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Examining Innovative Technologies in Wildlife Conservation and Ecotourism: Advancements, Applications, and Impacts. A Case Study of Yankari Game Reserve, Bauchi State, Nigeria

Fimber Stephen Agbu; & Bridget Bitrus Angbashim

Isa Mustapha Agwai I Polytechnic, Lafia, Nasarawa State, Nigeria, School of Science and Technology, Department of Tourism Management Technology.

Corresponding Author: agbu.fimber@gmail.com

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Abstract

Yankari Game Reserve, one of Nigeria's leading wildlife protection areas, faces several challenges, including poaching, environment degradation, and inadequate visitor engagement. This research examined innovative technologies to address these challenges, improve wildlife conservation efforts, and advance ecotourism involvements. By concentrating on progressions, applications, and effects of these technologies, the study provided actionable understandings and commendations for integrating current technological solutions. The research methodology was descriptive and employed a mixed-methods approach, and used semi-structured interview questions as data collection techniques to obtain information from park management and tourists. The researcher's on-site personal observation was also used to obtain data. Moreso, a systematic literature review was utilized for the study. Qualitative data analysis was used and the findings revealed that, currently the study area partially adopted innovative technology and in the verge of keying into innovative technology, the study also revealed that the

adoption and application of this technology in wildlife ecotourism development can positively enhance visitors experience and reduce manual or traditional method for park management. Moreso, innovative technologies adoption in wildlife ecotourism improve the ability to track wildlife movement, detect poaching activities and gather critical data on species population. The study recommended that management of the Yankari Game Reserve should prioritize the adoption and application of innovative technology for ecotourism development, engage stakeholders collaboration in the adoption of technology.

Keywords: Technology, Conservation, Ecotourism, Innovation, Impact

Introduction

The management of wildlife conservation and ecology in the 21st century has continually grown more complex, the challenges of wildlife conservation and ecological research have also witness more complexity due to habitat destruction, climate change and increased human – wildlife interactions. Urban developmental activities has continue to increase and encroach upon natural habitats, monitoring wildlife conservation and ecotourism becomes critical for understanding ecosystem dynamics and ensuring species survival. Traditional techniques, such as manual observation and tracking, can be laborious and may not yield timely or comprehensive data. The integration of new technologies for conservation can improve how the park authority monitor and measure changes to species and whole ecosystems (Pimm, 2015) which is critical to guide and evaluate management and policy decisions. Technology can provide novel data sources, expanded spatial and temporal coverage, access to real-time information and rapid processing and analysis for intervention (Pettorelli,Saf, and Turner, 2014)., The inclusion of real-time transmission and processing of data streams from acoustic devices has advanced remote detection and response to illegal logging (Marvin, 2016), the rapid growth and availability of technologies has been driven largely by adapting existing and consumer-oriented technologies to specific conservation needs (Snaddon, Petrokofsky, Jepson and Willis et al., 2013), including hobby drones for monitoring and response to threats (Pettorelli, et al., 2014), in situ molecular analyses in remote field settings 12, radar data to forecast bird migrations at continental scales (

Horton, 2018) and the application of block chain protocols for fisheries supply chain management (Howson, 2020). While these options are widely available for commercial application, they may lack features required for ecological conservation purposes such as limited durability and power efficiency, constraints from proprietary silos, or high technical knowledge barriers (Howson, 2020). In other cases, adoption of data-rich and real-time sensors can lead to secondary problems with managing large datasets that often require their own custom approaches and pipelines (Norouzzadeh, 2018). Such constraints are thought to limit the uptake of new tools, but only recently have efforts been made to assess the degree to which they restrict the use of technologies in conservation settings and how to prioritize improvements for future development (Hill, 2018). Managing the environment in the modern world is becoming daunting and requires the application of modern technology. The rate at which the world is polluted recently with materials released into the environment; and degraded because of the materials withdrawn from the environment are causes for concern.

