Scientific Research Publishing

Open Journal of Ecology, 2026, 16(11), 543-563
https://www.scirp.org/journal/oje
ISSN Online: 2162-1993
ISSN Print: 2162-1985

Activity Time Budget and Foraging Behaviour of Palm-Nut Vulture (*Gypohierax angolensis*) in Douala-Edea National Park, Cameroon

Marshall Elah Elaze[1*], Moses Tita Mogho Njoya[1,2], Piebeng Ghislain Noe Kougoum[3], Simon Awafor Tamungang[1,4]

[1]The Department of Forestry and Wildlife Technology (FWT), College of Technology, The University of Bamenda, Bambili, Cameroon
[2]Department of Zoology, Faculty of Science, The University of Bamenda, Bambili, Cameroon
[3]Department of Biological Science, Faculty of Science, University of Maroua, Maroua, Cameroon
[4]Laboratory of Applied Biology and Ecology, Faculty of Science, University of Dschang, Dschang, Cameroon
Email: *marshallelah@gmail.com, njoyamosea@yahoo.com, ghisvine@gmail.com, atamungang@yahoo.com

How to cite this paper: Elaze, M.E., Njoya, M.T.M., Kougoum, P.G.N. and Tamungang, S.A. (2026) Activity Time Budget and Foraging Behaviour of Palm-Nut Vulture (*Gypohierax angolensis*) in Douala-Edea National Park, Cameroon. *Open Journal of Ecology*, **16**, 543-563.
https://doi.org/10.4236/oje.2026.1611030

Received: July 30, 2026
Accepted: November 17, 2026
Published: November 20, 2026

Copyright © 2026 by author(s) and Scientific Research Publishing Inc.
This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).
http://creativecommons.org/licenses/by/4.0/

Open Access

Abstract

Understanding the activity time budget and foraging behavior of vultures is important for their effective conservation and planning, particularly in tropical wetland ecosystems witnessing increasing anthropogenic pressure, such as the Douala-Edea National Park. Activity patterns are a key element of birds' life history and behavior. Decisions about how activity budgets are structured can have important fitness implications for vultures. This study was designed to investigate the daily activity patterns and foraging behavior of the palm-nut vulture (*Gypohierax angolensis*) in Douala-Edea National Park. Data were collected during the wet season (August and September 2025) and the dry season (November and December 2025), using a blend of camera trapping and focal scan sampling, yielding a total survey effort of 124.92 km per season and an overall camera effort of 2000 hours. Observations were conducted across major habitat types including mangroves, swamps, flood forest, Atlantic coastal forest, and secondary forest. Activity budgets, feeding strategies, diet composition, and temporal habitat use were analyzed. Palm-nut vultures displayed five principal activities: feeding, soaring, preening, resting, and social interaction. Out of 461 behavioral scans on the various activities, feeding accounted for the largest proportion (48.1% in the dry season; 41.3% in the rainy season) followed by soaring (21.2% in the dry season; 19.6% in the rainy season) with a peak in the morning (06:00 - 09:00). Diet composition varied seasonally; palm/raphia seeds (31.6%) dominated during the wet season, while fish (29.2%) dominated during the dry season. Significant differences were observed in activity allocation across time periods of the day and between seasons; feeding rates ($F_{3,138} = 10.27$, $P < 0.05$)

and resting rates ($F_{3,138} = 5.38$, $P < 0.05$) differed significantly. In contrast, no significant difference was observed in preening, soaring, and social interaction across the four time slots. Based on food capture and handling techniques, High-speed diving (63.2%) was used mostly in the wet season, and picking (54.2%) was used mostly in the dry season. Based on food handling technique, gulping was used predominantly in both the dry season (54.2%) and wet season (52.6%), as against tearing then gulping. Habitat destruction, hunting for food, and its use for traditional medicine are major threats to the palm-nut vulture in the study zone; thus, habitat protection and community sensitization are recommended to support a long-term conservation effort in the Douala-Edea National Park.

Keywords

Palm-Nut Vulture, Time Budget, Foraging Behavior, Raptors, Douala-Edea National Park, Cameroon

1. Introduction

Douala-Edea National Park is a critical wetland zone for diverse avifaunal communities, including the ecologically significant palm-nut vulture. It is an old-world vulture belonging to the Accipitridae family with other birds like hawks, buzzards, kites, and eagles. Despite its dual role as a predator and as a scavenger, there is a profound lack of site-specific ecological data within central African wetlands [1]-[3], thus hampering the development of adequate conservation strategies. In Cameroon, rising anthropogenic pressures, notably hunting, logging, palm harvesting, and coastal development, are rapidly altering many habitats. While these disturbances likely disrupt the foraging and behavioral ecology of wetland-dependent species, the specific impacts on palm-nut vultures remain unquantified. Current conservation efforts are hindered by a lack of baseline data regarding the species' time-activity budgets and foraging strategies. Again, the absence of empirical research on how seasonal and environmental variables influence these behaviors prevents the development of evidence-based management plans. Consequently, without a comprehensive understanding of the vulture's feeding and behavioral responses to environmental stress, the long-term stability of both the species and its habitat remains at risk. Despite its broad distribution, ecological studies on the palm-nut vulture remain limited, particularly in Central Africa [2] [3]. Existing research has largely focused on general distribution, diet descriptions, or circumstantial observations, with few quantitative studies examining activity patterns and temporal variation in its behaviors.

Activity patterns are an important aspect of the life history and behavior of birds [4] [5]. To maximize survival and reproduction, animals must determine how to ensure security and structure periods of activity and relaxation. Food, shelter, and companionship are all essential resources, but conserving energy

while reducing risks such as predation, thermal stress, and starvation is also essential [6]. Additionally, because the advantages and disadvantages of quests like foraging and territorial defense can change over time to maximize fitness necessitates making calculated choices regarding the timing and intensity of activity [7]-[9]. Choices regarding the duration of activity are structured; there may be significant fitness implications and may be subject to significant selection pressure [10]-[12].

Habitat strongly influences the activity patterns of birds because it affects important factors such as food availability and predator presence [13] [14]. Birds generally organize their daily behaviors in ways that help them maximize food intake while reducing exposure to danger [15]. During periods of food scarcity or unpredictability, birds tend to forage more actively in the early morning to lower the risk of starvation [16]. Conversely, delaying activity until later in the day may reduce predation risk by allowing birds to maintain lower body mass and greater movability, although this strategy is more practical in habitats with abundant and predictable food resources [17]. In many temperate regions, birds balance starvation and predation risks through a bimodal activity pattern, concentrating activity in the morning and evening [14] [18]. However, in environments with low predator pressure, birds may remain active throughout the day [17]. Consequently, differences in habitat structure often produce noticeable variations in bird activity patterns due to changes in food availability and predator density [14].

Bird activity studies are significant in understanding their life history, physical condition, food availability, social structure, environmental conditions, as well as ecological conditions [19] [20]. An organism's daily activity is influenced by an individual's needs and interactions with other organisms, environmental factors such as ambient temperature, lighting, moisture, rainfall, and ecological factors such as food availability, group size, and predation [21]. Time-activity budgets are especially suitable for comparative studies, such as those among seasons of the year, sexes, and habitats [22].

2. Methods

2.1. Study Area

The study site shown in **Figure 1** is geographically positioned between latitude 3.40˚ - 3.58˚N and longitude 9.40˚ - 10.05˚E. The park covers a surface area of 2715.12 km^2 and comprises a variety of habitats, notably: mangroves, sandy beaches, estuaries, swamps, flood forests, secondary forests, and oil palm/Raphia dominated landscapes. The area experiences an equatorial climate characterized by heavy rainfall, high humidity, and relatively stable temperatures of 24˚C - 29˚C throughout the year. Rainfall is bimodal, with a long rainy (wet) season typically extending from March to October and a shorter dry season running from November to February.

