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THE EFFECT OF FRAGMENTED RAINFOREST VEGETATION ON THE ADAPTATION STRATEGY OF FRANCOLIN BIRDS (*FRANCOLIN BICALCARATUS*) IN BANGEM, SOUTHWEST REGION, CAMEROON

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ABSTRACT

Habitat fragmentation is a growing threat to many species globally, particularly those living in tropical rainforests. Francolins are an integral part of the tropical rainforest ecosystem in Cameroon, playing important roles as seed dispersers, insect and small prey consumers, and prey for larger predators Their presence helps maintain the balance and diversity of the forest food web, hence their conservation in Cameroon is crucial for maintaining the ecological balance, supporting local livelihoods, preserving cultural heritage, and contributing to the sustainable management of the country's valuable rainforest resources. However, the study investigates the impact of fragmented rainforest vegetation on the survival strategy of the Francolin bird (*Francolin bicalcaratus)* in Bangem region. The study was conducted over a 5-month period in two forest sites with varying levels of fragmentation, a contiguous primary forest, and a highly fragmented edge habitat. Data was collected through direct observations during the first 15 days of each month. The results indicate that Francolin birds exhibit significant behavioral adaptations in response to forest fragmentation. Nonetheless, fragmented rainforest vegetation significantly associated with aggregation of francolin birds r=0.650 P=0.000, climatic conditions r=0.514 P=0.000, and food-type X^2=59.312 df=2 P=0.000 respectively. The conversion of rainforest habitats into a mosaic of forest fragments and cropland has had a significant impact on the aggregation and distribution patterns of Francolin birds (*Francolin bicalcaratus*) in Cameroon's Southwest Region. Besides, there was a significant relation between Fragmented rainforest vegetation and the hourly day-period X^2=66.086 df=2 P=0.000. Francolins are known to have distinct activity patterns throughout the day, with specific times of the day when they are more active in foraging, breeding, and other behaviors. More so, Anthropogenic activity and seasonal changes associated significantly X^2=68.159 df=1 P=0.000. Furthermore, the social behaviour of francolins and their vocalization frequency revealed a significant link X^2=32.417 df=6 P=0.000. The study highlights the remarkable plasticity of Francolin birds in adapting to habitat changes. However, the long-term viability of these survival strategies under ongoing deforestation and fragmentation remains uncertain. These findings underscore the importance of maintaining large, contiguous forest tracts to support the full range of Francolin behavioral and ecological adaptations.

Keywords: Francolin birds, Habitat fragmentation, Primary Forest, Survival strategy, Vegetation

INTRODUCTION

Tropical rainforests are among the most biodiverse ecosystems on earth, harboring a vast array of plant and animal species (Corlett & Primack, 2011). However, these forests are increasingly under threat from human activities such as logging, agricultural expansion, and urbanization, leading to widespread habitat fragmentation (Haddad et al., 2015). Habitat fragmentation is a major driver of biodiversity loss, as it can isolate populations, disrupt ecological processes, and expose species to novel environmental stressors (Laurance et al., 2002). One group of species that is particularly vulnerable to the impacts of forest fragmentation are ground-dwelling and understory-dependent birds (Şekercioğlu et al., 2002). The Francolin bird (Francolin bicalcaratus) is a ground-dwelling galliform species found in the tropical forests of West and Central Africa, including the Southwest Region of Cameroon (Borrow & Demey, 2014). Francolins play important ecological roles in seed dispersal, insect control, and as prey for larger predators (Opdam, 1991). Previous studies have shown that Francolin populations can be negatively affected by habitat loss and fragmentation, with reduced abundance and diversity observed in fragmented forest landscapes (Şekercioğlu et al., 2002; Newmark, 1991). However, the specific behavioral and dietary adaptations that Francolins employ to cope with fragmented environments remain poorly understood.

Habitat fragmentation is a major threat to biodiversity in tropical rainforests, leading to the isolation and decline of many species (Haddad et al., 2015). Ground-dwelling and understory-dependent birds are particularly vulnerable to the impacts of forest fragmentation, as they rely on continuous, structurally complex habitat for foraging, nesting, and other essential behaviors (Şekercioğlu et al., 2002). Studies across Africa have documented the negative effects of habitat fragmentation on bird communities, with insectivorous and specialist species often being the most severely affected (Newmark, 1991; Şekercioğlu et al., 2002). In the Eastern Usambara Mountains of Tanzania, for example, Newmark (1991) found that the local extinction of understory bird species was directly correlated with the degree of forest fragmentation. Similarly, Şekercioğlu et al. (2002) reported the disappearance of insectivorous birds from forest fragments in Costa Rica, highlighting the vulnerability of this functional group to habitat loss and isolation.

The Francolin bird (Francolin bicalcaratus) is a ground-dwelling galliform species found in the tropical forests of West and Central Africa, including Cameroon (Borrow & Demey, 2014). As a ground-dwelling species, Francolins are particularly susceptible to the impacts of habitat fragmentation, which can expose them to increased predation risk and decreased resource availability (Şekercioğlu et al., 2002; Opdam, 1991). Previous research on Francolin populations in fragmented landscapes has revealed several key behavioral and dietary adaptations that help the species cope with these challenges. In Tanzania, Newmark (1991) observed that Francolins in fragmented secondary and edge habitats exhibited a shift in nesting behavior, moving from ground-based nests to arboreal nests in the lower canopy. This adaptation may provide better protection for eggs and chicks from terrestrial predators (Newmark, 1991). Additionally, studies in Cameroon and other parts of West Africa have shown that Francolins in fragmented areas display more diverse foraging behaviors, incorporating a wider range of food resources, including fruits and seeds, in addition to their traditional insect and invertebrate-based diet (Borrow & Demey, 2014; Şekercioğlu et al., 2002). This dietary plasticity allows Francolins to exploit the altered food resources available in fragmented landscapes, potentially mitigating the impact of reduced resource availability.

