Developing a GIS-GPS Tracking System to Monitor Wildlife Behavior in Udawalawe National Park: Implications for Sustainable Tourism Development and Wildlife Conservation

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Abstract: Wildlife trips in Sri Lanka are highly sought-after by nature enthusiasts. Udawalawe National Park is a prominent tourist destination known for its diverse habitats and rich wildlife, including water birds and elephants. As the third-most visited park in the country and the sixth-largest animal sanctuary in Sri Lanka, Udawalawe is located at the intersection of the wet and dry zones, characterised by plains dominated by topography despite some hilly terrain. The primary motivation for many visitors to the park is wildlife observation, and understanding animal behaviour and habitats is crucial for responsible and sustainable tourism. Therefore, this study aimed to monitor wildlife behaviour in Udawalawe National Park to identify optimal viewing places. This study used a mixed-methods approach utilising primary and secondary data, including field observations and direct and indirect discussions. This study utilises Geographic Information System (GIS) and Geographic Positioning System (GPS) technologies to create tracks and identify wildlife viewing places that may not be officially designated. The findings revealed that the peak viewing hours occurred during the evening period and that animals tended to congregate near water bodies throughout all seasons and times of the day. About 44% of locations rich in water were identified, and field observations showed that most animals gathered in these water-rich areas, conveniently located near newly discovered tracks. The study also identified hidden and uncommon locations for observing wildlife behaviour, providing new opportunities for tourists to explore and enjoy the park. The results of this study can assist in managing the park's surrounding environment and tourist attractions and contribute to the sustainable management and promotion of wildlife tourism in Udawalawe National Park. The newly discovered tracks and viewing places can enhance the wildlife viewing experience for tourists while minimising negative impacts on the animals and their habitats. This research adds to the knowledge base of wildlife behaviour monitoring and management in protected areas. It can be a valuable resource for future studies and conservation efforts in Udawalawe National Park and other similar ecosystems.

Keywords: Geospatial analysis; National park management; Nature-based tourism; Protected areas; Sustainable tourism; Wildlife behaviour monitoring.

1.0 Introduction

Wildlife viewing, a popular activity with both recreational and economic significance, has become a significant draw for tourists worldwide (Prakash et al., 2019; Suresh et al., 2021). Sri Lanka's National Parks, renowned for their diverse wildlife, including elephants, spotted deer, leopards, sloth bears, peacocks, and more, are particularly attractive for nature-based tourism (Sumanapala & Wolf, 2020). Among these national parks, Udawalawe National Park stands out as a prominent sanctuary with a renowned population of majestic elephants and Sri Lankan endemic birds, including spurfowl, red-faced malkoha, grey hornbill, and jungle fowl (Sumanapala & Wolf, 2020; Perera et al., 2021; Suresh et al., 2021). Udawalawe National Park, which spans an extensive area of 30,821 hectares and is located 165 kilometres from Colombo, Sri Lanka, was founded in 1972 to provide a sanctuary for wildlife displaced by the construction of the Udawalawe Reservoir and safeguard the catchment area. As posited by Suresh et al. (2021), Udawalawe National Park offers its visitors a range of recreational activities, including sightseeing, safaris, bird watching, night stays, and camping. It is worth noting that the park is accessible to the public throughout the year.

Visitors to the park can witness herds of elephants frolicking and bathing, enjoying ample space to roam. Moreover, the Felidae family is well represented in the park, with the Sri Lankan leopard, rusty-spotted cat, and fishing cat among the notable felines. The sloth bear, a rare species in Sri Lanka, is seldom seen. Other mammalian species include the Sri Lankan Sambar Deer, the Sri Lankan Axis Deer, the Indian Muntjac, the Sri Lankan Spotted Chevrotain, the Wild Boar, and the Water Buffalo. Inhabitants of the park also include the Golden Jackel, Asian Palm Civet, Toque Macaque, Tufted Grey Langur, and Indian Hare. The open garden attracts a diverse array of birds, including various species of eagles, while monitor lizards and 30 species of snakes roam the park. Garra ceylonensis, an endemic fish species, can also be found within its bounds. Moreover, the park features a safari resort and jeep tours, facilitating easy navigation and animal sightings. While safari jeep drivers are well-versed in the road systems and trails within national parks, visitors who bring their vehicles must employ a tracker, which has become a mandatory requirement to ensure privacy and safety.

