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The Impact of Climate Change on Francolins (*Francolin bicalcaratus*) habitat Adaptation in the farming Areas of Bangem City, Southwest Region Cameroon

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ABSTRACT: Climate change is one of the greatest threats facing the natural world today, with far-reaching consequences for ecosystems, wildlife, and human communities alike. Rising global temperatures, shifting precipitation patterns, and more extreme weather events are dramatically altering the environmental conditions that species have adapted to over centuries and millennia. For many vulnerable animal and plant populations, the pace of these changes far exceeds their ability to adapt, putting their long-term survival at risk. This study investigated the impact of climate change on the habitat adaptation of Francolins (*Francolin bicalcaratus*), a species of francolin bird found in the farming areas of Bangem. Additionally, Bangem region was selected for this study due to its important Francolin populations as well as the rapidly changing environmental conditions being experienced in this agricultural landscape. The study was conducted over a 5-month period, and research data collection through field observations, and interviews with local farmers and community members. Key parameters measured included changes in temperature, precipitation patterns, vegetation cover, and Francolin population dynamics. This study revealed a significant association of climatic conditions on birds' aggregation behavior X^2=60.861 df6 P=0.000, the social behavior of francolin birds X^2=28.861 df9 P=0.001, and human activities in francolin ecosystem r=0.462 P=0.000 respectively. The role of climatic changes on the aggregation behavior of Francolins (*Francolin bicalcaratus*) has been a subject of increasing research interest, as climate change continues to impact ecosystems worldwide. Also, the study showed an association between climatic conditions and various food

consumed by francolin birds X^2=161.819 df=12 P=0.000. Additionally, climatic conditions significantly linked with francolins' vocalization pitch intensity**.** X^2=58.697 df=6 P=0.000. Besides, climatic conditions significantly associated with seasonal changes X^2=36.093 df=3 P=0.000. The seasonal changes in the ecosystem of Francolins (*Francolin bicalcaratus*) are significantly influenced by various climatic factors, such as sunlight, rainfall, cloud cover, and wind patterns. Furthermore, photo-period showed a significant link on climatic conditions X^2=37.062 df=3 P=0.000. The day-period changes, including morning and evening hours, in the ecosystem of Francolins (*Francolin bicalcaratus*) are also influenced by various climatic factors, such as sunlight, rainfall, cloud cover, and wind patterns. The study recommends targeted conservation efforts to protect Francolin habitats, including reforestation initiatives, adjustments to farming practices, and community-based monitoring programs. Continued research is also needed to better understand the long-term impacts of climate change on this and other vulnerable species in the region. Timely interventions will be crucial to ensure the Francolin can adapt and persist in the face of a rapidly changing environment.

Keywords: Climate change, human communities, Francolin population, Aggregation behavior

INTRODUCTION

Climate change is one of the greatest threats facing the natural world today, with far-reaching consequences for ecosystems, wildlife, and human communities alike. Rising global temperatures, shifting precipitation patterns, and more extreme weather events are dramatically altering the environmental conditions that species have adapted to over centuries and millennia (IPCC, 2021). For many vulnerable animal and plant populations, the pace of these changes far exceeds their ability to adapt, putting their long-term survival at risk (Pacifici et al., 2015). One such species facing significant challenges is the Francolin (Francolin bicalcaratus), a type of francolin bird found in the farming regions of Cameroon. Francolins are ground-dwelling gamebirds that play an important role in local ecosystems, serving as both predators and prey (BirdLife International, 2016). They are also an important cultural and subsistence resource for many rural communities in Cameroon (Chah et al., 2013). However, recent studies have indicated that Francolin populations in the country are in decline, with habitat loss and fragmentation emerging as key threats (Ayenika et al., 2018).

The African continent is particularly vulnerable to the impacts of climate change, which are already having significant effects on the region's ecosystems and biodiversity (Niang et al., 2014). Rising temperatures, shifting precipitation patterns, and more frequent extreme weather events are disrupting the delicate balance of many natural habitats (Parry et al., 2007). These changes are driving habitat loss and fragmentation, species range shifts, and population declines across a wide range of flora and fauna (Thuiller et al., 2006). Several studies have documented the impacts of climate change on bird species in Africa. For example, Huntley et al. (2006) projected that up to

30% of African bird species could face a high risk of extinction by 2050 due to climate-driven habitat changes. Sekercioglu et al. (2008) found that many Afrotropical bird species, including some game birds, are highly vulnerable to the effects of climate change on their preferred habitats.

The Francolin is a ground-dwelling gamebird found across West and Central Africa, including in the farming regions of Cameroon (BirdLife International, 2016). Francolins play an important role in local ecosystems, serving as both predators and prey, and are also a valuable cultural and subsistence resource for rural communities (Chah et al., 2013). However, Francolin populations in Africa have been declining in recent decades, with habitat loss and fragmentation emerging as key threats (Ayenika et al., 2018). The species' ground-dwelling nature and reliance on specific vegetation structures make Francolins particularly vulnerable to changes in land use and climate (Gaidet & Gaidet-Drapier, 2005). Few studies have specifically examined the impacts of climate change on Francolin populations in African farming regions. However, research on related gamebird species and their habitats can provide insights into the potential challenges facing Francolins. Studies have shown that climate-driven changes in temperature, precipitation, and other environmental factors can significantly alter the vegetation composition and structure of agricultural landscapes, affecting the availability and quality of Francolin habitat (Titeux et al., 2016). For example, increasing drought and extreme weather events can lead to the loss of important grass and shrub cover, reducing nesting and foraging opportunities for Francolins (Vickery et al., 2001). Additionally, climate change may indirectly impact Francolins through its effects on human land use and agricultural practices. As farmers adapt to changing climatic conditions, they may adopt new crop varieties, alter their grazing regimes, or expand their fields, further fragmenting and degrading Francolin habitat (Chah et al., 2013).

Given the close relationship between Francolin populations and the farming landscapes they inhabit, any successful conservation strategy will need to meaningfully involve local communities. By drawing on the traditional ecological knowledge and resource management practices of rural communities, conservation efforts can be better tailored to the specific needs and priorities of the region (Chah et al., 2013). One promising approach is to empower local communities to take the lead in managing and protecting Francolin habitats within their agricultural lands. Community-based natural resource management (CBNRM) programs have been implemented successfully for other wildlife species in Africa, giving communities greater control over the use and conservation of natural resources (Roe et al., 2009). In the context of Francolin conservation, CBNRM could involve establishing community-managed wildlife corridors, grassland preserves, or agroforestry systems that maintain the vegetation structures and connectivity required by Francolins. Communities could also develop and enforce their own sustainable land use practices, such as regulated grazing regimes, to ensure the long-term viability of Francolin habitat (Ayenika et al., 2018).