Since Information and Communications Technology (ICT) have become a fundamental part of daily life (Volkodaeva, Balanovskaya and Rustenova, 2022) and its progressive impacts in any sector that has been fully adopted cannot be overemphasized. It is highly noted that developing nations of the world are gearing towards linking all economic activity to ICT based economy (Eleberi, 2021), in fact ICTs are transformative technologies that put intelligence at the edges of networks (Farounbi, 2013).

The connection of technology and wildlife conservation has added significant attention in recent years, particularly within the framework of ecotourism. As global alertness of environmental issues increases, innovative technologies are being harnessed to enhance conservation efforts and promote sustainable tourism practices. This research focuses on the improvements, applications, and influences of these technologies, specifically within the context of the Yankari Game Reserve in Bauchi State, Nigeria.

Innovative technologies such as artificial intelligence (AI), drones, and geographic information systems (GIS) are changing wildlife conservation approaches. Drones, for example, provide aerial surveillance abilities that allow for effectual monitoring of wildlife populaces and surroundings, enabling conservationists to gather data on animal activities and detect poaching happenings (Hodgson et al., 2017). Likewise, AI and machine learning algorithms are being hired to analyze huge datasets,

simplifying predictive modeling and decision-making procedures in conservation management (Bennett 2019).

In the situation of ecotourism, these technologies not only aid in conservation efforts but also enhance the visitor experience. Virtual reality (VR) and augmented reality (AR) applications offer immersive experiences that can educate tourists about wildlife and conservation issues, fostering a deeper understanding and appreciation of natural ecosystems (Falk et al., 2016). By integrating technology into the tourism experience, destinations can promote responsible travel behaviors and encourage visitors to contribute to conservation initiatives.

Ecotourism is defined as responsible travel to natural areas that conserves the environment and improves the well-being of local communities (International Ecotourism Society, 2015). It emphasizes sustainable practices that minimize environmental impact while providing economic benefits to local populations. In Nigeria, ecotourism has the potential to play a vital role in promoting conservation efforts, particularly in regions like Bauchi State, where natural resources are abundant but often under threat from unsustainable practices.

Yankari Game Reserve, as one of Nigeria's premier wildlife conservation areas, serves as a critical case study for examining the impacts of innovative technologies in ecotourism. The reserve is home to diverse wildlife species and offers various ecotourism activities, including guided safaris and educational programs. However, the reserve faces challenges such as poaching, habitat degradation, and insufficient funding for conservation efforts. By leveraging innovative technologies, Yankari Game Reserve can enhance its conservation strategies, improve visitor engagement, and generate revenue to support sustainable practices.

Despite the promise of innovative technologies, several challenges must be addressed to maximize their effectiveness in wildlife conservation and ecotourism. These include the high costs associated with technology implementation, the need for training and capacity building among local staff, and potential resistance from communities accustomed to traditional practices (Sigala, 2020). Furthermore, the integration of technology must be approached with sensitivity to local cultures and ecosystems to ensure that conservation efforts are both effective and respectful.

Opportunities for enhancing the role of technology in Yankari Game Reserve include developing partnerships with technology providers, investing in training programs for local personnel, and engaging tourists in conservation activities through technology-driven initiatives. By fostering a collaborative approach, the

reserve can create a sustainable model that benefits both wildlife conservation and local communities.

The integration of innovative technologies in wildlife conservation and ecotourism represents a significant opportunity for enhancing conservation efforts and promoting sustainable tourism practices. This research will explore the advancements, applications, and impacts of these technologies in the context of Yankari Game Reserve, providing insights into how they can be effectively utilized to address conservation challenges and improve the overall visitor experience. By examining the case of Yankari, this study aims to contribute to the broader discourse on sustainable tourism and wildlife conservation in Nigeria and beyond.

The increasing pressures on wildlife and natural resources due to human activities, climate change, and habitat destruction necessitate innovative approaches to conservation. Wildlife conservation and ecotourism are critical for preserving biodiversity while simultaneously providing economic benefits to local communities. In Nigeria, Yankari Game Reserve stands as a significant ecological asset, yet it faces numerous challenges, including poaching, habitat degradation, and insufficient funding for conservation initiatives.