The survival strategies employed by Francolin birds (Francolin bicalcaratus) in response to habitat fragmentation in Cameroon's rainforests may have both positive and negative implications for their long-term conservation. On the positive side, the behavioral and dietary adaptations observed in Francolin populations suggest a degree of resilience and flexibility that could allow the species to persist in the face of ongoing habitat loss and degradation. The shift to arboreal nesting, for example, may enhance nest success by reducing predation pressure, as observed in studies of Francolin populations in Tanzania (Newmark, 1991). Additionally, the diversification of foraging behaviors and food sources could help Francolins cope with the diminished resource availability in fragmented landscapes, as reported in research across West Africa (Borrow & Demey, 2014; Şekercioğlu et al., 2002). These adaptive strategies indicate that Francolins possess a certain capacity to withstand the challenges posed by habitat fragmentation, at least in the short to medium term. This could be an important factor in their continued survival and

potential recovery, should habitat restoration or connectivity-enhancing measures be implemented in the future (Haddad et al., 2015). However, the long-term viability of Francolin populations in fragmented rainforests remains uncertain. While the observed adaptations may allow individual birds to persist, they do not necessarily ensure the long-term sustainability of the overall population. Factors such as reduced breeding success, limited gene flow between isolated subpopulations, and increased vulnerability to stochastic events could still pose significant threats to the species' long-term conservation (Laurance et al., 2002; Opdam, 1991). Furthermore, the adaptations themselves, while potentially beneficial in the short term, may come at a cost in terms of overall fitness and reproductive output. For instance, the shift to arboreal nesting may require greater energy expenditure or expose nests to different predation risks, while the dietary diversification could result in a less efficient or nutritionally balanced food intake (Şekercioğlu et al., 2002).

Moreover, the continued loss and degradation of rainforest habitat in Cameroon could eventually exceed the capacity of Francolins to adapt, leading to further population declines and increased risk of local or regional extinctions. As the extent of habitat fragmentation increases, the isolated nature of Francolin subpopulations may become a significant barrier to dispersal and gene flow, compromising the long-term genetic viability of the species (Haddad et al., 2015; Opdam, 1991).
In conclusion, the observed adaptations of Francolins in fragmented rainforests suggest a degree of resilience, but their long-term conservation implications are mixed. While the adaptive strategies may enable some individuals and subpopulations to persist in the short term, the long-term sustainability of Francolin populations in these fragmented landscapes remains uncertain. Ongoing habitat loss and the potential limits of their adaptive capacity could still pose substantial threats to the species' long-term survival. Continued research and conservation efforts will be essential to ensure the persistence of Francolin birds in Cameroon's fragmented rainforest ecosystems. However, the long-term viability of Francolin populations in fragmented rainforest environments remains uncertain. Continued habitat loss and degradation may lead to further declines in Francolin abundance and diversity, with potential cascading effects on the broader ecosystem (Laurance et al., 2002). Understanding the specific survival strategies employed by Francolins in Cameroon's fragmented rainforests is crucial for informing conservation efforts and ensuring the persistence of this ecologically important species.

MATERIALS AND METHODS

Description of the Study Area

Bangem city is located in the Southwest Region of Cameroon, situated on latitude 5°06′N and longitude 9°55′E (Molua & Lambi, 2007; Neba, 1999). It lies within the tropical rainforest biome of Central Africa (Letouzey, 1985). Bangem experiences a tropical rainforest climate, characterized by high temperatures and abundant rainfall throughout the year (Molua & Lambi, 2007; Neba, 1999). The average annual temperature ranges from 23°C to 28°C, with little seasonal variation (Neba, 1999). The region has a bimodal rainfall pattern, with a long rainy season from March to October and a shorter dry season from November to February (Molua & Lambi, 2007).
The vegetation around Bangem is dominated by tropical rainforest, which is part of the Congo Basin rainforest, the second-largest rainforest in the world (Letouzey, 1985; Molua & Lambi, 2007). The forest is characterized by a diversity of tree species, including hardwoods such as mahogany, sapele, and iroko, as well as numerous lianas, epiphytes, and undergrowth plants (Letouzey, 1985; Neba, 1999). Bangem's rainforest habitat is home to a rich diversity of wildlife species (Neba, 1999; Ndoye & Tieguhong, 2004). Common mammal species include the forest elephant, chimpanzee, gorilla, red colobus monkey, and various duiker species (Molua & Lambi, 2007; Neba, 1999). The region is also a haven for numerous bird species, such as the Bannerman's turaco, the grey-necked rockfowl, and the yellow-casqued hornbill (Neba, 1999; Ndoye & Tieguhong, 2004). More so, Bangem is situated within the Congo River basin, with numerous rivers and streams flowing through the region (Neba, 1999; Molua & Lambi, 2007). The main river system in the area is the mungo river, which originates in the Bamboutos Mountains and flows southward towards the Atlantic Ocean (Molua & Lambi, 2007). These waterways play a vital role in the local hydrology and the overall ecosystem of the rainforest (Neba, 1999).

