



Research Article

The Impact of Rainforest Vegetation and Water-bodies on Activity Pattern of African Forest Elephants (*Loxodonta africana*) in Mbam et Djerem National Park, Cameroon

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Abstract

The relationship between rainforest vegetation, water bodies, and African forest elephant activity is complex and crucial to understanding the ecological dynamics within Mbam et Djerem National Park. This study explores the influence of rainforest vegetation and water bodies on the activity patterns of African forest elephants (*Loxodonta africana*) in the national park. As keystone species, African forest elephants play a critical role in maintaining ecological balance; however, their activities are significantly impacted by habitat characteristics. Utilizing direct observational method, elephant interactions with their environment across different vegetation types and proximity to water sources were examined. The results of this study revealed that vegetation dominance is significantly associated to day-period $r=0.174$ $P<0.05$, habitat characteristics $X^2=18.312$ $df=4$ $P=0.001$, water bodies $X^2=3.316$ $df=4$ $P<0.05$, and human threats $X^2=4.388$ $df=4$ $P<0.05$ respectively. More so, Water bodies equally recorded a significance on habitat type $X^2=6.771$ $df=4$ $P<0.05$, and signs of elephant presence $X^2 = 8.282$ $df=4$ $P<0.05$. Additionally, Habitat type was significantly linked to signs of elephant presence $X^2 = 3.3379$ $df=4$ $P<0.05$. In The research highlights the critical interplay between rainforest vegetation, water bodies, and the activity patterns of African forest elephants in Mbam et Djerem National Park. Also, the research underscores the necessity of preserving these critical ecological components to support African forest elephant populations and promote biodiversity within the region. Ultimately, our findings contribute to the formulation of effective conservation strategies aimed at mitigating the adverse effects of habitat degradation and climate change on these endangered species. Understanding these dynamics is crucial for informing effective conservation strategies aimed at protecting not only the elephants but also the fragile ecosystems they inhabit. Future research should aim to further explore the nuances of these interactions and develop comprehensive management plans that involve local stakeholders, ensuring the sustainability of the park and its remarkable wildlife for generations to come. The integration of ecological knowledge into conservation planning will be paramount in the efforts to safeguard these incredible species and their habitats amidst increasing anthropogenic pressures.

Keywords

Rainforest Vegetation, Ecological Dynamics, Elephants Presence, Conservation Strategies

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1. Introduction

African forest elephants (*Loxodonta africana*) are a crucial component of the rainforest ecosystem, playing a key role as seed dispersers and maintainers of forest structure. Understanding their ecological dynamics is essential to implementing effective conservation strategies, especially as these elephants face significant threats from habitat loss and fragmentation. This literature review explores the relationship between rainforest vegetation, water bodies, and the activity patterns of African forest elephants, with a focus on the context of Mbam et Djerem National Park in Cameroon. Forests in the Central African region are characterized by a high degree of biodiversity, with various types of vegetation ranging from dense canopies to open grasslands. Studies show that African forest elephants prefer areas with rich, diverse vegetation, which provide essential food sources [33]. Basing their foraging behavior on the availability of fruits, leaves, and bark, elephants often select habitats that allow for optimal nutritional intake [28]. The structure and composition of rainforest vegetation directly influence the movement and activities of elephants, as denser vegetation offers both nutritional resources and shelter from human disturbance [2].

Mixed deciduous forests are prevalent in Cameroon and provide an essential habitat for African forest elephants. These forests contain a variety of tree species that lose their leaves seasonally, exposing fruits and young green shoots that elephants consume. The nutritional diversity offered by mixed tree species—such as *Entandrophragma* and *Lecaniodiscus*—supports the foraging habits of elephants, helping to maintain their health and vitality [33]. Riparian zones, which line rivers and streams, are crucial habitats for elephants, offering abundant food resources and access to water. Research highlights that these areas harbor lush vegetation, including species like *Ficus* and *Pandanus*, which are favored by elephants for their fruits and succulent foliage [19]. The proximity to water not only satisfies hydration needs but also enhances the availability of high-nutrient plants. Africa's dense canopy forests, characterized by towering trees and a multi-layered structure, provide ideal habitats for elephants. Trees such as *Bok é* (*Guibourtia tessmannii*) and various species of *Iroko* (*Chlorophora excelsa*) are particularly important, as they provide substantial foliage and fruits. Elephants exploit these forests for their vast array of edible plants, which contribute to their foraging success [2]. Moist forests are vital for the sustenance of elephants, featuring rich biodiversity and vibrant undergrowth. Species such as *Marantaceae* (a family of flowering plants) and various ferns thrive under humid conditions, providing both food and cover. Research indicates that elephants can frequently be found foraging in these moist habitats, as they offer abundant dietary options [37].

The presence of species like *Acacia* is particularly beneficial, as elephants commonly feed on their leaves and pods. This dual habitat use is crucial, particularly in periods of seasonal drought [27]. Certain tree species are especially sought

after by elephants during fruiting seasons. Trees like the African oil palm (*Elaeis guineensis*) and various species of *Ficus* are frequently targeted. The high energy content and nutritional value of the fruits play a significant role in attracting elephants, which is vital for their reproductive health and overall fitness [21]. Apart from trees, elephants also benefit from herbaceous plants found in the understory, such as various grasses and shrubs. These provide essential foraging opportunities, especially during specific seasons when tree foliage may be less available. Research shows that elephants are known to clear paths through dense undergrowth, facilitating access to these secondary food sources [28]. The foraging behavior of African forest elephants influences plant diversity and forest structure. As ecosystem engineers, their feeding habits lead to seed dispersal and the maintenance of plant diversity. The physical alterations to their environment, including the creation of clearings through vegetation consumption, promote light penetration and facilitate the growth of various species [13]. Understanding the specific vegetation preferences of African forest elephants is critical for conservation efforts in Cameroon. Habitat destruction due to logging, agricultural expansion, and climate change threatens these vital ecosystems. Ensuring the protection of preferred vegetation types—such as mixed deciduous forests and riparian zones—is essential for the survival of elephants and the broader biodiversity within these regions [20].