However, despite Sri Lanka's reputation for nature-based tourism, several studies have highlighted the significance of effective park management and responsible tourism practices in ensuring visitors' satisfaction and promoting the long-term sustainability of wildlife tourism in Udawalawe National Park (Prakasha et al., 2019; Ranaweerage et al., 2015). Prakasha et al. (2019) focused on the five most-visited national parks in Sri Lanka: Yala, Wilpattu, Minneriya, Horton Plains, and Udawalawe National Park, respectively, addressing issues with park management, tour operators, and visitors' dissatisfaction with wildlife tourism experiences. Furthermore, Ranaweerage et al. (2015) showed that particular factors such as vehicle noise, proximity, and timing significantly influenced the behaviour of elephants during safari excursions. Notably, observations in the Udawalawe National Park of Sri Lanka revealed that these factors particularly impacted the feeding behaviours of elephants. Moreover, previous scholars have focused on elephant watching and its recreational impacts, with limited attention to other recreational activities and park management. Despite recognising the park's potential for sustainable nature tourism development, there is a lack of research on tourism aspects and wildlife behaviour in tourist-attractive areas, resulting in ongoing park management issues and visitors' dissatisfaction. While some wildlife viewing places in the park are well-known and frequented by tourists, there may be hidden and uncommon locations with the potential to be developed as new tourist sites. Currently, there is competition among jeep drivers and guides in Udawalawe National Park to show tourists the most wildlife, resulting in them targeting the same well-known places where animals are commonly spotted. However, other lesser-known locations may offer unique wildlife viewing opportunities. This study aims to discover and analyse new wildlife viewing sites in Udawalawe National Park, considering their unique specialties and the surrounding environmental settings, to identify these potential new wildlife behavioural viewing places.

2.0 Literature Review

2.1 Application of Geospatial Technology and Analytical Processes in National Parks

Applying geospatial technology and analytical processes in national parks has proven to be a valuable tool for understanding and managing various aspects of protected areas, including road network planning, wildlife tracking, and recreational behaviours. Several studies (Sakara et al., 2020; Bouten et al., 2013) highlight the significance of utilising GIS, GPS tracking technology, and Multidisciplinary Decision Support Systems (MDSS) to manage and conserve protected areas effectively. With the increasing importance of eco-tourism, sustainable management of protected areas like national parks has become a priority. Geospatial technology, including GIS and GPS tracking, has been widely used in understanding and managing wildlife and recreational behaviours in national parks, enabling effective management and protection of these valuable resources.

One of the key findings from the literature is the importance of prioritising visual quality in road network planning. Sakara et al. (2020) focused on designing road networks that prioritise visual quality for accessing protected areas. The study employed a MDSS utilising weighted line combination (WLC) as the MDSS method based on GIS. The GIS-based network analysis methodology was used to determine the optimal route to access existing and proposed visual perspectives in different seasons. By considering parameters for optical quality, this study introduced a new methodology for designing road networks that prioritises visual quality, which can aid in effectively managing and protecting resources with high visual quality in protected areas. Accordingly, using GIS-based MDSS methods, such as the WLC, allows for integrating visual quality parameters in road network design, ensuring visitors have a positive visual experience while accessing protected areas. This approach can contribute to sustainable tourism management and the protection of resources with high visual quality.

Furthermore, GPS tracking technology has proven valuable in understanding wildlife movements, resource utilisation, and habitat in protected areas. Studies (Fernando et al., 2015; Bouten et al., 2013) on elephant movements and bird behaviours have demonstrated the potential of GPS telemetry in generating high-quality data for guiding conservation efforts, reducing conflicts, and supporting effective management strategies. GPS tracking has also been valuable in studying recreational behaviours in protected areas, revealing insights into activity patterns, trip characteristics, and the spatial distribution of recreational activities (Bielaski et al., 2018). Fernando et al. (2015) highlighted that GPS telemetry is the sole method that yields accurate information on elephants' movement patterns, resource utilisation, and habitat. The researchers presented four case studies illustrating the significance of GPS data in guiding developmental efforts, reducing human-elephant conflict, and conserving elephants efficiently. This highlights the importance of GPS tracking technology in wildlife management and conservation efforts.

Similarly, GPS tracking technology has been used to understand recreational behaviours in protected areas. Bielaski et al. (2018) highlighted the growing prevalence of spatially unrestricted outdoor recreational activities in remote areas and introduced GPS tracking to monitor such activities. The authors utilised ArcGIS and Statistical Package for the Social Sciences (SPSS) for spatial and statistical analysis in their study titled "Application of GPS tracking for monitoring spatially unconstrained outdoor recreational activities in protected areas: a case study of ski touring in the Tatra National Park, Poland." The study provided detailed insights into the spatial and temporal aspects of skiers' behaviour, revealing significant differences in activity intensity, trip length and duration, and movement outside designated ski tourist areas across the valley. The authors concluded that GPS tracking is a reliable tool for spatial monitoring of unlimited outdoor recreational activities, and the findings can aid in developing improved guest management strategies for protected areas.

