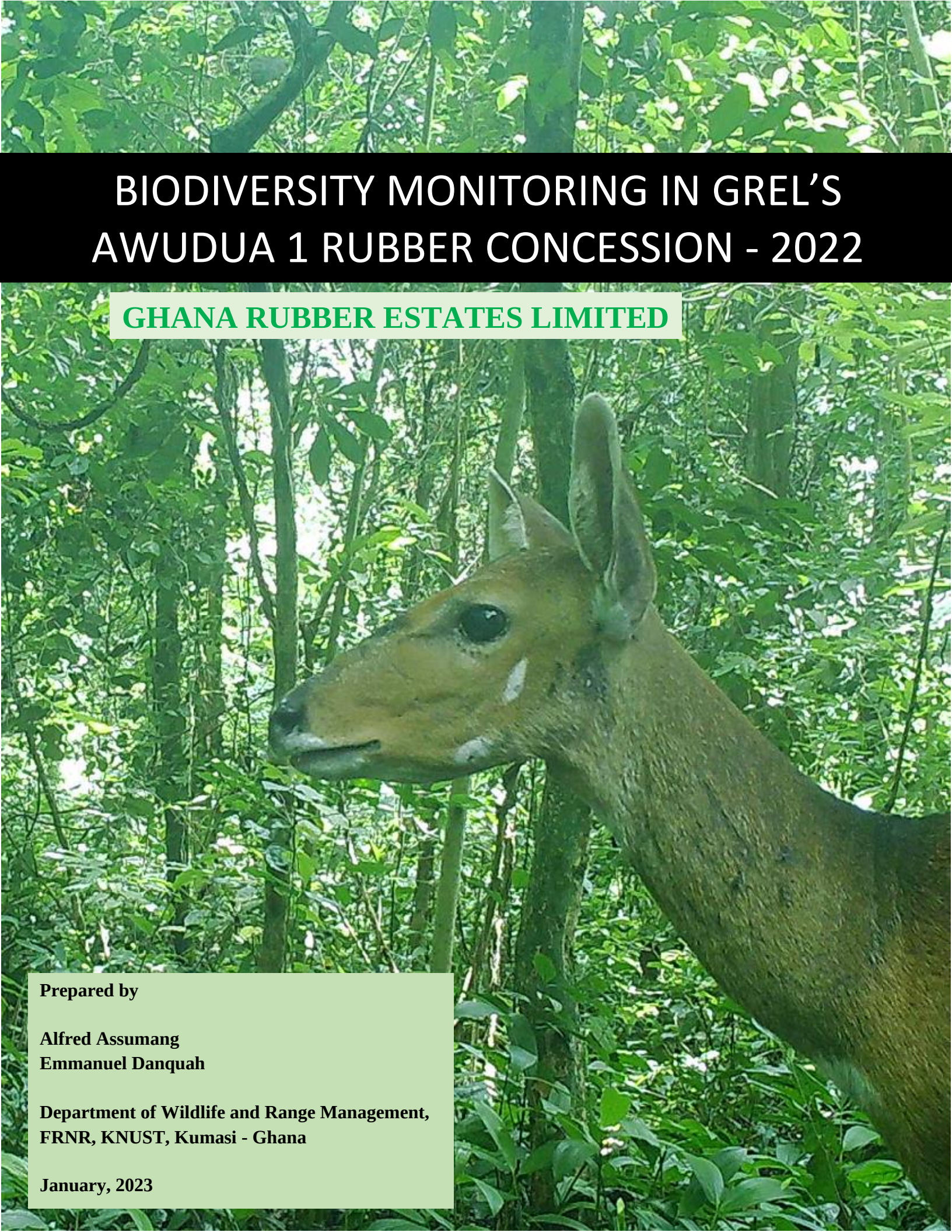
BIODIVERSITY MONITORING IN GREL'S AWUDUA 1 RUBBER CONCESSION - 2022

GHANA RUBBER ESTATES LIMITED



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January, 2023

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Report Produced for

Prepared By

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Faculty of Renewable Natural Resources
KNUST – Ghana

January, 2023

KNUST STRATEGIC MANDATE, VISION, MISSION AND CORE VALUES

Our Strategic Mandate

The Act establishing the University defines its mandate, which essentially is to provide higher education, undertake research, disseminate knowledge and foster relationships with the outside persons and bodies. The strategic mandate of the University is derived from Science and Technology in its name.

Vision

To build on KNUST's leadership as the premier science and technology university in Ghana and to be among the top ten Universities in Africa.

Mission Statement

KNUST exists to advance knowledge in science and technology through creating an environment for undertaking relevant research, quality teaching, entrepreneurship training and community engagement to improve the quality of life.

Core Values

KNUST is committed to attracting and developing excellent staff and students in order to contribute towards the achievement of the goals, targets and directions that the government has set for higher education. The following cherished values characterize the work and life of the University and are ingrained in all those who pass through the University.

In fulfilling the Vision and Mission of the University, the following Core Values would be adhered to:

Leadership in Innovation and Technology

We endeavour to maintain and strengthen our position as the premier Science and Technology University in the country leading in generating and exchanging new knowledge in innovation and technology, and offering service to government, industry and society.

Culture of Excellence

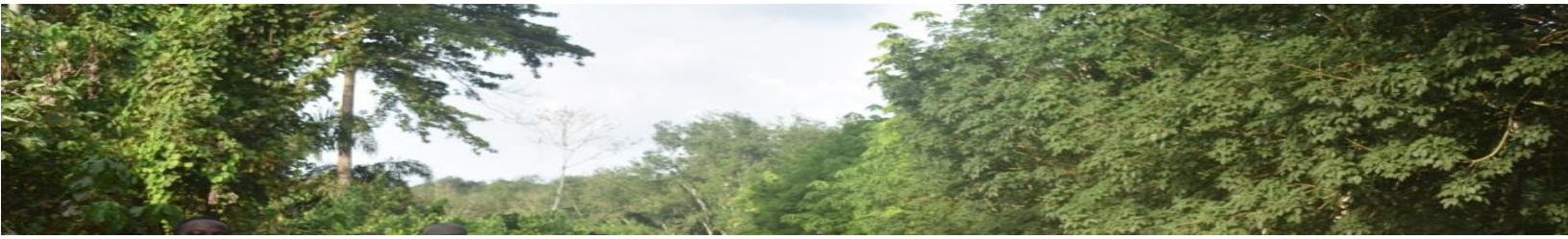
We strive to be the best and maintain a commitment to continuously improve upon our status in all our undertakings - research, teaching, entrepreneurship and service - for the development of society.

Diversity and Equal Opportunity for All

We ensure an environment of understanding and respect for cultural diversity and equal opportunity among students and staff. We uphold academic freedom in our quest to advance the frontiers of knowledge and in our attempt to attain self-development.

Integrity and Stewardship of Resources

We are dedicated to exhibiting the highest standards of professional ethics and integrity, efficient utilization of resources and a culture of accountability and responsibility in all our operations.



1.0 REPORT AT A GLANCE

Survey period

2nd September to 7th October 2022

Summary of Findings and Conservation Recommendations

1. Biodiversity

The Ghana Rubber Estates Limited (GREL) Awudua 1 Rubber Concession provides habitat for at least 47 plant species, 28 mammal, 64 bird, 10 reptile and 81 insect species. A summary of the findings from the fauna survey are presented in the table below.