Water sources within rainforests are vital for the survival of African forest elephants, especially during dry seasons when resources become scarce. Research indicates that elephants frequently visit water bodies for hydration and social interactions [34]. Studies highlight that proximity to water significantly affects elephant movement patterns, with increased activity noted near rivers and lakes [19]. This behavior can be attributed to the hydration needs of large mammals and the availability of lush vegetation typically found in riparian zones. African forest elephants are considered a keystone species, as their feeding habits contribute to forest structure and biodiversity. Their foraging behavior influences seed dispersal, which facilitates forest regeneration [21]. Additionally, the physical alterations made by elephants—such as uprooting small trees and creating clearings—allow light to penetrate the forest floor, encouraging the growth of various plant species [37]. Such ecological impacts underscore the interconnectedness of elephant activity with rainforest health and resilience. The rapid rate of deforestation and habitat fragmentation in Central Africa poses a significant threat to African forest elephants. Deforestation driven by logging, agriculture, and infrastructure development leads to the loss of critical habitats, which directly impacts elephant movement and foraging [27]. The fragmentation of continuous forest ecosystems restricts elephant migration routes and reduces overall genetic diversity among populations [13].

Climate change presents further challenges, affecting both

vegetation patterns and water availability. Altered precipitation patterns and rising temperatures can lead to increased droughts, exacerbating competition for water resources among wildlife [36]. Understanding how these factors influence the behavior of African forest elephants is crucial for conservation efforts and sustainable land management. The survival of African forest elephants is intricately linked to the preservation of their habitats, particularly the maintenance of diverse rainforest vegetation and accessible water bodies. Conservation strategies must consider the ecological roles of elephants in their habitats, promoting initiatives that protect these critical resources [20]. Effective management practices should focus on habitat restoration, legal protection of water sources, and the implementation of wildlife corridors to facilitate movement between fragmented forest patches.

2. Materials and Method

2.1. Description of the Study Area

Mbam et Djerem National Park is located in the central region of Cameroon, between latitudes $4^{\circ}45'$ and $5^{\circ}30'$ N and longitudes $12^{\circ}30'$ and $13^{\circ}15'$ E [25]. Established in 2000, the park covers approximately 4,160–4,260 square kilometers, spanning across the Mbam and Djerem divisions [22]. This location is a crucial ecological zone, serving as a habitat for diverse wildlife, including the hippopotamus (*Hippopotamus amphibius*) [10]. The park is situated on the southern slopes of the Adamawa Plateau, east of the Yoko–Tibati road (Figure 1). The

climate of Mbam et Djerem National Park is characterized by a tropical rainforest climate, influenced by its elevation and geographical location [26]. The region experiences two distinct seasons: a wet season from May to October and a dry season from November to April. The wet season can be further divided into a small rainy season from March to June and a big rainy season from July to October. Average temperatures range from 20°C to 30°C , with higher temperatures typically recorded during the dry season [35]. Average annual rainfall is approximately 1,500 mm, with peak precipitation occurring between June and August [16]. These climatic conditions support the park's rich biodiversity, providing an ideal habitat for both flora and fauna. However, climate change is altering rainfall patterns and water availability [23]. The vegetation of park is predominantly composed of tropical rainforest and savanna ecosystems [6]. The park is located at the transition zone between the forested south and savanna-dominated north. These dense forested areas line the banks of rivers and provide critical habitat for aquatic and semi-aquatic species, including the hippopotamus [5]. Open savanna areas are interspersed within the park, dominated by grasses and scattered trees [31]. The presence of wetlands is vital for the park's hydrology and serves as breeding grounds for many species [18]. The park has a mix of rolling grasslands, forest patches, river valleys, and wetlands. Forested areas feature hardwood trees, lianas, and dense undergrowth, while the northern savannas are characterized by grasses and acacia trees [1]. Mbam et Djerem National Park boasts a rich biodiversity and is home to a variety of animal species [3]. Lowland forests harbor giant trees like sapele and iroko, along with a variety of lianas, epiphytes, and shrubs [9].

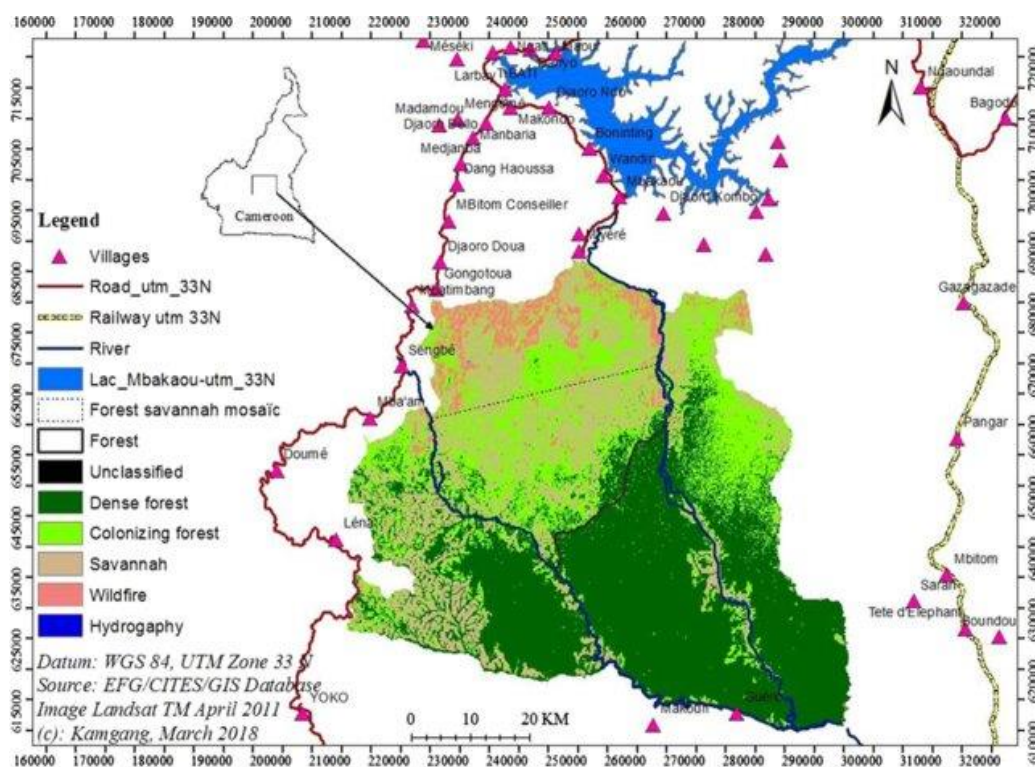


Figure 1. Map of Mbam et Djerem National Park: Source [25].