In addition to wildlife and recreational behaviours, GPS tracking technology has been utilised to study bird behaviour. Bouten et al. (2013) developed a flexible GPS tracking system for studying bird behaviour at multiple scales. The GPS tracker featured a GPS receiver, microprocessor, storage memory, solar panel, battery, and a three-axis accelerometer to monitor bird behaviour. The system also included a radio transmitter for two-way communication with ground-based antennas, enabling remote data download and measurement scheme updates. The system allowed researchers to study bird movements at different scales, from individual movements to long-distance migration. The study highlighted the potential of GPS tracking technology in studying bird behaviour and understanding the dynamics and interactions between the GPS receiver.

2.2 The Changing Perspective on Wildlife Tourism: Recognising the Multi-faceted Value of Wildlife

Wildlife tourism has undergone a shift in perspective in recent years, recognising the multi-faceted value of wildlife beyond just its aesthetic and tourism aspects. Extensive research has shed light on the ecological, economic, cultural, and emotional significance of wildlife in the context of tourism (Tapper, 2006; Chardonnet et al., 2002; McIntosh and Wright, 2017). Tapper (2006) emphasised the need for improved monitoring and control of wildlife viewing to safeguard animal species and their habitats. This highlights the ecological value of wildlife and the importance of responsible wildlife tourism practices to ensure the conservation of wildlife and their habitats for future generations. Chardonnet et al. (2002) research on "The Value of Wildlife" revealed that the international community has long underestimated the value of wildlife beyond its limited aesthetic and tourism features. The study highlighted wildlife's economic, nutritional, and environmental roles and cultural significance to human societies. This emphasises the monetary value of wildlife, including its potential to contribute to local community development through responsible wildlife tourism practices.

In addition to ecological and economic aspects, the emotional connection and experience of wildlife viewing have also gained recognition in recent years. McIntosh and Wright (2017) conducted a qualitative study on the significance of emotional connections in wildlife viewing experiences for tourists. The study identified proximity and species as critical factors in creating a meaningful encounter with wildlife but also highlighted the importance of the emotional connection formed during processing that experience. This underscores the emotional value of wildlife and the role of emotional connections in creating meaningful and memorable visitor experiences. The changing perspective on wildlife tourism calls for a holistic approach that recognises the multi-faceted value of wildlife. Responsible wildlife tourism practices should focus on ecological and economic aspects and consider cultural and emotional factors. By fostering emotional connections with wildlife, park and protected area managers can create more meaningful visitor experiences, promote responsible tourism practices, and contribute to wildlife conservation efforts. This includes involving local communities in wildlife conservation and community development initiatives and implementing effective wildlife monitoring and viewing controls.

3.0 Study Area

Udawalawe National Parks is one of the oldest and most-visited parks in Sri Lanka (Suresh et al., 2021). The park's landscape is predominantly flat, with some hilly areas. Much of Udawalawe is composed of hard crystal rocks from the pre-Cambrian period. The western and northern borders are closer to the transition zone than the Highlands or Khondaliate series. Various gneisses and granites occupy much of the park, with significant exposure of basement rocks in its Northwestern and eastern parts. The Udawalwe national park serves as a catchment area for the Udawalawe Reservoir, spanning two Sri Lankan provinces such as Uva and Sabaragamuwa (Figure 1). The park is located in the Ratnapura and Moneragala districts. It allocates the land along the lower reaches of the Walawe River for agricultural purposes while aiming to conserve the habitat of the displaced wildlife and ensure a flow of silt-free water. In 1972, Udawalawe National Park was established as a wildlife

reserve to provide sanctuary to animals displaced by the Udawalawe Reservoir construction. The park is home to various wildlife, such as elephants, buffaloes, deer, crocodiles, leopards, and exotic birds, covering an area of 308 square kilometres. It is considered a prominent national park and recognised for its significant population of wild Asian elephants (*Elephas maximus maximus*). As the closest national park to Colombo, it attracts local and foreign tourists who can participate in elephant safaris and wildlife observation.
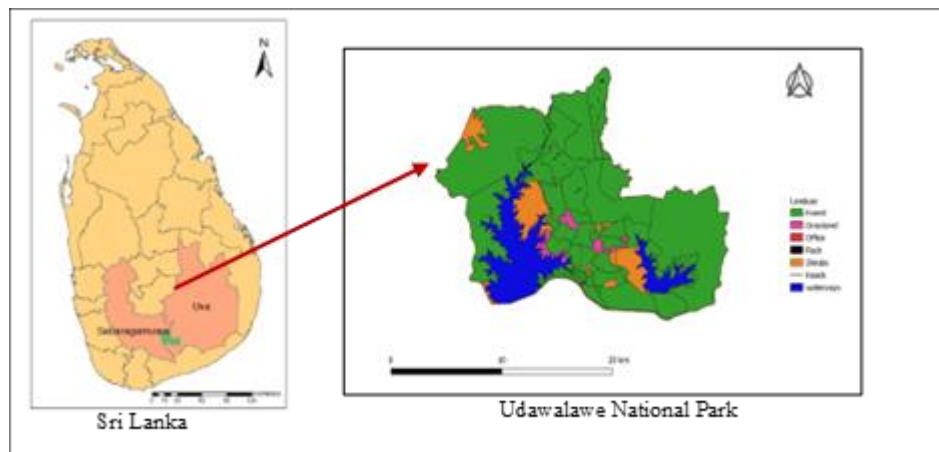