Despite the potential of innovative technologies—such as drones, artificial intelligence (AI), and geographic information systems (GIS)—to enhance conservation efforts and improve ecotourism experiences, their adoption in Nigeria remains limited. This gap highlights the need for a comprehensive examination of the availability and how these technologies can be effectively integrated into conservation strategies at Yankari Game Reserve.

The primary problem to address in this research is the underutilization of innovative technologies in wildlife conservation and ecotourism at Yankari Game Reserve. Although advancements in technology offer promising solutions for monitoring wildlife, enhancing visitor engagement, and promoting sustainable practices, there is a lack of empirical evidence regarding their applications and impacts in the context of Nigerian conservation efforts. This study investigated the current state of technology adoption in Yankari Game Reserve, assessed the effectiveness of these technologies in addressing conservation challenges, and explore their potential to enhance ecotourism.

Innovative technologies have the potential to revolutionize wildlife conservation by providing tools for real-time monitoring, data collection, and analysis. For instance, drones can be utilized for aerial surveillance to detect poaching activities, while AI can analyze large datasets to predict wildlife movements and habitat

changes (Hodgson et al., 2017). Understanding how these technologies can be applied in Yankari Game Reserve is crucial for developing effective conservation strategies.

RESEARCH QUESTIONS

The research poses the following research questions which demand answers.

1. What are the innovative technologies currently employed at Yankari Game Reserve to enhance wildlife conservation and ecotourism?
2. What are the positive impact of innovative technologies on wildlife ministry, protection and data collection of Yankari Game Reserve?
3. Can the use of innovative technology enhance visitors' experiences and engagement in Yankari Game Reserve?

LITERATURE REVIEW

This literature review synthesizes existing literature on innovative technologies in wildlife conservation and ecotourism, with a specific focus on Yankari Game Reserve in Bauchi State, Nigeria. The review addresses the objectives of identifying and evaluating current technologies, analyzing their impacts on wildlife monitoring and protection, assessing their role in enhancing visitor experiences, and proposing recommendations for their integration into conservation practices.

Innovative technologies have become progressively vital in wildlife conservation and ecotourism. Various studies highlight the use of technologies such as Geographic Information Systems (GIS), remote sensing, drones, and camera traps in monitoring wildlife populations and habitats. For instance, Modibbo et al. (2016) emphasize that GIS and remote sensing can provide accurate documentation of wildlife movements and habitat changes, which is crucial for effective management and conservation strategies in Yankari Game Reserve. Additionally, drones equipped with cameras are being utilized for aerial surveys, enabling conservationists to monitor large areas efficiently and detect poaching activities (Hodgson et al., 2017). These technologies facilitate the mapping of habitats, monitoring of land use changes, and tracking of wildlife movements. GIS enables the visualization of spatial data, aiding in the identification of critical habitats and migration corridors (Foody, 2008). Remote sensing provides real-time data on environmental changes, such as deforestation and habitat degradation, which are crucial for making informed conservation decisions (Turner et al., 2015).

The integration of artificial intelligence and computer vision into wildlife monitoring has gained significant attention in recent years, leading to a variety of innovative approaches aimed at enhancing conservation efforts. Several studies and projects have focused on using technology to analyze animal behavior, track movements, and facilitate ecological research.

One notable example is the work by Fujita et al. (2020), who developed a camera trap system that utilizes deep learning algorithms for automatic species recognition in wildlife monitoring. Their approach significantly reduced the manual effort required for data annotation and provided a scalable solution for monitoring diverse habitats. The authors demonstrated the effectiveness of convolutional neural networks (CNNs) in achieving high accuracy in species classification, highlighting the potential for AI to enhance traditional wildlife research methodologies. Leidner et al. (2018) introduced a system that combines acoustic monitoring with computer vision to study bird populations. By using a network of microphones and cameras, they could simultaneously capture vocalizations and visual behavior, providing a comprehensive understanding of avian interactions in their natural habitats. This multi-modal approach emphasizes the benefits of integrating different technologies for more effective wildlife monitoring.

