Anthropogenic Food Utilization and Seasonal Difference in Diet of *Cercopithecus lowei* at a Community Protected Forest in Ghana

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Abstract: In recent times, the diet and foraging behaviors of wild animals are influenced by anthropogenic foods since they often share their natural habitats with humans. We investigated the composition, preferred food item, contribution of anthropogenic food at garbage dump sites, and the seasonal effects on the diet of Lowe's monkeys (*Cercopithecus lowei*) in the Dwasidan Monkey Sanctuary, Ghana. We found that Lowe's monkeys fed on 13 plant species, as well as anthropogenic foods and invertebrates. The composition of plant diet changed seasonally: Lowe's monkeys relied more on buds in the dry season while they consumed more fruits in the wet season. However, anthropogenic food was a major component of the diet for both wet (34.8%) and dry seasons (41.3%), suggesting that the monkeys consistently rely on anthropogenic food throughout the year. Nevertheless, we did not observe any conflict between monkeys and local people. The results suggest that Lowe's monkeys heavily rely on anthropogenic food at human garbage dumps while they maintain a part of their foraging activities in the wild, indicating a need for the proper management of garbage as well as the protection of the natural habitats of Lowe's monkeys in the Dwasidan Monkey Sanctuary, Ghana.

Keywords: anthropogenic food; *Cercopithecus*; food availability; human settlement; Lowe's monkey

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1. Introduction

The seasonal fluctuation of food resources can influence the foraging behavior or diet of animals [1]. For example, animals can shift their diet to alternative food resources available or increase time spent feeding or traveling [2,3]. Many wild animals inevitably share their habitat with humans, which can easily change their diet to incorporate human foods because of the abundant and constant supply [4]. The impacts of uncontrolled garbage dumps in and around forested areas are becoming critical since an increase in human population has caused human settlements to expand around ecosystems [5]. Many primates are reported to alter their diets towards available and accessible garbage deposits around human settlements [6–9].

Anthropogenic food can often present high risk to wildlife by causing health problems through increased exposure to pathogens and bacterial diseases [10,11]. For example, feeding on garbage may infect the wildlife with trichina worms (*Trichinella spiralis*) and fish tapeworms (*Diphyllbothrium* spp.) as well as leptospira bacteria [12–14]. Furthermore, in some vultures and condors, human-mediated food consumption was found to be related to chick mortality, probably because of indigestible elements [15]. In addition, wildlife with an energy-rich anthropogenic diet were found to have a smaller range, had a shorter distance of dispersal, and adjusted their general behaviors including foraging, travelling, and socializing [8,16].

Although we cannot ignore the negative impact of garbage, if managed properly, anthropogenic food can offer additional nutrients for wild animals (i.e., fallback food), resulting in increased weights and survival rates, decreased infant mortality, and, ultimately, increased population size [17–22]. For example, in *Ursus americanus* (American black bear), individuals that fed on anthropogenic foods grew and matured more rapidly, gained more weight, and developed a more robust reproductive system than individuals that solely relied on plant foods [23]. When wild animals are already heavily dependent on anthropogenic food, totally removing the anthropogenic food may negatively affect their survival and may increase human–animal conflict due to animals seeking food in human-inhabited areas. Thus, a proper management of the accessible anthropogenic food should be prioritized [21,23].

The Lowe’s monkey (*Cercopithecus lowei*) is endemic to the upper Guinea rainforest and it is classified as vulnerable by the IUCN Red list [24] as its population size is decreasing due to habitat loss and degradation because of agriculture and human settlements [24]. The species is not exclusively arboreal and is mostly found close to ground cover in most forest types, including secondary forests, but not in marshy areas [25,26]. In Ghana, the species is found in a few protected areas including the Kakum Conservation Area [27] and Duasidan Monkey Sanctuary. In Duasidan, local people protect the Lowe’s monkeys, following their traditional cultural belief. However, the monkeys in the area rely on anthropogenic foods. The main diet of Lowe’s monkeys consists of fruits; however, they also feed on a wide range of plant parts including seeds, leaves, and buds [25]. Lowe’s monkeys are generally understudied and the seasonal variation in the consumption of both natural and anthropogenic food is not known for the species. In this study, we examined the diet of Lowe monkeys, emphasizing the seasonal foraging activity and preference for wild foods as well as the utilization of anthropogenic food at the Duasidan Monkey Sanctuary in Ghana. During the dry season, humidity is very low, causing insufficient water availability for plant physiological processes and resulting in insufficient food quantity and quality [28,29]. Biodiversity monitoring conducted at the Duasidan monkey sanctuary reported that food quality and quantity was low during the dry season [30]. This may compel many animals to move out of their abode to access alternative foods [31]. We expected the diets and preferred food of the Lowe’s monkeys to show seasonal variations because food is less commonly available in the dry season [30] and the anthropogenic foods function as an important food resource when natural food availability is low. Our study therefore aimed to (1) determine food categories consumed by Lowe’s monkeys in the sanctuary and their seasonal variations, (2) identify preferred plants and plant parts consumed and their seasonal variations, and (3) provide information on the seasonal use of anthropogenic food as a food source by Lowe’s monkeys.