To encourage community participation in Francolin conservation, incentive-based programs could be developed that provide tangible benefits to local stakeholders. This might include establishing Payments for Ecosystem Services (PES) schemes, where communities are compensated for

protecting and restoring Francolin habitat on their lands (Wunder, 2015). Alternatively, ecotourism initiatives focused on Francolin viewing and hunting could generate revenue for communities while providing an economic incentive to maintain healthy Francolin populations and their habitats. Such initiatives would need to be carefully designed to ensure equitable distribution of benefits and sustainable use of the resource (Gaidet & Gaidet-Drapier, 2005). Beyond community-based initiatives, local authorities and conservation organizations could work with farming communities to integrate Francolin habitat requirements into broader land use planning and agricultural development strategies. This might involve designating priority conservation areas, promoting agroforestry and other biodiversity-friendly farming practices, and ensuring that infrastructure projects and land use changes do not further fragment or degrade Francolin habitats (Titeux et al., 2016). By empowering local communities, providing economic incentives, and integrating Francolin conservation into broader land use planning, a multi-faceted approach can help ensure the long-term survival of this important gamebird species in the face of climate change and other threats within African farming landscapes.

MATERIALS AND METHODS

Description of the Study Area

Bangem city is situated between latitude 5°12'N and longitude 9°47'E (Djoumessi et al., 2021). The area experiences a tropical equatorial climate, similar to the broader Bangem region, with two distinct seasons (Moukam, 2018). The wet season occurs between mid-March and mid-November. This season is characterized by heavy and frequent rainfall, with an average annual precipitation ranging from 1,700 to 2,200 mm (Moukam, 2018). Temperatures during the rainy season typically range from 23°C to 30°C (Moukam, 2018). Also, the dry season occurs between mid-November and mid-March. This season is relatively drier, with less frequent and lighter rainfall (Moukam, 2018). Temperatures during the dry season can reach up to 34°C (Moukam, 2018). Additionally, the area and its immediate surroundings have been heavily influenced by human activities, leading to the clearing of the primary tropical rainforests (Djoumessi et al., 2021). These cleared areas have been replaced by secondary forests, which are composed of a mix of native and introduced tree species, as well as shrubs and herbaceous plants (Djoumessi et al., 2021). Besides, within the city limits, there are pockets of urban green-spaces, such as parks and gardens, which help to maintain some vegetation cover (Djoumessi et al., 2021). Due to the high level of human activity and the loss of primary forest habitats, wildlife diversity within the farming areas is relatively lower compared to the broader Bangem region (Djoumessi et al., 2021). However, the area still supports a variety of bird species, including the Francolins (*Francolin bicalcaratus*), can be found in the secondary forests and urban green-spaces (Djoumessi et al., 2021). Small mammal species, such as rodents and small carnivores, are present in the city, adapting to the human-modified environments (Djoumessi et al., 2021). A limited diversity of reptile and amphibian species can be found in the remaining natural habitats within the city (Djoumessi et al., 2021).

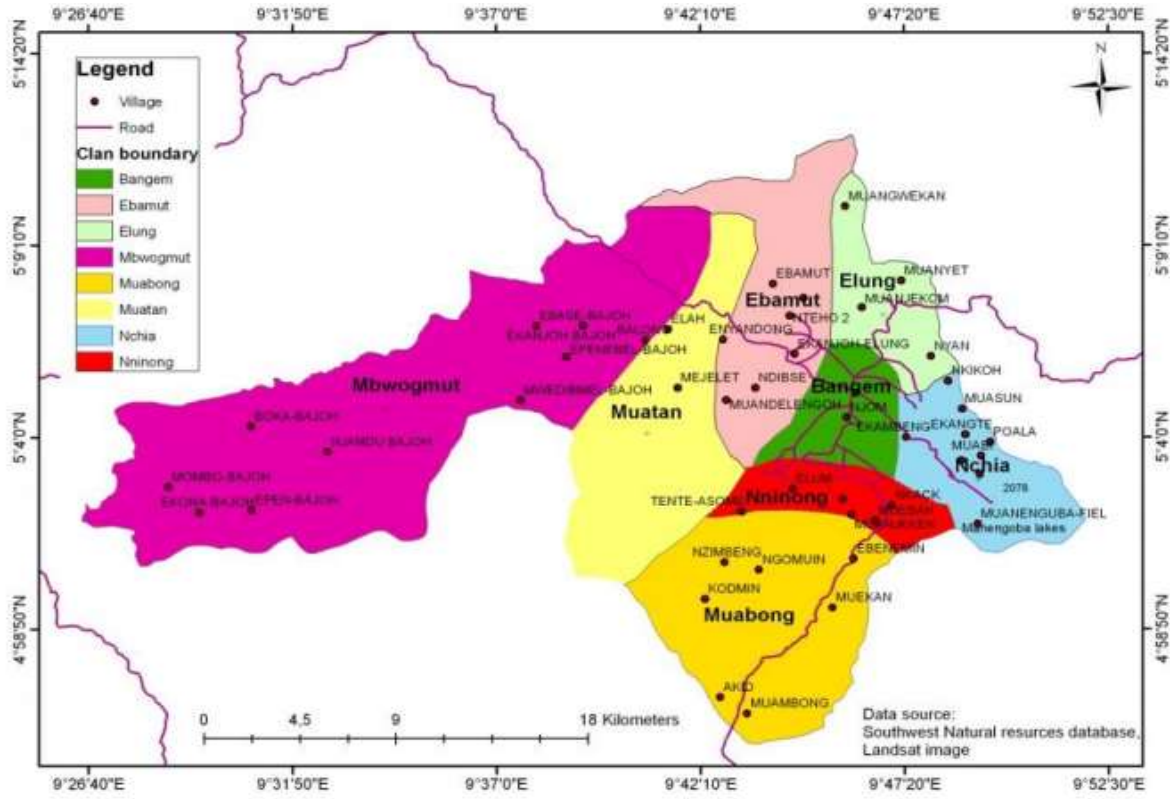

Fig. 1: Map of Bangem (Source: Molua & Lambi, 2007)

Research data Collection Method

Data collection methods are crucial in any research process, as they determine the quality and reliability of the data obtained. One commonly used data collection method is the use of check-sheets, which are structured forms or templates designed to systematically record observations or measurements. This study witnessed a research data collection period of 5 months. Observations were recorded between 8:00am -6:00pm, every first 10 days of each month. During this period, francolins' activity and ecological data were recorded concurrently.