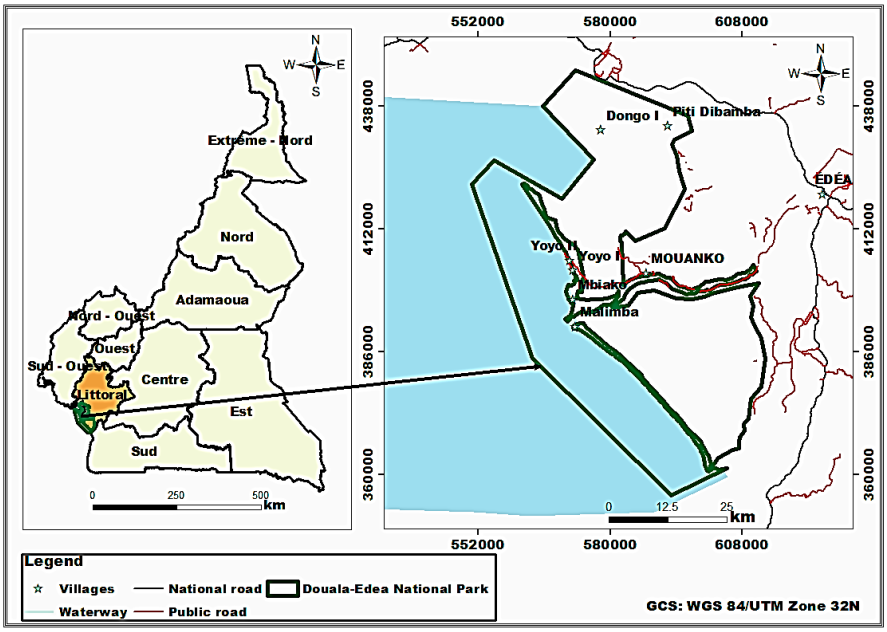


Figure 1. Map showing the location of Douala-Edea National Park.

2.2. Data Collection

Data were collected during the wet season (August and September 2025) and the dry season (November and December 2025). Two complementary methods were used: camera trapping and focal scan sampling.

Ten (10) camera traps (30 MP image resolution, infrared detection range of 15 m) were deployed at strategically selected locations such as riverbanks, open beaches, mangrove edges, and shaded forest areas as seen in Figure 2. Ten Cameras were installed at heights ranging from 2 - 5 m above ground level and programmed to operate daily from 06:00 to 18:00. The cameras were programmed such that each trigger could capture two photographs and a 15-second video per detection, to allow detailed observation of the species' behavior.

Direct behavioral observations were conducted using binoculars, with individual birds observed from a distance of 10 - 50 m to minimize disturbances. Five-minute scan samples [23] were taken at ten-minute intervals. A day was divided into four time periods: morning (06:00 - 09:00), midday (09:01 - 12:00), afternoon (12:01 - 15:00), and evening (15:01 - 18:00). Behaviors were categorized following Asokan [19] into feeding, soaring, preening, resting, and social interaction. Slokey® phone adapter was fitted to a 10 × 42 Diamondback binocular for direct photographs. For each scan sample, the following variables were recorded: GP's location, time of observation, activity at first detection (e.g., resting, soaring), foraging substrate, and habitat type. For camera trap observations, individual or consecutive photographs of the same bird were not considered independent records. Consecutive detections of the bird at the same camera station were grouped into a single detection event when they represented the same camera visit. A new independent camera trap was recognized only after a minimum of 30 minutes interval

without a detection, unless the subsequent photograph clearly showed a different individual.

2.2.1. Behavioural Categorization

Behavioral observations were classified using clearly defined categories so as to make the behavioral sampling procedure clear.

- **Feeding:** it was considered as any behavior directly associated with the acquisition and consumption of food; this included attempting to capture a prey item and swallowing or consuming the item. This observation was recorded when the bird was clearly engaged in obtaining or consuming a food resource.
- **Soaring:** it was defined as sustained flight in which the palm-nut vulture remained airborne with extended wings and used rising air currents to maintain altitude with little or no visible wing flapping. Circling, gliding, and thermal-assisted flight were included under soaring when the primary purpose of the bird appeared to be movement or aerial searching rather than direct prey capture.
- **Resting:** it referred to periods when the bird was stationary and inactive, usually perched on a tree, branch, or other elevated structures without simultaneously feeding, preening, socializing, or actively searching for food. The bird sitting quietly while conserving energy was therefore categorized as resting.
- **Preening:** it was considered the maintenance and arrangement of feathers using the bill. This included cleaning, aligning, and manipulating feathers. Preening was distinguished from resting because the bird was actively engaged in feather maintenance behavior.
- **Social interaction:** it was recorded when two or more palm-nut vultures were visibly engaged in behavior directed towards one another. These include mutual approaches, displays, courtship-related interactions, aggressions, chasing, physical contact, and other observable interactions between conspecifics. A bird merely occurring near another individual without any observable interaction was not considered as social interaction.

2.2.2. Categorization of Food Items

During feeding observations, food items were recorded only when they could be identified with reasonable confidence from direct observation, photographs, and video. Food items were classified into broad categories to minimize misidentification, including palm/Raphia fruits, fish, crabs, mollusks, insects, and others.

2.2.3. Classification of Food Capture Techniques

Food capture techniques were assigned according to the observable action immediately associated with obtaining the prey item. They included; high speed dive and picking.

2.2.4. Classification of Food Handling Techniques

Food handling behaviors were recorded separately from food acquisition. It described what the palm-nut vulture did with the food after obtaining it and/or dur-

ing consumption. Gulping and tearing then gulping were the two categories used.

2.3. Sampling Design

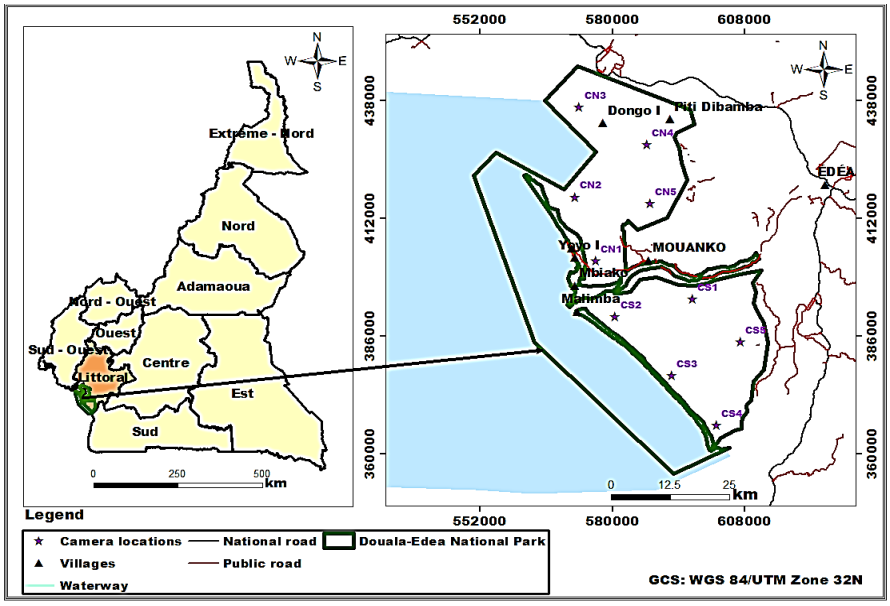


Figure 2. Map showing camera trap distribution in the park (CN = camera north, CS = camera south).

2.4. Statistical Analyses

Data were tested for normality using Q-Q plots and the Shapiro-Wilk test. To examine the effect of season and time interval on different behavioral activity patterns (feeding, soaring, resting, preening, and socializing) and One Way ANOVA was used to determine diet preferences. Descriptive analysis such as percentages, frequencies, tables, figures, and graphs were used to depict the activity time budget and feeding behavior of palm-nut vultures within Douala-Edea National Park.

2.4.1. Sampling Effort Estimation

Sampling effort was calculated as the total distance walked during each survey season. Because fixed straight lines were not used, survey effort was calculated separately for each transect and then pooled by sector (north and south), following standard practice for reconnaissance surveys in tropical environments [24] [25].

The sampling efforts (SE) for each recce transect (x) were calculated as:

$$SE(x) = \sum_{j=1}^{k} \left(L_{xj} \right)$$

where:

L = length (km) of the x^{th}. Segment walked along transect x.

k = number of segments constituting the transect between camera start and end point.