Summary of species of conservation interest recorded in the study area

IUCN Status	Flora	Mammals	Birds	Reptiles	Insects	Total
Critically Endangered (CR)	-	-	1	-	-	1
Endangered (EN)	-	1	-	-	-	1
Vulnerable (VU)	3	1	-	-	-	4
Near Threatened (NT)	2	1	-	-	-	3
Least Concern (LC)	30	25	63	10	-	128
Data Deficient (DD)		-	-	-	-	-
Not Evaluated (NE)	12	-	-	-	81	93
Total Species	**47**	**28**	**64**	**10**	**81**	**230**

Recorded tree species of conservation interest on the IUCN Red List of Threatened Species (2022) include two Near Threatened species (*Chrysophyllum albidum* and *Daniellia ogea*) and three Vulnerable species (*Heritiera utilis*, *Nesorgodonia papavifera* and *Pterygota macrocarpa*). No Black Star species was recorded in the HCV, however, one Gold, four Red, six Pink and nine Blue Star species were recorded. The remaining 27 species were of Green Star rating. Mammalian species of conservation interest were one carnivore (Tree Pangolin; *Phataginus tricuspis*; Endangered) and two primates Lowe's Mona Monkey; *Cercopithercus lowei* (Vulnerable), Bossman's Potto; *Perodicticus potto* (Near Threatened). All three species are also listed in Appendix II of CITES (species that are not necessarily threatened with extinction

but may become so unless trade is closely controlled). Locally, all primates and the tree pangolin are of special conservation importance in Ghana and are listed in Schedule 1 of the Ghana Wildlife Conservation Regulations (1995). Only one bird species, Hooded Vulture (*Necrosyrtes monachus*) is Critically Endangered). Nevertheless, members of the Family Accipitridae (birds of prey) and Falconidae (falcons) are listed as Schedule 1 species in Ghana. 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 significant increase in the number of fauna species recorded in the concession. GREL should continue to enhance the forest buffer through enrichment planting with preferred fruit bearing plants and create corridors that could link the neighboring buffers to ensure that the ecosystem remains healthy. Although no bats were recorded, further research should be conducted to determine occupancy and ecological role of bat species in the area including their significance as fruit dispersal agents.

2. Carbon Stock Assessments

The carbon stock assessment was conducted in the HCV. Total biomass estimated for trees in the HCV corresponded to 28.35 tons of carbon. A summary of the findings from the flora survey are presented in the table below.

Total carbon stock in trees with DBH≥10 cm in the HCV

Quadrat	Area(m2)	Area(ha)	Total carbon (Mg)	Carbon (tons)	Carbon(t/ha)
1	400	0.04	6.48	7.14	178.52
2	400	0.04	1.66	1.83	45.67
3	400	0.04	1.47	1.62	40.39
4	400	0.04	1.28	1.41	35.22
5	400	0.04	1.59	1.75	43.86
6	400	0.04	1.82	2.01	50.17
7	400	0.04	1.41	1.55	38.76
8	400	0.04	0.96	1.06	26.59
9	400	0.04	1.85	2.03	50.86
10	400	0.04	3.10	3.41	85.31
11	400	0.04	4.11	4.54	113.38
Total	**4400**	**0.44**	**25.72**	**28.35**	**708.73**

Quadrats 1 and 11 yielded highest carbon. This was followed by quadrat 10. Quadrat 8 yielded the lowest carbon stock. The carbon sequestration potential of the HCV is relatively high, taking into account its small size. GREL should continue to prioritize its conservation since its existence is important in the mitigation of greenhouse gas (GHG) emission.

3. Water Quality Assessment

A number of water quality parameters including the pH, conductivity of total dissolved solids (TDS), alkalinity, Nitrate, Ammonia, and Phosphate were analyzed for each collected water sample. A summary of the findings from the samples are presented in the table below.

Summary of surface water parameters recorded in the study area.

Site	pH	Conductivity µS/cm	TDS mg/L	Alkalinity mg/L	Nitrate mg/L	Ammonia mg/L	Phosphate mg/L
Upstream	6.63	35.4	27.25	22	0.209	<0.05	0.16
Downstream	6.76	37.3	29.25	24	0.211	<0.05	0.19
Middle	6.64	36.6	27.32	26	0.219	<0.05	0.21
8 J (Plantation)	6.22	30.0	23.26	21	0.173	<0.05	0.31
11 G (Plantation)	6.24	32.1	23.42	18	0.142	<0.05	0.23
Plantation	6.36	31.6	22.48	19	0.128	<0.05	0.21
RANGES							
Maximum	6.36	37.3	29.25	26	0.219	0	0.31
Minimum	6.14	30.0	22.48	18	0.128	0	0.16
Mean	6.23	33.8	25.50	22	0.180	0	0.22
WHO range	6.5 - 8.5	50 - 1500	0 - 1000	20 – 300	0 – 10	0 – 0.50	N/A

Most parameters tested for water quality were within the WHO acceptable ranges for portable water. This suggests that GREL's activities in the Awudua 1 concession have little adverse impact on water quality in the area and also safe for domestic use. Furthermore, the generally low values of the parameters recorded for the water samples suggest a decrease in chemical applications in the plantation which might have reduced the rate of chemical discharges and surface run-offs into nearby waterbodies. These general low values might have altered the acid-base equilibria and resulted in an increased acid capacity and generally low alkalinity. The Ankobra River that shares boundary with the concession should be included in future sampling to assess the level of pollution on the fringes of the HCV.

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BACKGROUND

2.0 BACKGROUND

2.1 INTRODUCTION

This study is designed to monitor the status of biodiversity and water quality within GREL's Awudua 1 Rubber

Rubber plantations play a significant role in wood production, ecosystem services and climate change mitigation (Carle et. al., 2002). Rubber plantations are grown to supply raw material for industry and for other uses, such as fuelwood and fiber. Rubber plantations also provide additional non-wood forest products and benefits that contribute to environmental, social, and economic sustainability.

Ghana Rubber Estates Ltd. (GREL) is a rubber plantation management company based in the Western Region of Ghana that is aimed at providing services in the field of rubber production and plantation management. Currently, the company has several concessions in Ghana where they are engaged in rubber production. The Awudua 1 Rubber Concession in the Awudua area have been in operation for over 10 years now. Over the period of operation, conscious efforts have been made to conserve biodiversity. The company among other best forest management practices, reforests degraded forest lands, restores buffer zones, and controls hunting and bushfires. To measure the effect of these activities on the prevalence of flora and fauna, monitoring of various variables including water quality are carried out periodically.

The current study incorporates a biological survey as a means of monitoring abundance of flora and fauna species in the concession and a carbon stock assessment to highlight the potential role of plantation-grown rubber in helping to mitigate climate change through carbon sequestration. A water quality study is also conducted to assess the impacts of plantation activities on waterbodies. The results of this study will be incorporated in the

management documentation. The existing survey reports in Awudua are important scientific references in monitoring and evaluation to identify problems, establish solutions to these problems in order to inform future projects.

2.2 SCOPE OF SERVICES FOR THIS ASSIGNMENT

Carry out a biological (flora and fauna) survey, carbon stock assessment and water quality assessment of GREL's Awudua 1 Rubber Plantation, near Awudua in the Western Region of Ghana. Scope of work includes developing survey tools and methodologies in consultation with GREL. For this assignment, it is required to submit field survey data and a comprehensive survey report.

As such, the survey had the following objectives:

- Determine the status (species diversity and distribution) of flora and fauna in the Awudua 1 Rubber Concession in the Western Region of Ghana.
- Investigate the presence or absence of threatened species as defined by the IUCN Red List 2022 and Ghana Wildlife Conservation Regulation Schedules.
- Assess carbon stock.
- Conduct a detailed chemical analysis of key water bodies within the concession to assess their water quality
- Identify any land use variations in biodiversity, carbon stock and water quality in the plantation.
- Establish impact of plantation development activities towards biodiversity, carbon stock and water quality conservation.

Transect walks were carried out from 2nd to 9th September 2022, but camera trapping continued to 7th October 2022. Transects and other sampling protocols were carried out from morning to mid-afternoon (07:00 – 17:00).

2.3 STUDY AREA

The Ghana Rubber Estates Limited (GREL) Awudua 1 Rubber Concession is situated within the Prestea-Huni Valley District in the wet evergreen forest zone of western Ghana (Figure 1). The area is generally undulating and falls within latitudes 5°20'30"N to 5°25'00"N and longitudes 2°04'00"W to 2°08'00"W.