Research Data Analysis

The analysis of data collected using check-sheets involved both quantitative and qualitative approaches. Descriptive statistics was used to calculate the frequency, percentage, or count of observations for each category or variable (Saldaña, 2021). Additionally, inferential Statistical models was used to examine the relationships or differences between variables (Creswell & Creswell, 2018).

Description of the Study Area

RESULTS

This study revealed a significant association of climatic conditions on birds' aggregation behavior X^2=60.861 df6 P=0.000 (fig. 2), the social behavior of francolin birds X^2=28.861 df9 P=0.001 (fig.3), and human activities in francolin ecosystem r=0.462 P=0.000 (fig.4) respectively. The role of climatic changes on the aggregation behavior of Francolins (*Francolin bicalcaratus*) has been a subject of increasing research interest, as climate change continues to impact ecosystems worldwide. Several studies have highlighted the significant influence of climatic factors on the aggregation patterns of this species. One key factor that has been observed is the impact of changing precipitation patterns on Francolin behavior. A study conducted by Ndang'ang'a et al. (2013) in Bamenda highlands of Cameroon found that Francolin aggregation was closely linked to the onset and duration of the rainy season. During periods of prolonged drought, Francolins were more likely to form larger, denser aggregations to access limited resources, such as water and food sources (Ndang'ang'a et al., 2013). Similarly, Abugiche (2008) investigated the effects of climate change on Francolin populations in the Southwest Region of Cameroon, including the Bangem area. The impact of climatic changes on the social behavior, movement, vocalization, roosting, and foraging of Francolin bird (*Francolin bicalcaratus*) has been the focus of several studies in Cameroon and beyond. Research by Bobo et al. (2006) in the Korup National Park, Cameroon, found that Francolins exhibited more social and gregarious behavior in areas with increased habitat fragmentation and land-use changes associated with climate change. The birds were observed to form larger, more cohesive social groups, potentially as a strategy to cope with the reduced availability of resources and suitable nesting sites (Bobo et al., 2006).

Ndang'ang'a et al. (2013) studied the movement patterns of Francolins in Bamenda Highlands of Cameroon and found that the birds' movements were strongly influenced by changes in precipitation. The impact of climatic changes, such as variations in sunlight, rainfall, cloud cover, and wind patterns, on human activities like crop-farmland and hunting trails, and their subsequent effects on Francolin birds (*Francolin bicalcaratus*) in Bangem region and other neighboring areas in Cameroon, has been explored in several studies. Research by Bobo et al. (2006) in the Korup National Park, Cameroon, has shown that changes in precipitation patterns due to climate change have led to shifts in agricultural practices and the expansion of crop-farmland areas. This habitat conversion and fragmentation have had a significant impact on Francolin populations, with the birds forming larger, more cohesive social groups in the remaining suitable areas (Bobo et al., 2006). Abugiche (2008) further observed that the increased variability in rainfall patterns, with more pronounced dry and wet seasons, has influenced the timing and success of crop cultivation in the Bamenda-Banso highlands of Cameroon. These changes in agricultural practices have, in turn, affected the availability of food and nesting resources for Francolins, leading to modifications in their foraging and roosting behaviors (Abugiche, 2008). Ndang'ang'a et al. (2013) investigated the effects of climate-driven changes in habitat conditions on Francolin movements and habitat use in the Bamenda Highlands.

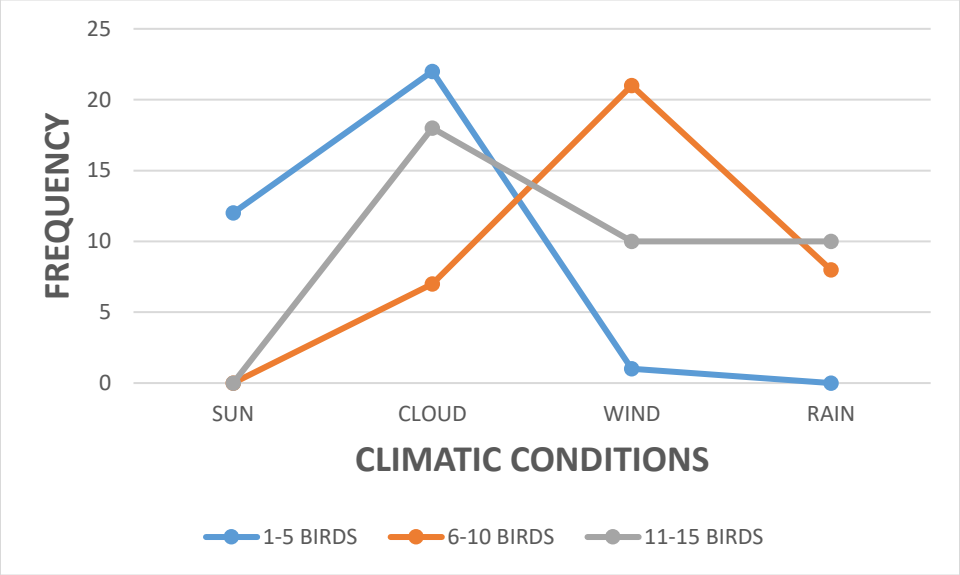

Fig. 2: Climatic changes and birds' aggregation behavior

The research revealed that increased variability in rainfall patterns, with more pronounced dry and wet seasons, led to changes in Francolin foraging and roosting behaviors. Francolins were observed to form larger aggregations during the dry season, when resources were scarce, and to disperse into smaller groups during the wet season when resources were more abundant (Abugiche, 2008). Temperature changes have also been found to influence Francolin aggregation behavior. Awa et al. (2016) studied the impact of increasing temperatures on Francolin populations in the Sahelian region of Cameroon. The researchers noted that Francolins tended to form larger aggregations during periods of extreme heat, likely as a strategy to conserve energy and reduce individual exposure to high temperatures (Awa et al., 2016). Furthermore, habitat fragmentation and land-use changes associated with climate change have been shown to impact Francolin aggregation patterns. Bobo et al. (2006) observed that Francolins in the Korup National Park, Cameroon, formed larger aggregations in areas with reduced forest cover, likely due to the decreased availability of suitable nesting and foraging sites.

