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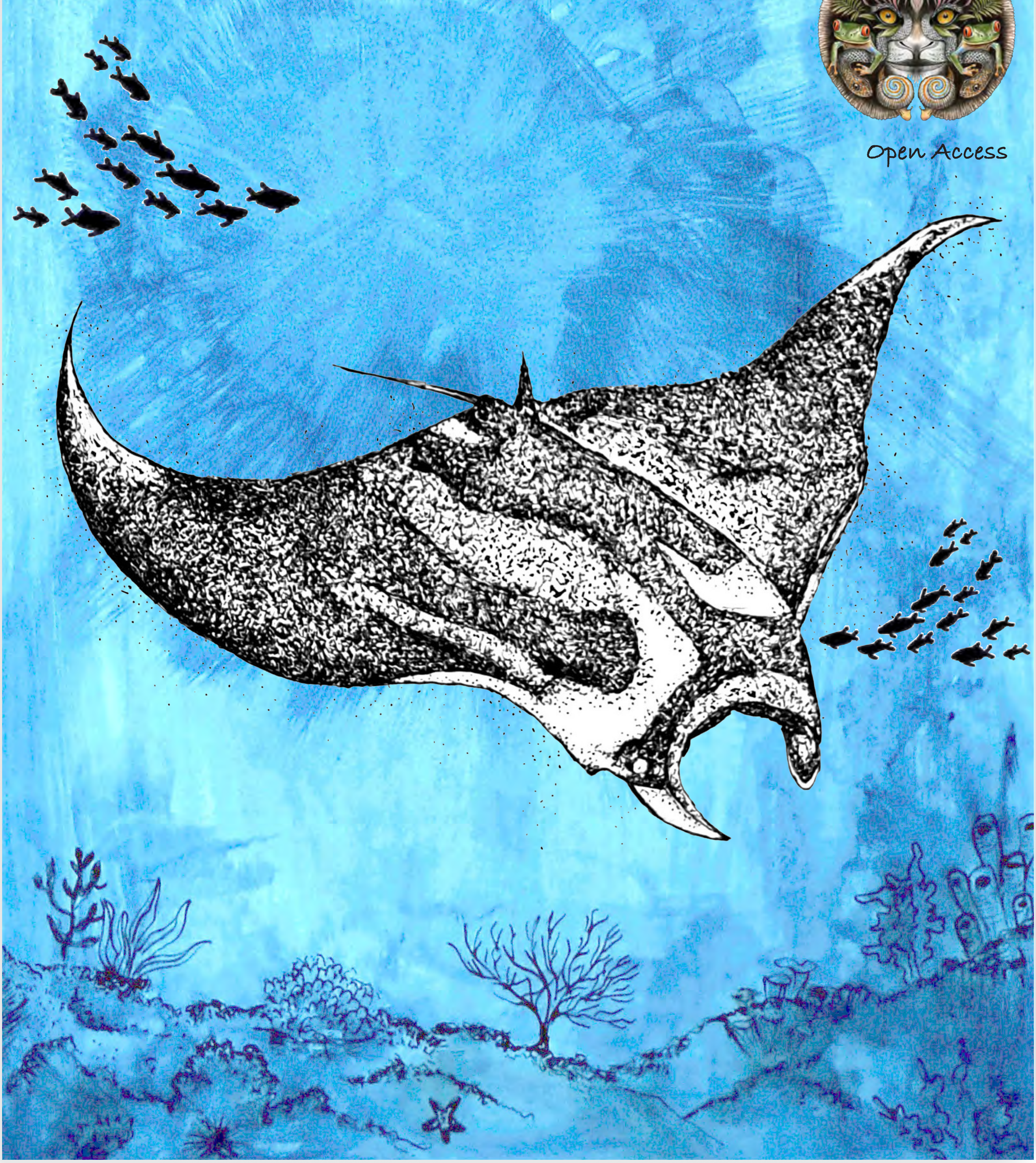

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Cover: Giant Oceanic Manta Ray *Mobula birostris* in ink on acrylic wash by Elakshi Mahika Molur adapted from scientific illustration by Roger Hall.

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COMMUNICATION

Current populations of *Colobus vellerosus* (Geoffory, 1834) & *Cercopithecus lowei* (Thomas, 1923) and land-use, land cover changes in Boabeng-Fiema Monkey Sanctuary, Ghana

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Abstract: Background and Research aim: This study evaluated the density of two primate species *Colobus vellerosus* and *Cercopithecus lowei* and the change in land-use types in Boabeng-Fiema Monkey Sanctuary in Ghana, from 2007 to 2019. Method: Total counts of individual monkeys were done in all six patches of forest in the Sanctuary in 2019. Using Landsat imagery, land-cover maps of the study area were examined to evaluate the change that has occurred over a nine-year period between 2010 and 2019. Results: A total of 602 individuals of *C. vellerosus* were counted in 34 groups (0.58 group/ha). Group locations were: 15 at Boabeng (0.12 groups/ha), five at Fiema (0.08 group/ha), three at Bomini (0.09 group/ha), four at Busuyna (0.13 group/ha), three at Bonte (0.06 group/ha), and four at Akrudwa (0.11 group/ha). *C. lowei* was only encountered at Boabeng and Fiema, with a total of 351 individuals distributed in 26 groups. In 2010, forest covered a land area of 1,540.08 ha, and it was estimated to have increased to 2,643.12 ha in 2019. Farmlands covered 5,069.07 ha in 2010, and in 2019 were estimated to cover 4,155.03 ha. Built-up areas in 2010 covered an area of 433.89 ha, and in 2019 had declined to 244.89 ha. Conclusion: The monkey populations have increased and spread to occupy all patches in the Monkey Sanctuary. On LULCC, 72% increase, 18% reduction, and 44% reduction in forest cover, farmland and built-up areas were observed respectively. Implications for conservation: There is a blend of traditional and conventional conservation efforts contributing to the increase in primate population, the occupancy of previously ‘empty’ forest patches and change in areas of land-use types.