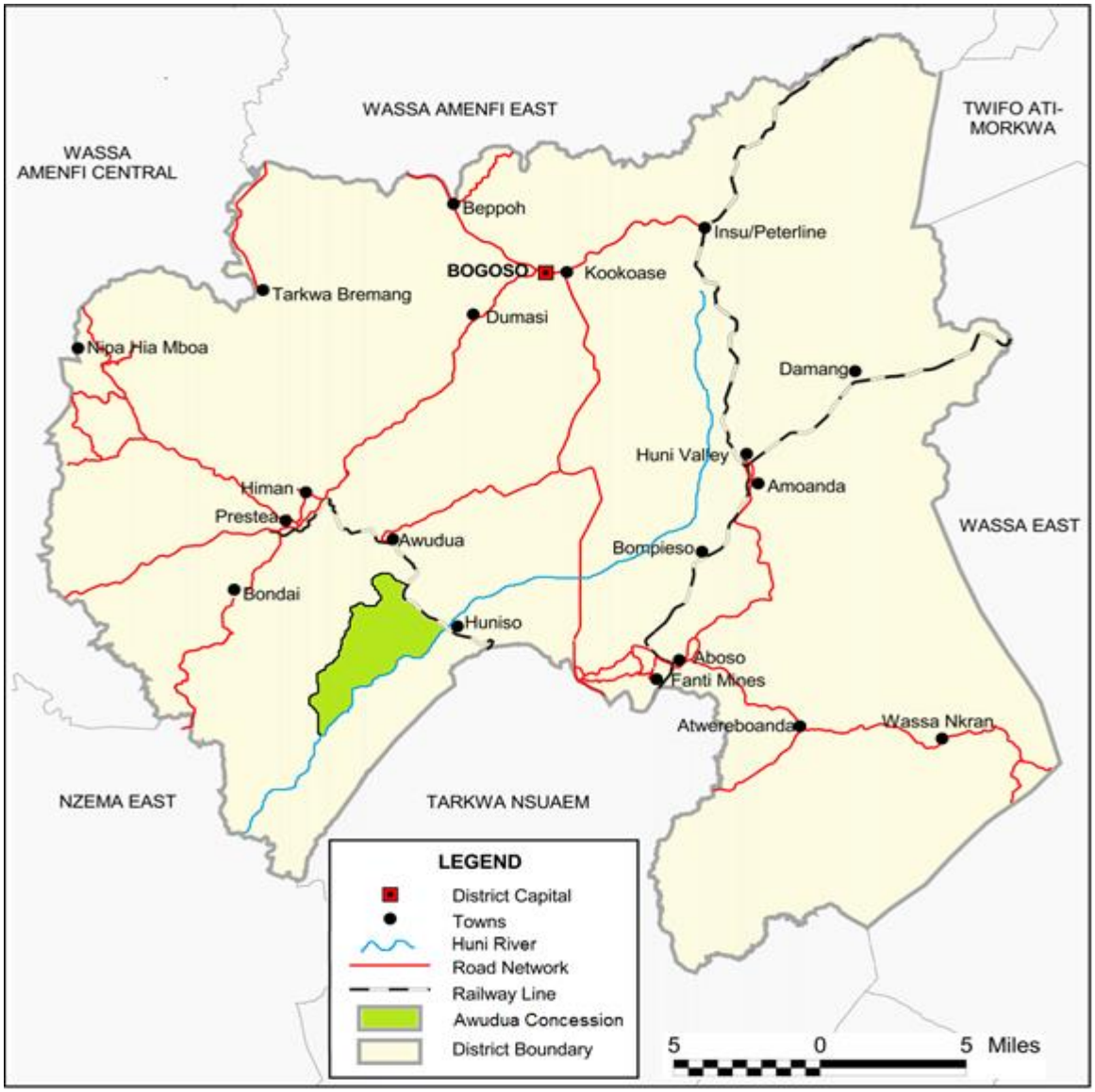

Figure 1: Location of GREL'Awudua 1 Concession in the Prestea/Huni Valley District

The area has a fairly uniform temperature, ranging between 26°C in August and 30°C in March. Sunshine duration for most part of the year averages 7 hours per day. Relative

humidity is generally high throughout the year. The concession is within the forest dissected plateau made up of pre-Cambrian rocks of Birimian and Tarkwaian formations. The concession is located between the Ankobra and Huni Rivers (Figure 2).

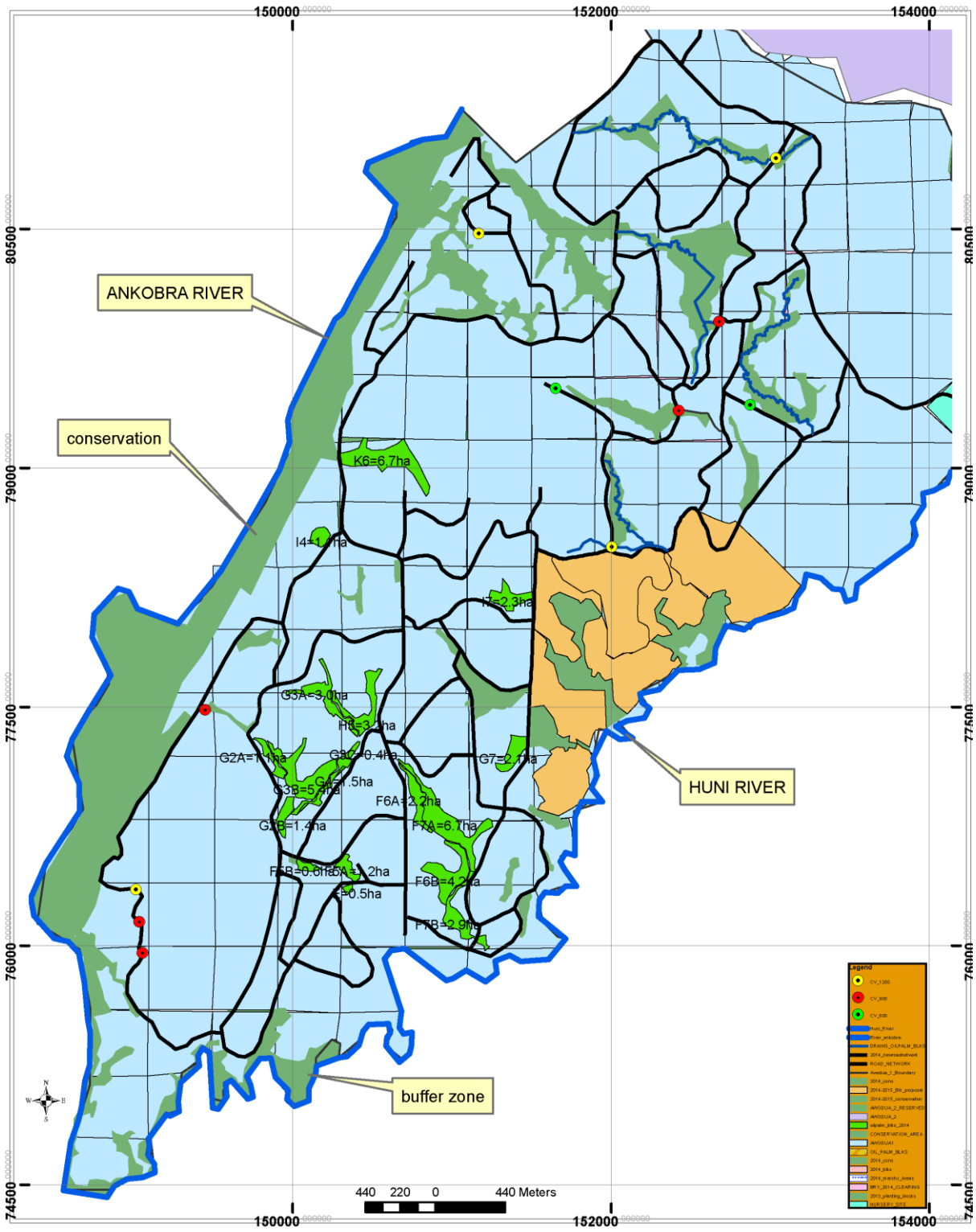

Figure 2: Map of the Awudua 1 Rubber Concession

The westernmost tip of the concession is delimited by the confluence of the Ankobra River which marks the north-western boundaries of the concession and the Huni River marking the southern and south-eastern boundaries (Figure 2). The concession forms part of the Ankobrah basin and is well drained by an intricate network of streams and rivers. The terrain of the concession is predominantly undulating with hilly areas, steep slopes and few scarps ranging between 150 meters to 300 meters above sea level. The area also contains a number of seasonally and permanently flooded swamps. At the peak of the rainy season, most rivers and streams overflow their banks extending the area of seasonally flooded swamps in the concession.

