2017 BIODIVERSITY MONITORING REPORT

FORM GHANA'S AKUMADAN TEAK PLANTATION

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PREFACE

This report describes the findings of the fauna survey of Form Ghana's Akumadan Teak Plantation in the Asubima and Afrenso Brohuma Forest Reserves, near Akumadan in the Ashanti Region of Ghana in December 2017. The study formed an integral part of an overall biodiversity monitoring in the plantation. In order to get experts and stakeholders input into this assessment the study organized consultations with key stakeholders and adopted a participatory approach to build the capacity of field staff to continue fauna monitoring. This is also to ensure that such key experts and institutions are informed of the assessment and to help gather relevant information about the status of species, identify information gaps and possible threats to species in the area.

Plate 1: A section of the teak plantation showing dense leaf litter

REPORT AT A GLANCE

Date of Fauna Survey

November 24 – December 2, 2017, January 2018

Major Results

The fauna team found the Form Ghana's Akumadan Teak Plantation to provide habitat for at least 58 fauna species [48 species of birds, 2 species of small mammals, 7 species of medium to large mammals and 1 bat species] (Table 1). Highest fauna abundance and diversity were recorded in forest buffers compared to within the teak plantation. Proximity to the buffer areas was responsible for a large proportion of variation in animal abundance.

Table 1: Summary of species of conservation interest recorded in survey

	Species Recorded	Species of Conservation Interest	
		International	Local
Birds	48	0	4
Small Mammals	2	0	0
Large Mammals	7	0	0
Bats	1	1	0

Summary Conservation Recommendations

None of the recorded species were of serious conservation interest on the IUCN Red List of Threatened Species (2017) or CITES schedules. However, the straw-coloured fruit bat (*Eidolon helvum*) is assessed as Near Threatened. Also, members of the Family Accipitridae (birds of prey) and Falconidae (falcons) are of special conservation importance in Ghana and are listed in Schedule 1 of the Ghana Wildlife Conservation Regulations (1995). Again, the African civet, common genet, cusimanse mongoose, bushbuck, Maxwell's duiker and members of the Family Columbidae (pigeons and doves) are of some conservation importance locally in Ghana and are listed as Schedule II species (Ghana Wildlife Conservation Regulations of 1995). Compared to previous surveys, there seems to be a decline of about 40% in number of mammalian species confirmed in the area. Most species were recorded in the forest buffers. Also further research should be conducted to determine occupancy and ecological role of bat species in the area including their significance as fruit dispersal agents.

1.0 BACKGROUND

1.1 Introduction

Forest plantations play a significant role in global wood production. As of the year 2000, there was an estimated 187 million hectares of plantation worldwide (Carle et. al., 2002). Forest plantations are grown to supply raw material for industry and for other uses, such as fuelwood and their potential to partially meet demand for wood and fiber for industrial uses is increasing. Forest plantations also provide additional non-wood forest products and benefits, from the trees planted or from other elements of the ecosystem that they help to create. They contribute to environmental, social, and economic benefits.

The expansion of plantations, and gains in forest productivity, will help reduce pressure on natural forests; this is already the focus of the forest policies adopted by several countries. In many countries, particularly in Africa traditional forest owners, such as forest industry companies or governments are known to be interested in managing forest lands. Governments which decades ago established forest plantations are now promoting private sector involvement to manage forest lands and invest in wood processing capacity (ITTO, 2009).

Form Ghana Ltd. is a forest plantation management company based in central Ghana that is aimed at reclaiming degraded forests by providing services in the field of reforestation and plantation management. The company was established in 2007 and is an affiliate company of Sustainable Forestry Investments B.V. in the Netherlands. Currently, the company has two concessions (Akumadan and Berekum) in Ghana where they are engaged in reforestation activities. The Akumadan area has been in operation for over 10 years now. Over the period conscious efforts has been made to control hunting and bushfires as these were of great priority as well as reforestation and buffer

zone restoration. To measure the effect of these activities on the prevalence of fauna, monitoring of birds and small and medium sized animals is done periodically.

Although, plantation forests have often been considered as a “quick fix” solution to the perennial problems of over exploitation of the natural forest resources, this notwithstanding most queries often raised against the use of forest plantations usually hub around their negative effects such as; low stability, low level of biodiversity, and the tendency of exotic species used for plantations to allegedly displace valuable indigenous tree species (Lugo et al, 1988; Berger, 1993; Smith, 1994). To forestall this situation environmental, biological and social impacts and functions of plantations must be considered and assessed when judging their sustainability (FAO, 1999).

It is in line with this aim that fauna survey was undertaken as part of the monitoring activities of the company. The survey provided information on the abundance and distribution of fauna species in the area and can be used to judge the extent to which the project is successful in protecting the wildlife in these areas.

In this context, the current study is specifically designed to gather information on the impact reforestation activities in Akumadan plantations on the environment, especially fauna. The results of this study will be incorporated in the management documentation.

1.2 Scope of Services Required for this Assignment

Carry out a fauna survey of Form Ghana's Akumadan Teak Plantation, near Akumadan in the Ashanti Region of Ghana. Scope of work include developing survey tools and methodologies in consultation with Form Ghana, carrying out biological (fauna) surveys of terrestrial large and small mammals and avifauna of the plantation. For this assignment, it is required to submit field survey data and a comprehensive fauna survey report.

The survey had the following specific objectives:

- Survey the fauna (mammals and avifauna) of Form Ghana's Akumadan Teak Plantation in the Ashanti Region of Ghana;
- Investigate the presence or absence of threatened species as defined by the IUCN Red List 2017 and Ghana Wildlife Conservation Regulation Schedules;
- Identify any land use variations in fauna in the plantation.

1.3 Specific tasks for this assignment include:

1.3.1 Desk-based study that will include but not limited to:

Scientific literature and project reports on fauna surveys conducted in the Ashanti Region of Ghana as well as other related literature on wildlife activities were examined and relevant information extracted. Furthermore, papers produced under Form Ghana's operational areas were consulted more especially those dealing with Asubima and Afrenso Brohuma Forest Reserves.

1.3.2 Species and habitat data:

Review of ecological literature, online data sources and published reference materials on ecosystems, habitats and protected areas within and around the concession (e.g. the existence and status of habitats, forest types and vegetation communities) and the fauna, with a special focus on species of national, regional and global conservation significance.

1.3.3 Field assessment

- ***Inventory of birds****:* Using rapid assessment and other appropriate sampling methodology, a bird survey will be undertaken in order to verify species of birds of conservation significance in the concession area including migratory species.
- ***Inventory of mammals****:* Undertake survey of both small and large mammals using a combination of methods including but not limited to transect searches to verify species of conservation importance and their habitats in the concessions.

1.3.4 Outputs

The expected outputs of this assignment are:

- A comprehensive report detailing observed species in the plantation, their habitats and relative abundance.
- A listing of all the species identified and their conservation significance using the IUCN's Red List of Protected Species 2017 and the relevant national list of protected species.
- Recommendations for the maintenance and the protection of biodiversity in the plantation. This will also include management recommendations.

Plate 2: The bird survey team

2.0 METHODOLOGY

2.1 Study Area Description

The Form Ghana Akumadan Teak Plantation comprises portions of the Asubima and Afrenso Brohuma Forest Reserves, located near Akumadan in the Ashanti Region of Ghana. The plantation area has been allocated to FORM Ghana Limited for commercial plantation development hence it is an operational site of FORM Ghana where they have been involved in reforestation over the past decade. The plantation covers an area of about 3500 ha. The area is ecologically located in the dry semi-deciduous forest zone (Figure 1) and experiences alternating dry and wet seasons.