Keywords: Endangered species, forest patches, human activities, indigenous knowledge, landscape, population dynamics, primates, protected areas, satellite imagery.

Abstract in Akan: Onipa dasani ase retrɛ ama nwuram moadoma ase reshe nanso Boabeng-Fiema Monkey Sanctuary ye baabi a wɔde amamre ne gyidi abɔ Efoɔ (Colobus vellerosus)ne Kwakuo (Cercopithecus lowei) ho ban besi nɛ. Saa nsroboa yi ase reyɛ atore wo yɛ man ne wiase nyinaa. Enti yɛ kenkan saa mmoa yi dodoɔ ɛna yesan whɛɛ senea ɔmanfoɔ nso de asaase no redi dwuma. Yɛ nyaa Efoɔ dodo oha-nsia ne mienu (602) a na wote akuo akuo aduasa-anan (34), a na wotete kwaewa nsia a ɛwowɔ hɔ no mu. Kwakuo no nso na wɔyɛ ahasa-aduonum-baako (351) a wote akuo akuo aduonu-nsia (26) wo kwaewa ɛwɔ Boabeng ne Fiema. Afei yɛ hunuu sɛ omanfoɔ no de asaase no ye kwae, afuo, ne adansie. Ye de toto mfie dumienu a atwam no a, ye hu se mmoa no ase atrɛ akɔ kwaewa a ɛwɔ ho no nyinaa mu na omanfoɔ no nso kwae no atre ama asaase a wode ye afuo ne nea ode si dan no deɛ ɛso ate.

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INTRODUCTION

Human population growth has had significant impact both directly and indirectly on the dynamics and structure of biological communities. This is because of the extension, growth, and dispersal of human populations, which have been greatly influenced by both the agricultural and industrial revolutions. Nonhuman primates are not exempt from problems associated with human population growth (Cowlishaw & Dunbar 2000). Early in the 1950s, it was discovered that the Red Colobus *Procolobus waldroni* was imperiled due to habitat loss and poaching, and Booth (1956) expressed the opinion that its extinction in the Gold Coast (now Ghana) in the near future could be considered to be a possibility. Booth therefore asked for effective laws that would safeguard the species as well as its habitats, but it is now likely to be extinct (Oates et al. 2000). Recent studies have clarified the realities that other related primates have probably now been extirpated from most protected areas (Wiafe 2021) or a few groups occur where enforcement against poaching has been intensified (Wiafe 2016).

In addition, Oates et al. (2000) attributed the recent extinction of primates to complacency, since primates in general have received much attention from conservation measures and are regarded as one of the few large orders of mammals not to have lost a taxon in the 20th century (Mittermeier et al. 1997). Oates et al. (2000), however, warned that such complacency may allow taxa that could have been saved by more vigorous and timely action to become extinct. The danger could be particularly acute in the case of taxa that have received little attention and live in parts of the world where biologists and conservationists focus less. Also, reports indicate that population trends for animals are more favorable in nations with higher development rankings (Barnes et al. 2016).

Other reports reveal that more than 50% of protected areas that contained *Colobus vellerosus* in the 1970s no longer contain it, and on average an 87% reduction in encounter rates of this species in six forest reserves in the last 30 years has been estimated (Matsuda-Goodwin et al. 2019). This suggests an equivalent reduction in population size in recent times. On the contrary, as of 2007, Boabeng-Fiema Monkey Sanctuary (BFMS) in Ghana harbored 365 individuals *C. vellerosus* (Kankam & Sicotte 2013) and has consistently been a site for a stable population of this endangered primate. Between 2007 and 2019 (about 12 years), no systematic census from the sanctuary has been published, probably because the population appears to be stable. However, the accelerated unwanted factors like deforestation, over-exploitation of resources, invasive species, human population increase, and weak legislation may have a great toll on the stable populations and therefore a regular census is required (Ntiamoa-Baidu 1995; Attuquayefio & Fobil 2005).

Land-use and land-cover change (LULCC) has been observed to be dynamic and accelerated in recent times, influenced by factors such as farming, estate development and mining, and aggravated by climate change impacts and adaptation. Bamford et al. (2001) echoed that LULCC is a major driving force of habitat modification and has important implications for the distribution of wildlife in ecosystems. The need to regularly analyze LULCC cannot be over-emphasized, as it can be used to predict changes in ecological systems and species population changes, as well as examine the factors responsible for such changes. In the Masai Mara ecosystem (Kenya), a 30-year LULCC indicated that a rapid land conversion had a drastic decline on a wide range of wildlife species (Mundia & Murayama 2009). In a study at BFMS in Ghana, Amankwa et al. (2021) concluded from a 26-year LULCC analysis of six-year intervals that the rapid changes were attributed to human population growth and associated activities.