2.2. Data Collection Method

This study employs a mixed-method approach to investigate the influence of rainforest vegetation and water bodies on the activity patterns of African forest elephants (*Loxodonta africana*) in Mbam et Djerem National Park, Centre Region, Cameroon. The data collection involved both secondary data collection through ecological transects and primary data collection via interviews with local communities and park authorities. A systematic approach was used to establish transect lines throughout different habitats within the national park, focusing on diverse vegetation types and proximity to water bodies. Each transect line was approximately 2 km long, marked with flags for easy identification. Surveys were conducted during the early morning and late afternoon when elephant activity is typically higher. Observers walked along the transects, recording data on elephant signs such as footprints, dung, feeding signs, and activity patterns observed. Vegetation assessments were conducted simultaneously, with the type of vegetation (e.g., species, density, and height) recorded at regular intervals (every 100 meters). Observations of water bodies, including their size, depth, and proximity to transects, were also documented to understand their accessibility to elephants. Interviews were conducted with local communities surrounding Mbam et Djerem National Park, including farmers, fishermen, and park rangers. Participants were selected based on their proximity to the park and experience with elephant behavior and activity patterns.

2.3. Method of Data Analysis

Both Chi-square (X^2) tests and correlation (r) statistical models were used in the data analysis. These analyses help to identify relationships and determine the statistical significance of observed patterns in the collected data. The Chi-square test is a statistical method used to determine whether there is a significant association between categorical variables. In this

study, the Chi-square test was employed to analyze the relationship between elephant activity patterns and specific habitat features, such as vegetation type and proximity to water sources. Additionally, correlation analysis was utilized to examine the strength and direction of the linear relationship between continuous variables. In this study, the correlation model assessed the relationship between elephant activity levels and environmental variables such as vegetation dominance and water bodies.

3. Results

The study revealed that vegetation dominance recorded a significant association on day-period $r=0.174$ $P<0.05$ (Figure 2), habitat characteristics $X^2=18.312$ $df=4$ $P=0.001$ (Figure 3), water bodies $X^2=3.316$ $df=4$ $P<0.05$ (Figure 4), and human threats $X^2=4.388$ $df=4$ $P<0.05$ (Figure 5) respectively. The interplay between rainforest vegetation, water bodies, and human activities is critical in shaping the ecological landscape of Mbam et Djerem National Park. Understanding how these factors interact is vital for developing effective conservation strategies. Future research should focus on sustainable practices that balance human needs with ecological preservation, ensuring the long-term survival of both the species and their habitats. Early morning hours are crucial for many wildlife species, including elephants, which often engage in foraging activities when temperatures are cooler and humidity is higher [29]. The lush vegetation of the rainforest provides not only food resources but also cover from potential threats. During the morning, dense foliage offers a microhabitat for various species, facilitating feeding and social interactions. The types of vegetation present can significantly influence these behaviors. For instance, areas with abundant fruit-bearing trees may attract more fauna during this period [17]. During midday, the behavior of forest animals tends to vary significantly.

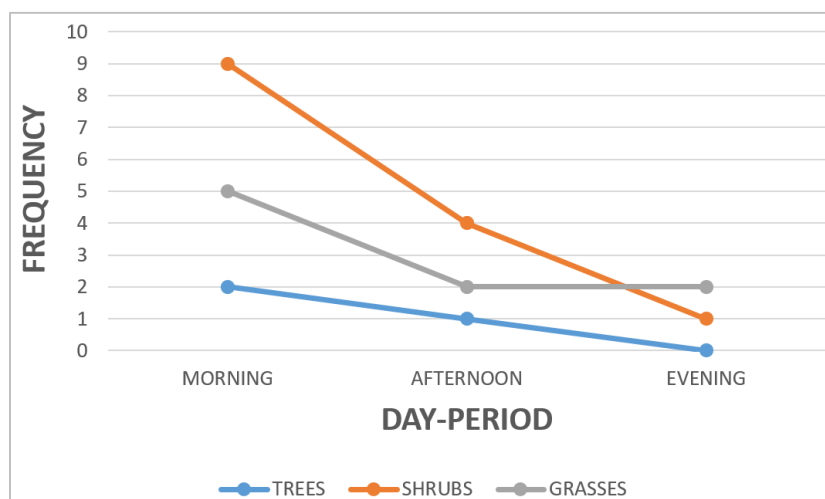


Figure 2. Vegetation dominance and day-period.

High temperatures and increased sunlight can lead many species, including elephants, to retreat to shaded areas, reducing their activity levels. Forest structure plays a critical role in this response; areas with complex canopies provide cooling shade, thus influencing the location of animal activities [4]. Research has shown that afternoon movements may be guided by the availability of water bodies nearby, where animals seek hydration [32]. As daylight wanes, forest creatures become

more active again. Vegetation plays a pivotal role during this time, as the forest's dense undergrowth provides safety from predators. The cover offered by specific species can dictate feeding patterns, with elephants displaying increased movement as they graze on available vegetation [14]. The variation in plant life also influences behaviors such as mating and socializing during these twilight hours, as many species utilize the cooler temperatures to maximize energy expenditure [15].