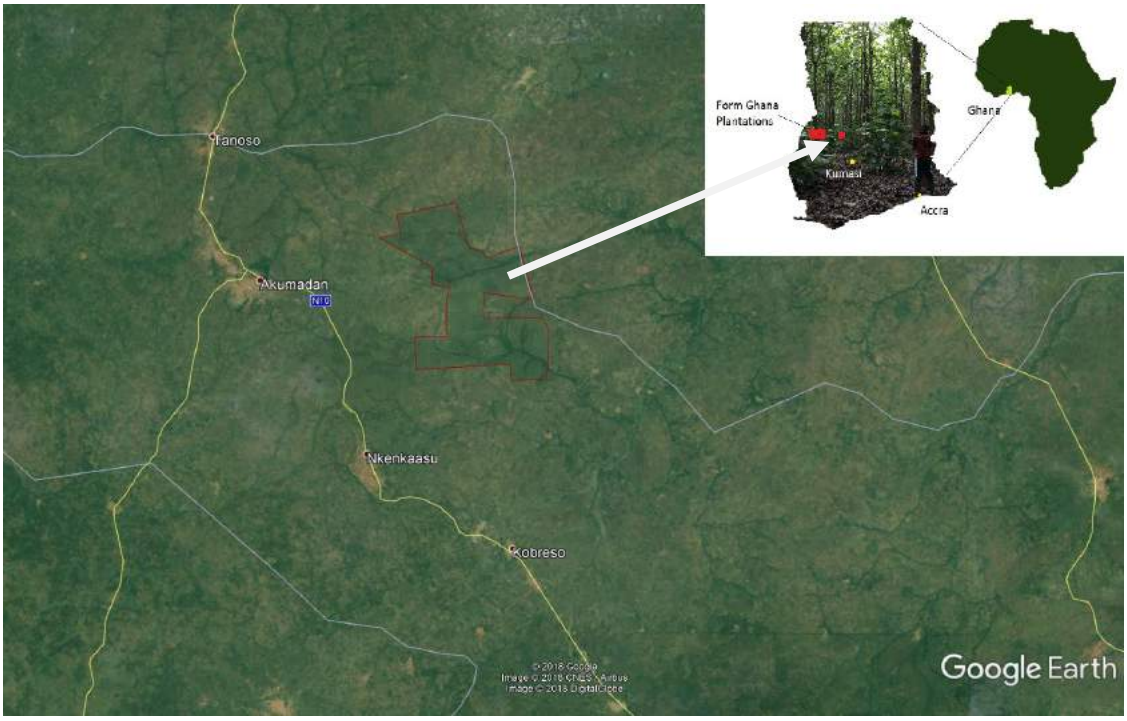

Figure 1: Location of Form Ghana's Teak Plantation with respect to Ghana and Africa

2.2 Data Collection

The team undertook a one-day reconnaissance (recce) exercise in the study site to have an overview of the area and test operational procedures. Monitoring data for all the fauna (birds and mammals) species was collected from existing transects used by De Laat, 2010; Manu, 2011 and Quansah 2011 (Figure 2). Field work was undertaken from 24th November to 2nd December, 2017 and in January 2018.

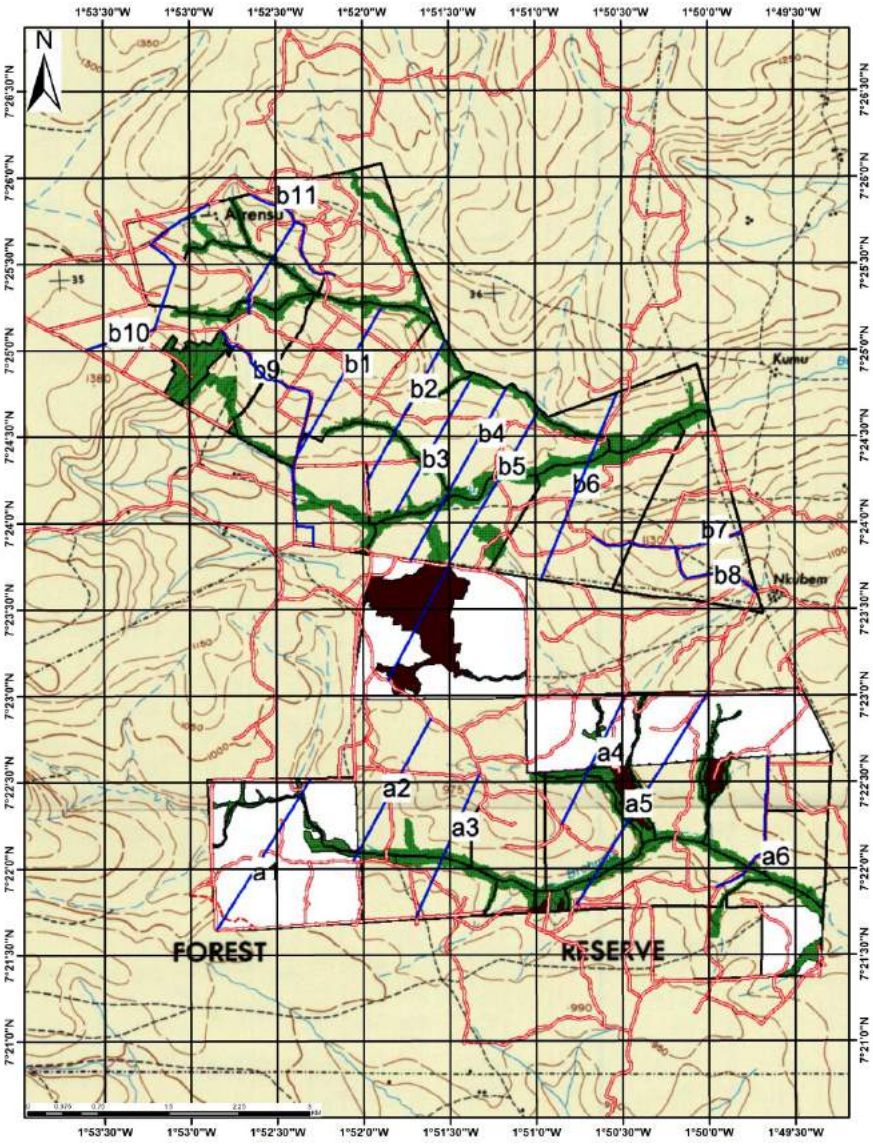

Figure 2: Map of study area showing distribution of transects in the plantation

2.2.1 Medium to Large Mammals

Medium to large mammal survey was conducted based on direct counts and record of their signs, using the line transect method (Burnham et al., 1980; Buckland et al., 1993, 2001). All the seventeen (17) transects of approximately 2km each used in previous monitoring exercises were followed for data collection. One survey team of three persons and led by a compass man (team leader) was maintained throughout the counts to ensure consistency in data collection procedures. GPS coordinates were recorded each time visual observations of a species or sign of their presence (tracks, walking trails, droppings, feeding signs burrows and nests) was observed.

2.2.2 Small mammals

Small mammal survey was conducted to determine species of small mammals in a specific area. The recommended procedures are a combination of live trapping and pitfall trapping with systematic sampling along index trap lines (transects) that are randomly placed within stratified sites. However, owing to the relatively short duration and financial constraints only live trapping using Sherman's live trap was done. Live trapping was also considered the standard as it captures all mammal species or age classes equally and does not remove significant proportion of biotic community as compared to snare or snap trapping. To compliment the trapping method for data collection opportunistic sightings were also made to detect some arboreal species including bat roosts that could not captured by the traps.