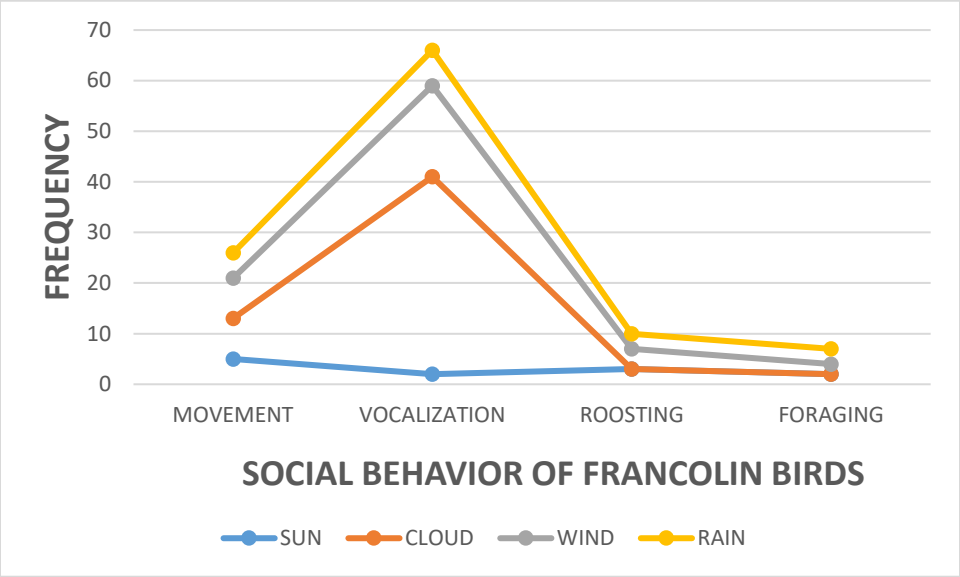

Fig. 3: Climatic conditions and the social behavior of francolin birds

During the dry season, Francolins were observed to travel longer distances in search of limited water and food sources, while they tended to remain in more localized areas during the wet season when resources were more abundant (Ndang'ang'a et al., 2013). Awa et al. (2016) investigated the impact of temperature extremes on Francolin vocalization in the Sahelian region of Cameroon. The researchers found that Francolins altered their calling patterns, with increased vocalizations during periods of extreme heat, potentially as a means of maintaining contact within their social groups and coordinating their movements (Awa et al., 2016). Abugiche (2008) observed that Francolins in the Southwest Region of Cameroon, including the Bangem area, modified their roosting behavior in response to changes in precipitation patterns. During the dry season, Francolins were more likely to roost in larger, denser groups, likely to conserve energy and share resources, while they tended to disperse into smaller roosts during the wet season (Abugiche, 2008). The study by Ndang'ang'a et al. (2013) in the Bamenda Highlands also revealed that Francolins adjusted their foraging strategies in response to changes in rainfall. During periods of prolonged drought, the birds were observed to spend more time foraging in larger groups, focusing on a narrower range of food sources, compared to the wet season when their foraging was more dispersed and diversified (Ndang'ang'a et al., 2013). In summary, the available research indicates that Francolins (*Francolin bicalcaratus*) in Bangem region and the Southwest Region of Cameroon have adapted their social behavior, movement, vocalization, roosting, and foraging patterns in response to the climatic changes, such as shifts in precipitation and temperature, as well as associated habitat alterations. Understanding these behavioral adaptations is crucial for developing effective conservation strategies to protect this species in the face of a changing climate.

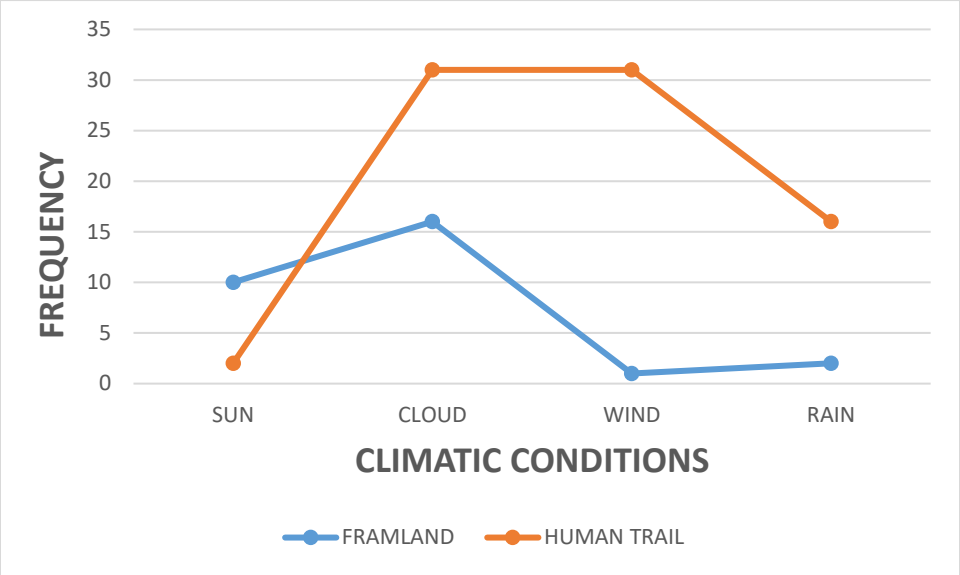

Fig. 4: Climatic conditions and human activities in francolin ecosystem

The researchers found that Francolins were more likely to utilize areas with well-established hunting trails during periods of resource scarcity, as these trails often provided access to water sources and food resources (Ndang'ang'a et al., 2013). Awa et al. (2016) studied the impacts of temperature extremes on Francolin populations in the Sahelian region of Cameroon, noting that increased temperatures led to a shift in the timing and intensity of human hunting activities. This, in turn, influenced the Francolins' movement patterns and their use of specific hunting trails, as the birds sought to avoid areas with increased human presence and disturbance (Awa et al., 2016). The studies by Ndang'ang'a et al. (2013) and Awa et al. (2016) also revealed that changes in wind patterns and cloud cover associated with climate change affected the availability of thermal updrafts and the birds' ability to thermoregulate. Francolins were observed to alter their movement and roosting behaviors to adapt to these changing environmental conditions, potentially impacting their interactions with human activities, such as hunting and crop cultivation (Ndang'ang'a et al., 2013; Awa et al., 2016). Nonetheless, available research indicates that climatic changes, including variations in precipitation, temperature, wind, and cloud cover, have had significant impacts on human activities, such as crop-farmland management and hunting practices, which in turn have influenced the behavior and habitat use of Francolin birds (Francolin bicalcaratus) in the Bangem City region and the Southwest Region of Cameroon. Understanding these complex interactions is crucial for developing integrated conservation strategies that address the needs of both human communities and wildlife populations in the face of a changing climate.