The objectives of this study were to determine the species densities in the forest patches; examine the population growth rate of the primates and determine the relationship between the species densities and patch sizes. We also assessed the change that has happened in land-use and land-cover over a decade.

METHODS

Study Area

This study took place at Boabeng-Fiema Monkey Sanctuary (BFMS) which comprises forest patches in the villages of Boabeng — 128 ha, Fiema — 62 ha, Bomini — 30.6 ha, Bonte — 33.5 ha, Busuyna — 54.1 ha, Akrudwa (Panin) — 32.2 ha, Kwaase — 4.9 ha, Tankor — 6.8 ha, Senya — 74.9 ha, and Akrudwa (Kuma) — 3.2 ha (Kankam & Sicotte 2013). BFMS is a community-based conservation area situated in the Bono-East Region of Ghana located on with 7.666N to 7.669N and 1.629W to 1.700W. The 499.2 ha Sanctuary is located in the Nkoranza North District on a flat terrain. BFMS is a dry semi-deciduous forest which lies in the savanna transition zone (Figure 1). The vegetation type is dominantly a primary mosaic forest (Hall & Swaine 1981; Fargey 1991). BFMS has two distinct seasons: rainy season between March and October and dry season between November and February with the mean annual rainfall of 1,250

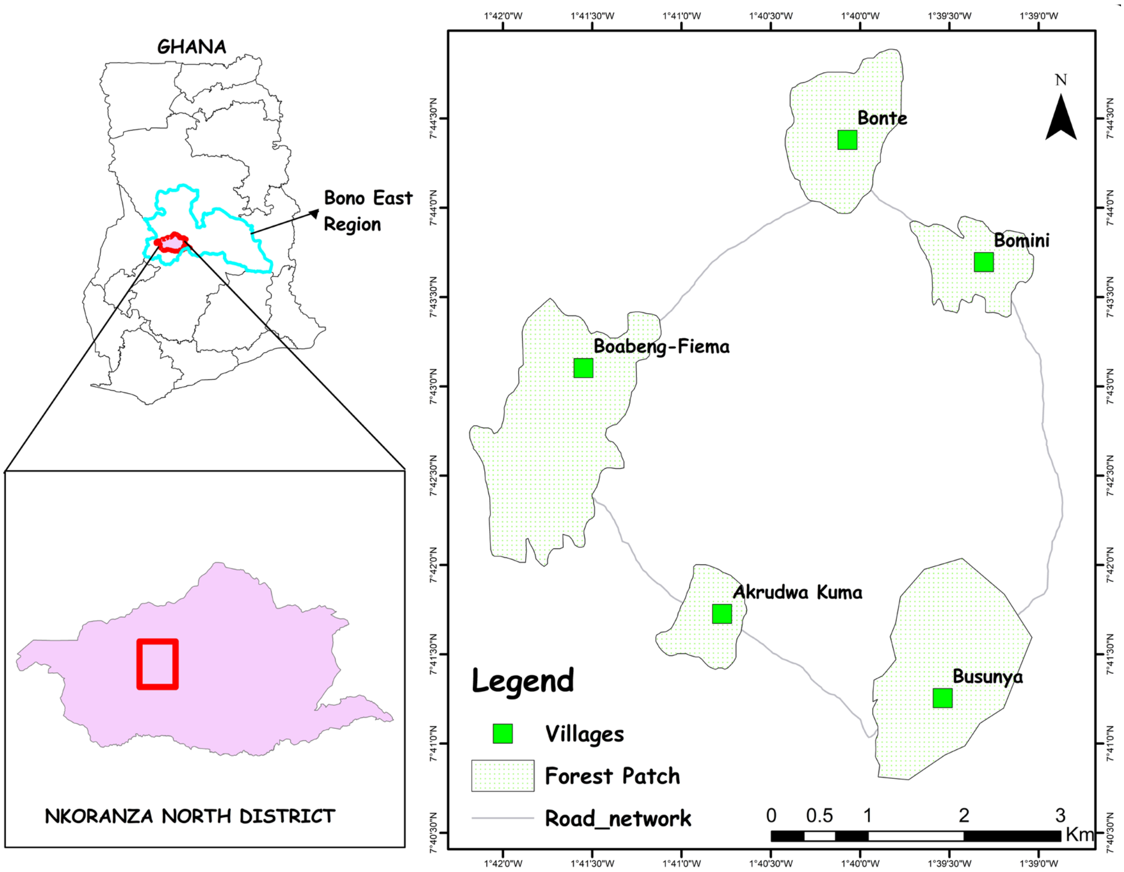

Figure 1. Study area (BFMS) showing villages and road linking the villages.

mm (Fargey 1991). The sanctuary is developed from the traditional belief of the local people, where hunting and killing of a primate is perceived as a taboo (Fargey 1991; Ntiamoa-Baidu 1995; Attuquayefio & Fobil 2005). The sanctuary is noted as a community-based conservation area with the community members in charge of managing its activities. *C. vellerosus* and *C. lowei* are the two primates in the sanctuary (Fargey 1991; Kankam 1997) with over 3,700 human inhabitants (G.S.S. 2010). The community members cultivate cashew, maize, yam, groundnut, cassava, and oil palm (Wiafe & Arku 2012).

Study species

Colobus vellerosus White-thighed Colobus and *Cercopithecus lowei* Lowe's monkey are two distinct primate species living sympatric in Boabeng-Fiema Monkey Sanctuary (BFMS) (Kankam & Sicotte 2013).