Five one-kilometer index trap lines (transects) were systematically selected from the previous monitoring transects taking into consideration the various microhabitats in the area. Two Sherman's live traps were placed at approximately 200m intervals from every trap station on each of the index trap lines. In order to standardize baiting, peanut

butter mixed with corn dough was used as bait. The baited traps were inspected every morning and rebaited for six continuous days. Trapped specimens were collected, identified to the species level based on their morphological appearances and by the help of Jonathan Kingdon's field guide.

2.2.3 Birds

Several techniques can be used in biodiversity assessment and monitoring programs but the choice of technique depends on several factors. Vegetation cover, temperature, season, humidity, topography, type of bird, time of day survey is conducted are all factors that affect the results obtained in bird survey (there are a lot more factors). In order to identify bird species in this project, we followed existing transects or quadrant lines. We walked transects when birds were most active, around sunrise and sunset. This way they are more easily seen or heard. Birds' counts began not less than 20 minutes after sunrise and ended 3-4 hours later and about 2 hours to sunset. During these periods, birds are known to be very active. Counts were done at random intervals but not less than 200m apart to minimize the possibility of double counting. A pair of binoculars was used to observe the birds for identification. Birds were also identified by their calls. Identified bird species were recorded on a data sheet. Birds' nomenclature followed Borrow and Demey, 2010.

2.2.4 GPS Readings

The transect positions are indicated in Table 2.

Table 2a: GPS readings of start and end points of line transects (Afrenso Brohuma FR portion)

Transects	**GPS Coordinates**	
	Longitude (W)	**Latitude (N)**
A1 start	1°52' 50.2"	7° 21' 38.7"
A1 end	1°52' 23.7"	7° 22' 28.7"
A2 start	1°52' 02.2"	7° 22' 02.5"
A2 end	1°51' 49.5"	7° 51' 38.2"
A3 start	1°51' 19.6"	7° 22' 32.3"
A3 end	1°51' 50.7"	7° 22' 29.4"
A4 start	1°50' 50.6"	7° 22' 15.4"
A4 end	1°50' 27.8"	7° 22' 29.4"
A5 start	1°50' 46.0"	7° 21' 47.2"
A5 end	1°50' 01.2"	7° 22' 59.2"
A6 start	1°49' 39,9"	7° 22' 35,3"
A6 end	1°49' 56.9"	7° 21' 52.7"

Table 2b: GPS readings of start and end points of line transects (Asubima FR portion)

Transects	**GPS Coordinates**	
	Longitude (W)	**Latitude (N)**
B1 start	1° 52' 18.2"	7° 24' 27.4"
B1 end	1°52' 03.0"	7°24' 47.3"
B2 start	1°51' 42.3"	7°24' 40.1"
B2 end	1°51' 58,8"	7°24' 15.5"
B3 start	1°51' 20.9"	7°24' 47.7"
B3 end	1°51' 38.4"	7°24' 23.6"
B4 start	1°51' 11.6"	7°24' 39.6"
B4 end	1°51' 26.9"	7°24' 17.3"
B5 start	1°50' 57.9"	7°24' 35.2"
B5 end	1°51' 30.0"	7°23' 45.0"
B6 start	1°50' 58.8"	7°23' 44.2"
B6 end	1°50' 48.4"	7°24' 16.8"
B7 start	1°49' 55.8"	7°23' 54.3"
B7 end	1°50' 33.4"	7°23' 51.7"
B8 start	1°49' 44.5"	7°23' 35.6"
B8 end	1°50'11,7 "	7°23' 50.4 "
B9 start	1°52' 28.9"	7°25' 02.6"
B9 end	1°52' 43.8"	7°24' 41.49"
B10 start	1°53' 34.5"	7°24' 59.4"
B10 end	1°53' 07.8"	7°25' 34.7"
B11 start	1°52' 33.3"	7°25' 52.1"
B11 end	1°52' 38.2"	7°25' 16.6"

2.3 Data Analysis

To avoid problems associated with complex counting and analyzing techniques we simply used an indirect technique such as an index count, which produces relative numbers or densities based on encounter rates. Here, relative means that we will not necessarily know exactly how many animals are present, but we will know whether numbers are going up, remaining stable or going down with monitoring.

2.3.1 Species Richness

Species' richness was calculated using Chao 1 richness index (Krebs 1989).

2.3.2 Species Diversity

The Shannon-Wiener index (Krebs 1989) was used to determine the diversity of mammal species on each transect.

2.3.3 Species Density

An indirect technique such as an index count, which produces relative numbers based on encounter rates, was used to estimate fauna species densities.

Encounter rate = [number of signs / total distance walked]----------(1)

Index counts relate animal numbers to an index of animal signs detected along line transects (Buckland *et al*., 2001; Barnes *et al*., 1997). The computer software StatView was used in the analysis.

2.4 Conservation status

The conservation status of the fauna in the area of influence was assessed using the global (International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (2017), CITES schedules and national (Ghana Wildlife Laws) criteria.

Plate 3: A section of the forest buffer

3.0 MAIN LANDUSE TYPES

3.1 Description of landuse types

Fauna abundances (large mammals, small terrestrial mammals and avifauna were estimated from two major land use types: teak plantation and forest buffers. The land use types are described in Table 3.

Table 3: Description of land use types surveyed in the study area

#	Land-use Type	Land-use Description
1	Teak Plantation	• Monocultures of *Tectona grandis* at various stages of growth.
2	Forest Buffers	• Remnant riparian forest patches buffering waterbodies within the plantation. • Width ranges from 10 – 20 m across rivers • Dominated by York and indigenous plant species

4.0 MAMMALS

Four mammal taxonomic groups (rodents, carnivores, ungulates and chiropterans), representing 9 Families, 10 Genera, and 10 Species were confirmed in the study area during the survey (Appendices 1, 2). The forest buffers ranked highest with a record of 10 mammal species, followed by the teak plantation (6) species (Figure 3). Similarly, the buffers were found to be richest and most diverse in overall fauna species (Table 4).

Table 4: Mammal richness and diversity indices generated by PAST 2.17c

	Richness Index		Diversity Index	
Management Zone	Bootstrap Mean	Bootstrap SD	Bootstrap Mean	Bootstrap SD
Teak Plantation	80.25	0.22	3.11	0.37
Forest Buffers	117.60	0.14	3.85	0.34

NB: SD is standard deviation

A total of 32 medium to large terrestrial mammal signs were recorded: 18 signs (53%) in the forest buffers and 16 signs (47%) in the teak forest (Appendices 2, 3, 4, and 5). The Maxwell's Duiker, Bushbuck and Giant Rats were the most abundant species recorded in the area. All three species were recorded fairly well in all the two land use types (Figure 3). Whiles these species were restricted to the Asubima portion of the plantation, the common genet was recorded only in the Afrenso Brohuma portion.

Two (2) species of small terrestrial mammals and one (1) bat species were recorded (Figure 3). The fire-footed rope squirrel was recorded in the teak plantation whiles the Tullberg's soft-furred rat and bat were observed to thrive in the buffer area.

Seventy-two percent (72%) of all mammal signs were recorded entirely in the forest buffers whiles only 28% were recorded in the teak plantation.