Figure 1: Location of the study area

Udawalawe National Park exemplifies an in-situ conservation area, with the Udawalawe Reservoir emerging as a crucial breeding habitat for aquatic birds. The park is home to remarkable natural features, such as the Kaltota escarpment and Diyawanna waterfall in the north, the highest peak in the west at 380 meters above sea level, and a dry land area of approximately 119 square miles or 29,000 hectares, excluding the reservoir. With a diverse array of flora and fauna, including plants, fish, amphibians, reptiles, birds, mammals, and butterflies, the park boasts spectacular scenic beauty, second only to Yala National Park. Tourists are particularly interested in the herds of 50 to 60 elephants that inhabit the park, attracting a growing number of nature-based tourists. Globally, nature-based tourism, particularly wildlife-based tourism, is rapidly expanding. Udawalawe is a favoured destination, ranked as the third most visited park in Sri Lanka and the sixth-largest animal sanctuary. As such, the present study endeavours to determine the most promising and novel wildlife observation locations.

4.0 Materials and Methods

To elucidate the primary issue of interest in the study locale, the current investigation endeavours to monitor the wildlife behaviour of tourist-attractive regions within Udawalawe National Park while simultaneously identifying potential sites for wildlife viewing that can be developed as tourist destinations. The analysis draws upon extensive literature reviews, research papers, books, magazines, newspapers, and other relevant data sources. Additionally, prior field observations were conducted to conduct preliminary assessments of the study area. This study employed a multi-method approach to data collection, utilising various field techniques to gather information. The research can be divided into three main sections, with field observations as a crucial component in understanding the study area. A total of 30 samples were randomly selected from a pool of 50 for analysis. Field observations were used to examine wildlife behavioural patterns, tourist attractions, and optimal locations for wildlife viewing.

Additionally, questionnaire surveys were conducted to gather preliminary data for analysis. Semi-structured questionnaires were utilised to gather information across a wide area, including data on animal behaviour and attractive locations within Udawalawe National Park. Formal information was obtained through interviews with relevant government officials in the study area. Semi-structured interviews were deemed most suitable for gathering formal details from interviewees. Data were collected through both in-person interviews and telephone conversations. Primary data on the research problem were gathered through direct discussions with five wildlife officers, 13 safari jeep drivers, and 12 guides. Through indirect discussions, targeted interviews were conducted with National Park Service officers, safari jeep drivers, and guides. Additional data were collected through telephone calls with individuals related to the research topic. Direct observation was also employed as a method of collecting information, in which subjects were observed in their familiar environment without any changes being made. This approach was used to monitor wildlife behaviour and tourist attractions. Verbal and written information accuracy was verified through direct field observation via interviews and participatory evaluation.

The analysis of the collected data was conducted using both qualitative and quantitative methods. Qualitative data analysis employed techniques and methods related to analysing non-numerical data. For instance, the behaviour of tourists and wild animals in Udawalawe National Park was studied using qualitative research. Quantitative data analysis, on the other hand, utilised statistical methods and graphical representations such as maps and charts. The GIS system was also employed for network analysis and map preparation. This research presented quantitative and qualitative data using various means, including structured essays, photographs, notes, and graphs. Data were analysed to identify trends and patterns in the variables. Photos and maps were used to present accurate qualitative and quantitative data. Conclusions and suggestions were drawn based on the analysed information and shown using charts, tables, maps, and photos. Both primary and secondary data collection methods were employed to gather information. Despite complications related to the validity of the questionnaire and interview method, the data were utilised to ensure the success of the research endeavour. Graphs were used to summarise large amounts of data and represent both primary and secondary data. Multiple variables were considered when presenting data using charts.

5.0 Results
5.1 Land Use Pattern

The land use pattern of Udawalawe National Park is shaped by its two primary drainage basins, the Walawe River and the Mau Ara. The park's habitat encompasses marshes, forests, grasslands, and the Udawalawe Reservoir, constructed in the mid-twentieth century to establish a wildlife sanctuary. The reservoir is significant for the park's diverse flora and fauna. The Udawalawe Reservoir is home to various

species of green and blue-green algae, such as Pedi strum, Scenedesmus, and Microsystems, indicating the richness of the aquatic ecosystem. The reservoir also supports a wide range of fish species, contributing to the overall biodiversity of the park.

