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Research Article

Preuss's Red Colobus Associations with Other Primates and their Threats in Korup National Park, Cameroon

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ABSTRACT

This study investigates the associations and threats facing the Critically Endangered Preuss's red colobus (*Procolobus preussi*) in Korup National Park, Cameroon. The scan sampling method was used with over 462 observation hours; we documented 76 Preuss's red colobus groups, resulting in 2,303 individual sightings. Our findings reveal that Preuss's red colobus associates with six primates: *Cercopithecus pogonias, Cercopithecus nictitans, Cercopithecus mona, Cercopithecus erythrotis, Cercocebus torquatus, and Mandrillus leucophaeus*. The most frequent associations were observed with *Cercopithecus nictitans and Cercopithecus pogonias*, while associations with Cercopithecus torquatus were least common. Behavioral observations showed that resting (29.74%), feeding (23.66%), and moving (23.14%) were the predominant activities of Preuss's red colobus during these associations. Questionnaires administered to 187 hunters from villages within and outside Korup National Park identified overhunting as the primary threat to Preuss's red colobus, followed by habitat destruction. Hunters aged 21-40 years were found to be the most active, engaging in both hunting and farming year-round. The study found no evidence of chimpanzee predation on Preuss's red colobus in Korup National Park. This research contributes valuable data on primate associations in the Cross-Sanaga-Bioko ecoregion and highlights the feasibility of studying this elusive species. The findings underscore the urgent need for enhanced conservation measures in Korup National Park, including strengthened anti-poaching efforts, improved alternative livelihood options for local communities, and targeted education programs. This study serves as a foundation for further research and conservation efforts, and future research aimed at preserving Preuss's Red Colobus and the maintenance of primates' communities in tropical forest ecosystems.

Keywords: *Procolobus preussi*, anthropogenic activities, Korup National Park, hunting, Habitat destruction, Activity pattern.

RÉSUMÉ

Cette étude examine les associations et les menaces pesant sur le colobe roux de Preuss (*Procolobus preussi*), une espèce en danger critique d'extinction, dans le parc national de Korup, au Cameroun. La méthode d'échantillonnage par balayage a été utilisée sur plus de 462 heures d'observation, permettant de documenter 76 groupes de colobes roux de Preuss, totalisant 2 303 observations individuelles. Nos résultats révèlent que cette espèce s'associe à six autres espèces de primates: *Cercopithecus pogonias*, *Cercopithecus nictitans*, *Cercopithecus mona*, *Cercopithecus erythrotis*, *Cercocebus torquatus* et *Mandrillus leucophaeus*. Les associations les plus fréquentes ont été observées avec *Cercopithecus nictitans* et *Cercopithecus pogonias*, tandis que les associations avec *Cercopithecus torquatus* étaient les moins courantes. Les observations comportementales ont montré que le repos (29,74 %), l'alimentation (23,66 %) et les déplacements (23,14 %) étaient les principales activités du colobe roux de Preuss lors de ces associations. Des questionnaires administrés à 187 chasseurs issus de villages situés à l'intérieur et à l'extérieur du parc national de Korup ont identifié la chasse excessive comme la principale menace pesant sur le colobe roux de Preuss, suivie par la destruction de son habitat. Les chasseurs âgés de 21 à 40 ans se sont révélés les plus actifs, pratiquant la chasse et l'agriculture tout au long de l'année. L'étude n'a trouvé aucune preuve de prédation par les chimpanzés sur le colobe roux de Preuss dans le parc national de Korup. Cette recherche fournit des données précieuses sur les associations entre primates dans l'écorégion Cross-Sanaga-Bioko

et démontre la faisabilité d'étudier cette espèce discrète. Les résultats soulignent l'urgence de renforcer les mesures de conservation dans le parc national de Korup, notamment par le renforcement des efforts de lutte contre le braconnage, l'amélioration des moyens de subsistance alternatifs pour les communautés locales et la mise en place de programmes éducatifs ciblés. Cette étude constitue une base pour des recherches et des efforts de conservation futurs visant à préserver le colobe roux de Preuss et à maintenir les communautés de primates dans les écosystèmes forestiers tropicaux.

Mots-clés : *Procolobus preussi*, activités anthropiques, parc national de Korup, chasse, destruction de l'habitat, régime d'activités.

1. INTRODUCTION

Associations among different species of primates are common in tropical forests. These associations can range from chance encounters to more structured relationships, often driven by shared resource use or mutual benefits (Gautier and Gautier-Hion, 1969; Struhsaker, 1978, 1981; Gautier-Hion et al., 1983; Galat and Galat-Luong, 1985; Cords, 1987, 1990a, b; Whitesides, 1989; Oates and Whitesides, 1990; McGraw, 1994). While some primates form poly-specific associations, others do not (Terborgh, 1990). Species that associate by chance encounters due to commonly used resources do not require a functional explanation (Waser, 1982).

Members of the genus Piliocolobus, such as red colobus monkeys, frequently associate with Cercopithecus monkeys in several African sites. For instance, red colobus monkeys often form close associations with Diana monkeys (*Cercopithecus diana*) in rainforest habitats. Research in Taï National Park, Ivory Coast, found that red colobus groups were closely associated with Diana monkeys for a significant portion of the time (Höner, 2006). This association is believed to provide mutual protection against predators, reducing predation pressure from ground predators and birds of prey (Noe and Bshary, 1997). Similar associations have been observed between red colobus and red-tailed monkeys (*Cercopithecus ascanius*) in Kibale National Park, Uganda, suggesting mutual protection against predation (Teelen, 2007). The anti-predation hypothesis is further supported by evidence showing increased formation of red colobus-Diana monkey associations during chimpanzee hunting seasons (Noë and Bshary, 1997).