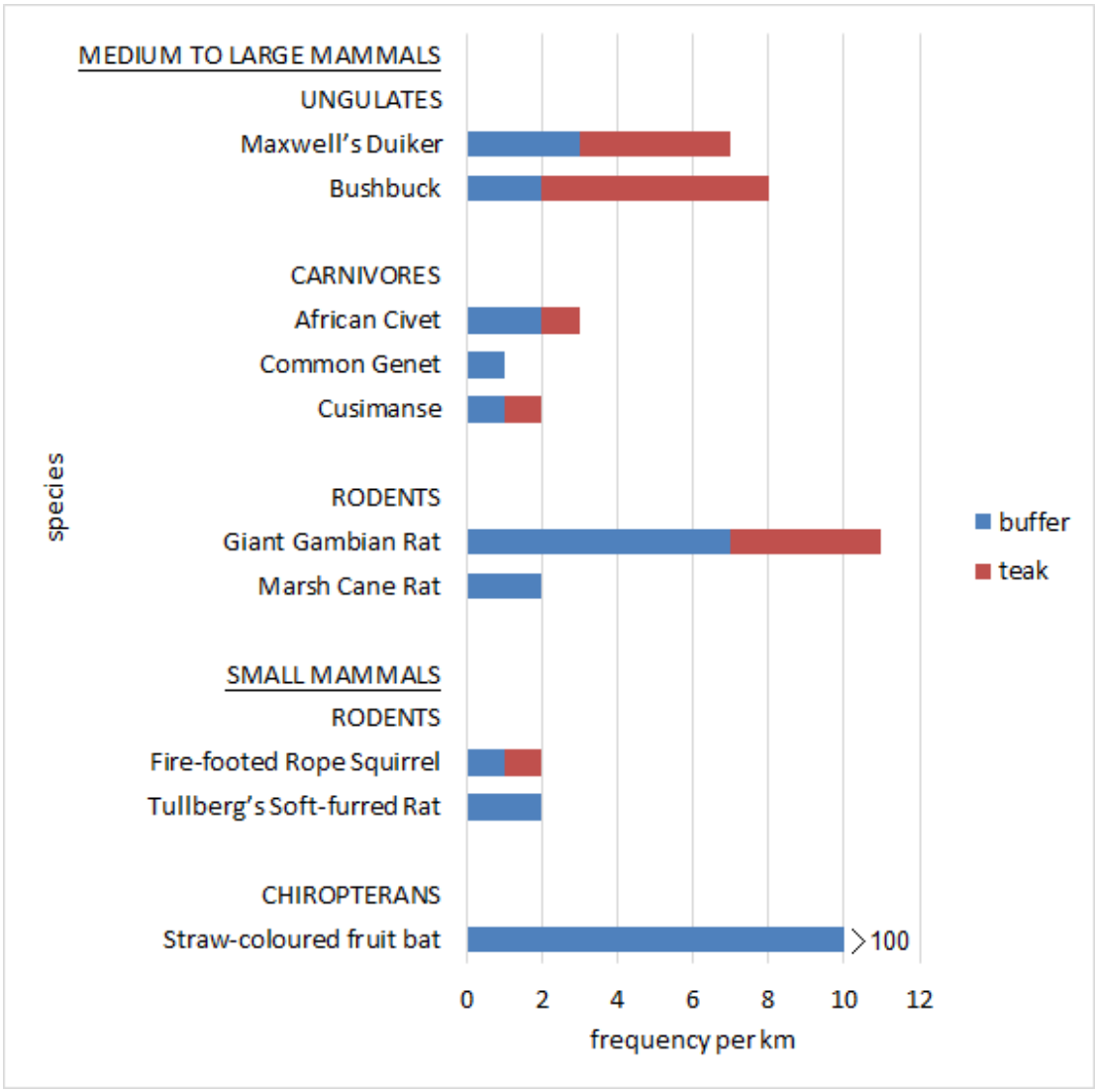

Figure 3: Abundance of mammal signs recorded in the study area

None of the recorded species were of serious conservation interest on the IUCN Red List of Threatened Species (2017) or CITES schedules. However, the straw-coloured fruit bat (*Eidolon helvum*) is assessed as Near Threatened. Also, the African civet, common genet, cusimanse mongoose, bushbuck and Maxwell's duiker are of lower conservation importance locally in Ghana and are listed as Schedule II species (Ghana Wildlife Conservation Regulations of 1995). The hunting, capturing or destroying of any species listed in Schedule II is absolutely prohibited between 1 August and 1 December in any

year. Similarly, the hunting, capturing or destroying of any young or adult accompanied by his young of any species listed in this schedule is absolutely prohibited at all times.

5.0 BIRDS

Forty-eight (48) Species, belonging to 41 Genera and 24 Families were recorded on transects (Figure 4; Appendix 3). Fifty-two percent (52%) of the species recorded belong to the Families Accipitridae, Columbidae, Pycnonotidae, Capitonida and Nectariniidae. The Common Bulbul, *Pycnonotus barbatus* (relative abundance of 18.0%), Red-eyed Dove, *Streptophelia semitorquata* (16.5%) and White-throated Bee-eater, *Merops albicollis* (14.7%) were the most recorded and widespread bird species in the Asubima portion of the plantation. The Red-eyed Dove (13.2%) and Common Bulbul (relative abundance of 10.3%) were also most abundant in the Afrenso Brohuma portion of the plantation.

Most of the bird species occurred in the forest buffers (39 species) while 24 species were recorded in the teak plantation. Most of the birds recorded were either forest fringe species or birds of degraded forests. None of the recorded birds are of special conservation importance on the IUCN List of Threatened Species 2017 or CITES schedules. However, generally members of the Family Accipitridae (birds of prey) and Falconidae (falcons) are of special conservation importance in Ghana and are listed in Schedule 1 of the Ghana Wildlife Conservation Regulations (1995). The hunting, capturing or destroying of any species listed in Schedule I is absolutely prohibited. Also, members of the Family Columbidae (pigeons and doves) are of lower conservation importance locally in Ghana and are listed as Schedule II species (Ghana Wildlife Conservation Regulations of 1995).