Known to be highly arboreal, *C. vellerosus* at BFMS has been found to intermittently travel on the ground (Schubert 2011). The diet has been observed to be mostly leaves, fruits, seeds, and flowers (Wong et al. 2006). This species has been reported in other protected areas in Ghana such as Kakum National Park, Cape Three Points Forest Reserve, Mole National Park, and Atewa Range Forest Reserve (Wiafe 2016, 2019, 2021). It is also reported to occur in Côte d'Ivoire's Bandama-Sassandra interfluvial zone (Gonedelé Bi et al. 2014), Togo's Togodo Faunal Reserve, (Segniagbeto et al. 2017), and Benin's Lama and Kikele Forest Reserves (Campbell et. al. 2008). It is currently classified as critically endangered on the IUCN (International Union for Conservation of Nature) Red List of Threatened Species (Matsuda-Goodwin et al. 2019) (Image 1).

C. lowei is usually found in primary, secondary, and gallery/riverine forest, and it is observed to be active in the lower forest strata and on the ground (Wiafe 2016; Wiafe et al. 2019). The diet of *C. lowei* includes mainly fruits but is supplemented with insects (Wiafe 2015). *C. Lowei* are also distributed in some parts of Ghana including Kakum Conservation Area, Cape Three Points, and Atewa Range Forest reserves (Oates et al. 2000; Wiafe 2016, 2021), and Côte d'Ivoire's Soko and Guelitapia forests (Gonedelé Bi et al. 2014). It is currently classified as vulnerable on the IUCN red list of species (Wiafe et al. 2019) (Image 2).

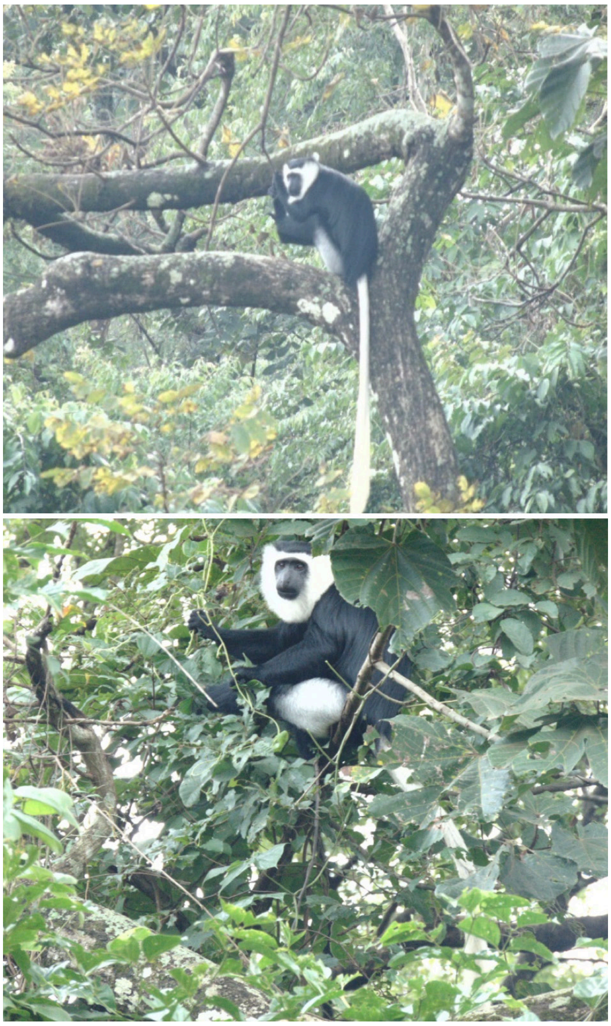

Image 1. A White-thighed Colobus *Colobus vellerosus* at B.F.M.S. © Wiafe E.D.

Image 2. Lowe's Monkey *Cercopithecus lowei* at B.F.M.S. © Wiafe E.D.

Survey design

The study included the existing patches of forest stands where the management of the sanctuary confirmed that those patches harbored monkeys for the past five years. The management also informed us that forest patches of Akrudwa (Kuma) and Akrudwa (Panin) have been merged as Akrudwa. Therefore, we surveyed in the following forests patches with respective sizes: Boabeng — 128 ha, Fiema — 62 ha, Bomin — 30.6 ha, Bonte — 33.5 ha, Busuyna — 54.1 ha, and Akrudwa — 37.4 ha (Figure 1). The vegetation type of the six patches has been described by Kankam & Sicotte (2013) as open forest mixed with savanna woodland. The already existing trails (tourist trails) were used for the study, and only accessible paths were used to assess the patches because the team decided not to disturb or destroy the vegetation in the area by creating new paths. To equalize sampling intensity, we used 17 transects of varying lengths ranging from 500–1,000 m to count monkeys in all the patches of forests. In total, 71,050 m of transect walks were made in specific patches as follows: Boabeng = 14,300 m, Fiema = 10,650 m, Bomini = 11,200 m, Busunya = 12,450 m, Bonte = 11,200 m, and Akrudwa = 11, 250 m.

Using Landsat Imagery, a land-cover map of the study area was made to examine the change that has occurred over a nine-year period between 2010 and 2019 (The image with less cloud was obtained in 2010 instead of years around 2007).