2. Materials and Methods

2.1. Study Area

The study site, the Duasidan Monkey Sanctuary (DMS), is a good example of a natural habitat of Lowe’s monkeys, situated near a human-dominated settlement. It is a community protected forest, about 1.8 ha in size, located on the outskirts of the Duasidan community (7.2408° N; 3.1144° W, Figure 1). The vegetation consists of small pockets of riverine forest with many woody and herbaceous plants consisting of vines and climbers [30]. The terrain is quite flat with the main Duasidan stream bordering the extreme end of the sanctuary. The sanctuary lies in a zone that experiences bimodal rainfall, reaching about 1015 mm per year, typically accompanied by a wet season (April–October) and a dry season (November–March). Rainfall is the lowest in January, with an average of 17 mm, and highest in September, with an average of 143 mm. The area has a tropical climate, with mean minimum temperatures of 21 °C and maximum temperatures of 26.8 °C. The local people in the community are predominantly farmers prioritizing food crops such as maize, cassava, plantain, and tree crops including cocoa and cashew. The people in the community dump garbage that is usually regular household (food and plastic) garbage at

the fringes of the sanctuary. In this area, killing or causing harm to the monkeys is taboo and people and the monkeys have been mingling peacefully at the study site for more than 120 years. A traditional setup, enacted local by-laws and taboos, enforced by the chiefs and community elders, is used for the conservation of primates as well as promotion of eco-tourism (personal observation).

Figure 1. Location map of the study site, Duasidan Monkey Sanctuary (red star), Ghana and the study species, Lowe's monkeys (*Cercopithecus lowei*). Sources for the map: Esri, USGS, FAO, NPS, OpenStreetMap Contributors, and the GIS User community. Photo credit: Edward Debrah Wiawe.

2.2. Data Collection

We collected data by alternating among three Lowe's monkey groups with each group consisting of 8–15 individuals (including adults and juveniles) between 06:00 a.m. and 06:00 p.m. during the wet season (June–July) and dry season (January–February) for eight days per month in 2017, which resulted in an average time of 9.75 ± 0.12 h per day and a total of 312 h. We kept a distance of about 10–15 m from the monkeys while following them to avoid disturbing the group and regularly scanned the group at 10-min intervals to observe the activities. We recorded the behaviors of the monkeys following these categories: feeding, moving (all activities that involve locomotion including walking, playing, running, and jumping) and resting (all activities that did not involve locomotion including grooming, lying, sitting, and sleeping). We recorded the behavior of the majority of monkeys as a representative of the behavior at that time (e.g., 90% of individuals foraging is recorded as foraging), while trying to detect as many individuals as possible. We used predetermined forest trails of lengths of 50 m during the observations.

Food items eaten by the monkeys were classified into plants, anthropogenic food, and invertebrates. We recorded the feeding activities of the monkeys through instantaneous scan samples at 10-min intervals. At each scan period, we recorded the food items of

the feeding individuals. We categorized plant food items into leaf, seed, fruit, flower, and bud. Furthermore, anthropogenic food was categorized into uncooked food/peel, leftover cooked food, and food in plastics (non-biodegradable materials/polythene bags). We assessed the presence of plant species in the Lowe's monkey habitat by randomly distributing six quadrats (50×50 m) in the wet and dry seasons and calculated the relative abundance of food plant species [32–35]. The number of feeding visits to a plant species as well as parts consumed were recorded and used to calculate the preference indices of a plant species (total number of observations on a particular plant species consumed/relative abundance of the plant species) by the Lowe's monkeys.