Plate 1: Camera trap shot of a bushbuck


FLORA
SURVEY

3.0 FLORA SURVEY

3.1 METHODOLOGY

3.1.1 Quadrat Methods

Survey methodology followed the previous monitoring protocols. Hence, 11 quadrats (20m x 20m) were placed in each of the three major land-use types i.e., HCVA (forest), rubber (rubber plantation) and the buffer (forest-rubber interphase), resulting in a total of 33 quadrats (Figure 3).

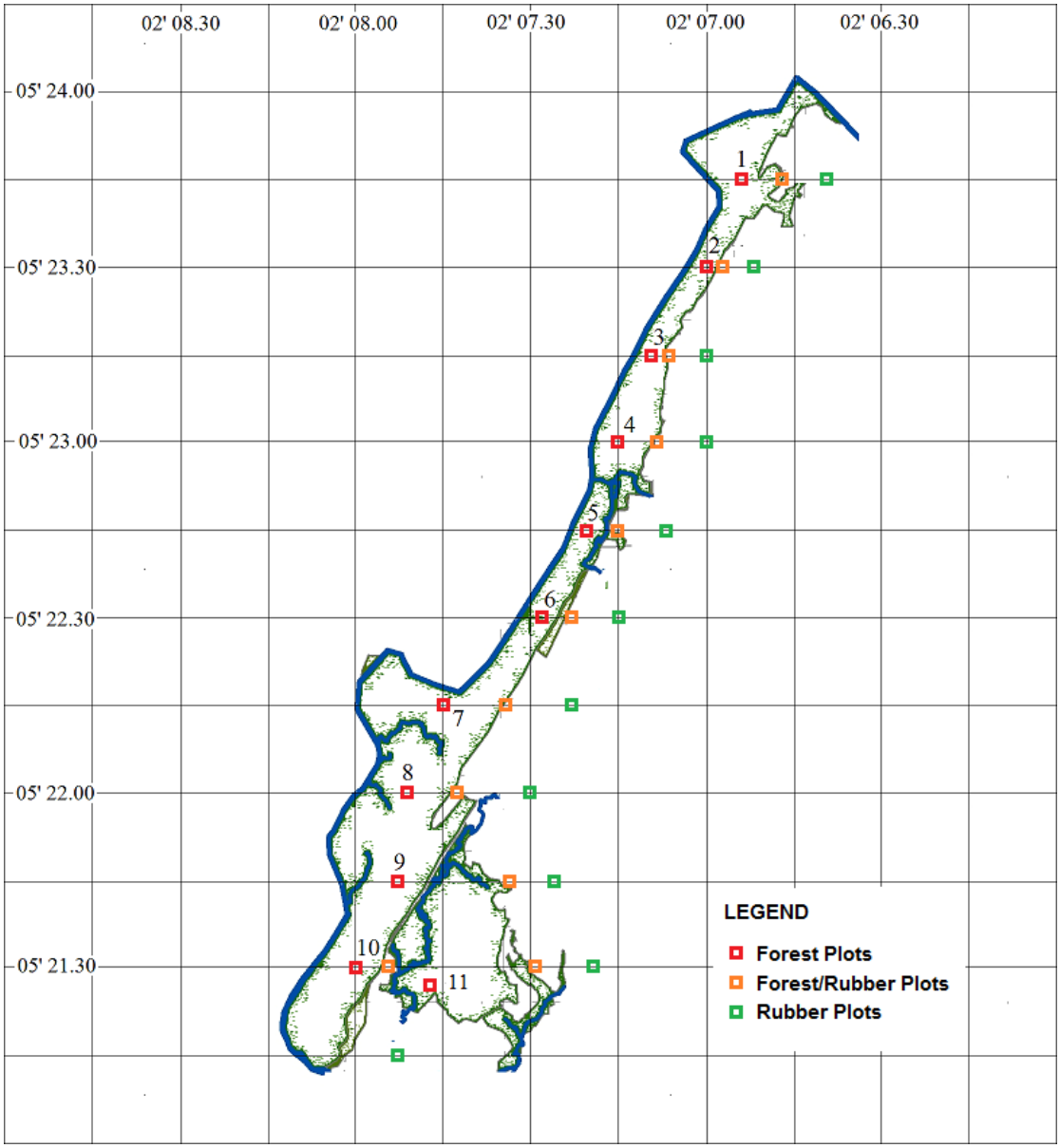

Figure 3: Distribution of quadrats in GREL's Awudua 1 Rubber Concession

The middle positions of the quadrats distributed in the three major land use types are indicated in Tables 1a, 1b and 1c.

Table 1a: GPS readings of middle of quadrats in the HCV

Center of Plot	GPS Coordinate (Lat/Lon hddd.dddddº)	
	Longitude (W)	Latitude (N)
HCVA 1	N5 23 45.0	W2 06 55.0
HCVA 2	N5 23 30.0	W2 07 00.0
HCVA 3	N5 23 15.0	W2 07 10.0
HCVA 4	N5 23 00.0	W2 07 15.0
HCVA 5	N5 22 45.0	W2 07 20.0
HCVA 6	N5 22 30.0	W2 07 28.0
HCVA 7	N5 22 15.0	W2 07 45.0
HCVA 8	N5 22 00.0	W2 07 52.0
HCVA 9	N5 21 45.0	W2 07 52.0
HCVA 10	N5 21 30.0	W2 08 00.0
HCVA 11	N5 21 26.7	W2 07 48.9

Table 1b: GPS readings of middle of quadrats in the buffer zone

Center of Plot	GPS Coordinate (Lat/Lon hddd.dddddº)	
	Longitude (W)	Latitude (N)
Buffer 1	N5 23 45.0	W2 06 39.0
Buffer 2	N5 23 30.0	W2 06 52.0
Buffer 3	N5 23 15.0	W2 07 10.0
Buffer 4	N5 23 00.0	W2 07 08.0
Buffer 5	N5 22 45.0	W2 07 15.0
Buffer 6	N5 22 30.0	W2 07 23.0
Buffer 7	N5 22 15.0	W2 07 34.0
Buffer 8	N5 22 00.0	W2 07 43.0
Buffer 9	N5 21 45.0	W2 07 34.0
Buffer 10	N5 21 30.0	W2 07 55.0
Buffer 11	N5 21 30.0	W2 07 29.0

Table 1c: GPS readings of middle of quadrats in the rubber plantation

Center of Plot	GPS Coordinate (Lat/Lon hddd.dddddº)	
	Longitude (W)	Latitude (N)
Rubber 1	N5 23 45.0	W2 06 48.0
Rubber 2	N5 23 30.0	W2 06 58.0
Rubber 3	N5 23 15.0	W2 07 00.0
Rubber 4	N5 23 00.0	W2 07 00.0
Rubber 5	N5 22 45.0	W2 07 07.0
Rubber 6	N5 22 30.0	W2 07 15.0
Rubber 7	N5 22 15.0	W2 07 22.0
Rubber 8	N5 22 00.0	W2 07 30.0
Rubber 9	N5 21 45.0	W2 07 27.0
Rubber 10	N5 21 15.0	W2 07 53.0
Rubber 11	N5 21 30.0	W2 07 19.0

Quadrats were demarcated with the help of ranging poles and distances measured with a linear tape. An access line was cut through the middle of the quadrat to facilitate movement through the quadrat, as shown in Figure 4.