Data Collection

Primate Species Enumeration

Six selected patches were visited to identify and count the two sympatric primates through visual observation of primate presence. Primate species censuses were carried out within the six patches simultaneously by three people in one group (18 people total). In each group, two members served as observers while one member served as a recorder of the observations. Every team was led by a Sanctuary staff member who was conversant with the territory of every primate group. The team walked through the existing trails in the patches to search for the primates with the help of binoculars used for scanning the canopy of the vegetation. When primates were spotted, the species were identified and counted, and the locations recorded. When a group of primates was spotted, GPS coordinates were noted at the center of the group spread. The process started at 06:00 GMT till they enumerated all the groups.

The census was done two times to cross-check whether all the subjects were encountered. To reduce observer bias, the start and end times of the census were clearly stated to all team members, and team members were also reshuffled between groups so that an area with species was not counted twice by the same group at the second time. The numbers were estimated based on 'good visibility' counts (Baker et. al. 2009).

Land-Cover Changes

To verify how the land-cover has undergone changes and its possible effect on the primate distribution, satellite images of the study area between 2010 and 2019 were analyzed. This study acquired a time frame series of two Satellite Landsat Images: Landsat 7 ETM (Enhanced Thematic Mapper), representing the year 2010, and Landsat 8 OLI (Operational Land Imager), representing the year 2019. These two images were all acquired through the Google Earth Engine platform which serves as a cloud-based system that houses several satellite images for earth observation analysis. The image resolution was 30 m which was quite good for image analysis. To select the best image, we considered images within the whole year with least cloud cover. The chances were that the resolution of the images from the dry season (December–March) was quite high, so images from December 2010 and December 2019 were used.

Data Analysis

Primate Density Calculations

The number of groups and individuals were tallied and totaled for each transect and patch.

The line transect method has been widely used and is considered the most accurate method of conducting wildlife surveys to study animal populations and calculate species density (Whitesides et al. 1988; Plumptre 2000; Buckland et al. 2001), and the commonly used software package DISTANCE has also been used for data analysis. However, the use of this method requires certain criteria or assumptions in order for the mathematical model to be applicable to the data (Buckland et al. 2001). Unfortunately, several constraints prevented use of this method. First, most of the time the monkeys detected the observer and started moving before the observer could detect them. Second, there was poor visibility in the forest which prevented the clear detection of the animals for accurate distance and angle measurements as well as lesser number of sightings than 40.

As the mathematical models associated with line transects model could not be applied to calculate densities, primate density was calculated by the ratio of number of group of monkeys or total individuals encountered to size of the forest patch or length of transect (Collinson 1985; Ellis 2003; Wiafe 2016).

Statistical analysis involved the use of 'R' statistical software version 4.2.1 (R Core Team, 2021). The Shapiro-Wilk normality test was used to check the normality of the abundances of *C. vellerosus* (response variable), and the result indicated that the response variable was not normally distributed ($W = 0.68949$, $p < 0.001$). Therefore, Marasquilo's test was used to get an overall Chi square to compare medians of abundance of *C. vellerosus* among all the six patches and pairwise comparisons of the abundance of *C. vellerosus* in any two different forest patches. The *C. lowei* was encountered in only two nearby patches (Boabeng and Fiema) and because of this we did not do any further statistical analysis. The *C. vellerosus* density change rate was calculated as follows:

$$\text{Growth rate} = \frac{Nt - No}{No}$$

Where:
Nt = density at current time (2019)
No = density at the beginning of the period (2007)

Since the time lag between the first and the second densities was 12 years the population growth rate per annum was calculated by dividing the growth rate by 12. For the *C. lowei*, there was no known published previous population to serve as basis to determine the change in population of the species, within the period.

Remote sensing analysis on land-cover

We preprocessed both images (Satellite Landsat images) in Google Earth Engine. The preprocessing steps include the following: (1) filtering of the image by the region of interest which was an extent of the area created as a feature; (2) filtering by the date ('2010-01-01', '2010-12-31') for 2010 and ('2019-01-01', '2019-12-31') for 2019; and (3) filtering by least cloud cover and a median composite of all the bands for the respective years.

A supervised land-cover classification was then performed by first creating training samples of the respective classes (forest, villages/communities, and agricultural fields). The training samples were created with the help of high-resolution images from Google Earth Imagery in comparison with other literature studies on classification and knowledge of the study area. With the training samples as inputs for the classification, we used a Classification and Regression Tree (CART) classification algorithm which is a predictive model that explains how outcome variables' values can be predicted based on other values in the Google Earth Engine that was used to classify the satellite images into the land-cover classes listed above. This procedure was validated as well with Google Earth Imagery again and other sources of literature (Allotey & Wiafe 2015) on classification within the same study area. A change detection table was generated where the area in terms of percentage and hectares of land-cover between 2010 and 2019 was generated to assess the changes that took place over time.

RESULTS

Population Densities of Primates

C. vellerosus were encountered and distributed in all the six patches of forest at BFMS: Boabeng, Fiema, Bomini, Busuyna, Bonte, and Akrudwa. In all, a total of 602 individuals were counted in 34 groups. These were made up of 15 groups of 315 individuals at Boabeng; five groups of 73 individuals at Fiema; three groups of 54 individuals at Bomini; four groups of 58 individuals at Busuyna; three groups of 36 individuals at Bonte and four groups of 66 individuals at Akrudwa. In terms of density per patch size, Boabeng recorded 2.46 individual/ha, 1.18 individual/ha at Fiema, 1.59 individual/ha at Bomini, 1.87 individual/ha at Busunya, 0.67 individual/ha at Bonte, and 3.88 individual/ha at Akrudwa (Table 1).