The total sampling effort for each sector was then calculated as:

$$SE\left(sector\right)=\sum_{x=1}^{n}\left(SE_{x}\right)$$

where: n is the number of transects per sector (north or south).

Camera sampling effort was calculated independently for the two seasons, then summed together as follows:

$$SE\left(wet\right)=\sum\left(\text{active camera hours during wet season}\right)$$

$$SE\left(dry\right)=\sum\left(\text{active camera hours during dry season}\right)$$

thus

$$SE\left(\text{total}\right)=\sum wet+\sum dry$$

2.4.2. Delling of Seasonal and Time of the Day Effect

A generalized linear mixed model (GLMM) with Poisson error structure was fitted [26]. The effect of season and time of the day on the activity of the palm-nut vulture was evaluated using a model that accounted for the factorial structure of the data. Season was categorized into wet and dry, while time of the day was divided into four slots: morning, midday, afternoon, and evening. The analysis evaluated both the independent effects of season and time of t day and their interactions, *i.e.*,

$$\mathbf{Y}\sim\text{season}+\text{Time}+\text{Time}\times\text{Season}$$

where: **Y** is Activity, Season is wet or dry, Time is morning, midday, afternoon, and evening, and Time × Season is the interaction between season and time of the day.

Thus, the model that best explained the data is:

$$\text{Activity}=\beta 0+\beta 1\left(\text{season}\right)+\beta 2\left(\text{Time}\right)+\beta 3\left(\text{Time}\times\text{Season}\right)+\alpha+\mu$$

where: $\beta 0$ is the intercept, μ is the residual variation, α is the random effect of sampling location, while $\beta 1$, $\beta 2$, and $\beta 3$, are respectively the marginal effects of season, time, and interaction between season and time of the day.

Tukey's HSD test was applied for post-hoc comparisons where multiple comparisons were performed, and pairwise comparisons were conducted to determine which specific time periods differed between seasons. Statistical significance was set at P = 0.05, and values were presented as mean ± standard error. Analyses were performed using R software version 4.4 [27].

3. Results

A total of eight transects were surveyed, with camera points serving as standardized start and end points. Transect lengths ranged from 13.97 km to 19.89 km in the northern sector and from 13.18 km to 18.21 km in the southern sector. Total sampling effort amounted to 63.11 km in the northern sector and 61.81 km in the southern sector, giving an average survey effort of 124.92 km per season (dry and wet), and total camera effort amounted to 2000 hours for the two seasons, as illustrated in **Table 1**.

Table 1. Sampling efforts of palm-nut vultures.

Sector	Transect	Length (km)	Camera	Global Sampling Effort (hours)
North Sector	CN1-CN2	14.14	CN1	153
	CN5-CN2	13.97	CN2	127
	CN3-CN4	19.89	CN3	377
	CN4-CN5	15.11	CN4	248
			CN5	99
North Total/Mean		**63.11**	**North Total**	**1004**
South Sector	CS2-CS1	13.18	CS1	299
	CS1-CS5	15.19	CS2	248
	CS3-CS5	15.23	CS3	61
	CS3-CS4	18.21	CS4	289
			CS5	99
South Total/Mean		**61.81**	**South Total**	**996**
Average Sampling Effort		124.92	Total camera effort	2000

3.1. Number of Detections of Palm-Nut Vultures in Douala-Edea National Park

A total of 126 individual palm-nut vultures were recorded during the dry season and 76 individuals during the rainy season, as shown in Table 2. The highest number of palm-nut vultures was recorded in the northern sector (108) as against 94 in the southern sector of Douala-Edea National Park. Detection rates differed between seasons, representing an approximate 40% seasonal decline.

Table 2. Number of detections of palm-nut vultures north and south of Douala-Edea National Park.

Sector	Dry Season	Rainy Season	Total Number of Individuals		
			Observed Number	Expected Number	Residuals
North	66	42	108	101	7
South	60	34	94	101	−7
No. of Individuals Observed N	**126**	**76**	**202**		
No. of Individuals Expected N	101	101			
Residuals	25	−25			

3.2. Overall Activity Budget

The variation in daytime duration among the observed activities within the same season and between seasons is illustrated in Figure 3. Palm-nut vultures were seen engaged in five major daily activities: feeding, soaring, preening, resting, and social interaction.

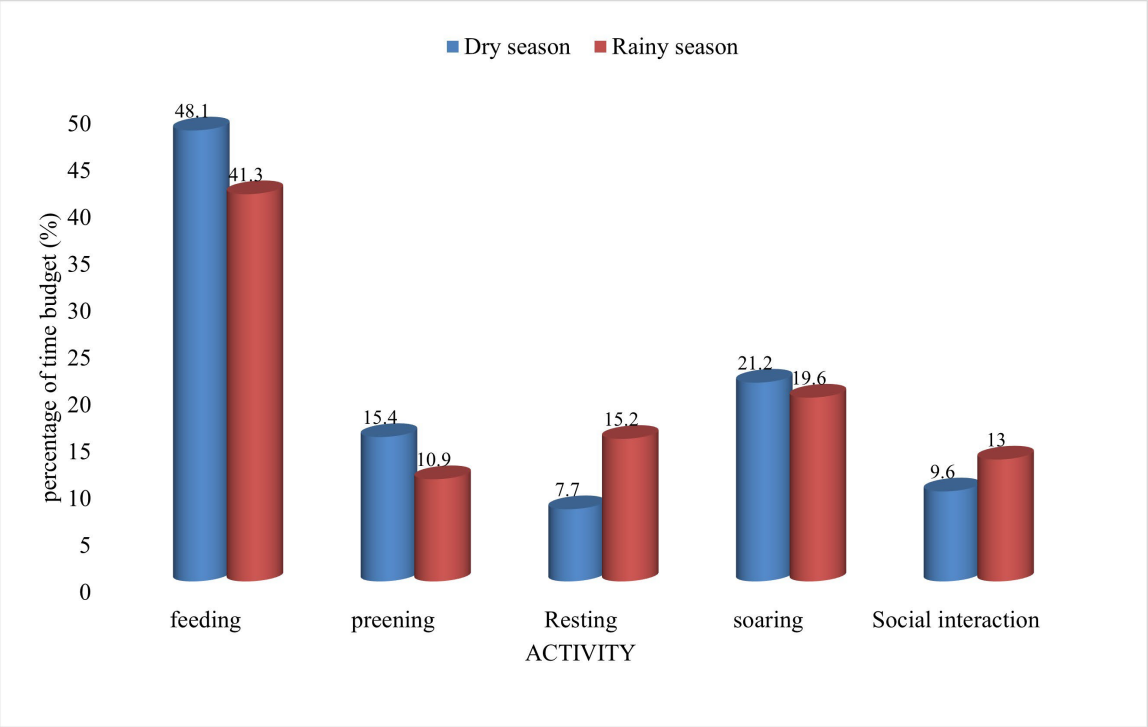


Figure 3. Time spent in different activities by palm-nut vultures within seasons.

Feeding accounted for the largest proportion of time (48.1% in the dry season; 41.3% in the rainy season), followed by soaring (21.2% in the dry season; 19.6% in the rainy season). Preening was more frequent in the dry season (15.4%) than in the rainy season (10.9%). Resting was higher in the rainy season (15.2%) compared to the dry season (7.7%). Social interactions were slightly more frequent in the rainy season (13%) than in the dry season (9.6%).

3.3. Activity during Different Time Slots of the Day

Table 3. Overall camera records of various activities in different time slots of the day.

	Time Slots (hours)							
Activity	6:00 - 9:00 Morning		9:01 - 12:00 Mid-day		12:01 - 15:00 Afternoon		15:01 - 18:00 Evening	
	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy
Feeding	**75**	**68.4**	20.8	26.3	0	5.3	4.2	0
Soaring	0	0	18.2	33.3	36.4	11.1	**45.5**	**55.6**
Preening	12.5	0	12.5	**40**	**75**	**40**	0	20
Resting	0	0	0	0	**66.7**	**57.1**	33.3	42.9
Social Interaction	0	16.7	**60**	**50**	40	16.7	0	16.7

Considering the percentage of activity during the various time slots recorded from

the camera traps (Table 3), it can be deduced that feeding was the main activity in the morning period for both seasons, while soaring was predominant in the evening in both seasons as well. Resting was more observed in the afternoon period, while social interactions were displayed more at midday. Finally, preening was displayed at midday and afternoon periods during the rainy season and in the afternoons during the dry season.