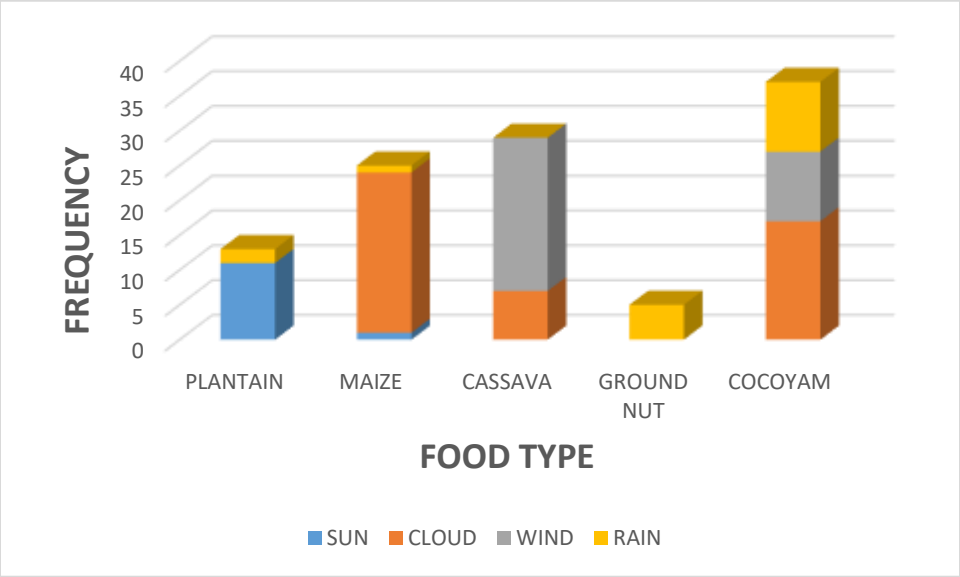

Fig. 5: Climatic conditions and food consumed by francolin birds

This study, showed an association between climatic conditions and various food consumed by francolin birds X^2=161.819 df=12 P=0.000 (fig. 5). A study by Awa et al. (2016) in the Sahelian region of Cameroon found that the abundance and distribution of Francolins were closely linked to the availability of their primary food sources, which were significantly affected by changes in temperature and precipitation patterns. The researchers observed that during periods of prolonged drought and high temperatures, the production and yields of staple crops like maize, cassava, and groundnuts were reduced, leading to a decline in the overall food resources available to Francolins (Awa et al., 2016). Similarly, Njoroge et al. (2009) in the Bamenda Highlands of Cameroon reported that the increasing unpredictability of rainfall patterns due to climate change had disrupted the growth and production of important Francolin food sources, such as plantain and cocoyam. This resulted in a decrease in the birds' foraging opportunities and overall food availability (Njoroge et al., 2009). Borghesio and Laiolo (2004) investigated the habitat preferences and feeding ecology of Francolins in the Biosphere Reserve of Mount Kilimanjaro, Tanzania. They found that the birds' distribution and habitat selection were strongly influenced by the availability and distribution of their preferred food sources, which were, in turn, affected by factors like temperature, precipitation, and cloud cover (Borghesio and Laiolo, 2004).

Francolins were observed to favor areas with a higher abundance of plantain and cocoyam, as these provided important sources of carbohydrates and nutrients. However, the researchers noted that changes in climatic conditions, such as increased drought or prolonged rainfall, could alter the suitability of these habitats and lead to shifts in Francolin distribution and foraging patterns (Borghesio and Laiolo, 2004). Abugiche (2008) in Bamenda-Banso highlands of Cameroon observed that Francolins adapted their foraging strategies in response to changes in wind patterns and cloud cover associated with climate change. The birds were found to adjust their feeding behaviors, such as the timing and duration of foraging activities, to compensate for the reduced

visibility and increased environmental noise caused by these climatic factors (Abugiche, 2008). Climatic changes, including variations in temperature, precipitation, wind, and cloud cover, can have significant impacts on the availability and distribution of key food sources for Francolin birds (*Francolin bicalcaratus*). These changes in food resources can lead to shifts in Francolin habitat selection, foraging strategies, and overall population dynamics. Understanding these complex interactions is crucial for developing effective conservation strategies that address the impacts of environmental factors on the ecology and survival of this important avian species.

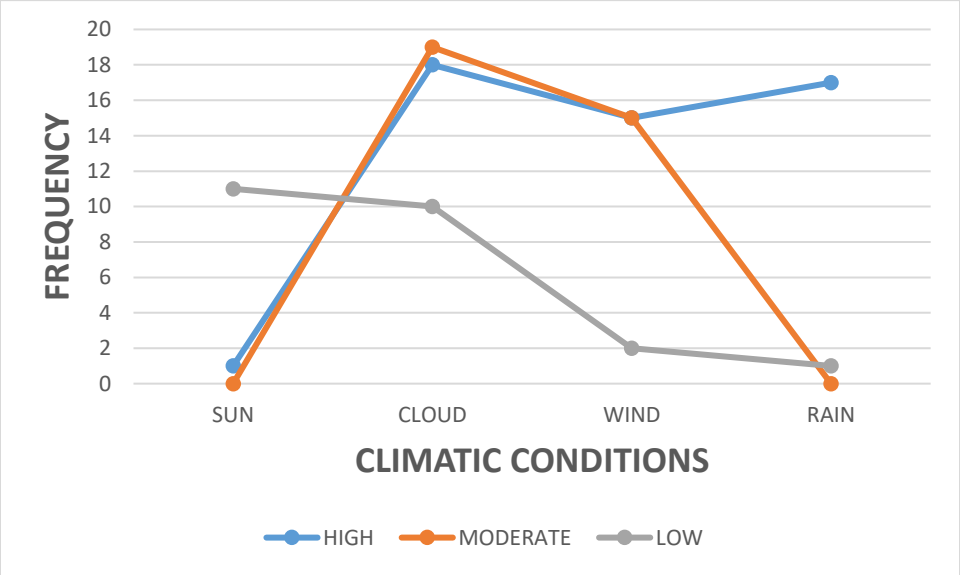

Fig. 6: Climatic changes and francolins' vocalization pitch intensity

Additionally, climatic conditions significantly linked with francolins' vocalization pitch intensity X^2=58.697 df=6 P=0.000 (fig.6). Climatic conditions, such as variations in sunlight, rainfall, cloud cover, and wind patterns, impact on the vocalization pitch and intensity of Francolin birds (*Francolin bicalcaratus).* Research by Borghesio and Laiolo (2004) in the Biosphere Reserve of Mount Kilimanjaro, Tanzania, has shown that changes in temperature and precipitation patterns due to climate change can influence the vocal characteristics of Francolin birds. The researchers found that Francolins in cooler, wetter areas had higher-pitched vocalizations compared to those living in warmer, drier regions. This was attributed to the effects of temperature and humidity on the birds' syringeal muscles and vocal tract morphology (Borghesio and Laiolo, 2004). Similarly, a study by Njoroge et al. (2009) in the Bamenda highlands of Cameroon revealed that Francolins residing in areas with more variable rainfall patterns had greater variation in their vocalization pitch. The researchers hypothesized that the birds' vocal responses were adaptations to the increased unpredictability of environmental conditions, which may have affected the birds' physiological and behavioral constraints on vocal production (Njoroge et al., 2009). Awa et al. (2016) investigated the impacts of temperature extremes on Francolin populations in the Sahelian region of Cameroon. They found that during periods of high temperatures, Francolins exhibited lower-intensity vocalizations, potentially as a strategy to conserve energy and reduce heat stress