The *C. lowei* were only encountered at Boabeng and Fiema, and in total, 351 individuals were distributed over 26 groups. In Boabeng, 18 groups were encountered with a total of 236 individuals, and eight groups of 115 individuals were encountered at Fiema (Table 2).

Further analysis indicated that the densities of *C. vellerosus* encountered in Boabeng differ significantly from that of all the other five patches (Fiema, Bomini, Busunya, Bonte, Akrudwa). On the contrary, the densities of *C. vellerosus* in all other forest patches were found not to be significantly different. (Marascuilo's test: Overall χ^2=37.97 df-5 p<.001: For pairwise comparisons – BBG-FM χ^2 = 12.59, df = 1, p<.02; BBG-BON χ^2 = 30.91, df = 1, p <.01; BOS-BON χ^2 = 12.14, df = 1, p <.03; BON-AKR χ^2 = 11.83, df = 1, p <.03); Likewise, Marascuilo's test for BBG-FM for C. vellerosus χ^2 = 0.001, df = 1, p <.98)

Table 1. Densities of *C. vellerosus* enumerated in the forest patches of BFMS (BBG—Boabeng | FM—Fiema | BOM—Bomini | BUSU—Busunya | BONTE—Bonte | AKRU—Akrudwa.

Forest patch	Number of groups	Number of animals	Area (ha)	Number of groups/ha	Density/ha
BBG	15	315	128	0.12	2.46
FM	5	73	62	0.08	1.18
BOM	3	54	34	0.09	1.59
BUSU	4	58	31	0.13	1.87
BONTE	3	36	54	0.06	0.67
AKRU	4	66	37	0.11	1.78
Total	34	602	346	0.09	1.74

Table 2. Densities of *C. lowei* enumerated in the forest patches of BFMS.

Forest patch	Number of groups	Number of animals	Area (ha)	Number of groups/ha	Density/ha
BBG	18	236	128	0.14	1.84
FM	8	115	62	0.13	1.85
BOM	0	0	34	0	0
BUSU	0	0	31	0	0
BONTE	0	0	54	0	0
AKRU	0	0	37	0	0
Total	26	351	346	0.07	1.01
	26	351	190	0.14	1.84

From the year 2007 to 2019 the densities of the *C. vellerosus* in the entire sanctuary increased by 70.0 % over 12 years at an average growth rate of 5.8% per annum. There was, however, variation in the growth rate in different forest patches as shown in Table 3.

Land-cover and Land-use Changes

The classification approach yielded two land-cover maps within the area from 2010–2019 (Image 3). In 2010, forest covered a land area of 1,540.08 ha, representing 21.87%, but the area was estimated to be 2,643.12 ha in 2019, representing 37.53%. (Forested area has increased by 1,103.04 ha, representing 15.66%). Farmlands (agricultural lands) on the other hand covered 5069.07 ha (71.97%) in 2010, but in 2019 these were estimated to cover 4155.03 ha (59.00%) (a reduction of 914.04 ha or 12.97%). Villages or built-up areas in 2010 covered an area of 433.89 ha (6.16%), but 244.89 ha (3.48%) in 2019 (a reduction of 189 ha or 2.68%) (Table 4).