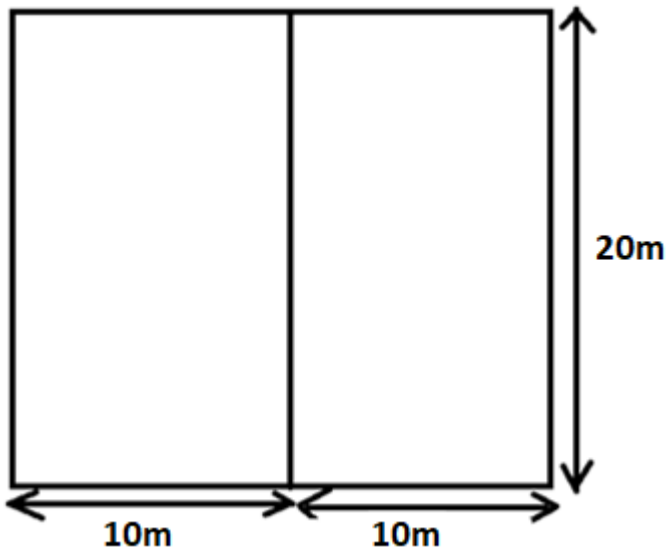

Figure 4: Shape and dimensions of a quadrat, showing the boundary distances and the access line at the middle. It covers an area of 400m².

3.1.2 Data Collection and Analysis

Carbon Stock Estimation

An approximately 1.0% sampling rate was used to determine the sample size for the estimation of the total carbon stock for the concession. Tree above ground biomass (*AGB*) was calculated using the allometric model of Chave *et al*. (2014) which uses tree height, stem diameter and wood density as covariates (Equation 1).

Equation 1…….. $AGB = 0.0673 \times (pD^2H)^{0.976}$

Where *AGB* is aboveground dry biomass (in kg); *p* is wood density (g/cm^3); *D* is diameter at breast height (cm) and *H* is the height (m). Tree carbon content was calculated from above ground biomass based on the assumption that carbon concentration is about half (47.5%) of the biomass (Proforest, 2019). The African Wood Density Database (Carsan *et al*., 2012) and Global Wood Density Database (Chave *et al*., 2009; Zanne *et al*., 2009) was used to generate information on wood density. For not evaluated species, the mean wood density of matching genus or matching family were adopted.

Habitat assessment and vegetation inventories

Habitat assessment and vegetation inventories comprised both qualitative and quantitative methods (White and Edwards, 2000). All habitat features including vegetation and land-use types were included in the survey to make a complete inventory for the study area. The enumeration team was made up of a tree spotter, a recorder and two assistants. Moving clock-wisely, all trees (dbh > 10cm) were systematically identified, measured and recorded. All trees encountered were identified to the species level (Hawthorne and Gyakari, 2006; Jonking and Hawthorne, 2006). Scientific as well as local names, if possible, were called to the recorder who in turn called back the same information to ensure that the right information is recorded.

A software; PAST 2.17c (Hammer et al., 2001) was used to determine species diversity and richness in the various land use types. Where appropriate, simple descriptive statistics was used and results presented in the form of graphs, tables and charts for easy observation and understanding.

3.1.3 Conservation Status

Flora conservation status were assessed using the rankings of the International Union for the Conservation of Nature (IUCN, 2022) and National Star Rating System.

International Union for Conservation of Nature and Natural Resources

The International Union for Conservation of Nature and Natural Resources (IUCN) Red List of Threatened Species (2022) provides taxonomic, conservation status and distribution information on taxa that have been evaluated using the IUCN Red List Categories and Criteria (Appendix 1a). The main purpose of the IUCN Red List is to catalogue and highlight those taxa that are facing a higher risk of global extinction (i.e. those listed as Critically Endangered, Endangered and Vulnerable). The IUCN Red List also includes information on taxa that are categorized as Extinct or Extinct in the Wild; and taxa that cannot be evaluated because of insufficient information (Data Deficient).

Star Rating System

The importance of flora species based on their individual threat from over-exploitation and forest degradation were rated based on the Star Rating System developed by Hawthorne and Abu-Juan (1995).

3.2 RESULTS

3.2.1 Tree Abundance and Diversity

There were very few indigenous trees recorded in the buffer and rubber, thus this section focused on the HCV which had the highest species diversity in terms of trees. A total of 196 trees, belonging to 26 families and 47 species were identified and recorded in the HCV. Majority of the species were from the families – Malvaceae (8.7%), Caesalpiniaceae (8.7%), Sapotaceae (8.7%), Ebenaceae (6.5%), Euphorbiaceae (6.5%), Meliaceae (6.5%) and Sterculiaceae (6.5%). (Figure 5).

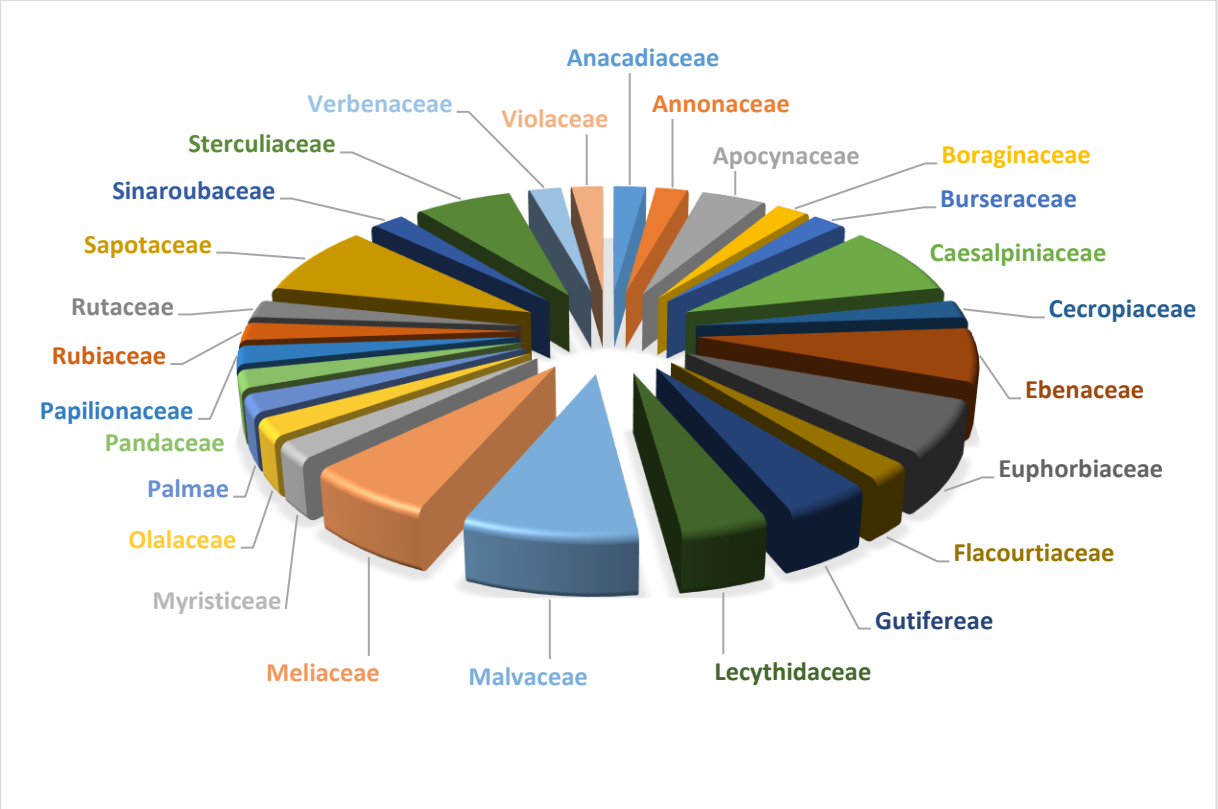

Figure 5: Composition of tree families recorded in the study area

Carapa procera (*n* = 21, RA = 10.7%), *Cola nitida* (*n* = 18, RA = 9.2%) and *Chrysophyllum subnudum* (*n* = 17, RA = 8.7%) were the most abundant tree species. A full list of tree species identified in the HCV is presented in Table 2. Some specific characteristics (height, diameter, biomass, carbon stock, etc.) of the individual tree species recorded in the various quadrats are presented in Appendix 1 to 11.