Chimpanzee predation is a significant threat to red colobus populations, particularly in areas where the two species coexist (Teelen, 2007; Watts, 2013; Morgan et al., 2013). Despite the potential for mutual protection, associations with red-tailed monkeys do not appear to provide red colobus with protection against chimpanzees (Teelen, 2007). However, interactions between pygmy chimpanzees and red colobus at Wamba, Republic of Zaire, did not show evidence of hunting (Ihobe, 2006). The decline in red colobus populations due to chimpanzee predation has been observed in various areas, raising concerns about the sustainability of this species (Watts, 2013).

However, to improve the conservation strategy of Preuss's red colobus (PRC), further research is needed on the predation relationship between the Chimpanzee and PRC. In addition to natural predation, red colobus monkeys face significant threats from human activities, particularly hunting and habitat loss (Struhsaker, 2005; Ikemeh, 2015; Fonkwo et al., 2017). These activities have led to serious population declines in some cases (Ikemeh, 2015). It is important to scientifically assess perceived human-wildlife conflicts, such as red colobus consumption of coconuts (Siex and Struhsaker, 1999). Human disturbances, including fire density and proximity to villages, have also been shown to impact the genetic structure of red colobus populations (Ruiz-Lopez, 2016).

In Cameroon, the first predation attempt by Nigerian-Cameroon chimpanzees (*Pan troglodytes ellioti*) on Preuss's red colobus (*Procolobus preussi*) was documented in the Ebo forest, where the activity lasted for 15 minutes and involved one chimpanzee and one red colobus (Morgan et al., 2013). In Korup National Park, *Pan troglodytes ellioti* do exist with a large population of Preuss's red colobus, but it has not been documented any predation. Many studies in other African countries have shown that chimpanzees are a non-human threat to red colobus (Oates and Whitesides, 1990; Terborgh, 1990; Zuberbühler and Wright, 2001), while other studies indicate human activities as threats to red colobus (Astaras, 2009; White, 1992; Chapman and Lambert, 2000; Mammides et al., 2008; Fonkwo et al., 2017). However, there is a lack of studies documenting chimpanzee predation on Preuss's red colobus in Korup National Park.

This study is the first of its kind in Korup National Park (KNP), Cameroon, and seeks to determine the polyspecific associations of Preuss's red colobus with other primates and identify the threats they face, contributing to the

conservation of this species through informed policy-making and stakeholder engagement. Specifically, we aim to: 1) Identify the different species of primates that associate with Preuss's red colobus and the frequency of their associations in KNP; 2) Determine the activity time budget of PRC associated with other primates; and 3) Evaluate the threats to Preuss's red colobus. By providing insights into the ecology and conservation challenges facing this critically endangered species, we aim to inform policymakers and conservation stakeholders, ultimately contributing to more effective protection strategies for Preuss's red colobus and its habitat.

The protection strategy will be developed based on need and research in the area. This study will inform strategic planning for conservation. The paper does not mention any other primate (not associated with PRC) that might be critically endangered. This would help understand the landscape and severity of the need, and when considering interdisciplinary collaboration, may be a benefit in effecting timely protection.