Additionally, the reservoir serves as a breeding ground for aquatic birds, highlighting its ecological significance. The picturesque lowlands and foothills surrounding the Walawe Reservoir, including features like the Kaltota escarpment and the Diyawinna waterfall in the northern region, add to the natural splendour of the park. The park's highest peak, rising to approximately 380 meters above sea level from its lowest point of 100 meters above sea level, is the Kaltota escarpment, a prominent geographical feature in the western region of the park.

The Udawalawe Reservoir also plays a crucial role in supporting the park's large elephant population, estimated to be around 250 permanent residents. Despite the lack of official tracks, GPS waypoints have been used to establish track lines that safari jeeps and other vehicles follow, leading to water bodies, campsites, and safari bungalows within the park. The water bodies and road network of Udawalawe National Park are illustrated in Figure 2, highlighting the importance of the reservoir as a focal point for wildlife viewing and tourism activities.
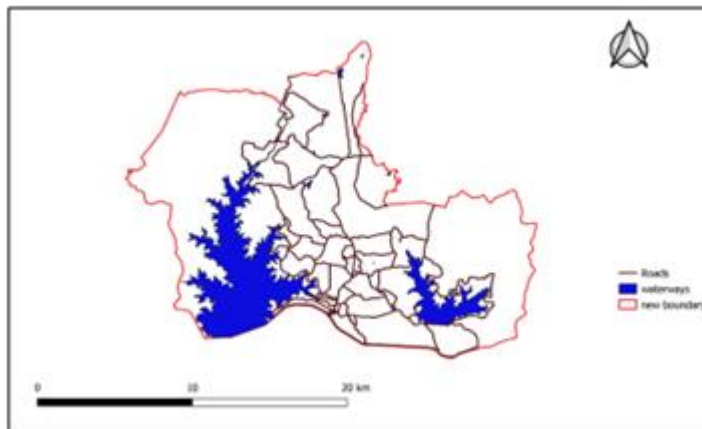

Figure 2: Water bodies and road network of the Park

5.2 Locations of the new wildlife viewing places

Observing wildlife in their natural habitat is a crucial aspect of scientific and recreational activities aimed at documenting the presence and abundance of species. In Sri Lanka, Udawalawe National Park offers opportunities for wildlife observation, including bird and elephant watching. The park's road network, established along the waterways, traverses various terrains, including swamps, grasslands, scrub, and tropical forests. Successful wildlife adventures allow visitors to comprehend the natural world and its inhabitants, leaving a lasting positive impression. The Udawalawe National Park is known for its abundant wildlife viewing opportunities, with various locations identified through field visits and marked on maps using QGIS software (Figure 3).
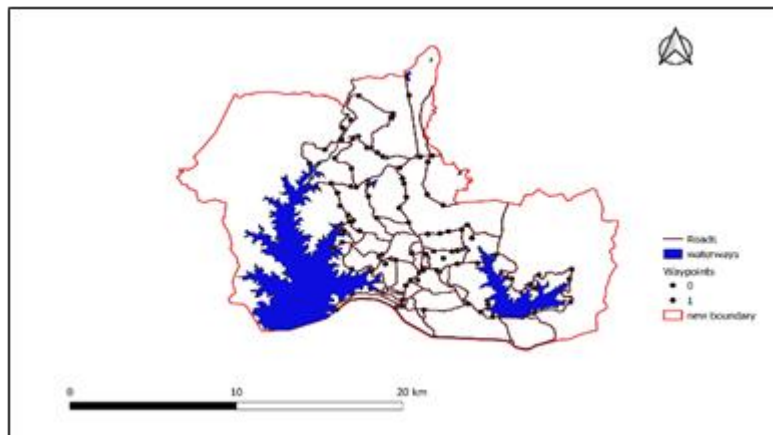

Figure 3: Locations of the new wildlife viewing places

These locations cater to the interests of both domestic and international tourists, offering opportunities for elephant safaris and observing diverse wildlife. By studying the environmental settings of these locations, researchers can gain insights into wildlife behaviour in the park and identify new places of interest for tourists. Field observations have revealed that wildlife in Udawalawe National Park tends to inhabit areas surrounding water sources. The park features two primary reservoirs and artificial ponds that fulfil the water requirements of resident animals. Most species congregate near water sources, which serve as fundamental sustenance, hydration, and shelter sources. As a result, locations near these water sources have been identified as optimal sites for observing wildlife behaviour.