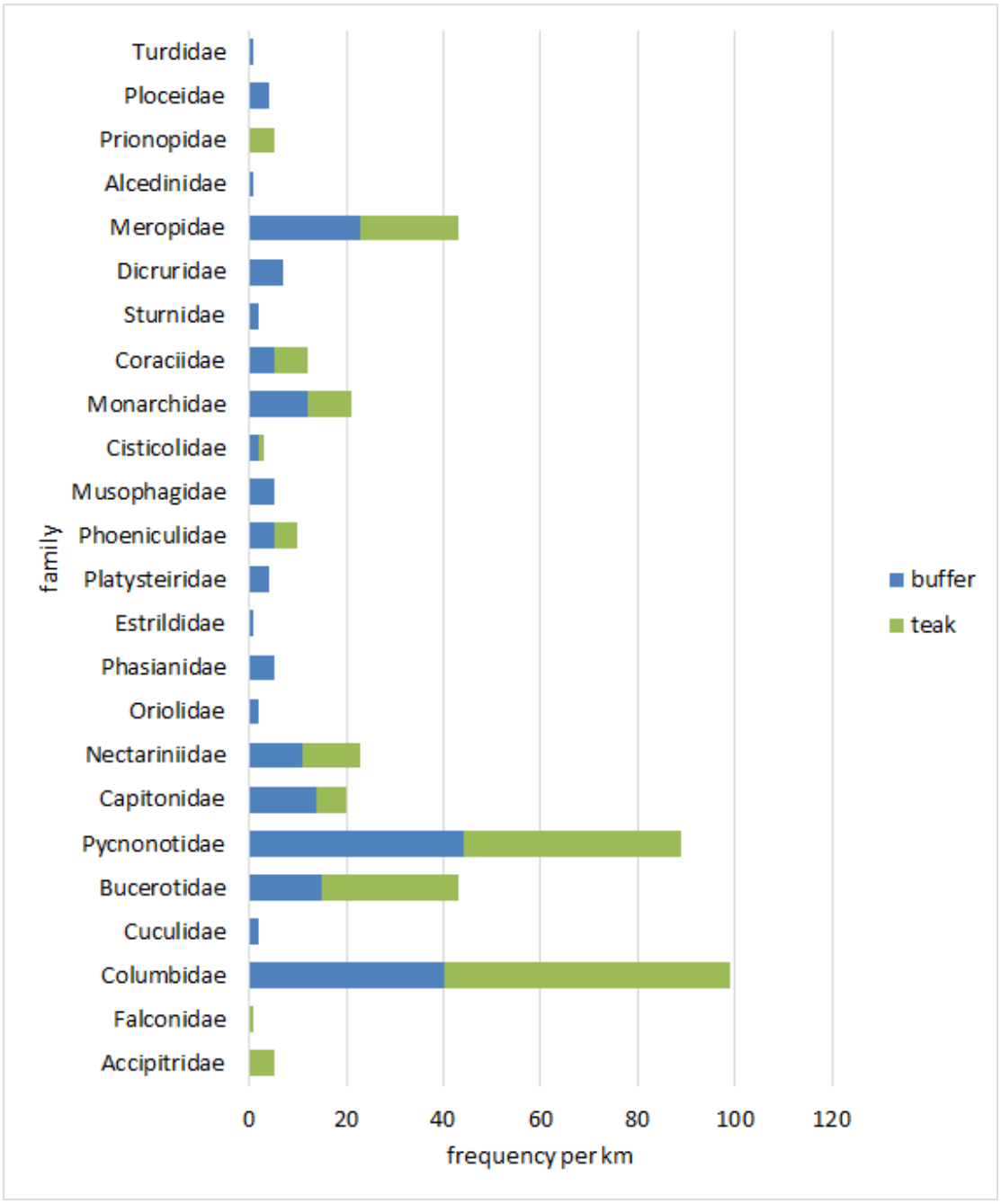

Figure 4: Abundance of bird signs recorded in the study area

6.0 DISCUSSION

The forest buffers occupy a critical position, which gives special interest and significance to the identity and distribution of species within the teak plantation. The forest buffers were found to support the most diversity of wildlife with a total of 58 vertebrate species identified. The commonest birds were bulbuls (Pycnonotidae), doves (Columbidae), bee-eaters (Meropidae). The area in general have a fairly rich avifauna with at least 48 species recorded and this may be mainly due to the abundance and variety of insect life forms in the area that serve as food.

The mammalian fauna of the area was however not impressive. Out of about seventeen (17) mammal species confirmed to be present in the area in 2010-2011 (De Laat, 2010; Manu, 2011 and Quansah 2011), only ten (10) were recorded in 2017-2018 including one bat species. This suggests that about forty percent of the previously identified species were not recorded. Species like brush-tailed porcupine, Mona (Lowe's) monkey, marsh mongoose, African palm civet, tree pangolin, Togo hare, warthog, bay duiker, tree hyrax and striped ground squirrel were not confirmed in the present survey. The diversity of small mammals was found to be very low in the study area. The generally low record of mammals and particularly of small mammals in the study area corresponds well to established low densities in teak plantations. Although low densities of mammals were recorded in the teak plantations, this could be due to several factors including harsh environmental conditions (lack of adequate food resources and cover in the plantation area) and potential migration to other areas in the dry season, the period of survey.

Fortunately, the plantation serves as a sanctuary for the straw-coloured fruit bat (*Eidolon helvum*), possibly in the dry season. *Eidolon helvum* is a large fruit bat that is the most widely distributed of all the African megabats. It is quite common throughout its area ranging from the southwestern Arabian Peninsula, across forest and savanna

zones of sub-Saharan Africa. They have recently been classified as Near Threatened on the IUCN Red List due to a decreasing population trend from hunting for bushmeat. It is considered a preferred species of bat for bushmeat in West Africa. Form Ghana has made several arrests of poachers in combatting this threat. It is suggested that Form Ghana implements collaborative wildlife management in and outside the protected areas using the Community Resource Management area (CREMA) approach.

Ongoing development of plantation activities might have adversely affected the populations of several large mammal, including canopy dwelling primates and possibly bird species over time. Weed control measures and plantation management practices such as weeding, spraying, fertilization and slashing of non-teak trees might have contributed to the decrease in number of species, particularly forest specialist species. The surviving fauna are adapted to secondary or plantations and might have persisted (Struhsaker and Oates, 1995). Also, Maxwell's duiker and bushbucks which were recorded in relatively higher numbers can probably withstand forest loss to a greater degree than more susceptible species like primates. Many of the species recorded are considered to be habitat generalists, capable of surviving in both mature forest and degraded and highly fragmented habitat.

Plate 4: A straw-coloured fruit bat

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 Priority Biodiversity Hotspots

The plantation may be very important for local and international bat migrations and hence can be an excellent focal point for research. Priority biodiversity hotspots identified in the study area are the forest buffers. Fortunately, these areas have been declared 'no go' areas by Form Ghana. Hence, the forest buffers could form the basis of incorporating wildlife management into future land use. Its implementation will have long-term significant and positive implications for a wide range of wildlife. This innovation itself is an opportunity that stands Form Ghana in good stead to enjoy support from many sides, especially government, ecologists and NGOs. Form Ghana should continue to enrich the forest buffer with preferred fruit bearing plants, provide watering points, and salt licks where possible to ensure that the ecosystem remains healthy. They should manage the forest buffer to improve breeding and /or survival rates by providing food/breeding sites/shelters, reduce poachers using the CREMA approach. Also compliance with aspects of the Forest Stewardship Council (FSC) principles for natural forest management are recommended.

7.2 Threats

The existing Form Ghana policy of conserving all riparian and buffer areas including their sensitive vegetation within the plantation is laudable and promotes high biodiversity conservation. However, more effort should be channeled into enforcing a hunting regulation in order to reduce deterioration of the status of wildlife in these areas.

7.3 Difficulties Encountered in Field

It was generally difficult to directly observe animals and their signs because of the volume of brittle and crispy leaf litter, which generated alarming noise during transect walk . This might have decreased the chances of success

8.0 REFERENCES

1. Barnes, R., F., W., Beardsley, K., Michelmore, F., Barnes, K., L., Alers, M., P., T., Blom, A. (1997) Estimating forest elephant numbers with dung counts and a geographic information system. *Journal of Wildlife Management* 61: 1384-1393.
2. Barrow, N. and Demey, R. (2008). Birds of Western Africa. A &C Black Publishers Ltd. London. Pp. 51
3. Berger, J.J. (1993). Ecological restoration and non-indigenous plant species: a review. Rest. Ecol. 1:74–82.
4. Buckland, S., T., Anderson, D., R., Burnham, K., P., Laake, J., L., Borchers, D., L. and Thomas, L. (2001). Introduction to distance sampling: estimating abundance of biological populations. Oxford University Press.
5. Buckland, S., T., Anderson, D., R., Burnham, K., P. and Laake, J., L. (1993). Distance sampling: estimating abundance of biological populations. Chapman & Hall, London.
6. Burnham, K., P., Anderson, D., R. and Laake, J., L. (I980). Estimation of density from line transect sampling of biological populations; *Wildlife Monogram* 72: 1-202
7. Carle, J., P. Vuorinen & A. Del Lungo, 2002. Status and Trends in Global Forest Plantation Development. *Forest Products Journal* 52(7/8): 12-23.
8. FAO, 1999. State of the world's forests. FAO. Rome, Italy.154 pp.
9. ITTO (2009). Encouraging Industrial Forest Plantations in the Tropics. Report of a Global Study. ITTO Technical Series No 33
10. IUCN (World Conservation Union) (2017). IUCN Red List categories and criteria. Version 3.1. IUCN Species Survival Commission. IUCN, Gland, Switzerland, and Cambridge, United Kingdom.
11. Krebs, C. J. (1989). Ecological Methodology. Harper-Collins Publishers, New York. 654 pp.
12. Laat, de N. (2010). Monitoring biodiversity in Asubima Forest Reserve Ghana. Form International and Wageningen University.
13. Lugo, A.E., Brown, S. & Chapman, J. (1988). An analytical review of production rates and stemwood biomass of tropical forest plantations. For. Ecol. Manage. 23:179–200.
14. Manu, A. P. (2011). Biodiversity monitoring in Asubima and Afrensu Brohuma Forest Reserves, Ghana. Form International B. V.
15. Quamsah, Y. K. (2011). A survey of medium sized mammals in Asubima Forest Reserve. College of Agriculture and Natural Resources, Faculty of Renewable Natural Resources, Department of Wildlife and Range Management.
16. Smith, C.T. (1994). Is plantation forestry good or bad for soils? New Zealand. For. 39:19–22.