3.4. Activity Pattern of Palm-Nut Vulture during Dry Season

The diurnal activity pattern of palm-nut vultures in the DENP during the dry season (Figure 4) reveals distinct temporal variation in behavioral activities, indicating that the species allocates different activities to specific periods of the day to optimize energy expenditure and resource acquisition.

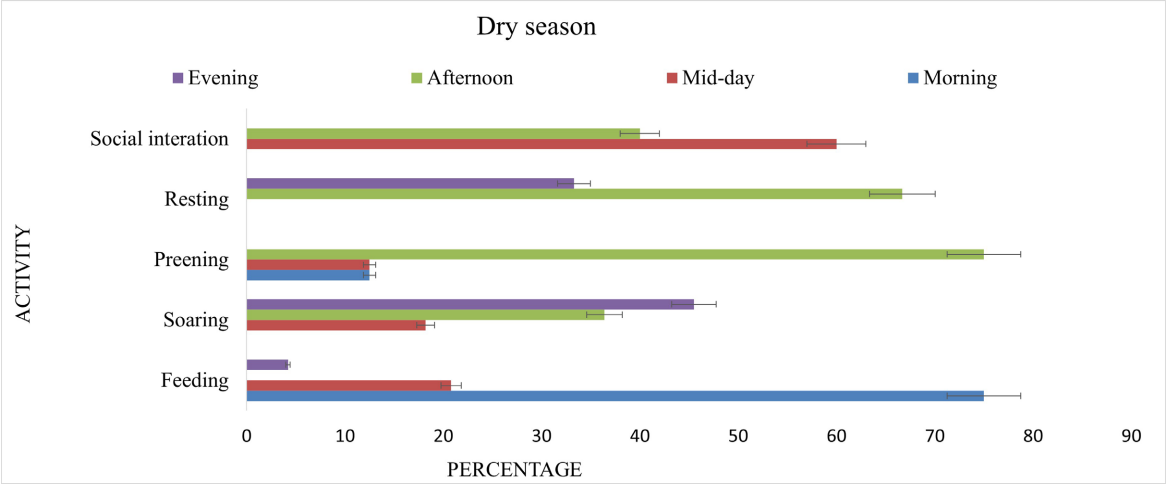


Figure 4. Diurnal activity pattern of palm-nut vulture during the dry season.

Feeding was the main activity during the morning hours, accounting for 75% of observations. Feeding activity declined sharply during midday (21%) and was almost absent during the afternoon and evening (0% - 4%). Preening was relatively uncommon during the morning hours, accounting for about 12% of observations in both the morning and midday. However, it increases remarkably in the afternoon, with a peak of 75%, before disappearing in the evening. Resting behavior was restricted to the afternoon and evening. Resting peaked during the afternoon (67%) and declined to around 33% in the evening. Social interactions were absent during the early morning and evening but occurred mainly during late morning (60%) and to a lesser extent during the afternoon (40%). These relations may involve pair bonding, territorial defense, or communication associated with feeding and Perch selection.

Overall, the dry season activity budget demonstrates a clear daily behavioral pace. Palm-nut vultures devote the early morning almost exclusively to feeding, shift towards soaring and social interactions during the late morning, allocate the hottest part of the day to preening and resting, and resume soaring during the even-

ing. This behavioral schedule reflects an adaptive strategy that balances food acquisition, energy conservation, thermoregulation, and plumage maintenance in response to the environmental conditions of the dry season in the Douala-Edea National Park.

3.5. Diurnal Activity Patterns of Palm-Nut Vulture during the Wet Season

Temporal division of the activity time budget of the palm-nut vulture during the wet season demonstrates a clear daily behavioral rhythm. Figure 5 illustrates the percentage of time allocated by the palm-nut vulture to different behavioral activities in the wet season.

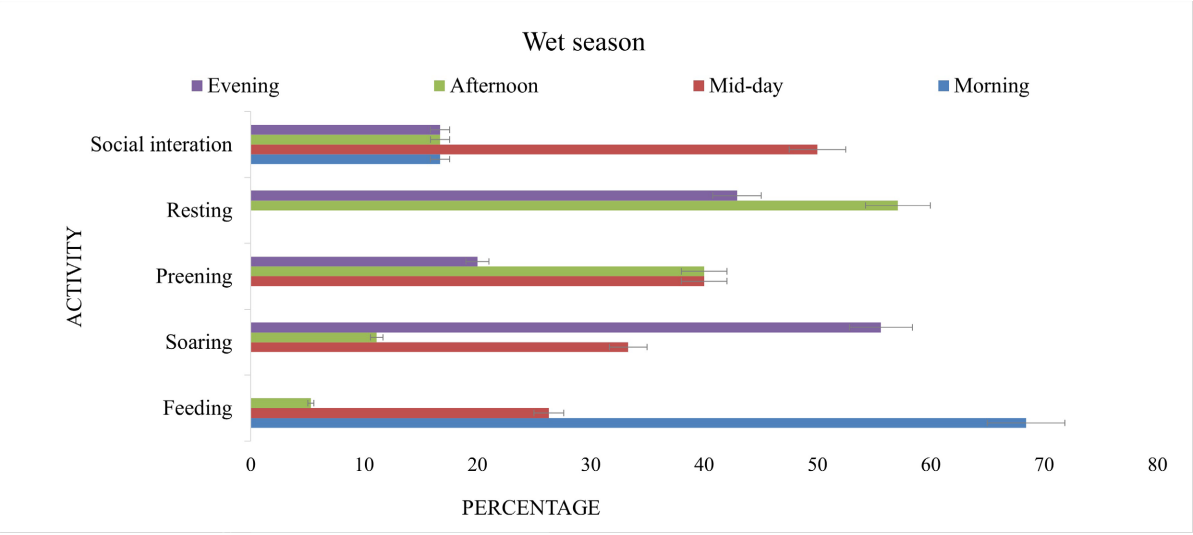


Figure 5. Diurnal activity pattern of the palm-nut vulture during the rainy season.

The result shows that feeding was the predominant activity during the early morning, accounting for approximately 67% of all observations. Feeding activity declined markedly during the late morning (approximately 26%) and became very low during the afternoon (about 5%), with virtually no feeding recorded in the evening. This pattern suggests that palm-nut vultures maximize food acquisition during the cooler hours of the day when prey is more accessible, and foraging is energetically efficient. Preening behavior occurred primarily during the midday and afternoon, representing about 40% of observations during each period, while a lower proportion (approximately 20%) was recorded in the evening. The absence of preening in the early morning suggests that birds prioritize feeding before engaging in maintenance behaviors. Resting behavior was concentrated during the afternoon and evening. Resting reached its highest level between 12:01 and 15:00 (approximately 57%), declining slightly during 15:01 - 18:00 (approximately 57%). The predominance of resting during the hotter part of the day likely reflects behavioral thermoregulation, allowing the bird to reduce energy expenditure and avoid heat stress. Soaring activity exhibited the opposite trend: it was absent dur-

ing the early morning, increased during the late morning (about 33%), declined during the afternoon (approximately 11%), and reached its highest level in the evening (about 56%). Social interactions were relatively uncommon throughout most of the day but peaked during the late morning (approximately 50%), whereas only about 17% occurred during the morning, afternoon, and evening. Increased social behavior during the late morning may be associated with pair bonding, territorial displays, or communication at communal feeding or perching sites.

Overall, the wet season activity pattern demonstrates a clear daily behavioral pace. Palm-nut vultures allocate the early morning primarily to feeding, the late morning to soaring, preening, and social interactions, the afternoon to resting, and the evening predominantly to soaring. This temporal partitioning reflects behavioral adaptations that optimize energy acquisition minimizes survival in the dynamic wetland ecosystem of the Douala-Edea National Park.