Table 2: Checklist of tree species abundances per plot and their conservation status in the HCV

	Species	Local Name	Family	Star Rating	IUCN	1	2	3	4	5	6	7	8	9	10	11	Total
1	*Aidia genipiflora*	Otwensono	Rubiaceae	Green	LC	0	0	0	0	0	0	0	0	0	1	0	1
2	*Allanblackia parviflora*	Sonkyi	Gutifereae	Green	NE	0	0	0	0	0	0	0	0	1	0	0	1
3	*Amphimas pterocarpioides*	Yaya	Caesalpiniaceae	Green	LC	0	0	0	0	0	0	1	0	0	0	0	1
4	*Berlina confusa*	Kwatafompaboanini	Caesalpiniaceae	Green	NE	3	0	0	2	2	0	1	1	0	0	1	10
5	*Berlinia tomentella*	Kwatafompaboabere	Caesalpiniaceae	Green	NE	0	0	0	3	2	1	1	0	0	0	0	7
6	*Carapa procera*	Kwakuobese	Meliaceae	Green	LC	8	2	3	1	0	2	1	0	1	1	2	21
7	*Chrysophyllum albidum*	Akasaa	Sapotaceae	Blue	NT	0	0	0	2	1	0	0	0	0	0	0	3
8	*Chrysophyllum subnudum*	Adasema	Sapotaceae	Green	LC	0	4	0	2	2	3	2	2	2	0	0	17
9	*Cola gigantea*	Watapuo	Malvaceae	Green	LC	0	0	2	0	0	0	0	0	0	0	0	2
10	*Cola lateritia*	Watapuo bere	Malvaceae	Green	LC	0	1	0	0	0	0	0	0	0	0	0	1
11	*Cola nitida*	Bese	Malvaceae	Pink	LC	2	2	2	2	2	0	4	2	0	2	0	18
12	*Cordia millenii*	Tweneboa	Boraginaceae	Green	LC	0	3	4	0	0	0	0	0	0	0	0	7
13	*Dacryodes klaineana*	Adwea	Burseraceae	Green	NE	1	0	0	0	0	1	0	0	1	0	1	4
14	*Daniellia ogea*	Hyedua	Caesalpiniaceae	Red	NT	0	0	0	2	2	0	0	0	0	0	0	4
15	*Diospyros cooperi*	French atweabere	Ebenaceae	Gold	NE	0	0	0	3	2	1	0	0	0	0	0	6
16	*Diospyros gabonensis*	Kusibiri	Ebenaceae	Blue	NE	2	0	0	0	0	0	0	0	0	0	0	2
17	*Diospyros sanza-minika*	Sanza mulika	Ebenaceae	Blue	LC	0	0	0	0	0	0	1	0	0	1	1	3
18	*Elaes guineensis*	Abe	Palmae	Pink	LC	3	0	1	0	0	0	0	0	0	0	0	4
19	*Funtumia africana*	Okai	Apocynaceae	Green	LC	0	0	0	0	0	0	0	0	0	2	0	2
20	*Funtumia elastica*	Frumtum	Apocynaceae	Green	LC	1	1	0	0	0	0	0	0	0	0	0	2
21	*Garcinia cola*	Tweapea	Gutifereae	Red	NE	0	0	0	1	1	0	0	0	2	1	1	6
22	*Guarea cedrata*	Kwabohoro	Meliaceae	Blue	LC	0	0	0	0	0	0	0	0	1	0	0	1
23	*Hannoa klaineana*	Fotie	Sinaroubaceae	Green	NE	0	0	1	1	0	0	1	0	1	1	1	6
24	*Heritiera utilis*	Nyankom	Sterculiaceae	Red	VU	1	0	0	3	3	0	1	0	1	2	2	13
25	*Lannea welwitschii*	Kumnini	Anacadiaceae	Green	LC	0	0	1	0	0	0	0	0	0	0	0	1

26	*Macaranga barteri*	Opam	Euphorbiaceae	Green	LC	0	1	4	0	0	0	0	0	0	0	0	5
27	*Manilkara obovata*	Berekankum	Sapotaceae	Blue	LC	0	0	0	2	2	0	0	1	1	1	4	11
28	*Margaritaria descoidea*	Pepea	Euphorbiaceae	Green	LC	1	0	0	0	0	0	0	0	0	0	0	1
29	*Microdesmis puberula*	Fema	Pandaceae	Green	NE	0	0	0	0	0	0	0	0	0	1	0	1
30	*Millettia rhodanta*	Tetetoa	Papilionaceae	Green	LC	0	0	0	1	2	0	0	0	0	0	0	3
31	*Myrianthus lebericus*	Nyankumanini	Cecropiaceae	Green	LC	0	0	0	0	0	0	0	0	0	0	1	1
32	*Napoleonaea vogelii*	Obua	Lecythidaceae	Green	LC	1	0	1	0	0	0	0	0	1	0	0	3
33	*Nesorgodonia papavifera*	Danta	Malvaceae	Pink	VU	0	0	0	0	0	0	0	0	0	0	1	1
34	*Petersianthus macrocarpus*	Esia	Lecythidaceae	Green	LC	0	0	1	0	0	0	0	0	0	0	0	1
35	*Pterygota macrocarpa*	Kyereye	Sterculiaceae	Red	VU	0	1	0	0	0	0	0	0	0	0	0	1
36	*Pycnanthus angolensis*	Otie	Myristiceae	Pink	LC	0	0	0	0	0	0	0	0	0	1	0	1
37	*Rinorea oblongifolia*	Mpawuotuntum	Violaceae	Green	NE	1	1	0	0	0	0	0	0	0	0	0	2
38	*Scaphopetalum amoenum*	Nsoto	Sterculiaceae	Blue	LC	0	0	0	0	0	0	0	0	1	0	0	1
39	*Scottellia klaineana*	Tiabutuo	Flacourtiaceae	Pink	LC	0	0	0	0	0	0	1	0	0	0	0	1
40	*Strombosia glaucescens*	Afena	Olalaceae	Green	LC	0	0	0	4	2	0	0	0	0	2	1	9
41	*Synsepalum ntimii*	Bakubere	Sapotaceae	Blue	LC	0	0	0	0	0	2	0	0	0	0	0	2
42	*Tabernaemontana africanus*	Obonawa	Apocynaceae	Green	LC	0	0	0	1	1	0	0	0	0	0	0	2
43	*Turreanthus africanus*	Appaye	Meliaceae	Pink	NE	1	0	0	0	0	0	0	0	0	1	0	2
44	*Uapaca heudelotii*	Kontanakoa	Euphorbiaceae	Blue	LC	0	0	0	0	0	0	0	0	0	0	1	1
45	*Vitex ferruguinea*	Otwentorowa	Verbenaceae	Green	NE	1	0	0	0	0	0	0	0	0	0	0	1
46	*Xylopia aethiopica*	Hwentia	Annonaceae	Blue	LC	1	1	0	0	0	0	0	0	0	0	0	2
47	*Zanthoxylum gilletii*	Okuo	Rutaceae	Green	LC	1	0	0	0	0	0	0	0	0	0	0	1
	Total					**28**	**17**	**20**	**30**	**24**	**10**	**14**	**6**	**13**	**17**	**17**	**196**

IUCN Status: NE Not Evaluated, LC Least Concern, VU Vulnerable, NT Near Threatened

3.2.2 Tree DBH Size and Height Trends

A relatively high proportion of trees in the samples was represented by relatively big individuals, i.e., belonging to the DBH classes 11-30 cm (83.7%) (Figure 6). Most trees in the samples were represented by individuals with DBH values of between 11 to 20 cm. Trees with DBH class less than 11 cm (sapling and pole stage) were least recorded. Few trees were beyond the mature age class (DBH >40cm). A majority of these large trees is represented by species of the Family Caesalpiniaceae, Malvaceae and Sapotaceae. The maximum DBH-value in the present sample is 68.9 cm and 68.1 cm recorded for *Hannoa klaineana*. Individuals of similar size were recorded for *Berlinia confuse* and *Mannilkara obovata*. Trees generally had an average DBH size class of 26.02 cm. Previously in 2015, 2016, 2017 and 2018 the peaks were within relatively lower DBH size classes. This suggests an increase in DBH over the years.