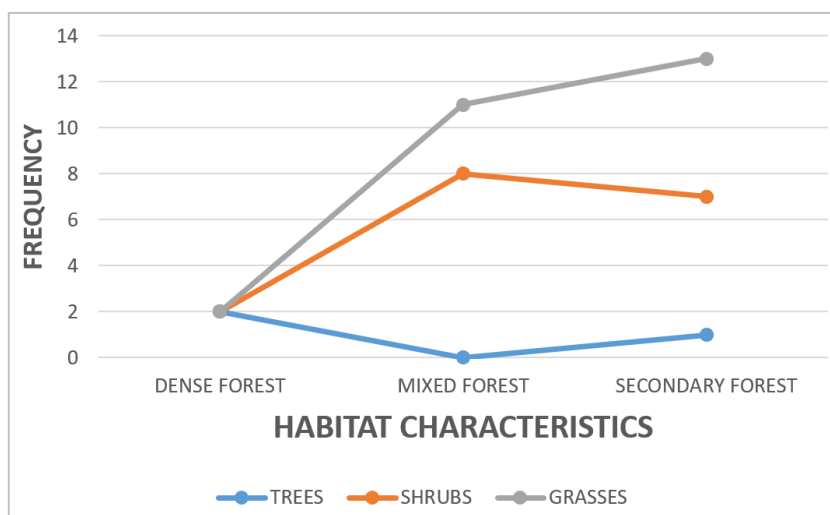


Figure 3. Vegetation dominance and habitat characteristics.

The dense forest offers cover for both poachers and the animals themselves, raising complex dynamics around protection and conservation. Local communities rely heavily on the forest for non-timber forest products (NTFPs). This gathering impacts vegetation through selective removal of plants, which can alter habitat structures, leading to changes in animal behavior and habitat availability [39]. The sustainability of such practices is often compromised when not managed properly, resulting in detrimental effects on biodiversity. Unsustainable

agricultural practices and encroachment into forested areas pose significant threats to rainforest ecosystems. The conversion of forestland into agricultural land not only leads to habitat loss but also fragments essential corridors for wildlife movement. Research indicates that as agricultural lands expand, the remaining patches of rainforest become increasingly isolated, hampering genetic diversity and increasing vulnerability to extinction [12].

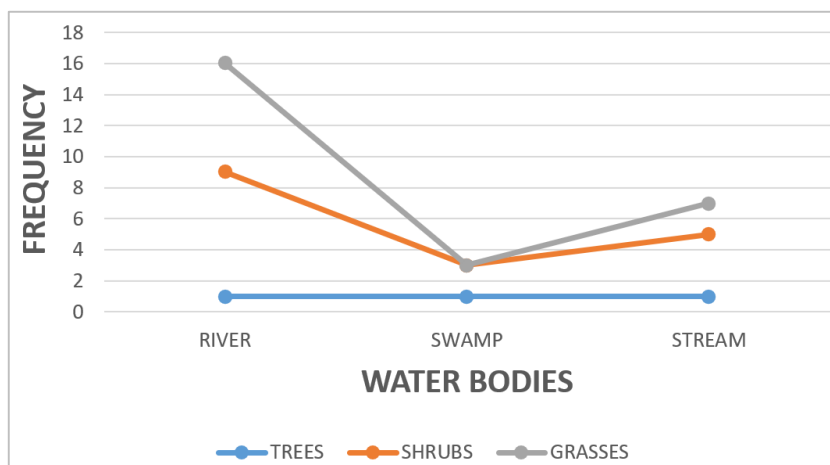


Figure 4. Vegetation dominance and water bodies.

Water bodies like rivers, streams, and swamps are critical in the rainforest ecosystem. They not only provide essential hydration for the wildlife but also act as natural corridors facilitating movement between different habitats. Elephants and other large mammals are known to create paths to water sources, which are heavily influenced by surrounding vegetation [40]. Water bodies contribute to habitat diversity, supporting various plants and animals that thrive in wet conditions.

These areas often support a different assemblage of species compared to drier habitats, with specific flora such as riverine forests that provide unique microhabitats [8]. The proximity to water can significantly enhance biodiversity and shape animal movement patterns, particularly for species dependent on these water sources for reproduction and feeding [30].

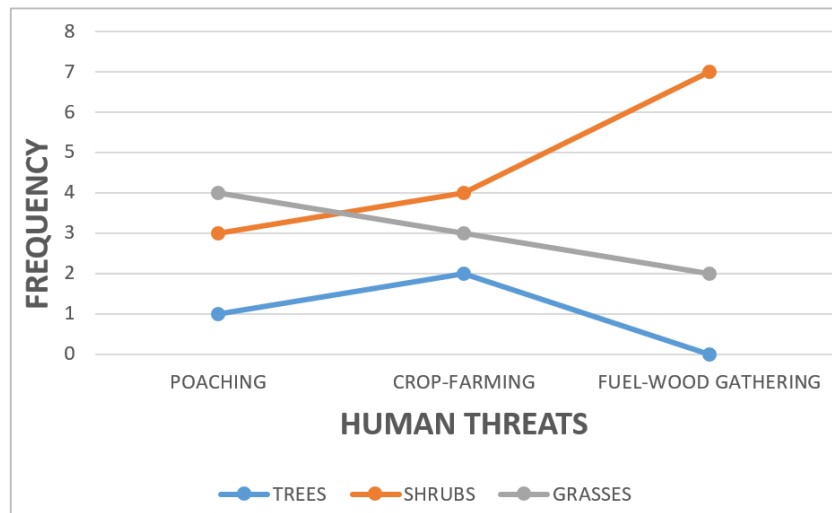


Figure 5. Vegetation dominance and human threats.

Poaching remains one of the most salient threats to wildlife in Mbam et Djerem National Park. Evidence suggests that poaching activities are concentrated near certain vegetation types that provide easy access to targets, including elephants and primates [24].