3.6. Temporal Variation in Activity Pattern of Palm-Nut Vulture within Seasons (Wet and Dry)

The observations were carried out in four time slots, and there was great variation among the activities within the four time slots, as observed in Figure 6.

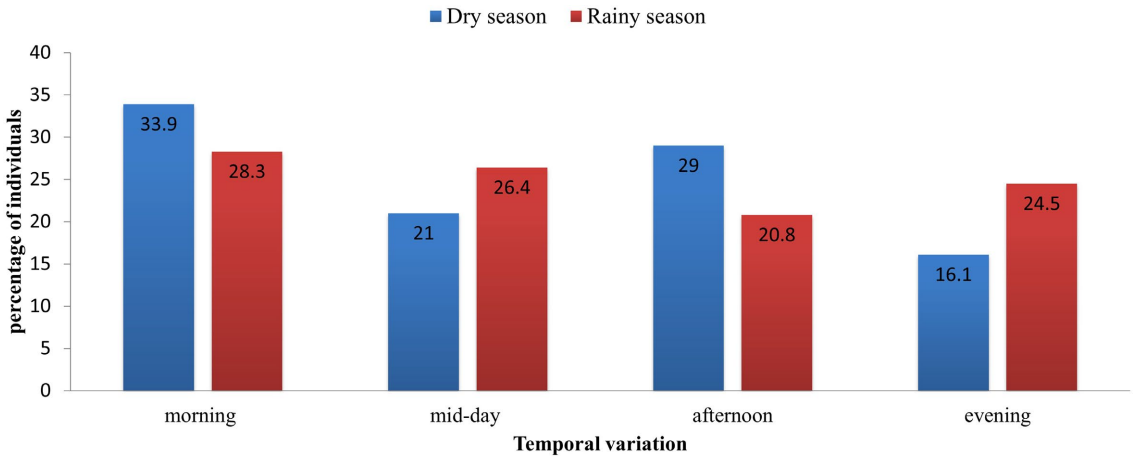


Figure 6. Showing diurnal temporal variation in activity pattern.

Activity levels varied significantly between the rainy and the dry seasons across the four time periods of the day. The results demonstrate clear seasonal variation in diurnal activity, reflecting the species' behavioral responses to changes in environmental factors, food availability, and weather conditions.

During the morning time slot, activity was highest in the dry season, accounting for 34% of the total daily activity, compared with 28% during the rainy season. This shows that palm-nut vultures were more active in the morning during the dry season, probably because of reduced cloud cover, lower humidity, and concentrated aquatic prey. At midday, the activity remained higher during the rainy season (27%) than during the dry season (20%). The increase in rainy season activity reflects prolonged foraging and movement associated with the widespread

availability of fruiting palms and other food resources during the rainy season.

An opposing trend was observed during the afternoon time slot: activity was considerably higher in the dry season (28%) than in the rainy season (22%). The predominance of afternoon activity during the dry season may reflect favorable soaring conditions created by strong thermal air currents, enabling individual vultures to soar efficiently while searching for food or suitable roosts. Again, evening activity was substantially greater during the wet season (26%) than during the dry season (15%). The increased evening activity during the rainy season could result from cooler temperatures and extended feeding or flight periods before roosting, as well as reduced thermal stress later in the day.

The mean proportion of time allocated for different activity categories by palm-nut vultures varied with season for feeding ($P < 0.05$) and soaring ($P > 0.05$) (Table 4).

Table 4. Mean proportion of time spent in different activities by the palm-nut vulture during dry and rainy seasons.

Mean Proportion of Time Spent (hours)				
Activity	**Dry Season**	**Rainy Season**	**F**	**P**
Feeding	136.4 ± 3.6	109 ± 2.1	19.532	**0.002**
Soaring	61.6 ± 1.9	42.8 ± 3.2	3.254	**0.007**
Preening	39.2 ± 4.1	47.8 ± 3.7	2.894	0.096
Resting	21.4 ± 0.9	43.8 ± 1.7	1.846	**0.038**
Social Interaction	19.5 ± 7.4	27.9 ± 5.2	2.312	0.154

Beyond seasonal variation, the mean proportion of time allocated to different activities also shifted according to the time of day. In both seasons, feeding was the predominant activity during the morning and the evening. Feeding and soaring were identified as the two principal activities, and their mean rates were compared using post hoc Tukey HSD pairwise tests. The analyses revealed significant differences in feeding ($P = 0.02$), soaring ($P = 0.01$), and resting ($P = 0.04$) rates across the four time slots.

During the rainy season, feeding rates differed significantly ($F_{3,138} = 10.27$, $P < 0.05$). Rates were higher in the morning than in the midday, lower at midday than in the afternoon, and higher in the evening than in the afternoon (Tukey HSD, $P < 0.05$). Soaring rates were also significant ($P = 0.01$), with morning values exceeding those recorded at midday, afternoon, and evening (Tukey HSD, $P < 0.05$). Significant variation was also observed in resting rates ($F_{3,138} = 5.38$, $P < 0.05$). In contrast, no significant difference was detected for preening ($F_{3,138} = 6.64$, $P > 0.05$) across morning, midday, afternoon, and evening periods, as well as in social interaction ($F_{3,138} = 7.21$, $P > 0.05$).

During the dry season, feeding accounted for the greatest proportion of time in both the morning and evening. A one-way ANOVA confirmed significant differ-

ences in feeding rates across the four time slots ($F_{3,108} = 16.34$, $P < 0.05$), with post hoc Tukey HSD tests showing that morning feeding rates were significantly higher than afternoon feeding rates ($P < 0.05$).

3.7. Foraging Behaviour of Palm-Nut Vulture

Diet composition varied slightly between seasons shown in Figure 7. During the rainy season, palm/raffia seeds (31.6%) dominated, followed by fish (26.3%) and insects (21.5%). In the dry season, fish (29.2%) dominated, followed by palm/raffia seeds (25%) and insects (16.7%). Occasional consumption of crabs, mollusks, and other aquatic organisms was observed in both seasons. Seasonal differences in prey type consumption were statistically significant ($P < 0.05$).

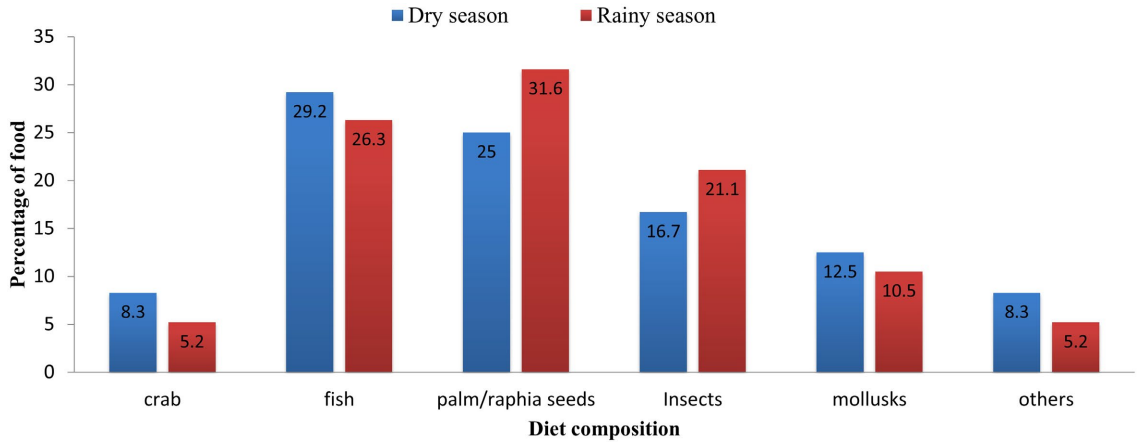


Figure 7. Diet composition of palm-nut vultures during seasons.

3.7.1. Food Capture Techniques

The palm-nut vulture (*Gypohierax angolensis*) uses two distinctive food capture techniques that combine high-speed diving and picking (Figure 8).