2. MATERIALS AND METHODS

2.1. Study site, location, and description

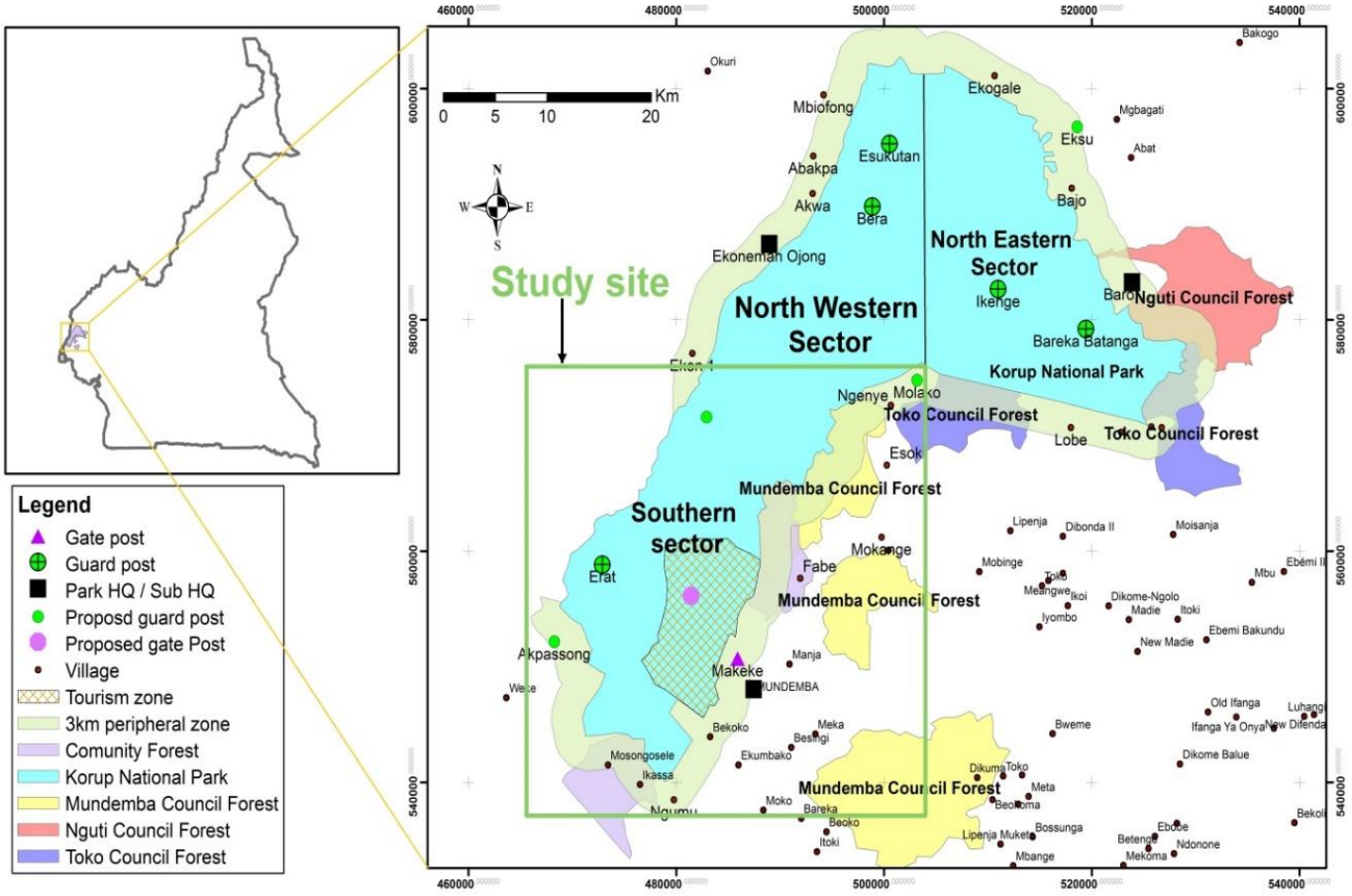

Figure 1: Map of Korup National Park showing the study site. Source: Adapted from MINFOF (2008).

Korup National Park is situated in the South West Region of Cameroon, spanning coordinates 4°53' to 5°28'N and 8°42' to 9°16'E (Figure 1). Established in 1986, KNP was the first protected area in Cameroon's humid forest zone, covering a total surface area of 1,260 km² of lowland rainforest (Oates et al. 2004). The park is bordered by the Ejagham Forest Reserve to the north and the Oban Division of Nigeria's Cross River National Park (CRNP) to the west, forming part of a larger transboundary protected area complex (Linder et al. 2012). KNP's establishment and subsequent expansion were primarily motivated by its exceptional biodiversity, particularly the presence of the critically endangered Preuss's red colobus (*Procolobus preussi*) (Oates et al. 2004). The park is characterized by its high annual rainfall, averaging 5,000 mm, and its elevation ranging from 50 to 1,079 m above sea level (Astaras 2009).

The map has been divided into three sectors: the western sector, the eastern sector, and the southern sector. The study was carried out in the southern sector, which also shares an international boundary with Nigeria. The Erat guard post is in this sector and villages within and outside the park where survey questionnaires were administered to hunters. Mapping the location of each of the hunters would further improve our understanding of the areas of concern and assist in future research. In this sector of the park, we also have proposed a gate post, the Makeke gate post, and the park headquarters in Mundemba (Figure 1).

2.2. Biodiversity

Korup National Park is a biodiversity hotspot, hosting a rich array of flora and fauna. The park is home to at least eight primate species (Table 1), including three endemic to the Cross-Sanaga-Bioko coastal forests ecoregion: the Cameroon red-eared monkey (Cercopithecus erythrotis camerunensis), the drill (Mandrillus leucophaeus leucophaeus), and Preuss's red colobus (Procolobus preussi) (Linder 2008; Oates 2011).

Table 1: Species of Primates found in Korup National Park

Primate species in KNP	Common Names	Red List Category (IUCN, 2020)
Cercopithecus nictitans ludio	Putty-nosed monkey	Least Concern
Cercopithecus pogonias pogonias	Golden-bellied crowned monkey	Vulnerable (A2cd)
Cercopithecus erythrotis camerunensis	Cameroon red-eared monkey	Vulnerable (A2cd)
Cercopithecus mona	Mona monkey	Least Concern
Procolobus preussi	Preuss's red colobus	Critically Endangered (A2cd)
Cercocebus torquatus	Red-capped mangabey	Vulnerable (A2cd)
Mandrillus leucophaeus leucophaeus	Drill	Endangered (A2cd)
Pan troglodytes vellerosus	Nigeria chimpanzee	Endangered (A4cd)

The park's plant life is highly diverse, with researchers recording 493, 620, and 9142 different tree species, including several endemic to the region, making it a biodiversity hotspot. This rich biodiversity underscores the park's significance for conservation efforts in the Guinea-Congo forest biome. (Newbery et al. 1998; Kenfack et al., 2006; Duncan et al., 2015)

2.3. Data collection method

We employed a systematic approach to collect data on Preuss's red colobus associations with other primate species in the southern part of Korup National Park (KNP). The study was conducted from March 2011 to November 2014, with data collection occurring for two weeks each month, from 06:00 to 17:00 daily, totaling 51 hours and 75 minutes of observation time. For primate associations, we utilized the Recce method, walking slowly and quietly along established trails to locate Preuss's red colobus groups associated with other primate species (Fonkwo et al., 2015). Both visual and auditory cues were used for species identification. Upon encountering a Preuss's red colobus group associated with other primates, we recorded the following information: 1. The name of the primate species, and 2. Activities of Preuss's red colobus and associated species.