17. Struhsaker, T.T. and Oates, J.F. (1995). The biodiversity crisis in southwestern Ghana. *African Primates* 1(1): 5-6.

Plate 5: A section of a river with its riparian buffer

Appendix 1a: Total medium to large mammal signs and relative abundance (%) for the Akumadan teak plantation - Afrenso Brohuma FR

Common Name	Scientific Name	A1	A2	A3	A4	A5	A6	Total	Rel Den (%)	IUCN Status	WD	CITES
RODENTS	***RODENTIA***											
Cane-rats	***Thryonomyidae***											
Marsh Cane Rat	*Thryonomys swinderianus*	0	0	0	0	0	1	1	16.7	LC	3	
Pouched Rats	***Cricetomyinae***											
Giant Gambian Rat	*Cricetomys gambianus*	0	1	0	0	0	0	1	16.7	LC	3	
CARNIVORES	***CARNIVORA***											
Mongooses	***Herpestidae***											
Cusimanse	*Crossarchus obscurus*	0	0	0	0	0	1	1	16.7	LC	2	
Genets and Civets	***Viverridae***											
African Civet	*Viverra civetta*	1	1	0	0	0	0	2	33.3	LC	2	
Common Genet	*Genetta genetta*	0	0	0	0	0	1	1	16.7	LC	2	
Number of signs		1	2	0	0	0	3	6				
Number of species		1	2	0	0	0	3	5				

Appendix 1b: Total medium to large mammal signs and relative abundance (%) for the Akumadan teak plantation – Asubima FR

Common Name	Scientific Name	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	Total	Rel Den (%)	IUCN Status	WD	CITES
RODENTS	***RODENTIA***																
Cane-rats	***Thryonomyidae***																
Marsh Cane Rat	*Thryonomys swinderianus*	0	0	0	0	1	0	0	0	0	0	0	1	3.4	LC	3	
Pouched Rats	***Cricetomyinae***																
Giant Gambian Rat	*Cricetomys gambianus*	1	0	0	1	0	2	3	0	0	2	1	10	34.5	LC	3	
CARNIVORES	***CARNIVORA***																
Mongooses	***Herpestidae***																
Cusimanse	*Crossarchus obscurus*	1	0	0	0	0	0	0	0	1	0	0	2	6.9	LC	2	
Genets and Civets	***Viverridae***																
African Civet	*Viverra s civetta*	0	0	0	0	0	0	1	0	0	0	0	1	3.4	LC	2	
UNGULATES	***UNGULATA***																
Bovids	***Bovidae***																
Bushbuck	*Tragelaphus scriptus*	4	0	0	1	0	2	0	0	1	0	0	8	27.6	LC	2	
Antelopes	***Antelopinae***																
Maxwell's Duiker	*Cephalophus maxwelli*	0	0	0	1	2	1	0	0	0	0	3	7	24.1	LC	2	
Number of signs		6	0	0	3	3	5	4	0	2	2	4	29				
Number of species		3	0	0	3	2	3	1	0	2	1	2	6				

Appendix 2a: Total small mammal and bat signs and relative abundance (%) for the Akumadan teak plantation - Afrenso Brohuma FR

Common Name	Scientific Name	A1	A2	A3	A4	A5	A6	Total	Rel Den (%)	IUCN Status	WD	CITES
RODENTS	***RODENTIA***											
Squirrels	***Sciuridae***											
Fire-footed Rope Squirrel	*Funisciurus pyrropus*	1	0	0	0	0	0	1	0.7	LC	3	
Murid Rats and Mice	***Muridae***											
Tullberg's Soft-furred Rat	*Praomys tullbergi*	0	0	0	0	0	1	1	0.7	LC	3	
BATS												
Chiropterans	**Chiroptera**											
Straw-coloured fruit bat	*Eidolon helvum*	0	0	0	0	150	0	150	98.7	NT	3	
Number of signs		0	0	0	0	150	1	152				
Number of species		1	0	0	0	1	1	3				

Appendix 2b: Total small mammal signs and relative abundance (%) for the Akumadan teak plantation – Asubima FR

Common Name	Scientific Name	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	Total	Rel Den (%)	IUCN Status	WD	CITES
RODENTS	***RODENTIA***																
Squirrels	***Sciuridae***																
Fire-footed Rope Squirrel	*Funisciurus pyrropus*	0	0	0	0	1	0	0	0	0	0	0	1	50.0	LC	3	
Murid Rats and Mice	***Muridae***																
Tullberg's Soft-furred Rat	*Praomys tullbergi*	0	0	0	0	0	0	0	0	0	1	0	1	50.0	LC	3	
Number of signs		0	0	0	0	1	0	0	0	0	1	0	2				
Number of species		0	0	0	0	1	0	0	0	0	1	0	2				

Appendix 3a: Total bird signs and relative abundance (%) for the Akumadan teak plantation - Afrenso Brohuma FR

Common Name	Scientific Name	A1	A2	A3	A4	A5	A6	Total	Rel Den (%)	IUCN Status	WD	CITES
Birds of Prey	***Accipitridae***											
Lizard Buzzard	*Kaupifalco monogrammicus*	0	0	1	0	0	0	1	0.7	LC	1	
Falcons	***Falconidae***											
Common Kestrel	*Falco tinnunculus*	0	0	0	0	1	0	1	0.7	LC	1	
Pigeons and Doves	***Columbidae***											
African Green Pigeon	*Treron calvus*	0	1	1	0	0	0	2	1.5	LC	2	
Red-eyed Dove	*Streptopelia semitorquata*	2	3	4	1	2	6	18	13.2	LC	2	
Tambourine Dove	*Turtur tympanistria*	1	0	1	2	1	4	9	6.6	LC	2	
Cuckoos and Coucals	***Cuculidae***											
Senegal Coucal	*Centropus senegalensis*	1	0	0	0	0	0	1	0.7	LC	3	
Hornbills	***Bucerotidae***											
African Grey Hornbill	*Tockus nasutus*	2	0	2	1	2	3	10	7.4	LC	3	
African-pied Hornbill	*Tockus fasciatus*	0	2	3	0	0	4	9	6.6	LC	3	
Wood-hoopoes	***Phoeniculidae***											
Black Scimitarbill	*Rhinopomastus aterrimus*	5	0	0	0	0	0	5	3.7	LC	3	
Green Hylia	*Hylia prasina*	0	0	0	0	0	2	2	1.5	LC	3	

Appendix 3a: Total bird signs and relative abundance (%) for the Akumadan teak plantation - Afrenso Brohuma FR