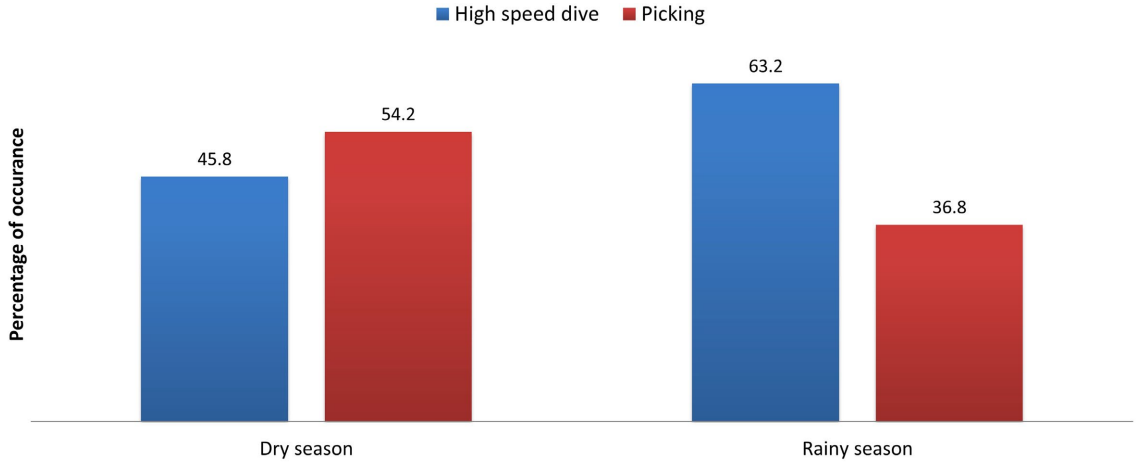


Figure 8. Food capture techniques observed in palm-nut vultures.

Rather than the tearing and scavenging typical of most vultures. These tech-

niques were used interchangeably, with picking (54.2%) peaking during the dry season and high-speed diving (63.2%) peaking during the rainy season.

3.7.2. Food Handling Techniques

Palm-nut vulture uses two simple but efficient food handling techniques as illustrated in Figure 9.

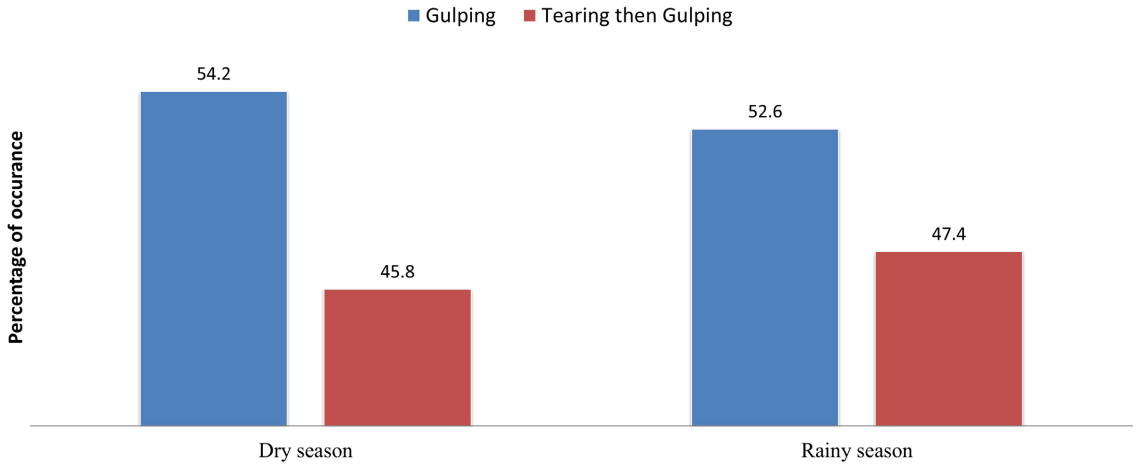


Figure 9. Food handling techniques of the palm-nut vulture.

It gulps, or tears, then gulps its prey, depending on the type and size of the food material. Small, soft, or easily manageable food resources like small fish and insects were swallowed whole. The birds lift their heads slightly and gulp the food directly, with minimal manipulation. Gulping was used dominantly in the two seasons (54.2% in the dry season and 52.6% in the wet season). This method was found to reduce food-handling time and exposure to competitors. Larger, tougher food items like crabs, large fish, and fibrous palm/raphia seeds were first torn into smaller pieces using the hooked beak before gulping. This technique allows the bird to process food that cannot be swallowed whole, and it accounted for 45.8% use in the dry season and 47.4% use in the wet season. Thus, reflecting behavioral flexibility in response to prey type and size.

4. Discussion

An evaluation of African vulture species by Thompson *et al.* [28], along with the work carried out by Carneiro [29], has emphasized a significant knowledge gap for the palm-nut vulture. The activity patterns observed in this study replicate behavioral adaptations to tropical climatic conditions and seasonal discrepancy in food availability for palm-nut vultures. Palm-nut vultures displayed distinct diel activity patterns in both the wet (rainy) and the dry seasons, with behavioral activities varying according to the time of day and seasonal environmental conditions.

In both seasons, feeding was intense during morning periods, showing that they exploit the cooler hours of the day when food resources are more accessible and

foraging is more efficient. We suggest that higher feeding rates at the beginning of the day may be due to the start of their day-to-day activities, which demand high energy requirements. In a contrasting study, it was confirmed that higher feeding at the end of the day may reflect the overnight energy requirement of birds [30]. Feeding activity declined progressively towards midday and became minimal during the afternoon and evening. The concentration of feeding in the early morning likely reflects increased prey availability and cooler environmental conditions that enhance foraging efficiency. Similar morning feeding has been widely reported among diurnal raptors, where morning hours provided favorable foraging conditions as an adaptive strategy to minimize energy intake before temperature rises [31]-[33].

Resting activity was concentrated during the afternoon (12:01 - 15:00), when ambient temperatures were maximum. Increased resting during midday likely helps minimize heat load due to high environmental temperatures; this was supported by [34]. [18] also confirmed that activities of many avian species are usually decreased at midday because of high temperatures, there by increase in resting. Other studies on the activity patterns of birds have revealed similar patterns of resting during the midday [35]. In a study on the Hooded vulture (*Necrosyrtes monachus*), it was observed that resting was high during midday and early afternoon in both the rainy and the dry seasons [36]; a similar pattern of resting during midday is practiced by the palm-nut vulture. Increased resting during midday periods, particularly in the dry season, is likely a response to elevated temperatures and humidity, allowing individual palm-nut vultures to conserve their energy. This might be because after spending a long time feeding and soaring, they rest to regenerate energy, escape from high temperatures, and preen their feathers to regain strength and freshness. As supported in another study, increased resting during the hot part of the day likely represents a behavioral adaptation to reduce heat stress and conserve energy under high ambient temperatures [37] [38]. Resting was relatively more frequent during the wet season, possibly because cloudy and humid conditions reduce opportunities for continuous soaring and foraging.

Preening occupied the smallest portion of the time activity budget and was usually performed in the early morning and late evening as a means of feather maintenance; they most often clean and preen their feathers during rest time. It was highly pronounced during the wet season, as they needed to preen their feathers after a heavy rain or bath. This indicates that feather maintenance is primarily undertaken during periods of reduced foraging activity, ensuring optimal plumage condition necessary for efficient flight and waterproofing, particularly in humid wetland environments [37] like the Douala-Edea National Park.

Soaring behavior increased as the day progressed in both seasons, reaching its highest levels during the evening. This trend, as supported by other studies, reflects the birds' use of stronger thermal air currents that develop later in the day, enabling energy-efficient flight and movement [39] across the park. However, soaring activity was more pronounced during the dry season, likely due to clearer

skies and stronger thermals associated with lower rainfall. This increase is likely associated with the formation of thermal air currents later in the day, enabling birds to travel efficiently while minimizing energy expenditure [39].

Socialization occurred mainly during midday (9:01 - 12:00) in both seasons, although they were generally infrequent compared with feeding and soaring. This activity was associated with pair closeness, territorial behavior, and communication at feeding and resting sites.