We defined associations as "clusters," with individuals considered part of the same cluster if they were within 50 meters (using a measuring tape) of each other, following established protocols (Whitesides, 1989; Chapman and Chapman, 1996; McGraw and Bshary, 2002). We further used scan sampling, which is a behavioral observation method used in wildlife research to record the activities of each visible individual in a group at regular, predetermined time intervals (Cords, 1990). It provides a snapshot of group behavior over time, allowing researchers to analyze activity patterns efficiently (Astaras, 2009). In this study, each encounter was observed for a minimum of 20 minutes unless the association disbanded earlier. Each individual's behavior was recorded during each scan and categorized into activities such as feeding, resting, moving, grooming, and playing. The percentages of time spent on each activity were calculated. After the initial observation, we searched the surrounding area within a 50-meter radius of the focal group to identify any additional associated species. These criteria of 50m have been used by several researchers to define the distance at which a neighboring group can be considered to be in association (Waser, 1980; Struhsaker, 1981; Whitesides, 1989; Cords, 1990; Oates and Whitesides, 1990). To ensure data

reliability, we considered encounters to be independent when they occurred at distances greater than 200 meters from each other (Astaras, 2009). Observations made under challenging conditions (e.g., heavy rainfall, dusk) were excluded from the analysis. Additionally, we actively searched for chimpanzees in the vicinity of red colobus groups to assess potential predation risks.

Furthermore, to evaluate threats to Preuss's red colobus, we administered questionnaires to hunters in ten villages surrounding KNP. A total of 187 questionnaires were completed, with the number of respondents per village based on hunters' availability and willingness to participate (Table 2); however, their willingness and availability serve as a limitation to this data due to the lack of randomization of the hunters. Threats were identified through a combination of direct field observation, interviews, and focus group discussion. (Ebile et al, 2022). Each threat, such as habitat destruction, hunting, and farming, was classified based on its frequency as perceived by local respondents.

Table 2: Number of hunters interviewed per village in relation to the population size in each of the villages in and out of the Korup National Park

Villages	Population (source: MINIFOF 2008)	Number of hunters interviewed
Bareka- Batanga	905	9
Bera	209	10
Erat	224	44
Esukutan	56	37
Ikenge	57	28
Ekoneman	256	12
Esoki	69	14
Lobe	197	8
Mokange	83	11
Ngenye	64	14
Total	**2209**	**187**

This mixed-methods approach, combining direct observations of primate associations with questionnaire-based threat assessments, provides a comprehensive understanding of both the ecological interactions and anthropogenic pressures affecting Preuss's red colobus in KNP.

The variation in the number of hunters in each village was due to the unavailability of hunters willing to participate in the study. Before visiting each village, the Chief and Council were informed about the study's purpose. All available hunters were then gathered and informed about the study's purpose, as well as the anonymous and confidential nature of their responses. Each hunter received a questionnaire, which included photographs of the different primate species present in KNP (Okon and Ekobo, 2007).

In cases where hunters could not read or write, team members assisted in filling out the questionnaires. An assistant was available to interpret the questions into the local dialect for those needing clarification. The questionnaire included both closed-ended and open-ended questions. The close-ended questions had a list of alternative answers: dichotomous questions required a Yes/No response, while other questions asked respondents to choose among multiple options. Questions on personal information, such as age (classified into 10-year intervals starting from 20 to over 50 years, which is the active age group for hunting), marital status, and family size, were included in the questionnaire. The frequency of each hunter's activity, such as farming and fishing, was recorded and analyzed to identify most of their common activity. Information on the market chain structure of Preuss's red colobus was also collected. For open-ended questions, respondents were free to provide their own answers.

2.4. Data analysis

Quantitative data were analyzed using SPSS software (version 22, IBM, Armonk, NY, USA), especially with the questionnaire responses. The activity pattern, hunter activities, and threats faced by the red colobus were computed. An MS Excel spreadsheet was utilized to display the data obtained from SPSS graphically.

3. RESULTS

3.1. Species of primate that associate with PRC

Our results show that Preuss's red colobus (PRC) was observed associating with other primate species 139 times. These associations were detected exclusively through direct observation. Out of the eight primate species present in KNP, the PRC was seen associating with five of them: the putty-nosed monkey, golden-bellied crowned monkey, Cameroon red-eared monkey, mona monkey, and red-capped mangabey. PRC did not associate with drills or chimpanzees. During these associations, the PRC was typically found in the emergent layer of the trees (Figure 2), while the other primates occupied either the middle or lower canopy levels. The mean group size recorded for all the associations of PRC was 31.9 ±18.4.

Figure 2: Three PRCs at the topmost parts of the forest tree canopy (image by author)

Figure 2 shows the image of three PRCs out of a group at the top of the forest canopy. They spent most of their day just resting with little movement. The other species of primates are close to them though not on the same tree that can give alarm calls anytime there is danger. This group of red colobus is found on a tree that has shed its leaves.

According to the questionnaire responses, 178 out of 186 participating hunters (95.2%) reported that PRC was associated with other primate species, including drills, while 9 hunters (4.8%) did not comment on the association of PRC with other primates. Table 3 presents the percentage of associations of Preuss's red colobus with other primate species based on both field observations and hunters' responses.