Morning and late evening are prime times for wildlife viewing, as animals within the park converge upon waterholes to forage for food and water. This facilitates sightings of various species, such as deer, crocodiles, cranes, and hornbills. Field observations have identified 164 locations that attract tourists due to unique animal behavioural patterns. Of these, 56% are located a considerable distance from water bodies, with no immediate access to water. However, the remaining 44% of locations are endowed with abundant water from the Udawalawe and Mau Ara reservoirs and other artificial ponds, serving as vital sources of sustenance for the park's animals. As a result, these locations offer ample

opportunities to observe animal behaviour regardless of the season. Accordingly, Udawalawe National Park in Sri Lanka provides more significant opportunities for wildlife observation, with water bodies playing a crucial role in attracting and supporting diverse wildlife. Field observations and mapping of optimal viewing locations can contribute to understanding wildlife behaviour in the park and enhance the visitor experience. Further research in this area can provide valuable insights for wildlife management and conservation efforts and inform sustainable nature-based tourism practices in the park.

In wildlife observation, the ability to discern patterns and carefully observe the natural surroundings, including elements such as water, rocks, and vegetation, is crucial for effectively detecting the presence of fauna. By becoming familiar with these patterns, one can discern subtle variations that may indicate the presence of wildlife. The study of animal behaviour, including individual, social, and reproductive behaviour, is of great interest to many scientists as it provides valuable insights into human behaviour. Engaging in wildlife observation requires creativity, enthusiasm, love, and patience towards all living beings. Udawalawe Park offers a unique opportunity for wildlife observation that takes visitors to areas they may not have access to otherwise. The experience of wildlife observation in Udawalawe Park can be unforgettable, leaving lasting positive memories. A successful wildlife observation adventure involves exploring the unpredictable world of nature.

The map presented in Figure 4 highlights the locations of wildlife behavioural attractions near and far from water sources, as identified through field observations. The map delineates two waypoints, with waypoint zero (0) designating the locations in the park where wildlife behaviour occurs at a considerable distance from water sources. In contrast, waypoint one (1) signifies the areas where wildlife behaviour transpires near water sources. The findings of this study indicate that animals tend to gather near water bodies, where they can find their basic needs, such as water, food, and shelter. Therefore, locations near water bodies are considered optimal for wildlife observation. The field observations reveal that animals congregate near water bodies, making these areas the most conducive for observing wildlife behaviour. However, it is worth noting that some locations, despite being far from water bodies, still attract wildlife due to unique behavioural patterns. This suggests that wildlife behaviour can vary and may not always be exclusively linked to water sources.
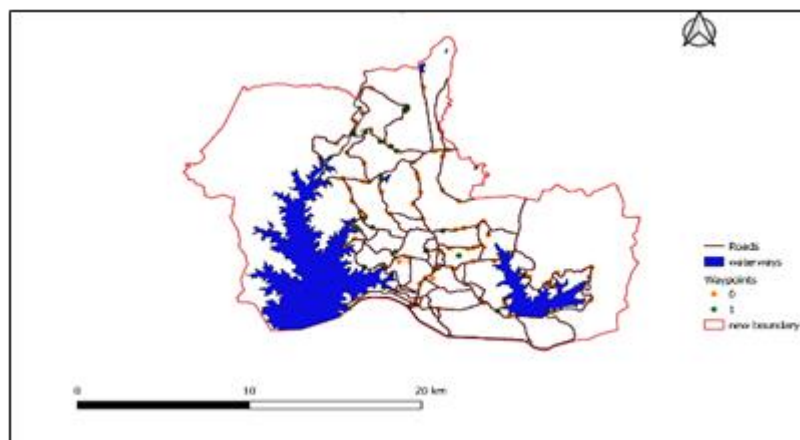

Figure 4: New wildlife watching places near and far from water sources

Effective wildlife observation requires the ability to discern patterns, carefully observe the surroundings, and become familiar with animal behaviour. Udawalawe Park offers opportunities for wildlife observation in unique locations, and understanding the behavioural patterns of animals can significantly enhance the experience. The findings of this study emphasise the significance of water sources as key locations for observing wildlife behaviour while highlighting that other factors may also influence animal activity. Wildlife observation is a fascinating and unpredictable adventure allowing a deeper appreciation and understanding of the natural world and its inhabitants.

5.3   Peak Hours to Watch Animals Behavior in the Park

In wildlife monitoring in Udawalawe National Park, the timing of observations plays a crucial role in capturing animal behaviour. The recommended observation hours span from 6 a.m. to 6 p.m., during which 164 GPS points have been identified as tourist-attractive wildlife locations. These locations exhibit varying peak times for animal activity, categorised into three distinct periods: Morning, Day, and Evening, as illustrated in Figure 5. The morning hours are designated from 6 to 10 a.m., the day hours from 10 a.m. to 2 p.m., and the evening hours from 2 to 6 p.m. Notably, the optimal time for wildlife observation is during dawn and dusk, with the highest level of animal activity observed during the evening hours. Specifically, 38% of animal activity occurs during the evening, while 29% occurs in the morning and 33% in the afternoon. This underscores the significance of the evening period for observing wildlife in Udawalawe National Park.