In another study, Mikula et al. (2019) developed a framework for detecting and classifying wildlife movements using drone imagery and machine learning techniques. Their research demonstrated that drones equipped with high-resolution cameras could efficiently cover large areas while providing real- time data on animal activities. The authors highlighted the advantages of using aerial imagery in monitoring elusive species, offering insights that ground-based methods could not achieve.

Moreover, the Wildlife Insights platform, a collaborative initiative, employs machine learning to analyze camera trap images from various regions worldwide. It aims to provide researchers and conservationists with tools to monitor wildlife populations and identify trends in biodiversity. By standardizing data processing and offering user-friendly interfaces, Wildlife Insights facilitates large-scale wildlife monitoring and supports global conservation efforts. Despite these advancements, challenges remain in ensuring accurate behavior classification and the ethical use of surveillance technologies. Studies like Bennett et al. (2021) emphasize the importance of addressing privacy concerns when implementing wildlife monitoring systems, advocating for the integration of data protection measures to ensure ethical practices in conservation research. This body of work

illustrates the growing convergence of AI, computer vision, and wildlife monitoring, showcasing the transformative potential of these technologies in enhancing conservation efforts. However, there is still a need for systems that provide real-time monitoring and analysis, enabling researchers to respond proactively to changes in wildlife behavior and environmental conditions. Our proposed AI- Driven Wildlife Behavior Monitoring System aims to fill this gap by offering an integrated solution for effective wildlife observation and analysis. In the future, this system could be expanded to include features such as autonomous drones for aerial monitoring and machine learning models that continuously improve based on new wildlife data. The real-time nature of this system ensures that conservationists can make informed decisions promptly, enhancing the overall effectiveness of wildlife protection efforts. By integrating cutting-edge AI and computer vision technologies, the AI-Driven Wildlife Behavior Monitoring System offers a comprehensive tool for researchers and conservationists, supporting the preservation of biodiversity and enabling proactive wildlife management in a rapidly changing world.

Advanced Perception is a pivotal aspect of AI-driven wildlife behavior monitoring systems, allowing them to interpret complex ecological environments, recognize animal behaviors, and facilitate real-time data- driven decisions. This enhancement builds upon primitive perception capabilities, utilizing deep learning and machine learning models to analyze patterns, monitor interactions, and predict wildlife movements. The implementation of advanced perception technologies is essential for effective conservation strategies, wildlife research, and habitat management, especially in areas prone to human-wildlife conflicts.

Ijeomah and Aiyeloja (2010), stated that, the use of camera traps in Yankari Game Reserve has facilitated the collection of data on species presence and population dynamics, allowing for better-informed conservation decisions. The application of innovative technologies has shown significant impacts on wildlife monitoring and protection.

Falk et al. (2016) suggest that such technologies can foster a deeper connection between tourists and the natural environment, promoting responsible tourism behaviors. In the context of Yankari Game Reserve, the implementation of technology-driven educational programs can enhance visitor engagement and awareness of conservation efforts, ultimately leading to increased support for wildlife protection initiatives. Innovative technologies play a crucial role in enhancing visitor experiences in ecotourism. The use of virtual reality (VR) and

augmented reality (AR) applications can provide immersive experiences that educate visitors about wildlife and conservation issues. GIS and remote sensing have enhanced habitat mapping and environmental monitoring, enabling conservationists to detect and respond to changes more effectively (Turner et al., 2015). Camera traps and drones have provided new methods for monitoring wildlife populations, reducing the need for intrusive human presence and minimizing disturbance to animals (Kucera & Barrett, 2011; Koh & Wich, 2012).
Radio telemetry and GPS tracking have offered detailed insights into animal movements and behavior, which are essential for developing effective conservation strategies. These technologies have facilitated the study of migration routes and habitat use, informing the creation of protected areas and corridors (Hebblewhite & Haydon, 2010). Biotechnology has enhanced the ability to monitor genetic diversity and manage breeding programs, ensuring the long-term survival of endangered species (Frankham, Ballou, & Briscoe, 2010).
Innovative technologies have also played a crucial role in enhancing visitor experiences and engagement in ecotourism. Virtual reality (VR) and augmented reality (AR) technologies offer immersive experiences, allowing visitors to explore natural habitats and observe wildlife in new and engaging ways (Jung et al., 2016). These technologies provide educational content, raising awareness about conservation issues and the importance of preserving biodiversity.
Mobile applications and interactive platforms enable visitors to track wildlife sightings, access real-time information, and participate in citizen science projects. These tools foster a deeper connection between visitors and the natural environment, promoting responsible and sustainable tourism practices (Ballantyne et al., 2011). In Yankari Game Reserve, such technologies could enhance the ecotourism experience by providing interactive maps, guided tours, and wildlife tracking features.