From the fieldwork, *Mandrillus leucophaeus* was not observed associating with PRC. However, analysis from the questionnaire responses indicated that 13.66% of hunters reported having seen such an association. *Cercopithecus pogonias* and *Cercopithecus nictitans* were the most frequently (n=44; 31.65%) observed primates associating with Preuss's red colobus during field encounters. *Cercocebus torquatus* showed the least association, with only 1 instance (0.72%). According to hunters' responses, *Cercopithecus nictitans* (42 instances, 23.73%) and *Cercopithecus erythrotis* (41 instances, 22.73%) were the primates most frequently seen associating with Preuss's red colobus. While Mandrillus leucophaeus was not observed associating with Preuss's red colobus during the field study, hunters

reported 24 instances (13.64%) of such associations (Table 3). The table also highlights that *Cercopithecus nictitans* were the most frequently associated primates in both the fieldwork and the questionnaires.

Table 3: Frequency occurrence of Preuss's red colobus associations with diurnal primates from field observation and questionnaires.

Species	% of association of Preuss's red colobus (n = 139) from fieldwork	% of association of Preuss's red colobus (n = 178) from questionnaire responses
Cercopithecus erythrotis	13.67	22.73
Cercopithecus mona	22.30	18.69
Mandrillus leucophaeus	0.00	13.64
Cercopithecus nictitans	31.65	23.73
Cercopithecus pogonias	31.65	12.62
Cercocebus torquatus	0.72	8.59

3.2. Activity pattern of PRC with other primates

Over a total of 462 hours, 76 groups of Preuss's red colobus were observed, resulting in 273 group scans and comprising 2,303 individual sightings. There were no clear limitations on repeated counts. The observed activities included feeding, moving, resting, social behaviors (such as grooming, mating, and playing), and other behaviors (urination, aggression, and vocalization). The primary behaviors observed were resting, feeding, and moving. Social behaviors and other activities were less frequent. The percentages of these different activities are illustrated in Figure 3.

PRC spends most of its time either feeding or resting, as shown in Figure 3, carrying the highest percentage of its activities. Resting was the most frequent activity observed when Preuss's red colobus was associated with other primate species, occurring 81 times (29.74%). During these periods, they were typically found in groups of two or more lying quietly on a branch, although occasionally a single individual was observed resting alone. While the red colobus was resting, other primate species were often seen playing or moving between branches. Feeding was the second most common activity for Preuss's red colobus when associating with other primate species, observed 65 times (23.66%). As a folivorous animal, the PRC spent its feeding time consuming young leaves such as *Lecomtedoxa klaineana* and *Xylopia aethiopica* (Figure 4). Other primates were observed feeding on a variety of plants and fruits different from those consumed by the PRC.

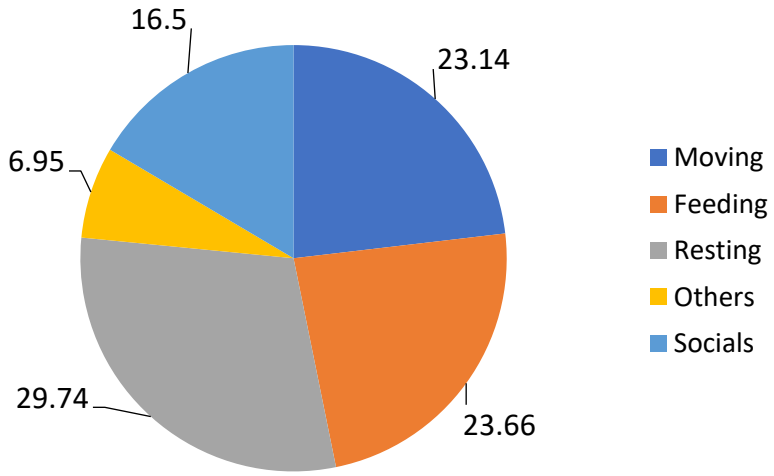

Figure 3: Distribution of relative frequencies of all recorded activities of Preuss's red colobus in Korup National Park.

Figure 4: A group of PRCs feeding on leaves at the top of the trees. (image by author)

Moving was the third most frequent activity, accounting for 23.15% of observations. Both PRC and other primates moved frequently, primarily in search of food or to escape danger. Field observations indicated that PRC generally moved from one area to another with other primates, mainly to find food. They seldom moved due to danger; even when alarm calls were made, PRC tended to move to the emergent layer of the tree and remain quiet or move a short distance before settling. The other primate species typically relocated when alarm calls were made. Social activities, including playing, grooming, and mating, accounted for 16.5% of the observed behaviors. PRC socialized only among themselves, even when in the presence of other primates. Infant PRCs were seen playing with each other in the higher canopy, while *Cercopithecus pogonias* and *Cercopithecus nictitans* played with each other in the lower canopy. PRC grooming involves two adults or a mother and infant caressing each other. Mating was observed between adult male and female PRC, as well as among other primate species of the same kind.

3.3. Threats to Preuss's Red Colobus

3.3.1. Threats faced by Preuss's red colobus in Korup National Park

The decline in the primate population is caused by various threats they face. Figure 5 highlights two of the main threats that led to the decline of Preuss's red colobus in KNP.