Common Name	Scientific Name	A1	A2	A3	A4	A5	A6	Total	Rel Den (%)	IUCN Status	WD	CITES
Bulbuls and Greenbuls	***Pycnonotidae***											
Common Bulbul	*Pycnonotus barbatus*	3	3	2	0	3	3	14	10.3	LC	3	
Swamp Palm Bulbul	*Thescelocichla leucopleura*	0	0	0	0	0	3	3	2.2	LC	3	
Little Greenbul	*Andropadus virens*	0	1	0	0	0	0	1	0.7	LC	3	
Yellow-W Greenbul	*Andropadus latirostris*	0	0	0	0	0	1	1	0.7	LC	3	
Grey headed bristlebill	*Bleda canicapillus*	0	0	0	0	4	0	4	2.9	LC	3	
Barbets/Tinkerbirds	***Capitonidae***											
Yellow-R Tinkerbird	*Pogoniulus bilineatus*	0	0	0	0	1	1	2	1.5	LC	3	
Sunbirds	***Nectariniidae***											
Collared sunbird	*Hedydipna collaris*	1	0	1	1	0	2	5	3.7	LC	3	
Copper Sunbird	*Cinnyris cupreus*	0	0	0	0	1	0	1	0.7	LC	3	
Green-headed sunbird	*Cyanomitra verticalis*	0	1	0	0	1	0	2	1.5	LC	3	
Olive-bellied Sunbird	*Cinnyris chloropygius*	0	0	2	0	0	0	2	1.5	LC	3	
Tiny Sunbird	*Cinnyris minullus*	0	0	1	0	0	1	2	1.5	LC	3	
Orioles	***Oriolidae***											
Black-winged Oriole	*Oriolus nigripennis*	0	0	0	0	0	1	1	0.7	LC	3	
Francolins	***Phasianidae***											
Ahanta Francolin	*Francolinus ahantensis*	1	0	2	0	0	1	4	2.9	LC	3	

Appendix 3a: Total bird signs and relative abundance (%) for the Akumadan teak plantation - Afrenso Brohuma FR

Common Name	Scientific Name	A1	A2	A3	A4	A5	A6	Total	Rel Den (%)	IUCN Status	WD	CITES
Waxbills/Weaver-Fs	***Estrildidae***											
Bronze Mannikin	*Spermetes cucullatus*	0	0	0	0	1	0	1	0.7	LC	3	
Wattle-eyes	***Platysteiridae***											
Common Wattle-eye	*Platysteira cyanea*	0	0	0	0	1	0	1	0.7	LC	3	
Turacos	***Musophagidae***											
Green Turaco	*Tauraco persa*	0	2	0	0	2	0	4	2.9	LC	3	
Camaropteras	***Cisticolidae***											
Yellow-B Camaroptera	*Camaroptera superciliaris*	0	0	0	1	0	0	1	0.7	LC	3	
Flycatchers	***Monarchidae***											
Red-B P'dise Flycatcher	*Terpsiphone rufiventer*	1	1	0	1	1	1	5	3.7	LC	3	
Rollers	***Coraciidae***											
Blue bellied Roller	*Coracias cyanogaster*	0	5	1	1	0	0	7	5.1	LC	3	
Drongos	***Dicruridae***											
Velvet-mantled Drongo	*Dicrurus modestus*	0	0	0	0	4	0	4	2.9	LC	3	
Bee-eaters	***Meropidae***											
White-throated Bee-eater	*Merops albicollis*	0	0	1	0	1	0	2	1.5	LC	3	

Appendix 3a: Total bird signs and relative abundance (%) for the Akumadan teak plantation - Afrenso Brohuma FR

Common Name	Scientific Name	A1	A2	A3	A4	A5	A6	Total	Rel Den (%)	IUCN Status	WD	CITES
Kingfishers	***Alcedinidae***											
Blue-breasted Kingfisher	*Halcyon malimbica*	0	1	0	0	0	0	1	0.7	LC	3	
Shrikes	***Prionopidae***											
White Helmet-shrike	*Prionops plumatus*	0	0	5	0	0	0	5	3.7	LC	3	
Malimbes	***Ploceidae***											
Blue-billed Malimbe	*Malimbus nitens*	0	0	0	0	2	0	2	1.5	LC	3	
Vieillot's black weaver	*Plceus nigerrimus*	0	0	0	0	2	0	2	1.5	LC	3	
Thrushes	***Turdidae***											
African Thrush	*Turdus pelios*	0	0	0	0	0	1	1	0.7	LC	3	
Number of signs		17	20	27	8	30	34	136				
Number of species		9	10	14	7	17	15	36				

Appendix 3b: Total bird signs and relative abundance (%) for the Akumadan teak plantation – Asubima FR

Common Name	Scientific Name	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	Total	Rel Den (%)	IUCN Status	WD	CITES
Birds of Prey	***Accipitridae***																
Black Kite	*Milvus migrans*	0	0	0	0	0	0	0	0	1	0	0	1	0.4	LC	1	
Black-shouldered Kite	*Elanus caeruleus*	0	0	0	0	0	0	0	0	0	1	0	1	0.4	LC	1	
Lizard Buzzard	*Kaupifalco monogrammicus*	0	0	0	0	1	0	0	0	0	0	0	1	0.4	LC	1	
Yellow-billed Kite	*Milvus migrans parasitus*	0	0	0	0	0	1	0	0	0	0	0	1	0.4	LC	1	
Pigeons and Doves	***Columbidae***																
African Green Pigeon	*Treron calvus*	0	0	0	0	2	3	0	0	0	0	0	5	1.8	LC	2	
Blue-spotted Wood Dove	*Turtur afer*	0	0	0	0	1	0	0	0	0	0	0	1	0.4	LC	2	
Red-eyed Dove	*Streptopelia semitorquata*	1	6	0	1	18	8	2	2	4	4	0	46	16.5	LC	2	
Tambourine Dove	*Turtur tympanistria*	1	3	1	0	4	5	1	1	1	1	0	18	6.5	LC	2	
Cuckoos and Coucals	***Cuculidae***																
Senegal Coucal	*Centropus senegalensis*	0	0	0	0	0	0	0	1	0	0	0	1	0.4	LC	3	
Hornbills	***Bucerotidae***																
African Grey Hornbill	*Tockus nasutus*	1	1	0	0	5	4	0	0	4	2	1	18	6.5	LC	3	
African-pied Hornbill	*Tockus fasciatus*	0	1	0	1	3	0	0	1	0	0	0	6	2.2	LC	3	
Wood-hoopoes	***Phoeniculidae***																
Forest Wood-hoopoe	*Phoeniculus casteneiceps*	0	0	0	0	1	0	0	0	0	0	0	1	0.4	LC	3	

Appendix 3b: Total bird signs and relative abundance (%) for the Akumadan teak plantation – Asubima FR