2.3. Data Analysis

We used Wilcoxon rank sum tests to examine seasonal differences in diet composition (i.e., proportion of plants, anthropogenic foods, invertebrates in diet), plant type (i.e., proportion of fruits, flowers, leaves, seeds, buds in diet), and anthropogenic food types (i.e., proportion of uncooked food/peel, leftover cooked food, and food in plastics). We also used the Shannon–Wiener diversity index (H') to calculate the diversity of plant species consumed by Lowe's monkeys and compared it between wet and dry seasons. To determine a preferred plant species, we calculated preference indices of plant species as total number of observations on a plant species consumed/relative abundance of that plant species in the six quadrats. We calculated the range of preference indices of a plant species and categorized them into three blocks: low (0–1.9), average (>1.9–3.9), and high (>3.9–6). We also ran a Wilcoxon rank sum test to examine seasonal difference in a preferred plant species. Statistical analyses were performed using R (R version 4.0.3, R core team 2020, Vienna, Austria).

3. Results

3.1. Activity Budgets

During the study period, the monkeys spent one-third of their time during the wet season feeding (30.1%; 57.8 h) and two-fifths (40.6%; 77.9 h) during the dry season. The monkeys spent two-fifths of their time during the wet season moving (40.1%; 76.9 h) and two-fifths (41.3%; 79.3 h) during the dry season. Finally, the monkeys spent one-third of their time during the wet season resting (29.8%; 57.2 h) and one-sixth (18.1%; 34.8 h, Figure 2) during the dry season. The monkeys spent significantly more time on feeding during the dry season than the wet season (Wilcoxon rank sum test; $N = 32$, $w = 256$, $p = 0.0001$) and significantly more time on resting during the wet season than the dry season (Wilcoxon rank sum test; $N = 32$, $w = 0$, $p = 0.0001$). There was no significant difference in the amount of moving between both seasons ($N = 32$, $w = 168$, $p = 0.158$).

Figure 2. Proportion of daily activities spent by Lowe's monkeys feeding ($p = 0.0001$), moving ($p = 0.158$), and resting ($p = 0.0001$) during the dry and wet seasons in the Duasidan monkey sanctuary, Ghana ($^{xxx} p < 0.001$). The line in the boxes represents a median value while the boxes represent interquartile ranges and whiskers represent the range of minimum and maximum values.

3.2. Food Categories

In both wet and dry seasons, plants (64.3% and 57.8%, respectively) constituted the highest proportion of food items consumed by Lowe's monkeys, followed by anthropogenic food (34.8% and 41.3%) and then invertebrates (0.9% each, Figure 3). We found no significant differences in the diet composition between the wet and dry seasons (Wilcoxon rank sum test: $N = 32$, $w = 87.5$, $p = 0.129$, anthropogenic food: $N = 32$, $w = 171$, $p = 0.107$, invertebrate: $N = 32$, $w = 128.5$, $p = 1.000$).

Figure 3. Percentage composition of plant, anthropogenic food, and invertebrates in the diet of Lowe's monkeys in the wet and dry seasons at Duasidan Monkey Sanctuary, Ghana (Wilcoxon rank sum test: $p > 0.05$).

3.2.1. Plants Consumed

We identified 24 plant species belonging to 17 different families from the study area. We observed that Lowe's monkeys consumed 13 plant species in the dry season and eight plant species in the wet season (Table 1). There was a significant difference in fruits and buds consumed by the monkeys between wet and dry seasons (both $N = 32$, fruits; $w = 23.5$, $p < 0.001$, buds; $w = 236.5$, $p < 0.001$) but a no-significant difference in seeds ($N = 32$, $w = 114$, $p = 0.455$), leaves ($N = 32$, $w = 153$, $p = 0.298$), and flowers ($N = 32$, $w = 120.5$, $p = 0.602$) between wet and dry seasons. The proportion of fruits consumed by the monkeys was higher in the wet season than the dry season ($71.2 \pm 3.3\%$), while the proportion of buds was higher in the dry season than the wet season ($44.8 \pm 3.9\%$; Figure 4).

Table 1. Preference indices of plant species consumed by Lowe’s monkeys in the Duasidan Monkey Sanctuary, Ghana.

Species	Dry Season		Wet Season	
	Number of Feeding Observations	Preference Indices	Number of Feeding Observations	Preference Indices
<i>Bombax buonopozense</i>	2	0.39 *	-	-
<i>Ceiba pentandra</i>	8	0.78 *	13	1.26 *
<i>Celtis milbraedii</i>	3	0.84 *	-	-
<i>Cola gigantean</i>	5	2.44 **	7	3.42 **
<i>Dacryodes klaineana</i>	1	0.19 *	-	-
<i>Discoglypsemna caloneura</i>	4	1.56 *	3	1.17 *
<i>Ficus exasperata</i>	8	3.13 **	14	5.47 ***
<i>Mangnifera indica</i>	7	2.27 **	6	1.95 **
<i>Milicia excelsa</i>	3	0.97 *	2	0.65 *
<i>Pycnanthus angolensis</i>	10	1.95 **	15	2.92 **
<i>Raphia hookeri</i>	9	1.75 *	12	2.34 **
<i>Spondias mombin</i>	1	0.39 *	-	-
<i>Terminalia ivorensis</i>	2	0.19 *	-	-

Diet preference: * low preference; ** average preference; *** high preference.