According to hunters from villages both inside and outside Korup National Park (KNP), overhunting and habitat destruction emerged as the primary threats to Preuss's red colobus (Figure 5). Hunters perceived overhunting as a greater threat to the PRC compared to habitat destruction, regardless of their location inside or outside KNP. Disease and trapping were included as variables of threats to PRC in the questionnaire, however, none of them were mentioned as a threat to PRC by the respondent. Hunters within KNP reported higher levels of concern regarding both overhunting and habitat destruction compared to those outside the park. Out of the 187 hunters surveyed, 52.94% (n=99) were from villages within KNP, and 20.32% (n=38) were from villages outside KNP, all identifying overhunting as the primary threat to Preuss's red colobus. During the interview, a hunter from a village within the KNP said, *"PRC are very slow and easy to kill, when they are in groups with other primates once an alert call is made the other primates will run away and only PRC will stay back."* He went further to say, *"We are always happy*

when we see PRC because we are sure to kill them." Other hunters mentioned that the main challenge in hunting PRC is their tendency to stay at the top of trees, making it difficult for bullets to reach them from such heights.

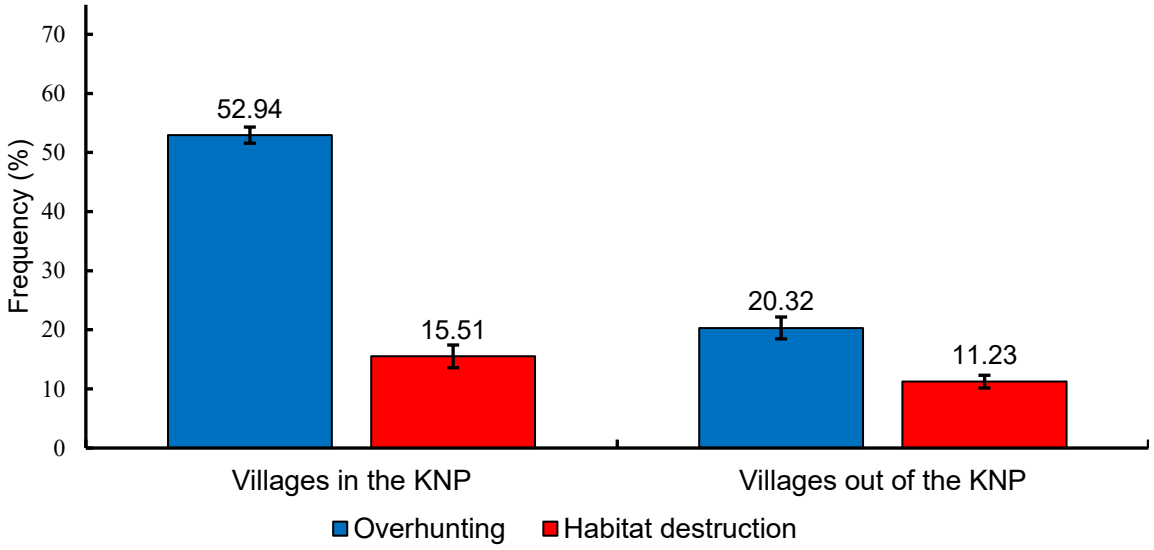

Figure 5: Hunters' view on threats to Preuss's red colobus in Korup National Park (KNP).

The t-test revealed no significant difference between responses from hunters inside Korup National Park who identified overhunting as the primary threat to Preuss's red colobus compared to those outside the park (p=0.025). There were no observations of chimpanzees in KNP during data collection, indicating no evidence that chimpanzees pose a threat to PRC.

3.3.2. **Hunters' personal information**

Questionnaires were administered to hunters in 10 villages, both within and outside Korup National Park. All respondents were male, as women do not engage in hunting in this region. Hunting is the principal threat to the PRCs in the KNP of Cameroon. The primary activities of these hunters were assessed as follows: hunting alone, hunting and farming, hunting and fishing, and a combination of hunting, farming, and fishing, varied by age group, as detailed in Table 4. The other activities carried out by the hunters were still anthropogenic, such as farming in nature, and were a threat to wildlife.

Table 4: Other activities of hunters by age group

Age-group	**Hunters' activities**				
(Years)	**Hunting (%)**	**Hunting and farming (%)**	**Hunting and fishing (%)**	**Hunting, farming, and fishing (%)**	**Total**
10-20	10.7 (n=20)	3.7 (n=7)	1.6 (n=3)	0.5 (n=1)	**16.5 (n=31)**
21-30	14.4 (n=27)	17.1 (n=32)	10.7 (n=20)	0	**42.2 (n=79)**
31-40	4.3 (n=8)	10.7 (n=20)	5.3 (n=10)	1.1 (n=2)	**21.4 (n=40)**
41-50	1.6 (n=3)	8.6 (n=16)	2.1 (n=4)	1.1 (n=2)	**13.4 (n=25)**
>50	1.6 (n=3)	3.2 (n=6)	1.6 (n=3)	0	**6.4 (n=12)**
Total	**33 (n=61)**	**43.3 (n=81)**	**21.3 (n=40)**	**2.7 (n=5)**	**100**

The majority of hunters in the age ranges of 21-30 years (n=32, 17.1%) and 31-40 years (n=20, 10.7%) primarily engage in hunting and farming, as shown in Table 4. These young, vibrant, and energetic males perform these activities year-round to provide for their families. They often own personal guns for hunting and have land for

farming. The result shows that hunters over 50 years old engage less frequently in these activities due to reduced energy and strength, making it difficult for them to trek long distances or work on hilly terrains, as illustrated in Table 4. From the respondents, family size also influences hunting activities in the Korup region. Larger families require more resources and income, compelling hunters to hunt more frequently to support their families. Approximately 75% of hunters have a family size of 1-5 members, followed closely by families with 6-10 members. Families with over 15 members are less common, comprising about 15% of the households.