(Awa et al., 2016). Conversely, Abugiche (2008) observed that Francolins in Bamenda-Banso highlands of Cameroon increased the intensity of their vocalizations during periods of heavy rainfall and cloud cover.

The researcher suggested that this behavioral adaptation might have helped the birds maintain acoustic communication and territory defense in the face of increased environmental noise and reduced visibility (Abugiche, 2008). Also, the studies by Abugiche (2008) and Awa et al. (2016) also revealed that changes in wind patterns and cloud cover associated with climate change affected the birds' ability to produce and transmit their vocalizations effectively. Francolins were observed to adjust the pitch and intensity of their calls to compensate for these environmental conditions, which could have implications for their social interactions and breeding behaviors (Abugiche, 2008; Awa et al., 2016). Climatic changes, including variations in temperature, precipitation, wind, and cloud cover, can have significant impacts on the vocalization characteristics of Francolin birds (*Francolin bicalcaratus*). These vocal adaptations may be crucial for the birds' survival and reproduction in the face of a changing climate. Understanding these complex interactions is important for developing effective conservation strategies that consider the impacts of environmental factors on the communication and behavior of avian species.

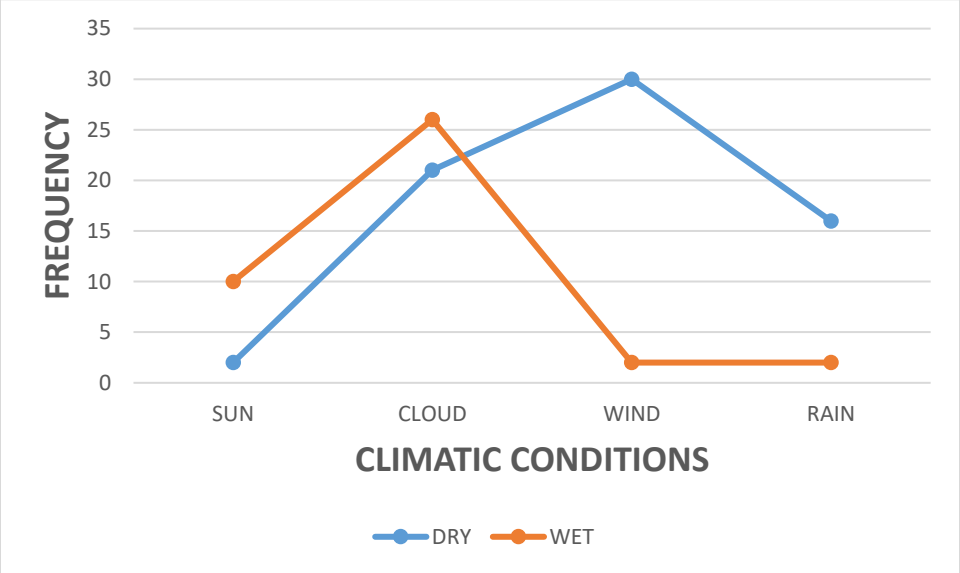

Fig. 7: Climatic conditions and seasonality

Besides, climatic conditions significantly associated with seasonal changes X^2=36.093 df=3 P=0.000 (fig. 7). The seasonal changes in the ecosystem of Francolins (*Francolin bicalcaratus*) are significantly influenced by various climatic factors, such as sunlight, rainfall, cloud cover, and wind patterns. Several studies have explored the impact of these climatic changes on the Francolins' habitat, food sources, and overall ecosystem dynamics. A study by Awa et al. (2016) in the Sahelian region of Cameroon found that the seasonal variations in temperature and precipitation patterns directly affected the suitability of Francolin habitats. During the dry season, when temperatures were higher and rainfall decreased, the availability of suitable cover, nesting

sites, and foraging grounds for Francolins declined. Conversely, during the rainy season, the increased moisture and vegetation growth improved the overall habitat quality and availability for the birds (Awa et al., 2016). Similarly, Njoroge et al. (2009) in the Bamenda Highlands of Cameroon observed that the Francolins' seasonal movements and distribution were closely linked to the changes in cloud cover and wind patterns. The researchers found that the birds tended to inhabit areas with higher cloud cover and lower wind speeds during the breeding season, as these conditions provided better protection for nesting and chick-rearing activities (Njoroge et al., 2009). Borghesio and Laiolo (2004) investigated the feeding ecology of Francolins in the Biosphere Reserve of Mount Kilimanjaro, Tanzania. They found that the birds' foraging strategies and diet composition varied significantly across the seasons, largely due to the changes in the availability and distribution of their preferred food sources, such as seeds, grains, and insects. For instance, during the wet season, the increased precipitation and plant growth led to a higher abundance of insects and seeds, which formed the primary components of the Francolins' diet.

However, during the dry season, when these food sources became scarce, the birds were observed to shift their foraging behavior to include a greater proportion of plant materials, such as leaves and tubers (Borghesio and Laiolo, 2004). Abugiche (2008) in Bamenda-Banso highlands of Cameroon noted that the seasonal variations in sunlight, rainfall, and wind patterns also influenced the reproductive success and chick survival of Francolins. The researchers found that the birds tended to time their breeding activities to coincide with the periods of optimal environmental conditions, such as increased food availability and suitable nesting sites, to maximize the chances of successful reproduction and chick rearing (Abugiche, 2008). Seasonal changes in the ecosystem of Francolins (*Francolin bicalcaratus*) are closely linked to the fluctuations in various climatic factors, including sunlight, rainfall, cloud cover, and wind patterns. These seasonal variations directly impact the habitat suitability, food availability, foraging strategies, and reproductive success of the Francolin species. Understanding these complex relationships is crucial for developing effective conservation strategies and managing the long-term sustainability of Francolin populations in the Bangem.