During the wet season, *Ficus exasperata* was the most preferred food item, with a preference index of 5.47, followed by *Cola gigantean* (3.42), *Pycnanthus angolensis* (2.92), and *Raphia hookeri* (2.37). During the dry season, *F. exasperata* was the still most preferred plant species, with a preference index of 3.13, followed by *C. gigantean* (2.44) and *Mangnifera indica* (2.27; Table 1). We found different diversity indices of plant species consumed by the monkeys for wet (Shannon–Wiener diversity index: $H = 1.92$) and dry seasons (Shannon–Wiener diversity index: $H^1 = 2.35$), with a higher diversity in the dry season.

Figure 4. Proportion of fruit ($p < 0.001$) and buds ($p < 0.001$) consumed by Lowe’s monkeys in wet and dry seasons in the Duasidan Monkey Sanctuary, Ghana (xxx $p < 0.001$). The line in the boxes represents a median value while the boxes represent interquartile ranges and whiskers represent the range of minimum and maximum values.

3.2.2. Anthropogenic Food Type Consumed

Lowe’s monkeys retrieved anthropogenic food by processing non-segregated anthropogenic foods at the dumpsites. Among the anthropogenic food types, leftover foods

(39.9%) constituted the highest proportion of the Lowe's monkeys' diet in the wet season, while uncooked food/peels (50.5%) constituted the highest proportion in the dry season. There were no significant differences in the proportion of anthropogenic foods consumed by Lowe's monkeys between wet and dry seasons for uncooked food/peels ($N = 32$, $w = 157$, $p = 0.274$), leftover foods ($N = 32$, $w = 113.5$, $p = 0.589$), and food in a plastic cover ($N = 32$, $w = 126.5$, $p = 0.968$).

4. Discussion

Lowe's monkeys at the Duasidan Monkey Sanctuary (DMS) seasonally altered their diet on plant parts while exhibiting seasonally stable feeding behaviors utilizing anthropogenic foods. Regarding the plant types, the monkeys consumed more fruits than other plant parts during the wet than the dry season, and more buds in the dry than the wet season. Lowe's monkeys spent more time to consume plant species and less anthropogenic food in the wet season than the dry season; however, the monkeys fed considerably often on anthropogenic food throughout the seasons, differing from our prediction. Our results suggest that (1) Lowe's monkeys seasonally adjust their diet on plant parts, probably according to nutrient content and availability, and (2) anthropogenic food has an important role in Lowe's monkeys' diet throughout the seasons.

The amount of time Lowe's monkeys spent feeding increased in the dry season. The seasonal variation in the activity budget of Lowe's monkeys is probably because of the low food availability season [29,30]; for instance, the animals spent more time foraging to compensate for the low quality of foods in the dry season [28,29]. This may maximize energy intake and helps to meet their daily nutrient requirements [21,36]. The Lowe's monkeys rested significantly more during the wet season. This result might indicate that the monkeys do not need to spend as much time foraging since food resources become more abundant during the wet season. This suggests that the activity budget of primates that feed on anthropogenic food may be altered seasonally [6,8]. Anthropogenic foods also can affect feeding time; for example, *Cercopithecus aethiops* (African green monkey) that feed on wild plants spend 40% of their time feeding compared with 20% for individuals of the same species that feed on anthropogenic foods [37]. Similarly, *Papio anubis* (Olive baboon) and *Macaca mulatta* (Rhesus macaque) spend 25% and 50% feeding on anthropogenic food but less than 17% and 27%, respectively, feeding on wild foods [38,39].