4. DISCUSSION

The study provides the first comprehensive assessment of Preuss's red colobus (Procolobus preussi) associations and threats in Korup National Park (KNP), Cameroon. The findings contribute valuable insights into this critically endangered species' ecology and conservation challenges. While primate associations are common in tropical forests and can range from chance encounters to structured relationships (Gautier and Gautier-Hion, 1969; Struhsaker, 1981; Cords, 1990a), the limitations of available data on Korup primates' home ranges, group densities, and foraging behaviors precluded the use of Waser's (1984) "gas" model approach. Nonetheless, our careful examination of the data, based on existing natural history information, field observations, and comparisons with reported red colobus associations, reveals important patterns. Consistent with studies in other African sites (Höner, 2006; Teelen, 2007), we observed Preuss's red colobus forming associations with other primate species, particularly Cercopithecus monkeys. These associations may serve multiple functions, including mutual protection against predators (Bshary, 1997; Noë and Bshary, 1997). However, unlike previous research documenting chimpanzee predation on red colobus (Teelen, 2007; Watts, 2013), our study did not find evidence of such predation in KNP, despite the coexistence of Nigerian-Cameroon chimpanzees (Pan troglodytes ellioti) and Preuss's red colobus in the park. This finding underscores the need for site-specific research to inform conservation strategies, as threats to red colobus populations may vary across their range.

4.1. Species of primate that associate with PRC

Our study provides compelling evidence of polyspecific associations involving Preuss's red colobus in Korup National Park, confirming our initial hypothesis. We observed PRC associating with five Cercopithecus species: *C. erythrotis, C. mona, C. nictitans, C. pogonias, Cercocebus torquatus, and Mandrillus leucophaeus*. This expands upon earlier findings by Edward (1992), who reported associations with only three Cercopithecus species. The discrepancy may be attributed to methodological differences, as we employed the recce method, while Edward used line transect and quadrat methods. Notably, our results indicate that *C. nictitans* and *C. pogonias* were the most frequent associates of PRC, accounting for 31.65% of observed associations. This aligns with previous studies suggesting that these associations may serve a protective function against predators (Noë and Bshary, 1997). The vigilant behavior of Cercopithecus infants in the lower canopy, as noted by Edward (1992) and Astaras (2009), likely contributes to early predator detection and alarm calling, benefiting the associated PRC groups. Interestingly, while our field observations did not record associations between PRC and Mandrillus leucophaeus, 13.64% of hunter responses reported such associations. This discrepancy highlights the value of incorporating local ecological knowledge in primate studies (Berkes *et al.,* 2000) and suggests that further investigation into potential PRC-drill associations may be warranted.

The prevalence of PRC associations with Cercopithecus species in KNP may be related to low dietary overlap between these taxa, as suggested by Struhsaker (2010) for red colobus and Cercopithecus in Kibale, Uganda. This contrasts with the high dietary overlap observed between Cercopithecus congeners in Gabon (Gautier-Hion, 1980), potentially explaining the stronger associations between folivorous PRC and frugivorous/omnivorous Cercopithecus species compared to associations among Cercopithecus congeners. Despite these protective associations, the reported decline in PRC populations over time suggests that other factors, particularly overhunting, may outweigh the benefits of these interspecific relationships (Struhsaker, 2005; Ikemeh, 2015). This underscores the complex interplay between ecological interactions and anthropogenic pressures in shaping PRC population dynamics in KNP.

4.2. Activity pattern of PRC with other primates

This research provides valuable insights into the behavioral ecology of Preuss's red colobus (PRC) in Korup National Park, particularly in the context of their associations with other primate species. Over 462 observation hours, we

documented 76 PRC groups, resulting in 2,303 individual sightings across various activities. The predominant behaviors observed were resting (29.74%), feeding (23.66%), and moving (23.14%), which aligns with the general activity patterns reported for other red colobus species (Struhsaker, 2010; Korstjens et al., 2010; Fonkwo et al., 2015). In addition, according to Fonkwo et al. (2015), seasonality is a factor that can lead to changes in the activities of PRC. During the rainy season, they spend more time resting, while during the dry season, they spend more time moving in search of food; this can also expose them to danger from hunting. The high frequency of resting behavior, particularly when associated with other primates, may serve multiple functions. It could be a strategy to conserve energy, given their folivorous diet (Chapman et al., 2007), or a means to maintain vigilance while benefiting from the protective association with more alert species like *Cercopithecus nictitans* and *C. pogonias* (Bshary and Noë, 1997). The observed feeding patterns, focusing on young leaves of species such as Lecomtedoxa klaineana and Xylopia aethiopica, confirm the specialized folivorous diet of PRC, contrasting with the more varied diets of their Cercopithecus associates (Gautier-Hion et al., 1980).

Interestingly, our observations of PRC movement patterns in response to potential threats differ from those reported by Bshary and Noë (1997) for red colobus in Taï Forest, Ivory Coast. While Cercopithecus species in our study area emitted alarm calls and fled upon detecting human presence, PRC often remained in the emergent layer or moved only short distances. This behavior could potentially increase their vulnerability to hunting when not associated with more vigilant species, supporting the hypothesis that polyspecific associations provide anti-predator benefits (Terborgh, 1990; Chapman and Chapman, 1996). The social behaviors observed, including play, grooming, and mating, occurred exclusively within PRC groups, even in the presence of other species. This intra-specific socialization, coupled with the spatial stratification of PRC in the upper canopy and Cercopithecus species in the lower strata, suggests a complex balance between the benefits of association and the maintenance of species-specific social structures (Waser, 1987).