The inhabitants of Udawalawe National Park tend to congregate near water sources, such as rivers and lakes, in search of essential resources like water and food. This behavioural pattern of wildlife makes it conducive for tourists to observe animals, particularly during the evening. Commonly sighted animals during this period include deer, crocodiles, water buffaloes, elephants, cranes, amphibians, and hornbills with their distinctive double beaks. Accordingly, the timing of wildlife observation is critical for capturing animal behaviour in Udawalawe National Park. The recommended observation hours of 6 a.m. to 6 p.m. and the identified peak times for animal activity during the morning, day, and evening periods provide valuable insights for planning wildlife monitoring activities. Understanding the behavioural patterns of animals and their affinity for water sources can significantly enhance the effectiveness of wildlife observation efforts, particularly during the evening hours when animal activity is at its peak.
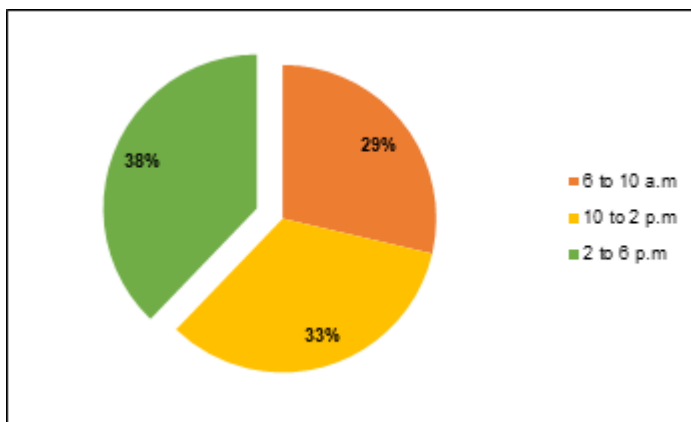
Figure 5: Peak hours to watch animals' behavior in the Park

6.0 Discussion

The land use pattern of Udawalawe National Park is characterised by the diverse habitats surrounding the reservoir, including marshes, forests, grasslands, and water bodies. The park's ecological significance is evident in its rich biodiversity, with numerous plant and animal species thriving in its diverse ecosystems and giving priority to elephants watching, causing to increase in visitor dissatisfaction. According to Prakash et al. (2019), the second most common reason for visitor dissatisfaction was the inadequacy of opportunities to observe diverse wildlife. Accordingly, this study establishes new track lines using GPS waypoints, facilitating different tourism activities developed within the park.

Bouten et al. (2013) and Barros et al. (2019) have used GPS tracking systems to study animal and visitor behaviour. The innovative use of GIS-GPS tracking systems for wildlife monitoring and tourism can serve as a model for the tourism industry and the Wildlife Conservation Department. It introduces social, economic, geographical, and environmental advancements, promoting and increasing the value of tourism in Udawalawe National Park. The proposed tracking system enables visitors to navigate the park efficiently and witness animals in their natural habitat. Furthermore, researchers can utilise this system to study the environmental setting and its impact on wildlife behaviour. Students can access the data for their studies with the support of responsible officers.

The Udawalawe Reservoir is a crucial water source for the park's flora and fauna. It is a major attraction for wildlife viewing and tourism, particularly for its large elephant population. Field observations reveal that animals in Udawalawe National Park commonly gather near water sources, which provide them with essential resources such as water, food, and shelter. The data collected from field observations also indicate that 44% of the locations in the park are rich in water, making these areas prime spots for observing wildlife throughout the year. This finding aligns with Naidoo et al. (2020). They found that ephemeral water sources significantly impacted the behaviour of African elephants and buffalos in Bwabwata National Park in Namibia. They suggest that future research should pay more attention to the impacts of ephemeral water sources on wildlife movement and distribution.

Moreover, the field of wildlife monitoring in Udawalawe National Park necessitates careful timing to observe animal behaviour effectively. The recommended observation hours are from 6 a.m. to 6 p.m. Based on the analysis of 164 GPS points identifying tourist-attractive wildlife locations, animal activity exhibits varying peak times categorised as morning, daytime, and evening, with the highest activity occurring during the evening period, reaching up to 38%. Understanding the behavioural patterns of the species of interest is crucial in determining the optimal time for wildlife observation. To facilitate this process, a map with a network analyst has been developed as a comprehensive guide for tourists to identify the best wildlife sanctuaries in Udawalawe National Park. The map lets tourists plan their visit based on their budget, available free time, and the species they are interested in observing.