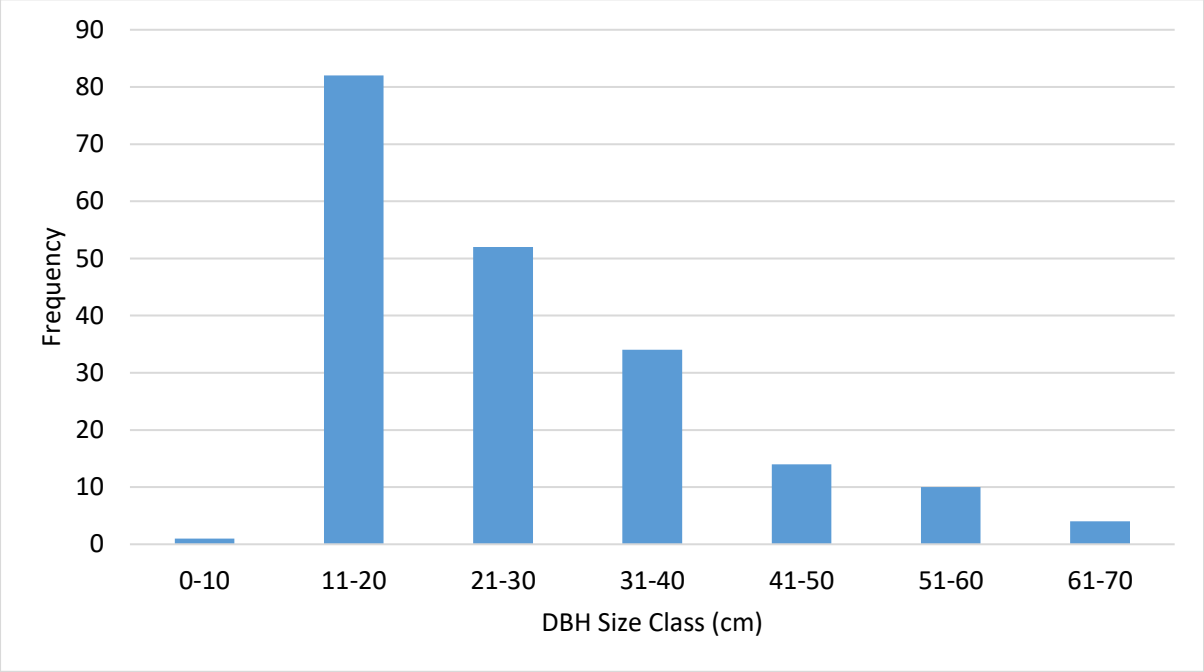

Figure 6: Relative DBH distribution in the HCV in 2022

As depicted in Figure 7, trees belonging to the second, third and fourth height classes (measuring 5-16 m) accounted for 90% of all trees in the samples. The remaining 10% were distributed over three height categories ranging from 0 to 4 m and 17 to 24 m. The tallest tree (*Berlinia confusa*) was measured at 23.4 m. Figure 7 also shows a double peak canopy in the tree height profile where the tree canopy of the HCV forest is predominantly built by trees within the height distribution of between 5 to 8 m and 13 to 16 m height classes. Notably,

there is a slight drop in the number of individuals reaching heights of between 9 and 12 m and a sharp decrease in numbers after 16 m height class (Figure 7).

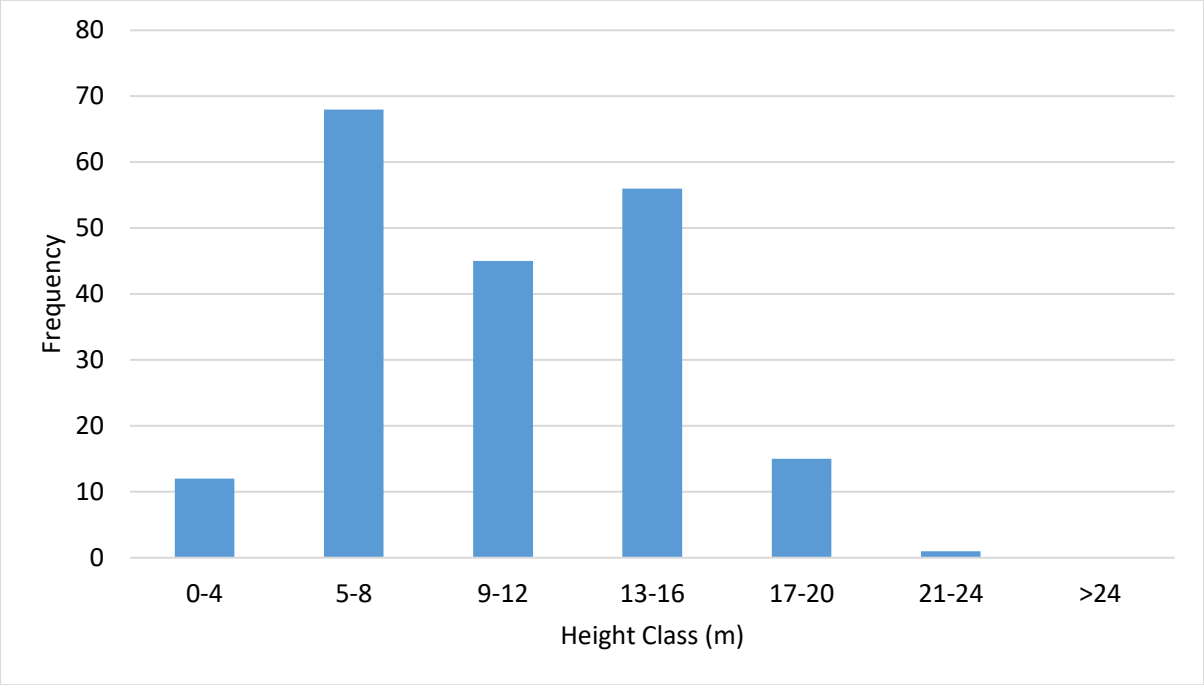

Figure 7: Relative height distribution in the HCV in 2022

3.2.3 Carbon Stock Estimation

Within the HCV, 0.44 ha of quadrats were surveyed. A total of 196 living trees including 197 stems with DBH ≥ 10 cm were sampled. These trees belong to 47 species in 26 families. The most abundant species in the HCV were shade species such as *Carapa procera*. These are plant species typical of disturbed forest. Total biomass estimated for these trees corresponded to 28.35 tons of carbon (Table 3).

Table 3: Summary of trees (N) and stems with DBH ≥ 10 cm and above ground carbon

Area designation	Area sampled (ha)	Stems	Carbon (tons)
Awudua 1 Rubber Concession	0.44	197	28.35

Within the HCV, quadrats 1 and 11 yielded highest carbon (Table 6). This was followed by quadrat 10. Quadrat 8 yielded the lowest carbon stock.