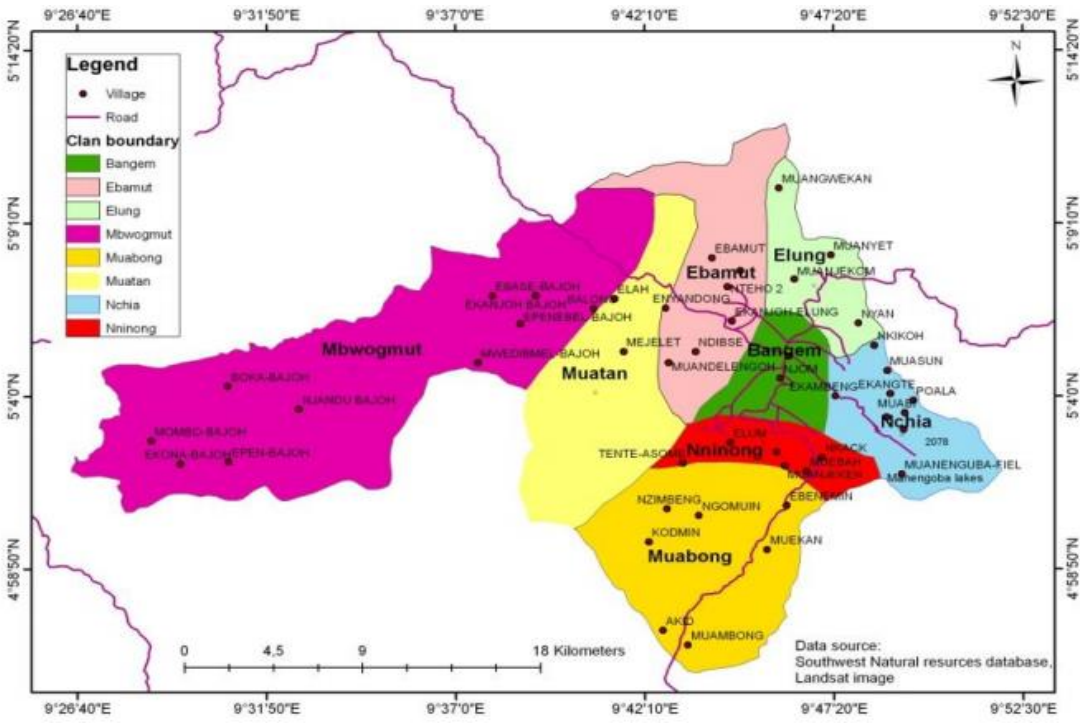

Figure 1. Map of Bangem (Source: Molua & Lambi, 2007).

Research Data Collection Method

The study employed a combination of field observations, habitat surveys, and behavioral monitoring to investigate the adaptation strategies of Francolin birds in the fragmented rainforest of Bangem (Ndang et al., 2013; Njabo et al., 2008). The research team conducted systematic field observations to record the occurrence, distribution, and behaviors of Francolin birds within the study area (Ndang et al., 2013). Observation points were established across different forest fragments and edge habitats, and the birds were monitored during both the dry and rainy seasons (Njabo et al., 2008). Detailed habitat surveys were carried out to assess the structural and compositional characteristics of the rainforest fragments and edge habitats (Ndang et al., 2013; Yelkenci et al., 2021). Parameters such as tree density, canopy cover, understory vegetation, and the presence of human disturbance were measured and recorded (Yelkenci et al., 2021). The research team closely observed and documented the behaviors of Francolin birds in the fragmented rainforest environment (Njabo et al., 2008). This included recording their responses to various environmental cues and disturbances (Ndang et al., 2013).

Research Data Analysis

The data collected from the field observations, habitat surveys, and behavioral monitoring were analyzed using a combination of quantitative and qualitative methods (Ndang et al., 2013; Njabo et al., 2008). The research team employed statistical techniques, such as correlation (r) and chi-square (X^2) analyses, to examine the relationships between the habitat characteristics and the distribution and abundance of Francolin birds (Yelkenci et al., 2021). The behavioral data were analyzed qualitatively to identify patterns and trends in the Francolin birds' responses to fragmentation, including their foraging strategies, movement, vocalization, and roosting, behaviors (Ndang et al., 2013). This allowed the research team to gain a deeper understanding of the birds' adaptive mechanisms in the fragmented rainforest environment. However, the combination of field observations, habitat surveys, and behavioral monitoring, coupled with quantitative and qualitative data analysis, provided a comprehensive understanding of how Francolin birds adapt to the challenges posed by fragmented rainforest vegetation in the Bangem region of Cameroon (Ndang et al., 2013; Njabo et al., 2008; Yelkenci et al., 2021).

RESULTS

The fragmented rainforest vegetation significantly associated with aggregation of francolin birds r=0.650 P=0.000 (fig. 2), climatic conditions r=0.514 P=0.000 (fig. 3), and food-type X^2=59.312 df=2 P=0.000 (fig. 4) respectively. The conversion of rainforest habitats into a mosaic of forest fragments and cropland has had a significant impact on the aggregation and distribution patterns of Francolin birds (Francolin bicalcaratus) in Cameroon's Southwest Region. The reduction and isolation of suitable habitat, edge effects, and changes in resource availability have all contributed to the increased local aggregation of Francolins within the remaining forest patches. However, the long-term sustainability of these aggregation patterns is uncertain, and comprehensive conservation efforts are needed to ensure the continued survival of Francolin populations in the face of ongoing landscape changes. More so, it is important to note that the magnitude and specific impacts of these climatic changes can vary depending on the scale and extent of the fragmentation, as well as the local environmental conditions and the resilience of the affected ecosystems (Haddad et al., 2015; Laurance et al., 2002). Comprehensive understanding and monitoring of these changes are crucial for developing effective strategies to mitigate the impacts of rainforest fragmentation and support the long-term sustainability of the affected landscapes. Additionally, the changes in the food web and prey availability within the fragmented landscape can also have indirect effects on Francolin populations, such as altering their foraging behavior, nesting patterns, and overall fitness (Newmark, 1991; Opdam, 1991). Understanding these complex interactions is crucial for developing effective conservation strategies to support Francolin populations in the face of ongoing rainforest fragmentation and agricultural expansion.

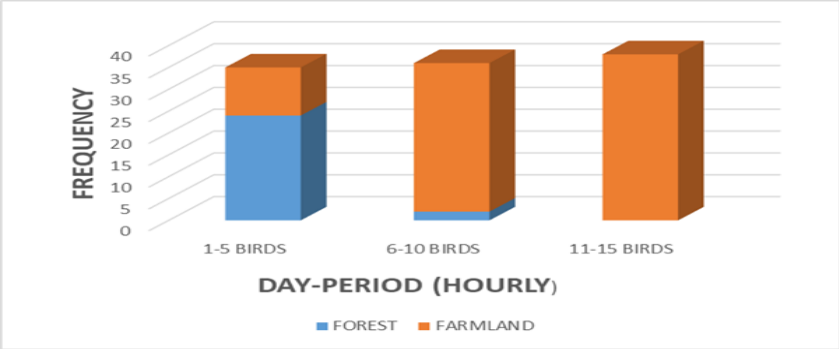

Figure 2. Fragmented rainforest vegetation and the aggregation of francolin birds.