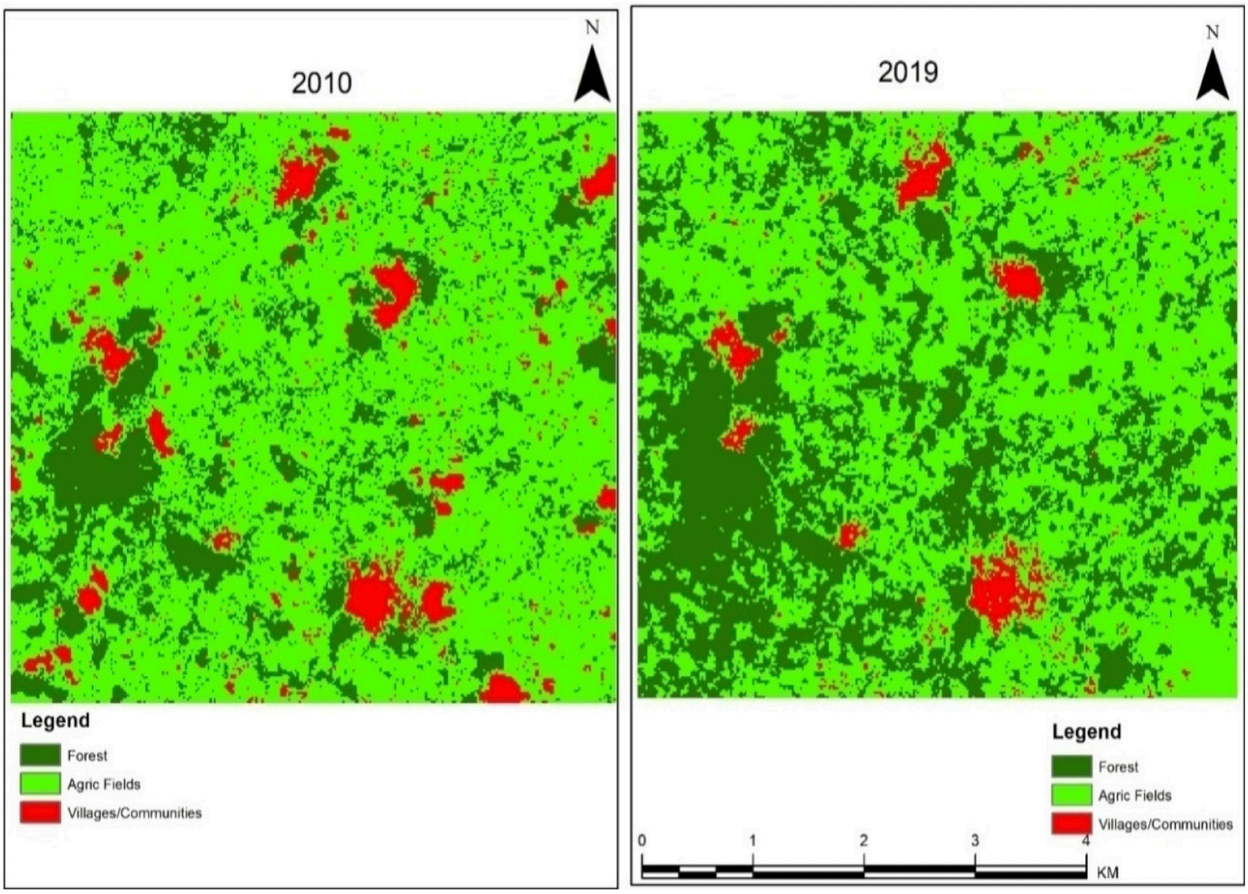

Image 3. Land cover changes in the study area (BFMS).

Table 3. Growth rates of densities of *C. vellerosus* in the six patches of forest in BFMS.

Forest patch	Density of 2019 (This study)	Density of 2007 (Kankam & Sicotte 2013)	Growth rate (%) in 12 years	Av. Growth/ annum (%)
BBG	2.46	1.63	50.98	4.25
FM	1.18	1.08	9.02	0.75
BOM	1.59	0.72	120.59	10.05
BUSU	1.87	0.13	1339.21	111.60
BONTE	0.67	0.44	51.52	4.29
AKRU	1.78	0.50	256.76	21.40
Total	7.68	4.50	1828.08	-
Average	1.28	0.75	304.68	-

Table 4. Classification table on land cover changes.

	2010		2019	
Class Names	Area (ha)	Area (%)	Area (ha)	Area (%)
Forest	1540.08	21.87	2643.12	37.53
Farm/Agric Lands	5069.07	71.97	4155.03	59.00
Villages/Communities	433.89	6.16	244.89	3.48
Total Area	**7043.04**	**100**	**7043.04**	**100**

DISCUSSION

The conservation of primates in BFMS has solely depended on traditional knowledge and belief until the early parts of 1970s when the government intervened to support the management of the sanctuary. Since then, the sanctuary has been combining the use of taboos and conventional law enforcement to prohibit hunting of the primates in the sanctuary (Attuquayefio & Fobil 2005; Saj et al. 2005, 2006; Wong & Sicotte 2005; Kankam & Sicotte 2013). Conservation education and other interventions such as eco-tourism, tree planting, and eco-friendly agriculture have been intensified since 2010. It could be deduced that within the six patches, *C. vellerosus* and *C. lowei* were not evenly distributed. Both were mostly concentrated at Boabeng and Fiema. This concentration could be attributed to historical distribution, the traditional belief of not hunting or killing primates, and the unsuitable nature of the other patches. The study area is a forest-savannah transition zone; thus, the unsuitable nature of some patches is the result of the limited number of trees, alongside the presence of some invasive species such as *Chromolaena odorata* (E.D. Wiafe, 2019 pers. obs.) which suppresses the growth of native plant species that might have been essential food sources for the primates. Due to the savanna dominated nature of a patch such as Bonte of size 33.5 ha (Table 4), it is mostly shrub and grassland with few trees. Thus, such an area becomes less attractive to the two species.

It was observed that *C. lowei* did not travel out of the patches of Boabeng and Fiema areas. This could be attributed to the fact that the local people of Boabeng and Fiema use human food to feed *C. lowei*, as the people believe that the primates are their ancestors (Wiafe & Arku 2012). This behavior of the people providing food for the primates may have increased the availability of feed for *C. lowei* to limit them in Boabeng and Fiema patches. The *C. lowei* further forages on crops cultivated by humans which usually causes antagonistic relationships. However, the people of Boabeng and Fiema have resolved to coexist and tolerate the destructive activities of the monkeys to some extent as opposed to the people of other patches. Notwithstanding, the *C. lowei's* absence in other patches is likely due to the natural dispersal pattern of the species as (compared to *C. vellerosus*). In *C. vellerosus* both sexes disperse, which makes it very easy for new groups to form and spread (Teichroeb et al. 2009, 2011), but in *C. lowei*, females are philopatric (Cowlishaw & Dunbar 2000). This means that new groups can only form by the fission of very large existing groups and these new groups of females would all have to find their way to a new fragment together. That is much more difficult and less likely than single colobus making the journey, and making it far easier for new groups to be created and to spread than for the female philopatric cercopethecines.