These findings support Waser's (1984) assertion that even chance encounters can lead to biologically significant associations. The prolonged co-occurrence of PRC with Cercopithecus species, once spatially associated, indicates that these relationships may confer mutual benefits beyond mere coincidental overlap of habitat use (Struhsaker, 1981; Edward, 1992). Future research should focus on quantifying the fitness consequences of these associations to better understand their ecological and evolutionary significance in the context of PRC conservation.

4.3. Threats to Preuss's Red Colobus

The research reveals that overhunting and habitat destruction are the primary threats to Preuss's red colobus (PRC) in Korup National Park (KNP), with overhunting being perceived as the more significant threat by hunters both inside and outside the park. This finding aligns with broader trends observed across African primate populations, where human predation often has a more severe impact than non-human predation (Oates, 1996). Unlike in Taï National Park, Ivory Coast, where red colobus faces significant threats from chimpanzees (Noë and Bshary, 1997), our study found no evidence of chimpanzee predation on PRC in KNP, highlighting the site-specific nature of threats to primate populations.

The prevalence of hunting as a threat can be attributed to several factors. The availability of affordable locally made shotguns and cartridges, as noted by Pollard (1997) and Ntumwel (2012), facilitates hunting activities. Our data show that younger hunters (21-40 years old) are the most active, engaging in both hunting and farming year-round. This demographic trend, coupled with the influence of family size on hunting frequency, underscores the complex socio-economic drivers of hunting pressure on PRC. The vulnerability of PRC to hunting is exacerbated by their biological and behavioral characteristics. Their large body size, group living habits, and conspicuous coloration make them easy targets (McGraw, 2007; Edem, 2002). Additionally, our observations of PRC's frequent feeding and resting behaviors suggest an abundance of food and suitable habitat, indicating that overhunting, rather than resource scarcity, is likely the primary driver of population decline.

The significant proportion (25%) of PRC in bushmeat sales in Mundemba town (Linder, 2008) further emphasizes the intensity of hunting pressure. This pressure is likely amplified by inadequate law enforcement, as suggested by reports of irregular patrols and limited restrictions on PRC harvesting (Bobo et al., 2017; Fonkwo et al., 2017). Furthermore, according to Fonkwo et al (2017), most of the people in the local community consider KNP as their

source of help to support their families. The lack of significant difference in perceived threats between hunters inside and outside KNP (p=0.025) suggests that park boundaries may not be effectively mitigating hunting pressure. These findings highlight the urgent need for enhanced conservation measures in KNP. Strategies should focus on strengthening anti-poaching efforts, improving alternative livelihood options for local communities, and implementing targeted education programs to reduce demand for PRC bushmeat. Nutrition-sensitive agriculture (NSA), which is a food-based approach such as home gardens, may provide an alternative source of food and income to the young hunters (Ebile et al., 2022). Future research should investigate the effectiveness of these interventions and explore the potential ecological impacts of PRC population decline on forest dynamics in KNP.

5. CONCLUSION

This pioneering study in the Cross-Sanaga-Bioko ecoregion provides critical insights into the ecology and conservation challenges facing the Critically Endangered PRC in KNP, Cameroon. Our findings underscore the complex interplay between primate associations and anthropogenic threats, with far-reaching implications for global primate conservation efforts. The poly-specific associations observed between PRC and six other primate species highlight the intricate social dynamics within tropical forest ecosystems. The frequent associations with Cercopithecus nictitans and C. pogonias suggest potential mutual benefits, possibly related to predator avoidance strategies. These findings contribute to our understanding of primate community ecology and emphasize the importance of preserving intact, multi-species primate assemblages for ecosystem function.

Alarmingly, our study confirms that human hunting poses the most significant threat to PRC survival in KNP. This pressure, driven by poverty and the need for both sustenance and income, reflects a global pattern of unsustainable exploitation of endangered species. The situation in KNP serves as a microcosm of the broader challenges facing primate conservation worldwide, where human needs often conflict with biodiversity preservation. Our research demonstrates that studying elusive and critically endangered primates like PRC is not only feasible but essential for informed conservation strategies. As one of the last strongholds of the PRC, KNP's importance cannot be overstated. The insights gained from this study provide a crucial foundation for targeted conservation actions and future research initiatives.

The research conducted in this study is critical to the global conservation effort and looks to the international conservation community to tackle the questions of inherent threats to PRCs and all endangered species due to overhunting and habitat loss. The question of social-economic challenges facing the region and the need to provide sustainable options to hunters is a topic for global conservation review to protect this valuable biodiversity hotspot and the critically endangered species within. This research is vital to the protection of primates in the KNP and Southwest Region of Cameroon and plays an important role in global conservation.

The global implications of our findings are profound:

1. They underscore the urgent need for integrated conservation approaches that address both ecological and socio-economic factors.

2. They highlight the importance of preserving intact primate communities for maintaining ecosystem health and resilience.

3. They emphasize the critical role of protected areas like KNP in safeguarding endangered species, particularly in biodiversity hotspots.

More research into the hunters and their threat to the overall area is needed to further prompt protective legislative changes.

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