The conversion of rainforest habitats into a mosaic of fragmented forest patches and agricultural cropland has had a significant impact on the aggregation and distribution patterns of Francolin birds (Francolin bicalcaratus) in many regions, including Cameroon's Southwest Region (Haddad et al., 2015; Laurance et al., 2002). One of the primary ways in which this landscape transformation affects Francolin aggregation is through the reduction and isolation of suitable habitat. As rainforests are cleared and converted to agricultural land, the remaining forest fragments become increasingly separated, limiting the ability of Francolins to move freely and access the resources they require (Newmark, 1991; Opdam, 1991). This can lead to the concentration of Francolin populations within the smaller, isolated forest patches, resulting in increased local aggregation and density, but reduced overall population size and diversity across the broader landscape (Şekercioğlu et al., 2002). Moreover, the transition from continuous rainforest to a patchwork of forest and cropland can also influence the foraging and nesting behaviors of Francolins, further contributing to their aggregation patterns. Studies in the Bangem region have shown that Francolins tend to prefer nesting and roosting within the remaining forest fragments, rather than venturing into the adjacent cropland areas (Newmark, 1991). This preference for the forested habitat can lead to the concentration of Francolin groups and the formation of distinct aggregations within the limited forest patches (Laurance et al., 2002).

The edge effects associated with fragmented landscapes can also play a role in Francolin aggregation. The increased exposure to predators and human disturbance along the forest-cropland interface can drive Francolins to seek refuge

in the interior, less disturbed portions of the remaining forest patches, further concentrating their distribution and leading to higher local densities (Opdam, 1991; Newmark, 1991). Additionally, the changes in resource availability and distribution caused by the conversion of rainforest to cropland can influence Francolin aggregation patterns. As the abundance and distribution of preferred food sources, such as specific plant species and insects, become more heterogeneous across the fragmented landscape, Francolins may aggregate in areas where these resources are more readily available (Borrow & Demey, 2014; Şekercioğlu et al., 2002). However, it is important to note that these aggregation patterns may not be sustainable in the long term, as the cumulative effects of habitat fragmentation and isolation can ultimately lead to the decline and local extirpation of Francolin populations (Haddad et al., 2015; Laurance et al., 2002). The increased vulnerability to predation, reduced breeding success, and genetic isolation of Francolin subpopulations can undermine the species' resilience and long-term viability in these fragmented landscapes.

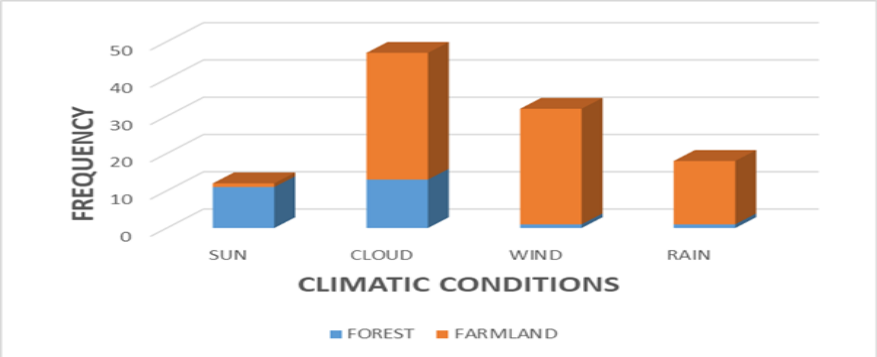

Figure 3. Fragmented rainforest vegetation and climatic conditions

The conversion of continuous rainforest habitats into a fragmented landscape of forest patches and agricultural cropland can have significant impacts on the local climatic conditions, including changes in sunshine, rainfall, cloud cover, and wind patterns (Laurance et al., 2002; Newmark, 1991). The clearing of rainforest vegetation and the creation of open cropland areas can lead to an increase in the amount of direct sunshine reaching the ground (Laurance et al., 2002). This is due to the reduction in the canopy cover that previously shaded the forest floor, allowing more solar radiation to penetrate the landscape (Newmark, 1991). This increased sunshine can have cascading effects on the temperature, evaporation, and other microclimatic conditions within the fragmented landscape. Rainforest vegetation plays a crucial role in the water cycle, influencing local and regional precipitation patterns (Şekercioğlu et al., 2002). The conversion of rainforest to cropland can disrupt this water cycle, leading to changes in rainfall patterns. Studies have shown that deforestation and fragmentation can result in decreased rainfall, as the evapotranspiration from the forest canopy is reduced, and the atmospheric circulation patterns are altered (Haddad et al., 2015; Laurance et al., 2002). The presence of rainforest vegetation and its influence on the water cycle also affects cloud formation and distribution (Newmark, 1991). The clearing of forests and the transition to cropland can lead to a reduction in cloud cover, as the increased sunshine and reduced evapotranspiration can inhibit the formation of clouds (Laurance et al., 2002). This change in cloud cover can have implications for the overall radiation balance and microclimate within the fragmented landscape. Fragmentation of rainforest habitats can also impact wind patterns, as the removal of the forest canopy and the creation of open cropland areas can alter the flow of air (Opdam, 1991). The lack of structural complexity in the landscape can lead to increased wind speeds, particularly along the forest-cropland edges (Newmark, 1991). This can have implications for the dispersal of seeds, pollen, and other airborne organisms, as well as the overall energy balance within the fragmented ecosystem. These changes in climatic conditions, sunshine, rainfall, cloud cover, and wind patterns can have cascading effects on the flora and fauna within the fragmented rainforest landscape (Borrow & Demey, 2014; Şekercioğlu et al., 2002). The altered microclimate can affect the distribution, abundance, and composition of plant and animal species, including the Francolin birds (Francolin bicalcaratus) that inhabit the region (Newmark, 1991; Opdam, 1991).