METHODOLOGY

Study Area/Site

Yankari Game Reserve, Bauchi State, Nigeria. Yankari is a significant wildlife conservation area and a popular ecotourism destination, making it an ideal location for examining the application and impact of innovative technologies. Yankari Game Reserve is a large wildlife park and former National Park located in Alkaleri Local Government Area, in the south-central part of Bauchi State, in northeastern Nigeria. It covers an area of about 2,244 km2 (866 sq mi) and has the coordinate

of 9°45′16″N 10°30′37″E. It is home to several natural warm water springs, as well as a wide variety of flora and fauna. The Yashi and Gaji rivers, along with their tributaries, constitute the area's principal watersheds. Wikki is the largest of the five warm springs in the game, which contributes to the reserve's natural beauty. The other four are Dimil, Gwana, Mawulgo, and Tudun Maliki water springs. Its year-round, consistent temperature of 31.1 °C makes it comfortable all year round. During its peak, Yankari drew thousands of tourists from both domestic and foreign countries, making it one of Nigeria's most visited tourist spots in history. Its location in the heartland of the West African savanna makes it a unique way for tourists to watch wildlife in its natural habitat. Yankari was created as a game reserve in 1956 by the British colonial administration but it was elevated to a national park and put under the Nigerian National Parks Service's federal jurisdiction in 1991 as Nigeria's biggest national park. Yankari was administered by the Parks Service until 2006, at which point the state of Bauchi took over management duties, restoring Yankari to its previous designation as a Game Reserve. It is the most popular destination for tourists in Nigeria and beyond, plays a crucial role in the development and promotion of tourism and ecotourism in Nigeria.

Data collection and Analyses

To comprehensively examine innovative technology in wildlife conservation and ecotourism in the study area, the research utilized a systematic literature review. Semi-structured interviews with key informants, such as park management officials, technology providers, conservation experts and park visitors was used to obtain information for the study. The interviews provided qualitative insights into the research topic. Also the researcher conducted in-site observations to document the use of innovative technologies in wildlife conservation monitoring and protection in Yankari Game Reserve.

Descriptive and exploratory data analysis was used to summarize the survey data. The interview data was transcribed cover to identity themes and pattern relation to the research objectives.

RESULT AND DISCUSSION

The study possess research question that demanded answer, i.e what are the innovative techniques currently employed at Yankari Game Reserve to enhance wildlife conservation and ecotourism? When the question on current technologies

employed by Yankari Game Reserve to enhance wildlife conservation and ecotourism was asked, the park management said, "we are fully aware of innovation technologies that enhance wildlife conservation management, but currently we are yet to fully key into the application and adoption of these technologies, accept for camera traps which is in use at the moment. We are also aware of the benefits of technologies application in wildlife conservation and ecotourism, based on that the State Government who is the ownership of the Game Reserve has given us the mandate to key in fully the innovative technologies used globally for wildlife conservation and ecotourism, as you can see, we are currently upgrading infrastructure around here to meet up global standard" the research team was on ground to ascertain to the upgrades going on in the aspect of infrastructure. More so, the research team were in site and examined the current technologies in the study area. The research discovered insignificant camera traps planted in the ecosystem. What are the positive impacts of innovative technologies on wildlife conservation monitoring, protection and data collection at Yankari Game Reserve? The study's effort to assess the effectiveness of technologies in enhancing wildlife monitoring, protection and data collection, was partially unsuccessful based on the evidence from the research observation on-site, where the study area is yet to adopt the application of innovative technologies in the ecotourism site. The objective was meant to reveal how technologies improve the ability to track wildlife movements, detect poaching activities and gather critical data on species population. However, several studies have focused on using technology to analyse animal behavior, track movements, and facilitate ecological research. A notable example is the study by Fujita et al. (2020), who developed a camera trap system that utilizes deep learning algorithms for automatic species recognition in wildlife monitoring. Their approach significantly reduced the manual effort required for data annotation and provided a scalable solution for monitoring diverse habitats. The research demonstrated the effectiveness of technologies as potentials to enhance traditional wildlife research methodologies.