Generally, palm nut vultures demonstrated a consistent daily behavioral pace across seasons, characterized by intensive feeding in the morning, increased soaring at midday, and resting and preening behaviors during the hottest hours. Seasonal differences suggest that the species adjusts its activity budget in response to changes in weather conditions, thermal availability, and food resources. The higher feeding intensity and soaring activity observed during the dry season indicate more favorable foraging conditions, whereas the wet season is characterized by relatively greater resting and a stronger reliance on fruiting palms. These findings are consistent with previous studies showing that tropical raptors synchronize their daily activities with prey availability, thermal conditions, and energetic requirements [33] [40].

The findings also demonstrate behavioral flexibility of the palm-nut vulture and highlight its ability to adapt to seasonal fluctuations within the marshlands of Douala-Edea National Park, an important trait that contributes to its ecological success and persistence in tropical coastal habitats [31] [40]. The findings further support the view that the species displays behavioral flexibility in response to environmental situations and seasonal resource availability [31] [40]. Seasonal differences in soaring, preening, and social interactions further indicate behavioral flexibility in response to changing climatic conditions and resource availability.

Diet analysis confirms the palm-nut vulture's unique ecological niche among raptors, characterized by a mixed diet of plant and animal materials. The ideal foraging substrate was fruiting palms and raffia seeds during rainy seasons, while fish dominated during the dry season. This is due to the greater abundance of fruiting palms during the rainy season compared to other foraging resources and also better cover while feeding, thus minimizing predation risk. The dominance of fish during the dry season and fruiting palm/raphia during the rainy season illustrates the species' opportunistic feeding strategy and its dependence on wetland and palm-rich habitats. This dietary flexibility enhances resilience to seasonal fluctuations, but also underscores susceptibility to habitat degradation, particularly the loss of fruiting palms, mangroves, and fish resources.

Palm-nut vultures exhibit maximal feeding in the morning, and in the afternoon, studies on other bird species yielded the same results. The differences recorded in periodic feeding activity indicate that birds spend more time feeding during the dry season compared to the wet season. This may be due to the scarcity of food items during the dry season that requires the birds to spend more time foraging to fulfill their energy requirements. In addition, the dry season provides fa-

vorable weather conditions to forage continuously, leaving much time for them to feed uninterruptedly. Human activities such as palm harvesting, fishing, logging, and coastal development influence food availability and disturbance levels, potentially altering activity patterns and foraging behavior of palm-nut vultures. Conservation of these habitats is therefore essential for sustaining its population in the Douala-Edea National Park.

Palm-nut vultures were observed picking and gulping food items, only occasionally tearing before gulping. Such food capturing and handling techniques may have an advantage in maximizing energy input with less energy expenditure in food handling and also as a means of efficient time budgeting of foraging activity in habitats such as the Douala-Edea National Park where human disturbance is common. Habitat destruction and human disturbance due to recreational activities are major threats to the palm-nut vulture and other avian species in Douala-Edea National Park that require immediate conservation measures.

From a conservation perspective, the findings emphasize the importance of maintaining habitat heterogeneity in the Douala-Edea National Park. Mangroves, riverine systems, flood forest, and palm-dominated landscapes all contribute to sustaining a viable population of the palm-nut vulture in the Douala-Edea National Park.

5. Conclusions and Recommendations

This study provided a detailed and systematic assessment of the activity time budget of the palm-nut vulture (*Gypohierax angolensis*) in the Douala-Edea National Park, one of Cameroon's most important coastal wetlands. By combining camera trapping and focal sampling across opposing seasons, the study offered strong insights into how this species allocates time to essential behaviors and adjusts its foraging strategies in response to seasonal and daily environmental differences. The study provided comprehensive baseline data on the activity time budget and foraging behavior of the palm-nut vulture (*Gypohierax angolensis*) in the Douala-Edea National Park. The findings highlighted the importance of habitat heterogeneity and seasonal resource availability in shaping behavioral strategies. Conservation efforts should prioritize the protection of wetlands, mangroves, and palm-rich landscapes within the Douala-Edea National Park. It is recommended that conservation authorities prioritize the protection of oil and raffia palm stands, regulate fishing activities within critical foraging zones, and strengthen enforcement against habitat destruction. Community sensitization programs involving local fishermen and farmers should be promoted to enhance awareness of the ecological importance of palm-nut vultures and wetland birds in general. Further research should focus on home range, breeding ecology, population dynamics, and long-term behavioral responses to environmental changes.

Acknowledgements

We are sincerely grateful to the authorities of Douala-Edea National Park, partic-

ularly to the Conservator Mvondo Fakouma Kenneth for his assistance and collaboration during field data collection. We are grateful to the local communities and traditional authorities of all the villages surrounding Douala-Edea National Park for their collaboration during the fieldwork. Special thanks to the Eco guards of Douala-Edea National Park, notably: Eliyah Clovis Eliyah, Mouamfeyap Aramiyawou, Npande Prospere, Kalke Terance, and Ebong Terence Ebong for their enthusiasm and devotion during the fieldwork. Not forgetting the local field guide Ebonda and the Engine Pilot Papi. A final thanks to Asekeu Frederick Nkakah (Big-Fredo) for his expertise in designing the maps and analyses of field-collected data. We end with special thanks to IDEAL WILD for the equipment they granted us, and to African Forestry and Wildlife Society (AFWS) for the technical follow-up.

Author Contributions

Marshall Elah Elaze: Conceptualization, methodology, investigation, data collection, formal analysis, writing-original draft, and writing-review & editing; **Simon Awafor Tamungang:** Writing—review & editing and supervisor; **Moses Tita Mogho Njoya:** Writing—review & editing, writing—original draft, and co-supervisor; **Piebeng Ghislain Noe Kougoum:** Conceptualization, writing—review & editing, and investigation. All the authors read and corrected the manuscript and agree with the current version for publication.

Conflicts of Interest

The authors declared no conflict of interest regarding the publication of this paper.

References

[1] Anderson, M.D. (2007) Vulture Crises in South Asia and West Africa … and Monitoring, or the Lack Thereof, in Africa. *Ostrich*, **78**, 415-416. https://doi.org/10.2989/ostrich.2007.78.2.47.127

[2] Ogada, D., Shaw, P., Beyers, R.L., Buij, R., Murn, C., Thiollay, J.M., *et al*. (2015) Another Continental Vulture Crisis: Africa's Vultures Collapsing toward Extinction. *Conservation Letters*, **9**, 89-97. https://doi.org/10.1111/conl.12182

[3] Ogada, D.L. and Buij, R. (2011) Large Declines of the Hooded Vulture *Necrosyrtes monachus* across Its African Range. *Ostrich*, **82**, 101-113. https://doi.org/10.2989/00306525.2011.603464

[4] Low, M., Eggers, S., Arlt, D. and Pärt, T. (2008) Daily Patterns of Nest Visits Are Correlated with Ambient Temperature in the Northern Wheatear. *Journal of Ornithology*, **149**, 515-519. https://doi.org/10.1007/s10336-008-0300-3

[5] Maruyama, P.K., Cunha, A.F., Tizo-Pedroso, E. and Del-Claro, K. (2010) Relation of Group Size and Daily Activity Patterns to Southern Lapwing (*Vanellus chilensis*) Behaviour. *Journal of Ethology*, **28**, 339-344. https://doi.org/10.1007/s10164-009-0193-5

[6] Di Blanco, Y.E., Spørring, K.L. and Di Bitetti, M.S. (2016) Daily Activity Pattern of Reintroduced Giant Anteaters (*Myrmecophaga tridactyla*): Effects of Seasonality and Experience. *Mammalia*, **81**, 11-21. https://doi.org/10.1515/mammalia-2015-0088

[7] Dall, S.R.X. and Boyd, I.L. (2002) Provisioning under the Risk of Starvation. *Evolu-*

tionary Ecology Research, **4**, 883-896.