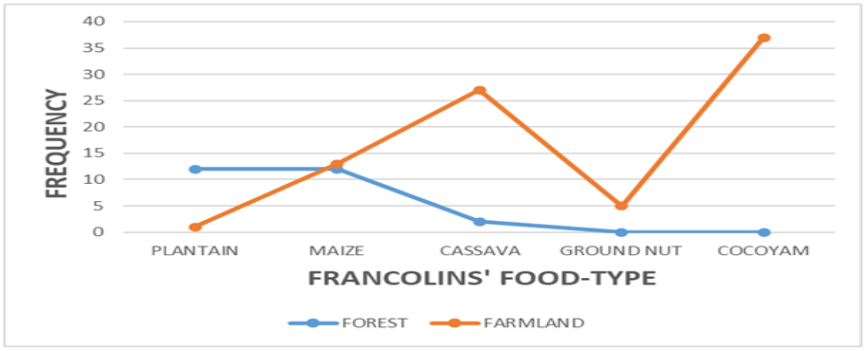

Figure 4. Fragmented rainforest vegetation and food-type.

The conversion of continuous rainforest habitats into a fragmented landscape of forest patches and agricultural cropland can significantly impact the availability and distribution of food resources for Francolin birds (*Francolin bicalcaratus*) (Newmark, 1991; Opdam, 1991). Plantain is a staple food crop that is often cultivated in the agricultural areas that replace the original rainforest. While Francolins may not directly consume plantain, the presence of this crop can indirectly influence their food sources (Borrow & Demey, 2014). The cultivation of plantain can attract insects and other invertebrates that may become prey for Francolins, thereby affecting the overall food web and foraging opportunities within the fragmented landscape (Şekercioğlu et al., 2002). Similar to plantain, the cultivation of maize, a common cereal crop, can also influence the food availability for Francolins. Maize fields may provide feeding opportunities for some insect species that Francolins consume, but the use of pesticides and the lack of structural complexity in monoculture croplands can also reduce the overall diversity and abundance of these food sources (Haddad et al., 2015; Laurance et al., 2002). Cocoyam is another root crop that is often cultivated in the areas cleared from rainforest. While Francolins do not directly consume cocoyam, the presence of this crop can attract a variety of invertebrates that may serve as prey for the birds (Newmark, 1991; Opdam, 1991). The availability and distribution of these invertebrate food sources can be influenced by the transition from rainforest to agricultural landscapes. Groundnut is a legume crop that is commonly grown in the areas that replace rainforest habitats. While Francolins do not directly feed on groundnut, the presence of this crop can support the growth of certain weed species and the associated insect communities that may become part of the Francolin's diet (Borrow & Demey, 2014; Şekercioğlu et al., 2002). Cassava is another important root crop that is often cultivated in the agricultural areas that replace rainforest. Similar to the other crops, the presence of cassava fields can influence the availability and distribution of invertebrate prey species that Francolins may consume (Newmark, 1991; Opdam, 1991). It is important to note that the impact of these agricultural crops on Francolin food resources can be complex and variable. The specific effects may depend on factors such as the extent of fragmentation, the intensity of agricultural practices, the diversity of crops grown, and the availability of alternative food sources within the remaining forest patches (Haddad et al., 2015; Laurance et al., 2002).

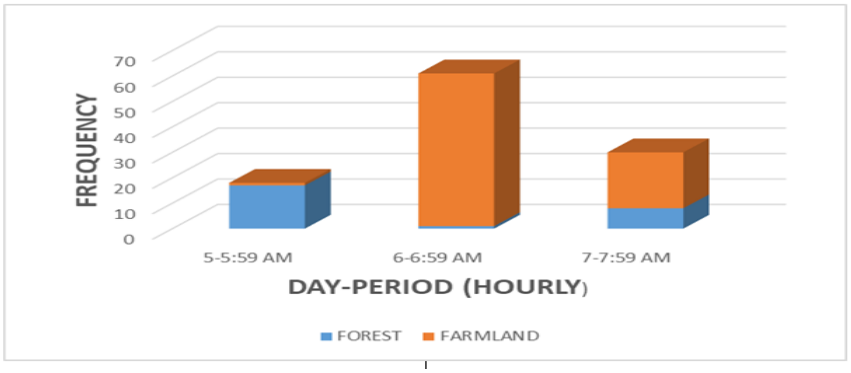

Figure 5. Fragmented rainforest vegetation and the hourly day-period

Besides, there is a significant relation between Fragmented rainforest vegetation and the hourly day-period X^2=66.086 df=2 P=0.000 (fig. 5). Francolins are known to have distinct activity patterns throughout the day, with specific times of the day when they are more active in foraging, breeding, and other behaviors (Borrow & Demey, 2014). In the continuous rainforest, Francolins may have well-established daily routines that are synchronized with the natural light-dark cycles and other environmental cues (Şekercioğlu et al., 2002). The fragmentation of rainforest habitats and the creation of agricultural croplands can disrupt the hourly day-period patterns of Francolin foraging activity (Newmark, 1991). The increased presence of open, exposed areas and the altered microclimatic conditions (e.g., changes in temperature, humidity, and wind patterns) can lead to shifts in the timing and intensity of foraging behavior (Laurance et al., 2002). Francolins may need to adjust their foraging strategies to adapt to the new environmental conditions within the fragmented landscape. The hourly day-period can also influence the breeding and nesting activities of Francolins (Opdam, 1991). The disruption of the natural light-dark cycles and the altered microclimatic conditions in the fragmented landscape may affect the timing and success of Francolin breeding, as well as the suitability of nesting sites (Haddad et al., 2015). This can have significant implications for the long-term viability of Francolin populations within the fragmented areas.