Common Name	Scientific Name	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	Total	Rel Den (%)	IUCN Status	WD	CITES
Bulbuls and Greenbuls	***Pycnonotidae***																
Common Bulbul	*Pycnonotus barbatus*	0	7	11	1	4	7	1	4	11	4	0	50	18.0	LC	3	
Simple Leaflove	*Chlorocichla simplex*	0	0	0	0	1	0	0	0	0	0	0	1	0.4	LC	3	
Swamp Palm Bulbul	*Thescelocichla leucopleura*	0	2	0	0	0	0	0	0	1	2	2	7	2.5	LC	3	
Little Greenbul	*Andropadus virens*	0	1	0	0	1	0	0	0	0	0	0	2	0.7	LC	3	
W-bearded greenbul	*Criniger barbatus*	0	0	1	0	0	0	0	0	0	0	0	1	0.4	LC	3	
Yellow-W Greenbul	*Andropadus latirostris*	0	0	0	0	1	0	0	0	0	0	0	1	0.4	LC	3	
Western Nicator	*Nicator chloris*	0	1	0	0	1	0	0	0	1	0	0	3	1.1	LC	3	
Grey headed bristlebill	*Bleda canicapillus*	0	0	1	0	0	0	0	0	0	0	0	1	0.4	LC	3	
Barbets/Tinkerbirds	***Capitonidae***																
Bearded Barbet	*Lybius dubius*	0	0	0	0	0	0	0	0	0	3	0	3	1.1	LC	3	
Hairy-breasted Barbet	*Tricholaema hirsuta*	0	0	0	0	2	0	0	0	0	0	0	2	0.7	LC	3	
Naked-faced Barbet	*Gymnobucco calvus*	0	0	1	0	4	0	0	0	0	1	0	6	2.2	LC	3	
Yellow-R Tinkerbird	*Pogoniulus bilineatus*	0	3	0	0	0	0	0	0	2	0	2	7	2.5	LC	3	
Sunbirds	***Nectariniidae***																
Collared sunbird	*Hedydipna collaris*	0	0	0	0	1	0	0	0	0	0	0	1	0.4	LC	3	
Copper Sunbird	*Cinnyris cupreus*	0	0	0	0	1	0	0	0	0	0	0	1	0.4	LC	3	
Green-headed sunbird	*Cyanomitra verticalis*	0	0	0	0	0	1	0	0	0	0	0	1	0.4	LC	3	
Olive-bellied Sunbird	*Cinnyris chloropygius*	0	0	0	0	1	1	0	1	1	1	0	5	1.8	LC	3	
Tiny Sunbird	*Cinnyris minullus*	0	0	0	0	2	0	0	0	1	0	0	3	1.1	LC	3	

Appendix 3b: Total bird signs and relative abundance (%) for the Akumadan teak plantation – Asubima FR

Common Name	Scientific Name	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	Total	Rel Den (%)	IUCN Status	WD	CITES
Orioles	***Oriolidae***																
Black-winged Oriole	*Oriolus nigripennis*	0	0	0	0	1	0	0	0	0	0	0	1	0.4	LC	3	
Francolins	***Phasianidae***																
Ahanta Francolin	*Francolinus ahantensis*	0	0	0	0	3	0	0	0	0	0	2	5	1.8	LC	3	
Waxbills/Weaver-Fs	***Estrildidae***																
Bronze Mannikin	*Spermetes cucullatus*	0	0	0	0	1	0	0	0	0	0	0	1	0.4	LC	3	
Wattle-eyes	***Platysteiridae***																
Common Wattle-eye	*Platysteira cyanea*	0	0	0	0	1	0	0	0	0	0	0	1	0.4	LC	3	
Turacos	***Musophagidae***																
Green Turaco	*Tauraco persa*	0	0	0	0	1	0	0	0	0	0	0	1	0.4	LC	3	
Camaropteras	***Cisticolidae***																
Grey-B Camaroptera	*Camaroptera brachyura*	0	0	0	0	1	0	0	0	0	0	0	1	0.4	LC	3	
Yellow-B Camaroptera	*Camaroptera superciliaris*	0	0	0	0	0	0	0	1	0	0	0	1	0.4	LC	3	
Flycatchers	***Monarchidae***																
Red-B P'dise Flycatcher	*Terpsiphone rufiventer*	0	1	0	0	5	1	0	0	3	2	7	19	6.8	LC	3	

Appendix 3b: Total bird signs and relative abundance (%) for the Akumadan teak plantation – Asubima FR

Common Name	Scientific Name	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	Total	Rel Den (%)	IUCN Status	WD	CITES
Rollers	***Coraciidae***																
Blue bellied Roller	*Coracias cyanogaster*	0	0	0	0	2	2	0	0	0	1	0	5	1.8	LC	3	
Starlings	***Sturnidae***																
Splendid Glossy Starling	*Lamprotornis splendidus*	0	0	0	0	1	0	1	0	0	0	0	2	0.7	LC	3	
Drongos	***Dicruridae***																
Velvet-mantled Drongo	*Dicrurus modestus*	0	0	0	0	2	0	1	0	0	0	0	3	1.1	LC	3	
Bee-eaters	***Meropidae***																
White-throated Bee-eater	*Merops albicollis*	0	33	0	0	4	1	0	0	0	0	3	41	14.7	LC	3	
Warblers	***Silviidae***																
Green Hylia	*Hylia prasina*	0	0	0	0	1	1	0	0	0	0	0	2	0.7	LC	3	
Number of signs		3	59	15	3	77	35	6	11	30	22	17	278				
Number of species		3	11	5	3	30	12	5	7	11	11	6	42				

Appendix 4: GPS coordinates of key fauna recorded in the plantation

Family and species	*Scientific name*	Observation	Transect	GPS Coordinates	
				Lat	Lon
Chiropterans	***Chiroptera***				
Straw-coloured fruit bat	*Eidolon helvum*	Roost	A5	N07 22' 15.1"	W001 50' 25.0"
Bovids	***Bovidae***				
Bushbuck	*Tragelaphus scriptus*	Footprint	B1	N07 24' 43.5"	W001 52' 06.2"
Bushbuck	*Tragelaphus scriptus*	Footprint		N07 24' 41.3"	W001 52' 07.8"
Bushbuck	*Tragelaphus scriptus*	Footprint		N07 24' 36.5"	W001 52' 11.8"
Bushbuck	*Tragelaphus scriptus*	Footprint		N07 24' 28.6"	W001 52' 17.3"
Mongooses	***Herpestidae***				
Cusimanse	*Crossarchus obscurus*	Footprint		N07 24' 36.5"	W001 52' 11.8"
Bovids	***Bovidae***				
Bushbuck	*Tragelaphus scriptus*	Footprint	B4	N07 24' 21.6"	W001 51' 23.8"
Antelopes	***Antelopinae***				
Maxwell's Duiker	*Cephalophus maxwelli*	Footprint		N07 24' 17.3"	W001 51' 26.9"
Antelopes	***Antelopinae***				
Maxwell's Duiker	*Cephalophus maxwelli*	Footprint	B5	N07 24' 24.3"	W001 51' 05.5"
Maxwell's Duiker	*Cephalophus maxwelli*	Footprint		N07 24' 24.3"	W001 51' 05.5"
Bovids	***Bovidae***				
Bushbuck	*Tragelaphus scriptus*	Footprint	B6	N07 23' 55.4"	W001 50' 54.1"
Bushbuck	*Tragelaphus scriptus*	Footprint		N07 24' 15.6"	W001 50' 50.1"

Antelopes	***Antelopinae***				
Maxwell's Duiker	*Cephalophus maxwelli*	Footprint		N07 23' 53.7"	W001 50' 54.2"
Bovids	***Bovidae***				
Bushbuck	*Tragelaphus scriptus*	Footprint	B9	N07 24' 57.1"	W001 52' 33.1"
Genets and Civets	***Viverridae***				
African Civet	*Civettictis civetta*	Dung		N07 24' 54.3"	W001 52' 34.7"
Antelopes	***Antelopinae***				
Maxwell's Duiker	*Cephalophus maxwelli*	Footprint	B11	N07 25' 38.7"	W001 52' 21.2"
Maxwell's Duiker	*Cephalophus maxwelli*	Dung			
Maxwell's Duiker	*Cephalophus maxwelli*	Footprint			

Plates

Plate 6: African grey hornbill

Plate 7: Bearded barbet

Plate 8: Maxwell duiker droppings

Plate 9: Red bellied paradise flycatcher

Plate 10: Red-eyed dove

Plate 11: Blue bellied roller

Plate 12: *Praomys tullbergi*

Plate 13: White-throated bee-eater

Plate 14: Colony of straw-coloured fruit bats

Plate 15: Lizard buzzard

Plate 16: Remains of small mammals

Plate 17: Blue-billed malimbe