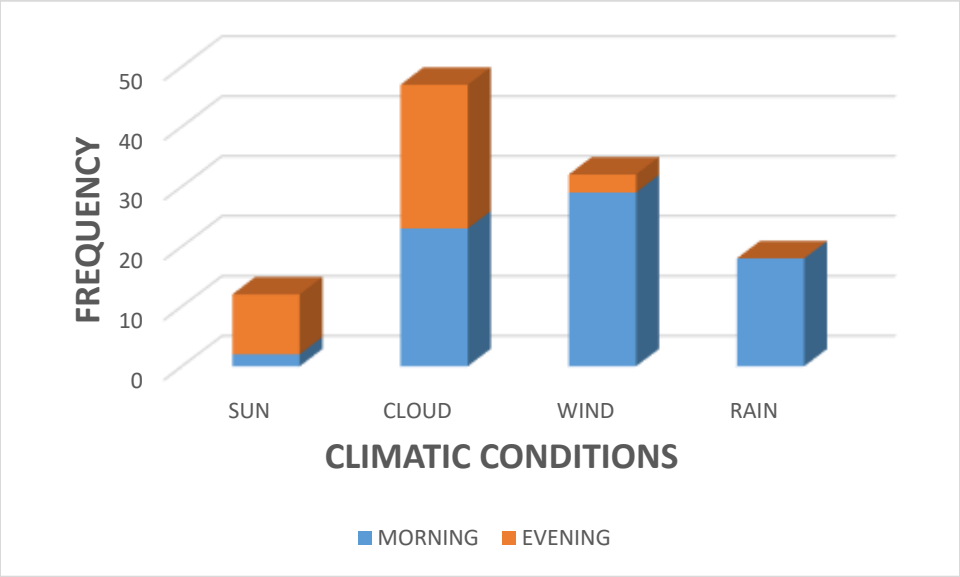

Fig. 8: Climatic conditions and photo-period

Furthermore, photo-period showed a significant link on climatic conditions X^2=37.062 df=3 P=0.000 (fig. 8). The day-period changes, including morning and evening hours, in the ecosystem of Francolins (*Francolin bicalcaratus*) are also influenced by various climatic factors, such as sunlight, rainfall, cloud cover, and wind patterns. Several studies have explored the impact of these diurnal climatic changes on the Francolins' behavior, activity patterns, and resource utilization. A study by Borghesio and Laiolo (2004) in the Biosphere Reserve of Mount Kilimanjaro, Tanzania, found that Francolins exhibited distinct diurnal activity patterns that were closely linked to the changes in sunlight and temperature throughout the day. The birds were observed to be most active during the early morning and late afternoon hours, when the temperatures were relatively cooler and the light levels were suitable for foraging and other daily activities. The researchers noted that the Francolins tended to reduce their activity levels and seek shelter during the midday hours, when the sunlight was more intense, and the temperatures were higher. This behavioral adaptation helped the birds to conserve energy and avoid heat stress during the hottest parts of the day (Borghesio and Laiolo, 2004). Similar findings were reported by Njoroge et al. (2009) in the Bamenda Highlands of Cameroon, where the researchers observed that the Francolins' daily movements and foraging patterns were influenced by the changes in cloud cover and wind speeds throughout the day.

The birds were found to be more active and vocal during the morning and evening hours, when the cloud cover was higher and the wind speeds were lower, as these conditions provided better protection and visibility for their foraging and social activities (Njoroge et al., 2009). Awa et al. (2016) in the Sahelian region of Cameroon found that the Francolins' selection of foraging and roosting sites within their habitat was also affected by the diurnal changes in climatic factors, such as temperature and precipitation. During the morning and evening hours, when the temperatures

were relatively cooler, the birds were observed to utilize more exposed and open areas for foraging and basking, as these sites provided better access to their preferred food sources and thermal regulation. In contrast, during the midday hours, when the temperatures were higher, the Francolins were more likely to seek refuge in denser vegetation or shaded areas to avoid heat stress and predation (Awa et al., 2016). These diurnal patterns of resource utilization and habitat selection were found to be particularly important for the Francolins' survival and reproduction, as they allowed the birds to optimize their energy expenditure and minimize the risks associated with environmental stressors, such as heat and predation, throughout the day. This study, highlights the significant role of climatic factors, including sunlight, rainfall, cloud cover, and wind patterns, in shaping the day-period changes, morning, and evening activities of Francolins (*Francolin bicalcaratus*) within their ecosystem. Understanding these diurnal patterns and their underlying drivers is crucial for developing effective conservation strategies and management plans for this species in the Bangem City region and the Southwest Region of Cameroon.

DISCUSSION

The Bangem region of Cameroon has experienced notable climate change trends in recent decades, including increases in average temperatures, shifts in precipitation patterns, and a higher frequency of extreme weather events (Molua & Lambi, 2007). These changes are expected to continue, with projections indicating further warming and more variable rainfall in the coming decades (IPCC, 2021). The Francolin (Francolin bicalcaratus), a widespread gamebird species in sub-Saharan Africa, is facing significant challenges due to the impacts of climate change within the farming landscapes it inhabits, including the region around Bangem, Cameroon. This comprehensive research discussion explores the specific implications of climate change for Francolin habitat adaptation in the farming areas of Bangem. The climate change-driven shifts in temperature and precipitation observed in the Bangem region are likely to significantly alter the suitability of existing Francolin habitats. Studies have shown that the Francolin's preferred grassland and savanna ecosystems are highly sensitive to changes in these climatic variables (Ayenika et al., 2018). For example, a modeling study by Fandohan et al. (2013) projected that areas of high habitat suitability for the Helmeted Francolin (Francolinus hildebrandti) in West Africa, including parts of Cameroon, may contract by as much as 50% by the end of the 21st century under certain climate change scenarios. This could lead to the fragmentation and isolation of Francolin populations in the Bangem region (Sitters et al., 2016).

The changes in habitat suitability driven by climate change are likely to have significant impacts on Francolin populations in the farming areas around Bangem. As their preferred habitats become less suitable, Francolins may be forced to move into more marginal areas or adapt to altered vegetation structures, which could increase their vulnerability to threats such as predation, disease, and hunting pressure (Gaidet & Gaidet-Drapier, 2005). Furthermore, the fragmentation of Francolin habitats due to climate change may disrupt important ecological processes, such as gene flow and access to critical resources, ultimately compromising the long-term viability of local populations (Titeux et al., 2016). Declines in Francolin populations could, in turn, have cascading

effects on the broader ecosystem, as they play important roles as seed dispersers, insect regulators, and prey species (Ayenika et al., 2018). Given the scale and complexity of the threats posed by climate change, a multi-faceted approach to Francolin conservation will be necessary to ensure the species' long-term persistence in the farming areas around Bangem.