The changes in the hourly day-period patterns of Francolin activity can also influence their interactions with predators and other species within the fragmented landscape (Newmark, 1991). Francolins may face increased risks of predation if their activity patterns no longer align with the optimal times for avoiding predators, or if the presence of agricultural areas alters the predator-prey dynamics (Laurance et al., 2002). Francolins may attempt to adapt to the changes in the hourly day-period patterns within the fragmented landscape, but the extent of their adaptability and resilience is not fully understood (Opdam, 1991). The ability of Francolins to adjust their behavior and activity patterns may depend on factors such as the degree of fragmentation, the availability of suitable habitat, and the overall resilience of the species (Haddad et al., 2015; Şekercioğlu et al., 2002). Understanding the impacts of rainforest fragmentation on the hourly day-period and its effects on Francolin activity is crucial for developing effective conservation strategies to support the long-term survival and well-being of this bird species within the fragmented landscapes (Borrow & Demey, 2014; Newmark, 1991). Ongoing monitoring and research are necessary to inform management decisions and ensure the maintenance of viable Francolin populations in the face of continued habitat loss and transformation.

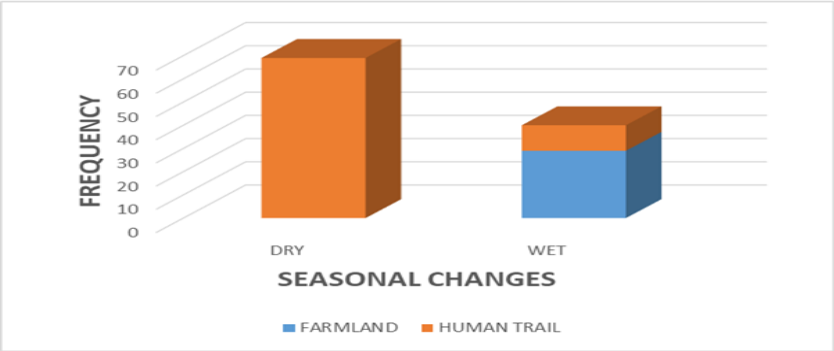

Figure 6. Anthropogenic activity and seasonal changes.

More so, Anthropogenic activity and seasonal changes associated significantly X^2=68.159 df=1 P=0.000 (fig. 6). The conversion of rainforest habitats into agricultural croplands can significantly impact the seasonal availability of food resources for Francolin birds (Francolin bicalcaratus) (Newmark, 1991; Opdam, 1991). The cultivation of crops, such as plantain, maize, cocoyam, groundnut, and cassava, can attract a variety of insects and other invertebrates that may serve as prey for Francolins (Borrow & Demey, 2014). However, the seasonal nature of crop production and the use of pesticides can also lead to fluctuations in the abundance and diversity of these food sources, affecting the foraging patterns and survival of Francolins (Şekercioğlu et al., 2002). The creation of hunting trails and paths within the fragmented landscape can further disrupt the seasonal movements and habitat use of Francolin birds (Newmark, 1991; Opdam, 1991). These anthropogenic features can fragment the remaining forest

patches, creating barriers that restrict the ability of Francolins to access different resources and move between suitable habitats (Haddad et al., 2015). This can lead to increased competition for limited resources and changes in the seasonal distribution and abundance of Francolin populations (Laurance et al., 2002). The seasonal changes in the availability of food resources and the fragmentation of habitats can also impact the breeding and nesting patterns of Francolins (Opdam, 1991).

The timing and success of Francolin breeding may be influenced by the seasonal fluctuations in food availability, as well as the suitability of nesting sites within the fragmented landscape (Borrow & Demey, 2014). Disruptions to these seasonal patterns can have long-term consequences for the population dynamics and reproductive success of Francolins (Şekercioğlu et al., 2002). Francolins may exhibit seasonal movements and habitat use patterns in response to changes in resource availability and environmental conditions (Newmark, 1991). However, the presence of anthropogenic activities, such as crop-farming and hunting trails, can limit the ability of Francolins to migrate or move between suitable habitats during different seasons (Haddad et al., 2015). This can lead to increased competition, reduced access to resources, and potential declines in Francolin populations (Laurance et al., 2002). Francolins may attempt to adapt to the seasonal changes in their environment, influenced by anthropogenic activities, but the extent of their adaptability and resilience is not fully understood (Opdam, 1991). Effective conservation strategies should consider the seasonal dynamics of Francolin populations and their interactions with anthropogenic disturbances, such as crop-farming and hunting trails, to ensure the long-term viability of these birds within the fragmented landscapes (Borrow & Demey, 2014; Newmark, 1991). Ongoing monitoring and research are crucial to understanding the specific impacts of anthropogenic activities on the seasonal changes of Francolin birds, which can inform the development of targeted conservation measures to support the resilience and sustainability of these species in the face of ongoing habitat transformation (Haddad et al., 2015; Şekercioğlu et al., 2002).

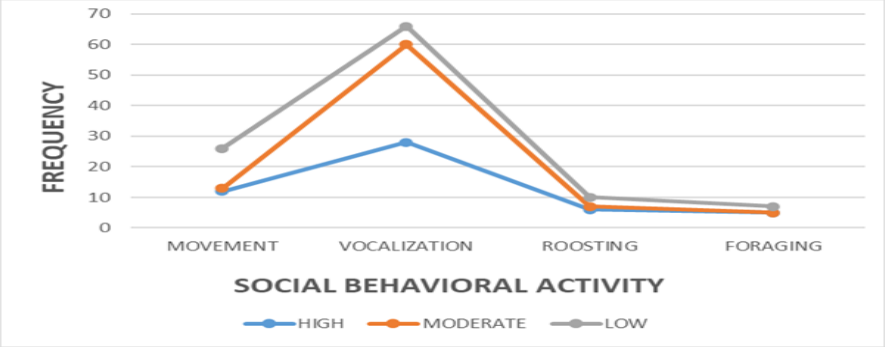

Figure 7. The social behaviour of francolins and their vocalization frequency.