Furthermore, Prakash et al. (2019) pointed out that poor park management in Sri Lanka, mainly including heavy traffic congestion inside the park, lack of wildlife viewing opportunities, poor conditions of trails, a flawed interpretation, poor implementation of visitor guidelines and obstructions of wildlife viewing are caused to enhance tourist dissatisfaction. Sometimes, the lack of official tracks results in safari jeep drivers targeting easily accessible locations, causing tourists to miss out on the best wildlife observation spots and traffic congestion. The proposed tracking system will be the best solution to minimise park management issues in Udawalawe National Park. It will be helpful to enhance wildlife trip quality, including conservational and educational activities. The implementation of the tracking system can provide coverage of the entire park, including tourist attractions, and a map or route instructions can help tourists make the most of their wildlife tours. Accordingly, using GIS-GPS tracking systems for wildlife monitoring and tourism in Udawalawe National Park offers significant benefits regarding practical wildlife observation, research opportunities, and sustainable tourism development. This study presents a novel approach to wildlife monitoring in Sri Lanka and is a valuable tool for tourists, researchers, and students. It also highlights the need for further efforts in waterway development, addressing illegal activities, and improving tourist routes in the park to enhance the overall wildlife observation experience and promote responsible tourism practices.

7.0 Conclusion

This study reveals that the peak hours for wildlife viewing are during the evening, near water bodies where animals congregate for essential resources. It highlights the significance of timing for maximising the chances of successful wildlife sightings. The findings of this study emphasise the critical role of timing in wildlife monitoring efforts in Udawalawe National Park. The recommended observation hours of 6 a.m. to 6 p.m. and identifying peak times for animal activity at different GPS points provide valuable insights for planning effective wildlife viewing activities. The results indicate that the evening hours, from 2 to 6 p.m., show the highest level of animal activity, with a maximum of 38%, making it the optimal time for a safari and wildlife observation. This information can be crucial for tourists seeking to observe diverse wildlife species in Udawalawe National Park. By focusing on water-rich areas highlighted on the map, tourists can increase their chances of observing wildlife and avoid getting lost or distracted. The study has identified potential tourist sites for wildlife viewing and their unique characteristics, which can assist in managing the park's surrounding environment and tourist attractions.

Moreover, the investigation has revealed hidden, uncommon, and optimal locations for observing wildlife behaviour, particularly near waterways, such as the Udawalawe Reservoir, Mau Ara Reservoir, and artificial ponds. Furthermore, the observation that animals in Udawalawe

National Park tend to congregate near water sources during the evening hours, possibly for essential needs such as water and food, presents an opportunity for tourists to witness a diverse array of wildlife species, including deer, crocodiles, water buffaloes, elephants, cranes, amphibians, and hornbills with their distinctive double beaks. The findings highlight the importance of considering ecological factors and animal behaviour in wildlife monitoring and tourism planning. This study also highlights the need to develop waterways, as artificial ponds are insufficient for large animals such as elephants, which require mud to protect themselves from the sun's rays. These animals travel long distances in the dry season to find water, affecting the surrounding villages and farmers.

Using GIS-GPS tracking systems to monitor wildlife behaviour in Udawalawe National Park introduces innovation in the tourism industry and wildlife conservation efforts. This study can serve as a model for other destinations, showcasing the potential of technology in enhancing visitor experiences while promoting tourism's social, economic, geographical, and environmental aspects. Researchers and students can also benefit from accessing the tracking system for their studies, examining the impact of the surrounding ecological setting on wildlife behaviour. Furthermore, the findings of this study highlight the need for the development of waterways in Udawalawe National Park to ensure the availability of resources for large animals such as elephants and to mitigate adverse impacts on surrounding villages and farmers. Additionally, the implementation of the tracking system can help address issues such as illegal businesses and plantations in the park, as well as provide a route guide for safari jeep drivers to ensure tourists have access to the best locations.

The findings of this study contribute to understanding the temporal dynamics of wildlife activity in Udawalawe National Park, providing important insights for park management authorities, tour operators, and tourists in optimising wildlife viewing experiences. However, further research could explore additional factors such as seasonal variations, weather conditions, and human disturbance to comprehend better the underlying mechanisms driving wildlife activity patterns in the park. Creating the tracking system and using GIS-GPS technology in wildlife monitoring and tourism planning in Udawalawe National Park has significant implications for enhancing visitor experiences, promoting sustainable tourism practices, and contributing to wildlife conservation efforts. Further research and collaborative efforts among park authorities, tour operators, researchers, and local communities can continue to refine and improve the tracking system, making it a valuable tool for responsible and sustainable wildlife tourism in the future. While this study has provided valuable insights into the temporal dynamics of wildlife activity in Udawalawe National Park, further research could delve deeper into the underlying factors driving these patterns, such as seasonal variations, weather conditions, and human disturbance. Additionally, understanding the potential impacts of wildlife tourism on animal behaviour and habitat use could be a fruitful avenue for future research.

Conflicts of Interest: The authors declare no conflict of interest.

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