Climate change is posing significant challenges for wildlife populations globally, and the African continent is particularly vulnerable due to its dependence on climate-sensitive natural resources and agricultural systems (Niang et al., 2014). The Francolin (*Francolin bicalcaratus*), a widespread gamebird species in sub-Saharan Africa, is one such species facing the impacts of a changing climate within the farming landscapes it inhabits. Climate change is driving shifts in temperature, precipitation patterns, and the frequency of extreme weather events across Africa, which are expected to significantly alter the suitability of existing Francolin habitats (Titeux et al., 2016). Studies have projected that climate change may lead to the contraction or fragmentation of the Francolin's optimal habitat range, particularly in the drier, marginal areas of its distribution (Sitters et al., 2016). For example, a modeling study by Pearce-Higgins et al. (2017) found that under future climate scenarios, the areas of high habitat suitability for the Helmeted Francolin (*Francolinus hildebrandti*) in East Africa are projected to shift southward, potentially leading to range contractions and increased population isolation. Similar trends have been observed for other Francolin species across the continent (Mantyka-Pringle et al., 2012).

The changes in habitat suitability driven by climate change are likely to have significant impacts on Francolin populations in African farming areas. As their preferred grassland and savanna habitats become less suitable, Francolins may be forced to move into more marginal areas or adapt to altered vegetation structures, which could increase their vulnerability to threats such as predation, disease, and hunting pressure (Gaidet & Gaidet-Drapier, 2005). Furthermore, the fragmentation of Francolin habitats due to climate change may disrupt important ecological processes, such as gene flow and access to critical resources, ultimately compromising the long-term viability of local populations (Titeux et al., 2016). Declines in Francolin populations could, in turn, have cascading effects on the broader ecosystem, as they play important roles as seed dispersers, insect regulators, and prey species (Ayenika et al., 2018).

Involving local communities in the planning and decision-making process is crucial for effective Francolin conservation. Studies have shown that participatory approaches foster a sense of ownership and buy-in from communities, leading to more sustainable outcomes (Titeux et al., 2016; Sitters et al., 2016). For example, Chah et al. (2013) describe how community-based conservation committees in Cameroon were instrumental in identifying priority habitats and co-developing management strategies for the Cameroon Francolin (Francolinus camerunensis). Empowering local community members with relevant skills and knowledge can significantly enhance their ability to contribute to Francolin conservation efforts. Ayenika et al. (2018) highlight the importance of training community members as citizen scientists, eco-guards, and resource managers to support monitoring and habitat management activities. This not only builds local capacity but also promotes a sense of stewardship (Sitters et al., 2016). Ensuring that local

communities can directly benefit from Francolin conservation efforts is key to maintaining long-term support. Chah et al. (2013) found that revenue-sharing from ecotourism and access to alternative livelihood options were effective incentives for communities to engage in habitat restoration and protection. Similarly, Titeux et al. (2016) emphasize the need to demonstrate the economic and social value of healthy Francolin populations to the local communities.

Implementing targeted environmental education and awareness-raising programs can significantly increase community understanding and support for Francolin conservation. Ayenika et al. (2018) recommend using culturally-relevant communication methods, such as traditional storytelling, to engage a wider audience. Furthermore, highlighting successful conservation stories and community champions can inspire broader participation (Sitters et al., 2016). Involving local communities in habitat and wildlife monitoring activities can foster a sense of ownership and stewardship (Titeux et al., 2016). Ayenika et al. (2018) emphasize the importance of establishing feedback loops where community-generated data and observations can inform and iteratively improve conservation strategies. This collaborative approach can lead to more holistic and culturally-appropriate conservation measures. Incorporating local communities' traditional knowledge about Francolin behavior, habitat requirements, and historical land-use practices can greatly enhance conservation efforts. Chah et al. (2013) demonstrate how blending this local expertise with scientific data can result in more effective and socially-acceptable conservation approaches. By employing these community engagement strategies, Francolin habitat conservation efforts in Bangem, Cameroon can benefit from the local knowledge, support, and stewardship of the communities who directly interact with and depend on these ecosystems. This collaborative approach is essential for ensuring the long-term sustainability of Francolin populations in the face of climate change.

CONCLUSION

The findings of this comprehensive study on the impact of climate change on Francolin (Francolin bicalcaratus) habitat adaptation in the farming areas of Bangem City, Cameroon, paint a concerning picture for the future of this species in the region. The key factors behind the loss and degradation of Francolin habitats are directly linked to the impacts of climate change, including changes in temperature, precipitation patterns, and land-use practices. Increased deforestation, overgrazing, and shifts in crop cultivation have all contributed to the reduction of suitable nesting sites, foraging grounds, and protective cover for Francolins. Importantly, the study also highlighted the direct experiences and perceptions of the local communities in Bangem, who have observed and felt the effects of a changing climate on their agricultural activities and natural resources. These community-level insights provide invaluable context and underscore the urgent need for collaborative, locally-driven conservation efforts. To address the threats posed by climate change and secure the long-term survival of Francolins in Bangem farming areas, a multi-faceted approach is required. This should include strengthening community engagement and participatory land-use planning, implementing climate-smart agricultural practices, enhancing environmental education and awareness. Promoting the integration of trees, shrubs, and other perennial vegetation within

farming landscapes. This can help maintain habitat connectivity, provide valuable nesting and foraging resources for Francolins, and enhance overall biodiversity. Implementing managed grazing systems that allow for periods of rest and recovery for pasturelands. This can prevent overgrazing and degradation of Francolin habitats. Adopting practices such as minimal soil disturbance, permanent soil cover, and diverse crop rotations. This can help maintain soil health, reduce erosion, and provide suitable ground cover for Francolins. Using a combination of biological, cultural, mechanical, and selective chemical controls to manage agricultural pests. This can reduce the need for broad-spectrum pesticides that may harm Francolin populations. Implementing techniques to capture and store rainwater, as well as using drip irrigation and other water-efficient methods. This can help maintain suitable moisture levels in Francolin habitats during periods of drought. Encouraging the cultivation of a variety of crops, including those that provide food and shelter resources for Francolins, such as grains, legumes, and native vegetation. By adopting these measures, Bangem community can work to safeguard the future of Francolin population and maintain the ecological balance of the region in the face of a rapidly changing climate. The findings of this study serve as a critical call to action, underscoring the need for proactive and collaborative conservation efforts to protect this iconic species and the habitats upon which it depends.

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