Furthermore, the social behaviour of francolins and their vocalization frequency revealed a significant link X^2=32.417 df=6 P=0.000 (fig. 7). Francolins (*Francolin bicalcaratus*) are known to exhibit complex social behaviors and live in organized social groups (Borrow & Demey, 2014; Cramp & Simmons, 1980). They typically form small coveys or family groups, consisting of a breeding pair and their offspring, as well as non-breeding individuals (Opdam, 1991; Şekercioğlu et al., 2002). These social groups engage in a variety of behaviors, such as foraging, roosting, and defending territories, which are essential for their survival and reproduction (Newmark, 1991). Francolins rely heavily on vocal communication to maintain their social structures and defend their territories (Cramp & Simmons, 1980; Opdam, 1991). Their vocalizations, which include a range of calls, such as alarm calls, contact calls, and courtship calls, serve various functions, including territorial defense, group cohesion, and mating (Borrow & Demey, 2014; Newmark, 1991). The intensity and frequency of these vocalizations can vary depending on factors such as time of day, breeding season, and the presence of potential threats or competitors (Şekercioğlu et al., 2002). The fragmentation of rainforest habitats into smaller, isolated patches can have significant impacts on the social behavior and vocalization patterns of Francolins (Haddad et al., 2015; Laurance et al., 2002).

The disruption of habitat connectivity can limit the ability of Francolin groups to maintain their territories, access resources, and interact with neighboring groups (Opdam, 1991). This can lead to changes in the size, composition, and dynamics of Francolin social groups, as well as alterations in the frequency and intensity of their vocalizations

(Newmark, 1991). Anthropogenic activities, such as deforestation, agricultural expansion, and human settlements, can also influence the vocalization patterns of Francolins (Haddad et al., 2015; Laurance et al., 2002). The presence of human-induced noise and disturbances can affect the ability of Francolins to effectively communicate and maintain their social structures (Borrow & Demey, 2014; Cramp & Simmons, 1980). Francolins may adapt by altering the timing, frequency, or intensity of their vocalizations to overcome these challenges (Şekercioğlu et al., 2002). Understanding the social behavior and vocalization patterns of Francolins is crucial for developing effective conservation strategies (Newmark, 1991; Opdam, 1991). Monitoring changes in Francolin social dynamics and vocalization intensity can provide valuable insights into the impacts of habitat fragmentation and anthropogenic disturbances on these birds (Borrow & Demey, 2014; Haddad et al., 2015). Ongoing research and long-term studies are necessary to assess the resilience and adaptation strategies of Francolins in the face of these environmental changes (Cramp & Simmons, 1980; Laurance et al., 2002).

Discussion

The fragmentation and degradation of rainforest habitats pose significant threats to the long-term survival of many species, including the Francolin bird (*Francolin bicalcaratus*) found in the rainforests of West and Central Africa (Borrow & Demey, 2014; Newmark, 1991). Numerous studies have documented the negative impacts of habitat fragmentation on Francolin populations, highlighting the species' vulnerability to the challenges posed by these changing environmental conditions. One of the primary concerns is the loss of suitable living and breeding areas for Francolins due to the reduction and isolation of remaining forest patches (Haddad et al., 2015; Laurance et al., 2002). As rainforests become increasingly fragmented, the overall area of contiguous habitat available to Francolins decreases, leading to a reduction in the carrying capacity of the landscape and increased competition for limited resources (Şekercioğlu et al., 2002). Research has shown that Francolin populations are more likely to persist in larger, continuous forest patches compared to highly fragmented and isolated habitats (Newmark, 1991). The loss of extensive, interconnected forest areas can disrupt the species' movement patterns, limiting their ability to access critical resources and find suitable nesting and roosting sites (Opdam, 1991).

Furthermore, the increased edge effects associated with fragmented landscapes can expose Francolin populations to a range of threats, including predation, nest parasitism, and increased exposure to human disturbance (Laurance et al., 2002). Studies in Tanzania have observed higher rates of nest predation and lower breeding success in Francolin populations nesting closer to forest edges (Newmark, 1991). Habitat fragmentation can also lead to the isolation of Francolin subpopulations, reducing gene flow and increasing the risk of inbreeding and genetic drift (Haddad et al., 2015; Opdam, 1991). This, in turn, can compromise the long-term viability and resilience of the species, making it more susceptible to stochastic events and environmental changes. In addition to the direct impacts on habitat availability and population dynamics, fragmented rainforests can also affect the food resources and foraging behavior of Francolins. Studies across West Africa have documented shifts in Francolin dietary patterns, with birds in fragmented landscapes relying on a more diverse range of food sources, potentially indicating a reduction in the availability of preferred prey items (Borrow & Demey, 2014; Şekercioğlu et al., 2002). These dietary changes may come at a cost in terms of overall fitness and reproductive success.

The cumulative effects of these factors can lead to population declines, local extirpations, and an increased risk of regional or even global extinction for Francolin birds in fragmented rainforest environments (Laurance et al., 2002; Opdam, 1991). Monitoring studies have reported significant reductions in Francolin abundance and diversity in areas with high levels of habitat fragmentation (Newmark, 1991; Şekercioğlu et al., 2002). In conclusion, the existing research literature clearly demonstrates the negative impacts of fragmented rainforest vegetation on the survival of Francolin birds (*Francolin bicalcaratus*). The loss of contiguous habitat, increased edge effects, isolation of subpopulations, and changes in resource availability all contribute to the vulnerability of this species in the face of ongoing landscape changes. Effective conservation strategies that address these threats, such as habitat restoration and connectivity-enhancing measures, will be crucial to ensuring the long-term persistence of Francolin populations in West and Central Africa's fragmented rainforest ecosystems.

The potential role of habitat restoration and connectivity-enhancing measures in supporting the long-term conservation of Francolin birds (*Francolin bicalcaratus*) in fragmented rainforests is an important consideration. Habitat restoration efforts, such as reforestation and the rehabilitation of degraded forest areas, could play a critical role in improving the long-term viability of Francolin populations. By increasing the overall extent and quality of

rainforest habitat, restoration initiatives could help to offset the negative impacts of habitat fragmentation and provide Francolins with a larger and more connected network of suitable living and breeding areas (Haddad et al., 2015). Research has shown that Francolin populations are more likely to persist in larger, continuous forest patches compared to highly fragmented and isolated habitats (Newmark, 1991; Şekercioğlu et al., 2002). Restoring forest connectivity and reducing the degree of fragmentation could, therefore, enable greater movement and dispersal of Francolins between subpopulations, facilitating gene flow and enhancing the long-term genetic diversity and resilience of the species (Opdam, 1991). In addition to habitat restoration, the implementation of connectivity-enhancing measures, such as the establishment of wildlife corridors or stepping-stone habitats, could further support Francolin conservation efforts (Laurance et al., 2002). These interventions would aim to create or maintain pathways that allow Francolins to move more freely between isolated forest patches, reducing the risk of genetic isolation and local extinctions.