[8] Higginson, A.D., McNamara, J.M. and Houston, A.I. (2012) The Starvation-Predation Trade-Off Predicts Trends in Body Size, Muscularity, and Adiposity between and within Taxa. *The American Naturalist*, **179**, 338-350. https://doi.org/10.1086/664457

[9] McNamara, J.M., Higginson, A.D. and Verhulst, S. (2016) The Influence of the Starvation-Predation Trade-Off on the Relationship between Ambient Temperature and Body Size among Endotherms. *Journal of Biogeography*, **43**, 809-819. https://doi.org/10.1111/jbi.12695

[10] Larivée, M.L., Boutin, S., Speakman, J.R., McAdam, A.G. and Humphries, M.M. (2010) Associations between Over-Winter Survival and Resting Metabolic Rate in Juvenile North American Red Squirrels. *Functional Ecology*, **24**, 597-607. https://doi.org/10.1111/j.1365-2435.2009.01680.x

[11] Speakman, J.R. (2008) The Physiological Costs of Reproduction in Small Mammals. *Philosophical Transactions of the Royal Society B*: *Biological Sciences*, **363**, 375-398. https://doi.org/10.1098/rstb.2007.2145

[12] Quinn, J.L., Cole, E.F., Bates, J., Payne, R.W. and Cresswell, W. (2012) Personality Predicts Individual Responsiveness to the Risks of Starvation and Predation. *Proceedings of the Royal Society B*: *Biological Sciences*, **279**, 1919-1926. https://doi.org/10.1098/rspb.2011.2227

[13] McCabe, J.D. and Olsen, B.J. (2015) Tradeoffs between Predation Risk and Fruit Resources Shape Habitat Use of Landbirds during Autumn Migration. *The Auk*, **132**, 903-913. https://doi.org/10.1642/auk-14-213.1

[14] Reyes-Arriagada, R., Jiménez, J.E. and Rozzi, R. (2015) Daily Patterns of Activity of Passerine Birds in a Magellanic Sub-Antarctic Forest at Omora Park (55a Degrees S), Cape Horn Biosphere Reserve, Chile. *Polar Biology*, **38**, 401-411. https://doi.org/10.1007/s00300-014-1596-5

[15] Bonkewitzz, A.N. (1997) Behavior and Social Organization of the African Jacana *Actophilornis africanus*. Ph.D. Thesis, University of Natal.

[16] Macleod, R., Barnett, P., Clark, J.A. and Cresswell, W. (2005) Body Mass Change Strategies in Blackbirds *Turdus merula*: The Starvation-Predation Risk Trade-Off. *Journal of Animal Ecology*, **74**, 292-302. https://doi.org/10.1111/j.1365-2656.2005.00923.x

[17] Macleod, R., Gosler, A.G. and Cresswell, W. (2005) Diurnal Mass Gain Strategies and Perceived Predation Risk in the Great Tit *Parus major*. *Journal of Animal Ecology*, **74**, 956-964. https://doi.org/10.1111/j.1365-2656.2005.00993.x

[18] McNamara, J.M., Houston, A.I. and Lima, S.L. (1994) Foraging Routines of Small Birds in Winter: A Theoretical Investigation. *Journal of Avian Biology*, **25**, 287-302. https://doi.org/10.2307/3677276

[19] Asokan, S., Ali, A.M.S., Manikannan, R. and Nithiyanandam, G.T. (2010) Population Densities and Diurnal Activity Pattern of the Indian Roller *Coracias benghalensis* (Aves: Coraciiformes) in Nagapattinam District, Tamil Nadu, India. *Journal of Threatened Taxa*, **2**, 1185-1191. https://doi.org/10.11609/jott.o2308.1185-91

[20] Houhamdi, M. and Samraoui, B. (2008) Diurnal and Nocturnal Behavior of Ferruginous Duck *Aythya nyroca* at Lac des Oiseaux, Northeast Algeria. *Ardeola*, **55**, 59-69.

[21] Lillywhite, H.B. and Brischoux, F. (2012) Is It Better in the Moonlight? Nocturnal Activity of Insular Cottonmouth Snakes Increases with Lunar Light Levels. *Journal of Zoology*, **286**, 194-199. https://doi.org/10.1111/j.1469-7998.2011.00866.x

[22] Holmes, R.T., Black, C.P. and Sherry, T.W. (1979) Comparative Population Bioenergetics of Three Insectivorous Passerines in a Deciduous Forest. *The Condor*, **81**, 9-

20. https://doi.org/10.2307/1367848

[23] Altmann, J. (1974) Observational Study of Behavior: Sampling Methods. *Behaviour*, **49**, 227-266. https://doi.org/10.1163/156853974x00534

[24] Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L. and Thomas, L. (2001) Introduction to Distance Sampling: Estimating Abundance of Biological Populations. Oxford University Press.

[25] Walsh, P.D. and White, L.J.T. (1999) What It Will Take to Monitor Forest Elephant Populations. *Conservation Biology*, **13**, 1194-1202. https://doi.org/10.1046/j.1523-1739.1999.98148.x

[26] Lemon, J. and Grosjean, P. (2019) prettyR: Pretty Descriptive Stats. R Package Version 2.2-3 Edition.

[27] R Core Team (2024) R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing.

[28] Thompson, L.J., Krüger, S.C., Coverdale, B.M., Shaffer, L.J., Ottinger, M.A., Davies, J.P., *et al*. (2021) Assessing African Vultures as Biomonitors and Umbrella Species. *Frontiers in Conservation Science*, **2**, Article ID: 729025. https://doi.org/10.3389/fcosc.2021.729025

[29] Carneiro, C., Henriques, M., Barbosa, C., Tchantchalam, Q., Regalla, A., Patrício, A.R., *et al*. (2017) Ecology and Behaviour of Palm-Nut Vultures *Gypohierax angolensis* in the Bijagós Archipelago, Guinea-Bissau. *Ostrich*, **88**, 113-121. https://doi.org/10.2989/00306525.2017.1291540

[30] Kelly Jeffrey, F. (1998) Behavior and Energy Budgets of Belted Kingfishers in Winter. *Journal of Field Ornithology*, **69**, 75-84. https://digitalcommons.usf.edu/jfo/vol69/iss1/12

[31] Ferguson-Lees, J. and Christie, D.A. (2001) Raptors of the World. Houghton Mifflin.

[32] Newton, I. (1979) Population Ecology of Raptors. Bloomsbury Publishing.

[33] Thiollay, J. (2006) The Decline of Raptors in West Africa: Long-Term Assessment and the Role of Protected Areas. *Ibis*, **148**, 240-254. https://doi.org/10.1111/j.1474-919x.2006.00531.x

[34] Tewodros, K. and Afework, B. (2013) Population Status, Feeding Ecology and Activity Pattern of Helmeted Guinea Fowl (*Numidia meleagris*) in Abijata-Shalla Lakes National Park. *African Journal of Environmental Science and Technology*, **7**, 49-55.

[35] Megaze, A. and Bekele, A. (2013) Diet Preference and Activity Patterns of Great White Pelicans (*Pelecanus onocrotalus*, Linnaeus, 1758) at Lake Hwassa, Ethiopia. *Ethiopian Journal of Biological Sciences*, **12**, 211-222.

[36] Desalegn, T., Alemneh, C. and Shasho, G. (2025) Abundance, Diurnal Activity Patterns and Conservation Challenges of Hooded Vulture (*Necrosyrtes monachus*) in Wolkite and Butajira Towns, Gurage Zone, Ethiopia. *International Journal of Avian & Wildlife Biology*, **9**, 84-90. https://doi.org/10.15406/ijawb.2025.09.00238

[37] Martin, P. and Bateson, P. (2007) Measuring Behaviour. 3rd Edition, Cambridge University Press. https://doi.org/10.1017/cbo9780511810893

[38] McKechnie, A.E. and Wolf, B.O. (2009) Climate Change Increases the Likelihood of Catastrophic Avian Mortality Events during Extreme Heat Waves. *Biology Letters*, **6**, 253-256. https://doi.org/10.1098/rsbl.2009.0702

[39] Pennycuick, C.J. (2008) Modelling the Flying Bird. Academic Press.

[40] Brown, L.H., Urban, E.K. and Newman, K., (1982) The Birds of Africa. Vol. 1, Princeton University Press.