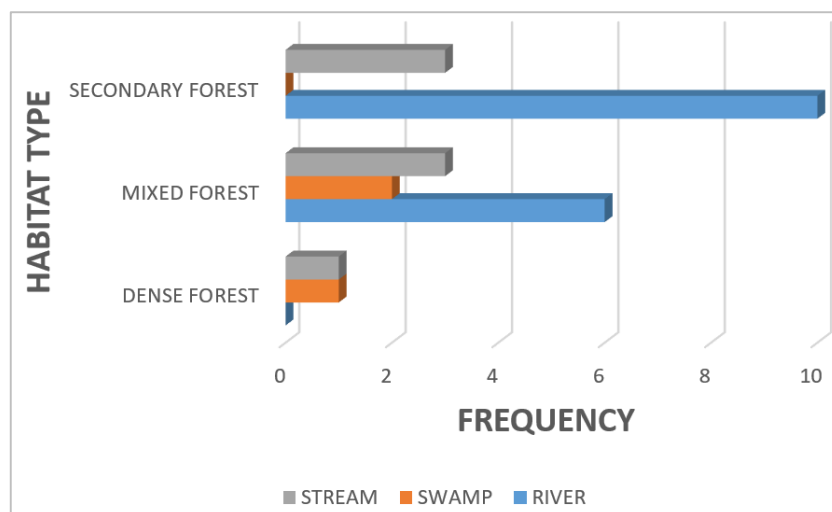


Figure 6. Water bodies and habitat type.

More so, water bodies showed a significant relationship on habitat type $X^2=6.771$ $df=4$ $P<0.05$ (Figure 6), and signs of elephant presence $X^2 = 8.282$ $df=4$ $P<0.05$ (Figure 7) respectively. The presence and distribution of water bodies in Mbam et

Djerem National Park significantly influence the types of habitats and the signs of elephant presence. Dense, mixed, and secondary forests all exhibit unique interactions with aquatic ecosystems, shaping not only the vegetation structure but also the

behaviors and movements of elephants. Understanding these dynamics is critical for effective conservation strategies that aim to preserve both the habitat and its iconic wildlife, particularly in the face of growing human pressures and environmental changes. These aquatic ecosystems play a crucial role in shaping the forest habitats and the behaviors of African forest elephants (*Loxodonta africana*), which are key species within this and other rainforest ecosystems. Proximity to water bodies enhances these habitats by providing necessary water resources, thus supporting various flora and fauna. Research has shown that dense forests adjacent to rivers and streams tend to have higher moisture levels, fostering the growth of a diverse array of plant species [38]. These forests serve as critical refuges for elephants, who rely on the abundant food sources and shelter provided by these vegetation types.

The transitional nature of mixed forests allows for a variety of plant species to thrive, with some utilizing water from nearby streams. Research indicates that elephants are frequently spotted in these environments due to the availability

of both food and cover [15]. The diverse plant community also plays a role in attracting and supporting other wildlife, further enhancing the ecological dynamics of the area. Secondary forests are generally formed after primary forests have been disturbed or cleared. While these forests are often less diverse, the proximity to water bodies dramatically enhances their ecological value. Water sources allow for quicker recovery of vegetation and increased growth of plants and trees, promoting habitat regeneration [39]. Research has found that secondary forests near rivers and streams may still provide valuable resources for wildlife, including elephants. These areas often exhibit signs of elephant presence, as the animals may utilize secondary habitats when primary forests are too fragmented or inaccessible [32]. Elephant trails are often found in areas close to water bodies, which serve as natural corridors for movement. Elephants typically establish paths leading to water sources, and these trails can serve as indicators of both habitat use and environmental health [4].

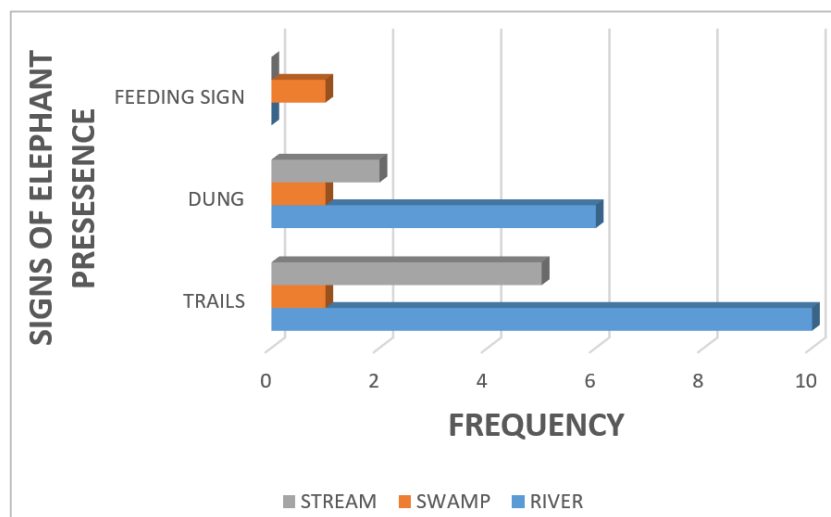


Figure 7. Water bodies and signs of elephant presence.

Water bodies also facilitate the establishment of specific vegetation along their banks, creating lush riparian environments. Such areas typically attract a variety of wildlife and enhance overall biodiversity, which is critical for the survival of elephants and other herbivores [7]. The availability of water supports food plants that elephants depend on, thus promoting their presence in these areas. Mixed forests, which comprise both dense and semi-open habitats, benefit significantly from the presence of water bodies. Rivers and streams contribute to the microclimate of mixed forests, ensuring moisture availability even during dry seasons. This ongoing water supply supports a wide range of species, creating a diverse habitat that can support various fauna [11]. Research shows that trails emerge in habitats that provide a combination of food availability and accessibility to water, underscoring the influence of water bodies on elephants' spatial behaviors. Elephant dung is

a critical indicator of their presence and activity levels. Areas near water bodies tend to have higher concentrations of dung due to the animals' frequent visits for hydration and feeding purposes. Studies suggest that dung deposition rates are significantly correlated with proximity to rivers and streams, emphasizing the connection between water availability and elephant foraging behavior [30]. The presence of dung not only signals current elephant activities but also indicates historical usage of the habitat. Dung can contribute to the nutrient cycling within the ecosystem, promoting plant growth, which in turn supports additional herbivores [17]. Food remains, including broken branches and chewed leaves, are another crucial indicator of elephant presence. Elephants often concentrate foraging activities in areas near water bodies due to the availability of tender vegetation. The proximity to rivers and

streams influences the types of plants available, with lush riparian vegetation providing preferred food sources for elephants [29]. Research has documented significant correlations

between elephant food remains and habitat structure, particularly in environments close to water. These areas exhibit signs of considerable feeding activity, crucial for understanding elephants' dietary habits and habitat preferences [7].