Our results regarding the seasonal change in Lowe's monkeys' plant diet suggest that other plant parts can have an important role when fruit availability is low. For example, buds are known to have high water content [40] and chemical elements such as ascorbic acid [41], which may help the Lowe's monkeys to fulfill their dietary requirement, especially during the dry season. Our results also suggest that buds can be fallback food for the monkeys, similarly to the results from other studies [42–44]. When it comes to preferences, Lowe's monkeys did not have a seasonal preference on plants. This might be because the preferred plants of Lowe's monkeys at the Duasidan Monkey Sanctuary produce different consumable parts at different periods of the year. For example, *Raphia hookeri* produces different parts including fruits and leaves in the wet and dry seasons [45–48]. Plants that primates feed on often have different parts readily available and in sufficient quantity throughout the year [33,34,49]. This was most evident in our study, revealing that the Lowe's monkeys highly consumed Anacardiaceae, Moraceae, and Bombaceae species, most of which produce plant parts available for several months of the year covering both dry and wet seasons. Moreover, the plant species preferred in both seasons by the Lowe's monkeys might have high nutrition, especially *Ficus exasperata*, *Cola gigantea*, *R. hookeri*, *Pycnanthus angolensis*, and *Mangifera indica*, as shown in other studies [50,51].

The impact of anthropogenic food on wild animals is gaining attention by conservationists worldwide [52]. Several studies confirmed that primates spend large amounts of their feeding time consuming anthropogenic food [6,9]. For example, *Cebus libidinosus* (Capuchin monkeys) spend 38% of their feeding time on anthropogenic foods [50] and *Papio* sp. spend 25% [33,38] and 20% [6] of their feeding time on anthropogenic foods.

We found that Lowe's monkeys fed on anthropogenic food in both wet and dry seasons, indicating that the species consumes anthropogenic food all year round. Our results indicate that anthropogenic food is not serving as fallback food for the period with low fruit availability, but as a stable food resource for the Lowe's monkeys. Similar to our study, Sabbatini et al. [53] found that capuchin monkeys constantly consume food they obtained from the garbage. However, Macdonald et al. [54] suggested that the presence of anthropogenic food in the diet of animals could be because of a lack of naturally occurring foods.

Many factors may regulate the consumption of anthropogenic foods, including fewer efforts in processing and digesting food items as well as high nutritional value [9,55]. The anthropogenic food sources are highly likely to provide nutrition gains to the monkeys [21,23]. Furthermore, the monkeys inspected (i.e., handling and smelling) substances before eating and they sometimes rejected a substance after inspection, indicating that they were probably able to distinguish between perished and still edible foods and waste. Wild Rhesus monkeys (*Macaca mulatta*) were found to adopt a similar strategy when feeding on garbage to avoid the risk of ingesting plastic [36]. Thus, the Lowe's monkeys may have a similar strategy when selecting anthropogenic food.

Despite the potential benefits of anthropogenic food to wild primates, a principal concern regarding anthropogenic food intake is the alteration of their behaviors and health condition due to nutritional values and contamination [55]. For instance, the activity budget of primates that feed on anthropogenic food is mostly altered, with minimum time spent feeding and more time resting [6,8]. There is a direct relationship between an animal's activity budget and its bioenergetic allocation. Any changes in the activity budget can negatively affect bioenergetic allocations of the animal. This could result in reduced abilities of the individuals to survive and reproduce [56,57]. Managing garbage as a food supplementation tool has been discussed for many decades [58]. The two opposing ends are either to control wildlife feeding on garbage or stop wildlife from utilizing garbage dumps. The general current consensus is to restrict access; for example, officials of the Yellowstone National Park in the 1970s closed all dumps to eradicate the provision of anthropogenic food to bears in and around the National Park [59]. Here, we would like to emphasize the comparatively high volume of anthropogenic food as a food source of the Lowe's monkey. However, if access to anthropogenic foods is not restricted, in the future, an unequal access to foods at the garbage site could result in competition within or among the groups and potentially affect the good health and robustness of the individuals in the group [55]. Limited access to such foods could also cause monkeys to troop to the homes of people, resulting in conflict, although we have not yet observed any direct conflict between the Lowe's monkeys and local people at the Duasidan Monkey Sanctuary, in opposition to the study conducted in Boabeng-Fiema Monkey Sanctuary [60]. This suggests that abruptly removing the access to garbage dumps might have a short- to medium-term abrupt negative effect on the monkeys, given their reliance on the anthropogenic foods. While proper management of the garbage would allow the monkeys to take advantage of anthropogenic foods, a long-term plan for gradual reduction of the human-mediated foods and preventing monkeys' habitat degradation will be required for the species' conservation. The traditional authorities of the Duasidan community are recommended to liaise with the Wildlife Division of Ghana, the technical department responsible for wildlife conservation in Ghana, and also engage non-governmental organization (NGOs) to develop a sustainable management plan for the monkey sanctuary. Even though our study area covers a relatively small area, its conservation is of valuable importance as it is one of the few areas in Ghana to harbor the remaining populations of Lowe's monkeys.

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