are particularly useful for monitoring wildlife health in remote or resource-limited settings. Advanced imaging techniques combined with artificial intelligence allow for detailed examination of tissue samples. AI algorithms can quickly analyze images to identify pathological changes and diagnose diseases, often with greater accuracy than traditional methods. This technology accelerates the diagnostic process and provides valuable data for research and conservation efforts [46]. Environmental DNA (eDNA) analysis involves detecting genetic material shed by organisms into their environment. This non-invasive method can be used to monitor wildlife populations and detect the presence of pathogens in water, soil, or air samples. eDNA provides a powerful tool for early detection of disease outbreaks and monitoring biodiversity [28].*

Advanced diagnostic tools are revolutionizing wildlife disease monitoring and tracking. These technologies provide fast, accurate, and comprehensive data on pathogen presence and dynamics, enabling timely and informed decision-making. By harnessing these tools, researchers can better understand disease ecology, protect wildlife populations, and ensure the health and sustainability of ecosystems.

3.٤ Data Analytics and Artificial Intelligence

Data analytics and artificial intelligence (AI) are at the forefront of revolutionizing wildlife disease monitoring and tracking. These technologies enable researchers to handle and analyze massive datasets efficiently, uncover hidden patterns, and make predictive models that are crucial for understanding and managing wildlife diseases [13]. Wildlife monitoring generates vast amounts of data from various sources, including satellite tracking, remote sensing, and field observations. Data analytics tools can integrate these diverse datasets, providing a comprehensive view of wildlife health and disease dynamics. This integration is essential for identifying correlations and trends that might not be evident from individual data sources [10]. AI and machine learning algorithms excel at identifying patterns and making predictions. By analyzing historical and real-time data, these models can predict disease outbreaks, track the spread of pathogens, and identify factors contributing to disease transmission. Predictive modeling helps in developing proactive strategies for disease prevention and control, enabling timely interventions that can mitigate the impact of outbreaks [2]. AI technologies, particularly those involving machine learning, can analyze complex data sets to recognize patterns related to disease outbreaks. For instance, AI can identify early signs of disease by analyzing behavioral changes in wildlife captured through GPS collars or remote sensing. These patterns can then be used to trigger alerts and prompt further investigation [33]. AI-powered systems can automate the monitoring process, continuously analyzing data from various sensors and cameras. This automation enables 24/7 surveillance of wildlife health, ensuring that any unusual activities or signs of disease are quickly detected and addressed. Automated systems reduce the reliance on human observation, making monitoring more efficient and less prone to errors [21]. Combining data analytics with geospatial technologies allows researchers to map disease occurrences and visualize the spread across different regions. Geospatial analysis can reveal hotspots of disease activity and help identify environmental factors that influence disease transmission. This spatial understanding is crucial for targeted interventions and resource allocation [12]. AI-driven decision support systems provide actionable insights for wildlife managers and policymakers. These systems can simulate different scenarios, evaluate the potential outcomes of various interventions, and recommend the most effective strategies for disease control. Decision support systems enhance the ability to make informed decisions based on data-driven evidence. AI and data analytics are also instrumental in analyzing genomic data from pathogens and hosts. This analysis can reveal genetic variations that affect disease susceptibility and resistance, helping scientists understand the evolution and adaptation of diseases. Genomic insights are valuable for developing targeted treatments and vaccines [38]. AI facilitates collaboration among researchers by enabling efficient data sharing and collaborative analysis. Platforms powered by AI can aggregate data from multiple studies, standardize it, and make it accessible for collaborative research. This collective approach accelerates the pace of discovery and innovation in wildlife disease monitoring [19].

Data analytics and AI are transforming wildlife disease monitoring and tracking by providing powerful tools for data integration, predictive modeling, and automated monitoring. These technologies enhance our ability to detect, understand, and respond to wildlife diseases, ultimately supporting the conservation of biodiversity and the protection of ecosystems.

4. *Discussion and conclusion*

The integration of new technologies in wildlife disease monitoring and tracking represents a paradigm shift in our approach to understanding and managing wildlife health. These advancements have not only improved the efficiency and accuracy of data collection but have also opened up new avenues for research and conservation efforts [15, 25]. These tools have transformed the way we track wildlife movements and behaviors, providing real-time data that is crucial for identifying disease patterns and understanding the spread of pathogens. By monitoring the migration routes and habitat use of wildlife, researchers can pinpoint areas at risk for disease outbreaks and develop targeted interventions [14]. Remote sensing technology, coupled with drones, has significantly enhanced our ability to monitor wildlife in their natural habitats. These tools allow for the non-invasive collection of data, enabling researchers to detect signs of disease, monitor environmental conditions, and gather biological samples from hard-to-reach areas. The use of thermal imaging and high-resolution cameras further improves the accuracy and efficiency of these methods [18]. The advent of next-generation sequencing, CRISPR-based diagnostics, and portable PCR devices has revolutionized pathogen detection and genetic analysis. These technologies provide rapid, accurate results, allowing for the early detection of diseases and the development of targeted treatments. Metagenomic analysis and biosensors offer comprehensive insights into the microbial communities within wildlife populations, further enhancing our understanding of disease dynamics [37]. The application of AI and machine learning in wildlife disease monitoring has greatly improved our ability to analyze large datasets and predict disease outbreaks. AI-driven predictive models and decision support systems enable researchers to identify patterns, assess risks, and develop effective disease management strategies. The integration of geospatial analysis and genomic data analysis provides a holistic view of disease ecology, facilitating informed decision-making and conservation planning [21]. Despite the significant progress made, there are still challenges to be addressed. The high cost and complexity of some technologies can be a barrier to widespread adoption, particularly in resource-limited settings. Additionally, the ethical implications of using certain technologies, such as drones and GPS collars, must be carefully considered to ensure that wildlife is not unduly stressed or harmed. Moving forward, continued collaboration between technologists, conservationists, and policymakers will be essential to develop sustainable and ethical approaches to wildlife disease monitoring [34].

New technologies have fundamentally transformed wildlife disease monitoring and tracking, offering innovative tools that enhance our ability to detect, understand, and manage diseases in wildlife populations. Satellite tracking and GPS collars provide real-time insights into animal movements and behaviors, while remote sensing and drones enable non-invasive data collection in remote areas. Advanced diagnostic tools facilitate rapid pathogen detection, and data analytics combined with artificial intelligence offer powerful methods for analyzing complex datasets and predicting disease outbreaks. Together, these technologies provide a comprehensive framework for proactive wildlife disease management, contributing to the conservation of biodiversity and the protection of ecosystems. As we continue to refine and integrate these technologies, their potential to improve wildlife health and support sustainable conservation efforts becomes increasingly promising..

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