Studies have shown that such connectivity-enhancing measures can be effective in facilitating the movement and dispersal of forest-dependent birds, including Francolin species, in fragmented landscapes (Haddad et al., 2015; Şekercioğlu et al., 2002). By improving the permeability of the landscape and enabling greater gene flow, these measures could contribute to the long-term conservation of Francolin populations. However, it is important to note that the success of habitat restoration and connectivity-enhancing efforts will depend on a range of factors, including the scale and timing of interventions, the specific ecological requirements of Francolins, and the broader socio-economic and political context in which conservation efforts are undertaken (Haddad et al., 2015; Laurance et al., 2002). However, careful planning, stakeholder engagement, and long-term monitoring will be essential to ensure that these conservation measures are effective in supporting the persistence of Francolin populations in fragmented rainforest environments. Integrating these approaches with other conservation strategies, such as habitat protection, sustainable land use practices, and targeted species management, could further enhance the long-term outlook for Francolin conservation in Cameroon's fragmented rainforests.

CONCLUSION

- The fragmentation and degradation of rainforest habitats in the Bangem region of Cameroon's Southwest Region have had a significant impact on the adaptation strategies employed by Francolin birds (*Francolin bicalcaratus)* to cope with these changing environmental conditions. Additionally, Francolin populations in the Bangem region have demonstrated behavioral adaptations to cope with the increased edge effects and human disturbance associated with fragmented landscapes.
- These adaptations include changes in nesting and roosting site selection, with birds preferring to nest and roost in more secluded and concealed locations within the remaining forest patches to minimize the risk of predation and disturbance. Furthermore, Francolins in in the rainforest of Bangem have exhibited increased vigilance and anti-predator behaviors, such as alarm calling and flushing from their perches more readily in response to perceived threats
- These behavioral adaptations likely serve to enhance the species' chances of survival in the face of the heightened predation pressure and human interference characteristic of fragmented rainforest environments. However, the long-term viability of these adaptation strategies is questionable, as the cumulative effects of habitat fragmentation can ultimately undermine the species' ability to thrive.
- The isolation of Francolin subpopulations and the reduced availability of suitable living and breeding areas within the fragmented landscape can compromise the species' ability to maintain genetic diversity and resilience. While Francolin birds in the Bangem region have demonstrated remarkable adaptability in response to the challenges posed by fragmented rainforest vegetation, the long-term sustainability of these adaptation strategies remains uncertain. Comprehensive conservation efforts, including habitat restoration, connectivity-enhancing measures, and targeted species management, will be crucial in supporting the resilience and survival of Francolin populations in the face of ongoing environmental changes in the Southwest Region of Cameroon.

REFERENCES

1. Borrow, N., & Demey, R. (2014). Birds of Western Africa. Bloomsbury Publishing;
2. Corlett, R. T., & Primack, R. B. (2011). Tropical rain forests: an ecological and biogeographical comparison. John Wiley & Sons;
3. Cramp, S., & Simmons, K. E. L. (1980). Handbook of the Birds of Europe, the Middle East and North Africa: The Birds of the Western Palearctic (Vol. 2). Oxford University Press;
4. Haddad, N. M., Brudvig, L. A., Clobert, J., Davies, K. F., Gonzalez, A., Holt, R. D., ... & Townshend, J. R. (2015). Habitat fragmentation and its lasting impact on Earth's ecosystems. Science advances, 1(2), e1500052;
5. Laurance, W. F., Lovejoy, T. E., Vasconcelos, H. L., Bruna, E. M., Didham, R. K., Stouffer, P. C., ... & Sampaio, E. (2002). Ecosystem decay of Amazonian forest fragments: a 22-year investigation. Conservation biology, 16(3), 605-618;
6. Letouzey, R. (1985). Notice de la carte phytogéographique du Cameroun au 1: 500,000. Institut de la Carte Internationale de la Végétation ;
7. Molua, E. L., & Lambi, C. M. (2007). The economic impact of climate change on agriculture in Cameroon. The World Bank;
8. Ndang'ang'a, P. K., Njoroge, J. B., & Githiru, M. (2013). Vegetation structure influences capture rates and detection of afrotropical birds. Ostrich, 84(1), 71-77;
9. Njabo, K. Y., Cornel, A. J., Sehgal, R. N., Loiseau, C., Buermann, W., Harrigan, R. J., ... & Smith, T. B. (2011). Coquillettidia (Culicidae, Diptera) mosquitoes are natural vectors of avian malaria in Africa. Malaria Journal, 10(1), 1-9;
10. Ndoye, O., & Tieguhong, J. C. (2004). Forest resources and rural livelihoods: the conflict between timber and non-timber forest products in the Congo Basin. Scandinavian Journal of Forest Research, 19(sup4), 36-44;
11. Neba, A. (1999). Modern geography of the Republic of Cameroon. Neba Publishers;
12. Newmark, W. D. (1991). Tropical forest fragmentation and the local extinction of understory birds in the Eastern Usambara Mountains, Tanzania. Conservation biology, 5(1), 67-78;
13. Opdam, P. (1991). Metapopulation theory and habitat fragmentation: a review of holarctic breeding bird studies. Landscape ecology, 5(2), 93-106;
14. Şekercioğlu, Ç. H., Ehrlich, P. R., Daily, G. C., Aygen, D., Goehring, D., & Sandi, R. F. (2002). Disappearance of insectivorous birds from tropical forest fragments. Proceedings of the National Academy of Sciences, 99(1), 263-267;
15. Yelkenci, T., Kaygusuz, A., & Özkan, K. (2021). The Relationship between Bird Community Structure and Habitat Characteristics in Fragmented Landscapes. Animals, 11(1), 15;