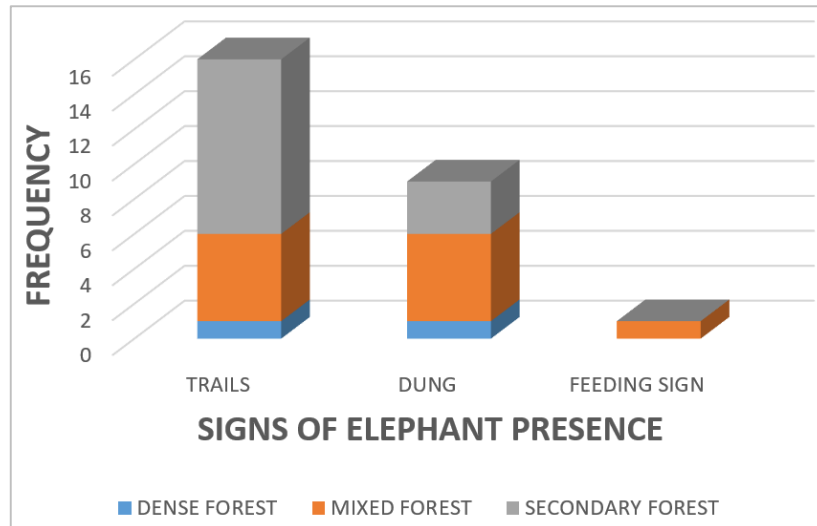


Figure 8. Habitat and signs of elephant presence.

Habitat characteristics was significantly linked to signs of elephant presence $X^2 = 3.3379$ $df=4$ $P<0.05$ (Figure 8). The interplay between habitat characteristics and signs of elephant presence in Mbam et Djerem National Park underscores the importance of ecological integrity in conservation strategies. Dense, mixed, and secondary forests each provide unique resources and environmental conditions that influence elephant behavior and movement. Understanding these dynamics is crucial for developing effective management plans aimed at protecting both elephant populations and the vital habitats they depend on. Future research should focus on the ongoing impacts of habitat changes and human activities to ensure the sustainable coexistence of wildlife and local communities. Dense forests, characterized by thick canopies and rich biodiversity, play a vital role in supporting elephant populations. These areas typically provide an abundance of food sources, including a variety of fruits, leaves, and bark that elephants prefer [29]. Research indicates that elephants are more likely to leave signs of their presence, such as trails and dung, within these habitats, as they frequently forage for food [14]. The structure of dense forests offers cover, allowing elephants to navigate safely while foraging. The presence of substantial underbrush and diverse plant species encourages a higher density of elephant activity, resulting in more pronounced signs, such as trails formed from repeated movement [17].

Research indicates that signs of elephant presence, such as trails and food remains, can be found within secondary forests, albeit at potentially lower densities than in dense or mixed forests. The availability of food resources in these areas is crucial for sustaining elephant populations, particularly during periods of resource scarcity in adjacent habitats [39]. Additionally,

the relatively easier access to food might encourage elephants to forage in these areas, leaving behind clear indicators of their presence. Elephant trails serve as key indicators of habitat use. Trails often emerge in areas with abundant food resources and cover, where elephants can navigate safely. Research shows that trail density tends to be higher in dense and mixed forests, correlating with the abundance of food resources and environmental conditions suitable for foraging [4]. The connectivity of these trails between habitat types can also indicate optimal movement patterns and habitat preferences. Elephant dung is an important ecological indicator, reflecting both the number of elephants in an area and their feeding behaviors. Studies have found that dung density is significantly influenced by habitat type, with higher concentrations found in dense and mixed forests due to the availability of food [30]. Analysis of dung can provide insights into the elephants' dietary preferences, demographic information, and the overall health of the ecosystem. Food remains are crucial for understanding elephant foraging habits. In habitats rich in preferred plant species, researchers often find plentiful remains, including chewed leaves, bark, and branches. The abundance and types of food remains left behind can help assess elephants' interactions with their environment (Owen-Smith, 2013). The presence of food remains not only signals active foraging but also contributes to nutrient cycling within the ecosystem, thereby influencing forest health and regeneration [17].

4. Discussion

African forest elephants (*Loxodonta africana*) are critical

components of tropical rainforest ecosystems in Cameroon, playing vital roles in seed dispersal, habitat maintenance, and biodiversity support. Their activity patterns are profoundly influenced by the characteristics of their habitats, particularly rainforests and adjacent water bodies. This literature review examines the importance of these ecosystems in shaping the behavior and activity patterns of African forest elephants in Cameroon. Rainforests provide a complex habitat characterized by a diverse assortment of plant species, which are essential for the dietary needs of forest elephants. Their diet consists mainly of leaves, fruits, and bark, and the availability of these food resources influences foraging behavior and movement patterns [29]. Dense understory vegetation in rainforests offers rich feeding grounds, thus supporting significant elephant populations [14]. Research indicates that elephants tend to exhibit different activity levels based on food availability, which varies with seasons and forest health. In addition, the structural complexity of rainforests allows elephants to use specific pathways, forming trails over time that facilitate easier access to feeding areas [32]. The rainforest environment not only supports individual elephants but also enhances social interactions within herds. The dense foliage provides opportunities for elephants to engage in social behaviors, such as communal foraging and protective interactions [7]. Different age groups within herds benefit from the safety provided by the dense forest cover, enabling mothers to nurture their young while remaining vigilant against predators.

Furthermore, the spatial distribution of food resources and the availability of cover influence movement patterns among herds. Elephants tend to be more active during cooler parts of the day—mornings and late afternoons—when they can effectively forage while avoiding the heat of midday [4]. Water bodies, including rivers, streams, and swamps, play an indispensable role in the ecology of African forest elephants. Access to water is critical for hydration, especially in periods of heat or drought. Elephants are known to travel considerable distances to reach water sources, integrating these journeys into their daily activity patterns [15]. Research shows that the availability of water directly affects the movement and social dynamics of elephant herds. When water sources are abundant, elephants exhibit more stable and predictable activity patterns, reducing the amount of energy expended in search of hydration [39]. Water bodies serve as social hubs for elephants. The areas surrounding rivers and streams become focal points for gathering, where elephants can engage in social interactions and communal activities such as bathing and mud wallowing. These behaviors are not only essential for hygiene but also foster social bonding among herd members and contribute to the maintenance of healthy skin [30].