On the other hand, *C. vellerosus* were found in all the six patches, and this is not different from the report of previous studies by Kankam (1997), Saj et al. (2005), and Wong et al. (2006). In 2003, Wong and colleagues confirmed the presence of *C. vellerosus* at Bonte and Akrudwa in addition to Boabeng, Fiema, Bomini and Akrudwa, just as Kankam's report in 1997 and Kankam & Sicotte (2013). It has been reported that Bonte has two groups of *C. vellerosus* in the area with only one resident group (Kankam & Sicotte 2013).

Over the past decades, *C. vellerosus* population in western Africa has experienced drastic decline resulting from habitat loss and bush meat trade. Several studies (Fargey 1991; Kankam 1997; Wong & Sicotte 2005; Kankam & Sicotte 2013) at BFMS have shown that *C. vellerosus* population has been increasing. As reported by Wong & Sicotte (2005), this increment within the sanctuary can be related to the movement from the small patches (within the study area) with less food resources available to the larger patches which provide adequate resources for primates' survival.

Comparing the current census to the last census of 2007 (Kankam & Sicotte 2013), the total number of groups of *C. vellerosus* has increased from 29 to 34 (Table 1) as follows: Boabeng has increased from 13 to 15; Fiema has reduced from six to five; Bomini has increased from one to three; Bonte from two to three; Busunya from three to four; and Akrudwa from two to four. Note that Kankam & Sicotte (2013) reported one group at Konkrompe, but the sanctuary managers negated their current presence. The average density in 2007 was 0.75 perha and in the present study (2019) it was 1.28 per ha (Table 3). Comparative analysis indicated that the population growth is 70% spread over 12 years at an average growth rate of 5.9% per annum (though there were specific variations in growth at the patch level) (Table 3). This comparison must be viewed with caution since different surveyors and different data analysis methods were used.

As a community-based conservation area in the central Ghana, the people have consciously made efforts to increase forest cover through planting of trees in the villages, roadsides, and alongside agricultural crops in the farmlands. Also, the decline in the cover of the villages (build-up) indicates that more trees have been planted in the villages and that the people have promoted natural regeneration of forests in previous opened areas. Comparing this study's results to the last land-cover analysis done in 2007, Allotey & Wiafe (2015) reported that settlement expansion due to the increasing human population in the area led to a 22.4% decline of the forest cover. Meanwhile, agricultural land-use yielded a 54.5% increase in land-cover, and build-up 23.1%. Tree harvesting has not been reported to have caused a change in forest cover in the area. This is probable because primate habitats are prohibited for human use in the sanctuary, but Amankwa et al. (2021) recently reported charcoal and lumber production in the surrounding areas. The results of this study showed increases in forest cover by 71.62%, 18.03% reduction in farmland, and 43.56% reduction built up areas. This improvement in forest cover creates better conditions for *C. vellerosus* groups to disperse to occupy all patches in the nearby communities.

IMPLICATIONS FOR CONSERVATION

BFMS is the only conservation area harboring such endangered primates amidst human activities such as agriculture and settlement expansion. Therefore, both traditional and conventional knowledge have been necessary to put human activities under control, which has allowed for the regeneration of the forest cover in the study area. This creates a good impression about the forest cover, hence a good condition for *C. vellerosus* group dispersal to occupy all patches in the proximity. Also, the population of the *C. vellerosus* has increased and more than doubled within the 12-year period, showing that when species are protected against hunting and habitat destruction, their population will increase (Wiafe 2016). The community members support the conservation of the primates and protect their habitats to promote primate tourism, and as a result contribute to the population stabilization and increase in the area of distribution and occupancy. At present, habitat destruction, habitat degradation, overexploitation, and poaching of wild animals, as well as climate change have been identified as the major threats to wildlife in the world (Hogue & Breon 2022). In that case, any efforts to reduce the impacts must be embraced and supported.

The results of this study do not conform to the totality of the notion that small patches of habitat support smaller populations and if individuals are unable to migrate to other suitable habitat areas, the population becomes isolated, putting them at risk of extinction. However, with the institution of the combination of traditional and conventional conservation intervention in highly fragmented environments (as shown in this study), conserving parts of acceptable primate habitats (forest patches) and prohibiting hunting have allowed the primates to migrate between these different locations, occupy the previous 'empty' patches as well as increased their populations. Existing evidence suggests that some primate species, such as Chimpanzees *Pan troglodytes* (McLennan 2008), Orangutans *Pongo* spp. (Spehar & Rayadin 2017), and Samango monkeys *Cercopithecus albogularis labiatus* (Nowak et al. 2017), have extremely high behavioral flexibility, allowing them to survive in human-modified landscapes. Additional evidence is the forest patches in Belize's Community Baboon Sanctuary in which Steinberg (1999) found that a population of Black Howler monkeys *Alouatta pigra* increased by 138% over 13 years when forest buffer strips along property boundaries and strips of forest across large cleared areas were maintained. As a result, the population grew from 840 to over 2,000 individuals (138 %), indicating that they have a high level of behavioral plasticity that allows them to survive in human-modified environments.

We therefore recommend that the government should prioritize the protection of the sanctuary and channel resources to support the conservation of the two species in the sanctuary. Regular population monitoring at short intervals should be carried out by the Sanctuary Management Authority in collaboration with the research institutions in order to predict the dynamics of population growth and events that can affect the primates' population. In addition, a land-use change monitoring regime should be implemented in the area so as to invest resources in the land-use type that favor both the human and non-human primates.

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