The third research question, 'Can the use of innovative technologies enhance visitor's experience and engagement in Yankari Game Reserve? The study sampled fifty (50) tourist on-site within the period of field survey and the following questions were asked:

a. How did you learn about Yankari Game Reserve?
b. Do you use any online booking systems or mobile apps to plan and book visit to Yankari Game Reserve?

c. To what extend will you say technology enhanced visitor experiences?
d. What are the technological features you like to see more of in ecotourism destination like Yankari Game Reserve? Options were provided' like virtual tours and interactive maps, mobile apps with park information and navigation, online booking and payment options, social media engagements and update.

How the tourist to Yankari Game Reserve learn about the destination, 80% of the tourist learn about the destination through the online travel websites, social media and 20% learned from word of month. On if they use online booking systems to plan and book visit, 50% of the tourist to Yankari Game Reserve use online booking system to plan visit. While 50% of the tourist prefer travel and tour agents or call the destination reservation desk. The extend of which technology can enhance visitor experience, the research poses this question despite the poor application of technology in the area of study, the question was meant to seek the tourist general knowledge on innovative technologies. All the respondents believed innovative technologies can undoubtly enhance visitor's experience and satisfaction at wildlife conservation and ecotourism destinations. Also on what technological features they like to see more of in ecotourism destination, mobile apps with park information navigation and online booking and payment options were proffered more.

DISCUSSION

The findings of the study present valuable insights into the positive impact of innovative technologies on wildlife conservation and ecotourism in Yankari Game Reserve Bauchi, Nigeria. The findings revealed that currently, the adoption and application of innovative technologies in Yankari Game Reserve is yet to take effect as it is also evidence based on the research on-site observation that work is ongoing to adopt the application. Literature review in the study and based on the various authors opinions, revealed that innovative technologies adoption and application in wildlife ecotourism improve the ability to track wildlife movement, detect poaching activities and gather critical data on species population, and technological approach can significantly reduce the manual effort required for data innovation.

From the visitor's experience perspective in innovative technologies enhancement, the study reveals that online booking system or mobile apps to plan and book visit

to tourist destination and technological features like mobile apps with path information and navigation etc can positively impact on visitor's experience at wildlife and ecotourism destinations. The finding is consistent with previous study by Law et al, (2014), that online platform, mobile applications and social media have become integral tools for tourism businesses to engage with customers, promote their offerings, and enhance service quality and Pichlerova et' al (2021) support the notion that technologies have the potential to enhance visitor experiences, support conservation efforts and promote sustainable practices. In conclusion, the study provides empirical insights of the positive impacts of innovative technologies on wildlife conservation and ecotourism in the study area. The application of this technological features in Nigeria wildlife conservation and ecotourism is challenged and call for wildlife management in Nigeria to urgently key into technology innovation. Future research in the Nigeria context could investigate more and also explore the areas of negative impacts of innovative technologies on wildlife and ecotourism to balance a sustainable technology.

RECOMMENDATIONS

Based on the findings of this research, the following recommendation were made for park authorities to effectively leverage technology for sustainable ecotourism development in Nigeria.

1. Management of Yankari Game Reserve prioritize technological features like social media engagement and updates mobile apps with information and navigation to enhance park experience.
2. Invest in user-friendly online platforms and mobile applications. These platforms should offer and provide valuable information on trip planning and booking, payment options and sustainable ecotourism practices.
3. To engage stakeholders collaboration to bridge technology gap.
4. Develop a sustainable technological features and training for Yankari Game Reserve.

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