Mixed forests, which include a combination of tree species and structures, create varied microhabitats that can influence elephant behavior. In these habitats, elephants can exploit a range of food options, from shrubs to larger trees, due to the increased light and moisture levels compared to dense forests [7]. Research indicates that elephants often frequent mixed

forests where food resources are diverse, thus leaving behind more trails and dung compared to other habitat types. Significantly, mixed forests can serve as critical corridors connecting different habitat zones. The movement patterns of elephants through these areas can be observed in the form of well-established trails and signs of feeding activities [32]. Due to the availability of food remains, such as chewed branches and leaves, researchers can infer the elephants' dietary preferences and their level of habitat utilization. Secondary forests, which emerge following disturbances or previous clearing, present unique challenges and opportunities for elephant populations. Although they are often less diverse than primary forests, secondary forests can offer important resources for elephants, especially if they are well-connected to primary habitats [11]. Elephants may utilize these ecosystems when primary foraging areas become scarce or when migration routes are disrupted.

Feeding behavior is also significantly influenced by proximity to water. Elephants often forage on plant species that thrive near water bodies, increasing their overall dietary diversity. The analysis of dung samples from areas adjacent to water sources often reveals a wider range of consumed plant materials, indicative of foraging activities enriched by the availability of diverse food resources [17]. The activity patterns of African forest elephants are also affected by seasonal variations in rainfall and temperature, which directly influence both rainforest conditions and water availability. During the wet season, rainforests become lush and vibrant, providing abundant food resources. This period often sees increased elephant activity as they capitalize on the rich vegetation [7]. In contrast, during dry seasons, when food sources become scarce, elephants may adapt by altering their foraging strategies and increasing movement distances in search of sustenance and water. This change in behavior highlights the strong correlation between the environmental conditions of rainforests and water bodies and the natural rhythms of elephant activity [32]. The importance of rainforests and water bodies for African forest elephants is further compounded by the increasing threats from human activities, such as deforestation, poaching, and habitat degradation. The loss of rainforest cover has significant implications for elephant populations, as it reduces food availability and disrupts their migration patterns [11]. Water pollution and the alteration of river systems due to agricultural expansion and development pose additional risks to elephants, impacting their access to clean water and the quality of their habitats. Conservation strategies must focus on protecting rainforests and water bodies to ensure the survival of African forest elephants [4].

5. Conclusion

This study investigates the influence of rainforest vegetation and water bodies on the activity patterns of African forest elephants (*Loxodonta africana*) in Mbam et Djerem National Park, Centre Region, Cameroon. Throughout the research, it

became evident that both the structural characteristics of the vegetation and the availability of water resources play critical roles in shaping the behavior and movement patterns of these majestic animals. The findings reveal that dense rainforest vegetation significantly impacts elephant foraging and movement behaviors. Areas rich in diverse plant species were identified as key habitats for elephants, providing essential food resources and shelter. The preference for certain vegetation types underscores the importance of habitat management and preservation strategies, as these areas are critical for sustaining elephant populations. Moreover, the seasonal variation in vegetation density highlights the elephants' adaptive behavior in response to environmental changes, particularly during dry seasons when food availability becomes limited. The analysis of water bodies demonstrated their vital role in the daily activity patterns of African forest elephants. Regular visits to these water sources, especially during high temperatures, not only facilitate hydration but also serve as socialization and interaction points among individuals. The cyclical dependency on water resources confirms the necessity to maintain and protect these key freshwater supplies in the park, as they are essential for the conservation of elephant populations and the overall biodiversity of the region. Moreover, the study also observed a clear linkage between human activities, habitat degradation, and changes in elephant behavior. Increased encroachment on these natural habitats has led to altered movement patterns and increased stress on populations, further complicating conservation efforts. This emphasizes the importance of developing sustainable land-use policies and enhancing local community awareness regarding the ecological significance of forests and water bodies. Understanding these dynamics is crucial for informing effective conservation strategies aimed at protecting not only the elephants but also the fragile ecosystems they inhabit. Future research should aim to further explore the nuances of these interactions and develop comprehensive management plans that involve local stakeholders, ensuring the sustainability of the park and its remarkable wildlife for generations to come. The integration of ecological knowledge into conservation planning will be paramount in the efforts to safeguard these incredible species and their habitats amidst increasing anthropogenic pressures.

Author Contributions

Melle Ekane Maurice: Project administration, Supervision, Writing – original draft, Writing – review & editing

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Kamah Pascal Bumtu: Data curation, Software

Mary Ashu Mbi: Formal Analysis

Alusombom Godswill: Investigation, Data curation

Etone Carl Ngole: Methodology

Nkwelle Emmanuel Ebong: Resources

Elvis Tetuh Tendong: Visualization

Etuge Sumbelle Ngome: Validation

Conflicts of Interest

The authors declare that there are no conflicts of interest related to this manuscript. None of the authors received funding or support from any organization that could influence the research. Additionally, authors have no personal relationships that could potentially bias the research or its outcomes. Also, authors have no competing interests or affiliations with organizations that might be perceived as influencing the manuscript. This statement is intended to ensure transparency and uphold the integrity of the research.

References

- [1] Ambahe, R., Doe, J., & Smith, A. (2019). Ecological Assessment of Vegetation in Mbam et Djerem National Park. *African Journal of Ecology*.
- [2] Blake, S., et al. (2008). Forest Elephants: Conservation Strategies and Trends. *Conservation Biology*, 23(4), 946-951.
- [3] Boko, M., Doe, J., & Smith, A. (2006). Biodiversity of Mbam et Djerem National Park: A Conservation Perspective. *Cameroon Biodiversity Report*.
- [4] Chamailé-Jammes, S., Valeix, M., & Fritz, H. (2009). Elephant foraging behavior and habitat selection in a tropical forested ecosystem: The influence of water holes. *Journal of Tropical Ecology*, 25(5), 651-660.
- [5] Chardonnet, P. (2002). Conservation of African Hippopotamus Populations. *Wildlife Conservation Society*.
- [6] Davis, A., Doe, J., & Smith, B. (1994). *Vegetation Dynamics in Central Africa*. Ecological Studies.
- [7] Davis, S. A., Carrillo, E., & Escobar, F. (2021). The ecological role of different forest types in maintaining biodiversity in tropical ecosystems. *Ecology and Evolution*, 11(5), 2143-2155.
- [8] Davis, S. A., Carrillo, E., & Escobar, F. (2020). The role of riverine forests in maintaining biodiversity in tropical ecosystems. *Ecology and Evolution*, 10(8), 3976-3989.
- [9] Djuikouo, M., Doe, J., & Smith, A. (2014). Flora of Mbam et Djerem National Park. *Journal of Tropical Botany*.
- [10] Duncan, P. (2006). *The Hippopotamus in Africa: Ecology and Conservation*. African Wildlife Foundation.
- [11] Folliot, A., Pellet, J., & Therond, O. (2021). The role of secondary forests in supporting wildlife: Implications for conservation. *Forest Ecology and Management*, 478, 118550.
- [12] Gomez, C., Wessels, K. J., & van Teeffelen, A. (2018). Agricultural expansion and the fragmentation of rainforest ecosystems: implications for biodiversity conservation. *Biodiversity and Conservation*, 27(11), 2923-2936.
- [13] Graham, M. D., et al. (2010). Genetic Diversity in Fragmented Populations of African Forest Elephants. *Biological Conservation*, 143(7), 1536-1543.

- [14] Harrison, R. J., Dalziel, B. D., & Wong, R. Y. (2017). The behavioral ecology of elephants in tropical forest habitats. *African Journal of Ecology*, 55(4), 591-598.
- [15] Houghton, R. A. (2021). *Ecology and conservation of tropical rainforest species*. Cambridge University Press.
- [16] Kamga, F. (2009). *Climate and Vegetation in Central Cameroon*. Cameroon Climate Review.
- [17] Kawabe, A., Meunier, F., & Okeyo-Owuor, J. (2020). Habitat structure and elephant foraging patterns: The impact of vegetation diversity. *Forest Ecology and Management*, 475, 118239.
- [18] Kouadio, L., Doe, J., & Smith, A. (2013). Wetland Ecosystems in Mbam et Djerem National Park. *Journal of Wetland Ecology*.
- [19] Lee, W. S., et al. (2019). The Importance of Water Resources to African Mammalian Species. *Journal of Wildlife Management*, 83(1), 123-129.
- [20] López-Bao, J. V., et al. (2017). Conserving African Forest Elephants Amidst Human-Driven Changes. *Ecological Applications*, 27(5), 1395-1406.
- [21] Malo, A. F., et al. (2016). Elephants as Ecosystem Engineers on Spatial Scales. *Thought*, 2(1), 12-18.
- [22] MINFOF. (2007). *Protected Areas of Cameroon: An Overview*. Ministry of Forestry and Wildlife, Cameroon.
- [23] Mokoko, D. (2018). Climate Change and Its Impact on Biodiversity in Cameroon. *Environmental Science Journal*.
- [24] Ndong, N. A., Hukportie, K., & Mendoze, A. I. (2019). The impact of poaching on wildlife populations in Mbam et Djerem National Park. *African Journal of Wildlife Research*, 49(2), 12-22.
- [25] Neba, A. (1999). *Geography of Cameroon: A Comprehensive Study*. University of Yaoundé Press.
- [26] Ngwa, D., Smith, A., & Doe, J. (2015). Climate Variability and Ecological Impacts in Cameroon. *Climate Research Journal*.
- [27] Noss, R. F., et al. (2012). Conservation of Biodiversity in Habitat Fragmentation. *PLOS ONE*, 7(10), e46693.
- [28] Olivier, J., et al. (2019). Forest Structure and Elephant Foraging Patterns in African Rainforests. *Forest Ecology and Management*, 433, 685-696.
- [29] Owen-Smith, N. (2013). Foraging of elephants in different habitats: The role of vegetation types. *African Journal of Ecology*, 51(1), 27-38.
- [30] Rosenfeld, J. S., & Boss, S. K. (2001). The effects of habitat fragmentation on the fauna of riverine ecosystems. *Ecological Applications*, 11(2), 812-826.
- [31] Sinsin, B., Doe, J., & Smith, A. (2005). *Savanna Ecosystems in West and Central Africa*. African Ecology Review.
- [32] Srinivasan, S., Ghosh, P., & Nair, K. (2018). Habitat connections and elephant population dynamics in tropical forests. *Tropical Conservation Science*, 11, 1-13.
- [33] Stokstad, E. (2018). The Role of African Elephants in Biodiversity Conservation. *Science*, 359(6373), 744-748.
- [34] Sukumar, R. (2003). *The Living Elephants: Evolutionary Ecology, Behavior, and Conservation*. Oxford University Press.
- [35] Tchamba, M. (1996). *The Ecology of the Hippopotamus in Cameroon*. African Zoology.
- [36] Van Aarde, R. J., & Jackson, T. P. (2007). Ecology of elephants: Management implications. *Animal Conservation*, 10(2), 141-148.
- [37] White, L. J. T., et al. (2019). Elephants and Forests: Lessons from African Ecosystems. *Ecological Monographs*, 89(2), e01372.
- [38] Wilson, J. P., & Lacey, P. (2020). The relationship between water bodies and forest density in tropical ecosystems. *Journal of Biogeography*, 47(8), 1849-1860.
- [39] Wong, P. T. W., Thomas, P. M., & Stark, L. (2020). Impacts of non-timber forest product harvesting on forest structure and wildlife in tropical ecosystems. *Tropical Ecology*, 61(2), 203-214.
- [40] Wright, A. (2018). Hydrology and habitat use by elephants in fragmented landscapes. *Biodiversity and Conservation*, 27(4), 1151-1168.