Table 4: Total carbon stock in trees with DBH≥10 cm in the HCV

Quadrat	Area(m2)	Area(ha)	Total carbon (Mg)	Carbon (tons)	Carbon(t/ha)
1	400	0.04	6.48	7.14	178.52
2	400	0.04	1.66	1.83	45.67
3	400	0.04	1.47	1.62	40.39
4	400	0.04	1.28	1.41	35.22
5	400	0.04	1.59	1.75	43.86
6	400	0.04	1.82	2.01	50.17
7	400	0.04	1.41	1.55	38.76
8	400	0.04	0.96	1.06	26.59
9	400	0.04	1.85	2.03	50.86
10	400	0.04	3.10	3.41	85.31
11	400	0.04	4.11	4.54	113.38
Total	**4400**	**0.44**	**25.72**	**28.35**	**708.73**

3.2.4 Species of Conservation Interest

Recorded tree species of conservation interest on the IUCN Red List of Threatened Species (2022) include two Near Threatened species (*Chrysophyllum albidum* and *Daniellia ogea*) and three Vulnerable species (*Heritiera utilis*, *Nesorgodonia papavifera* and *Pterygota macrocarpa*).

No Black Star species, botanical species of the highest priority in Ghana's color-coded conservation categories (Table 5), were recorded in the HCV.

Table 5: A key to Ghana's star ratings for botanical species

Star	Description
Black	Globally rare – high priority for careful management
Gold	Globally restricted
Red	Heavily exploited in Ghana
Scarlet	Threatened in Ghana by overexploitation
Pink	Of commercial interest
Blue	Somewhat rare in Ghana
Green	Of little conservation concern

Sources: Hawthorne and Abu-Juam 1995; Hawthorne and Gyakari 2006

However, One Gold, four Red, six Pink and nine Blue Star species were recorded. The remaining 27 species were of Green Star rating as indicated in Figure 8.

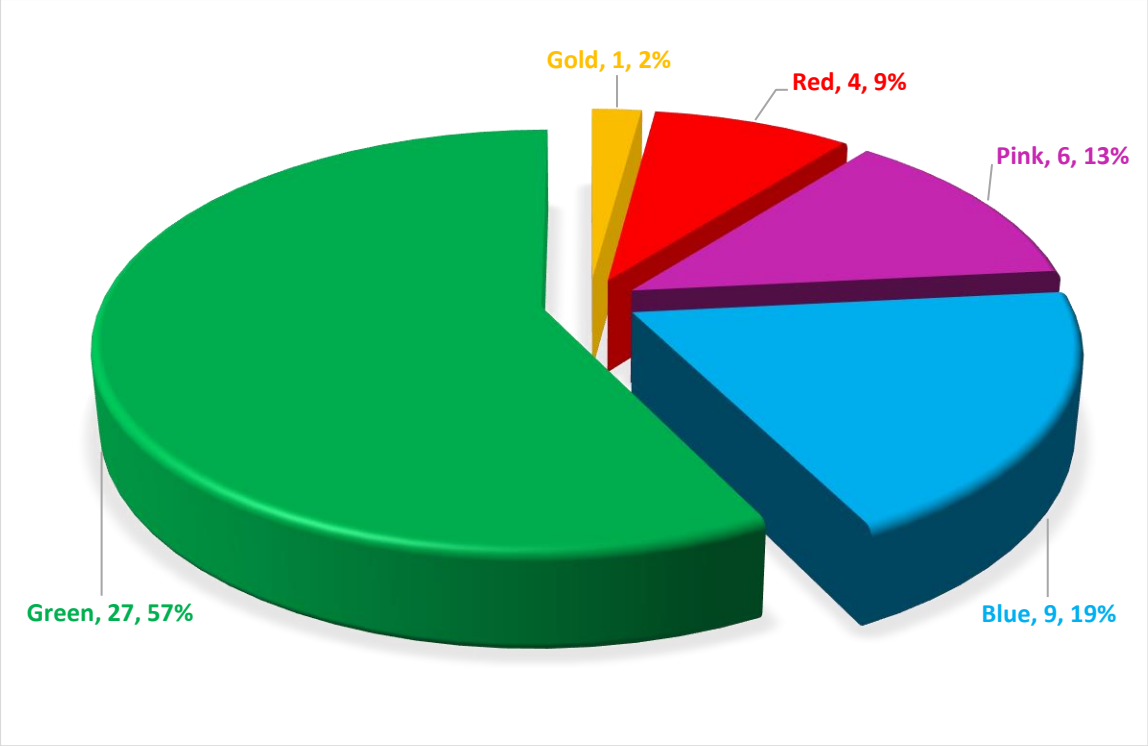

Figure 8: Distribution of tree Star ratings recorded in the HCV

FAUNA SURVEY

4.0 FAUNA SURVEY

4.1 METHODOLOGY

4.1.1 Transects Methods

A sign count survey using the line transect method (Burnham *et al.*, 1980; Buckland *et al.*, 1993, 2001) was conducted. Five hundred (500) meter line transects were placed across the middle of each flora quadrat to aid comparison between flora and fauna. Hence, 11 transects were distributed in each of the three major land-use types i.e., HCV, rubber and buffer, resulting in a total of 33 line transects.

One survey team of two technicians and led by a team leader was maintained throughout the counts to ensure consistency in data collection procedures. The technicians consisted of experts in taxonomically well-known groups for ready identification of organisms. Navigation was done with a compass and a GPS to reach the starting point of each transect. All animal signs seen along the transect centerline were recorded. The compass man directed the line cutter whilst all team members walked in line towards the line cutter, scrutinizing the undergrowth and foliage on either side for animals or their signs including droppings, trails, feeding activity and vocalizations. All signs of the same species seen within 2m were scored as one encounter. Straight line transects were as much as possible maintained throughout the survey. Much care was put in maintaining the accurate locations of the start, mid-point, and end of the transect.

4.1.2 Data Collection and Analysis

Mammals

All mammal signs including feeding activities were recorded in the survey to make a complete species list for each plot. Visual Encounter Surveys (VES) of mammals and their signs (tracks, trails, droppings, feeding signs, burrows, roosts, and nests) were standardized and conducted systematically along line transects. Small mammal sampling involved casual observations and refuge examinations (searching under rocks, logs, in rotten tree stumps, in leaf litter, old termite mounds and rodent burrows) along transects. Opportunistic sightings were also made to detect any arboreal species including bat roosts. One survey team of three persons and led

by a compass man (team leader) were maintained throughout the counts to ensure consistency in data collection procedures. Camera traps were also mounted at strategic locations in the HCV to increase detectability of species.

Herpetofauna

Herpetofauna (reptile and amphibian) surveys involved casual observations and refuge examinations (searching under rocks, logs, in rotten tree stumps, in leaf litter, old termite mounds and rodent burrows) along the transects. Some information was also obtained from local people through interviews.

Birds

Bird surveys were conducted along the transects using point counts. The line transects within the sampling sites, were walked during the early hours of the day and evenings. Direct observations, including VES as well as vocal records were used to determine bird species occurrence. A pair of binoculars and zoom cameras were used to observe the birds for identification. Birds' nomenclature followed Borrow and Demey (2014). Care was taken to remain at any point of bird activity and record the species present, particularly mixed-species flocks. Thus, rate of observer movement was inversely proportional to level of bird activity.

Insects

Visual counts and sweep net methods were used to sample all insects. Transect walk counts were used for conspicuous species, such as butterflies.

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

Animal sign density = [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).

Where appropriate, simple descriptive statistics was used, and results presented in the form of graphs, tables and charts for easy observation and understanding.

A software; PAST 4.03 (Hammer et al., 2022) was used to determine species diversity and richness in the various land use types. Differences in the number of flora per land use and between survey periods were compared using Kruskal Wallis nonparametric analyses. Where appropriate, simple descriptive statistics was used and results presented in the form of graphs, tables and charts for easy observation and understanding.

4.1.3 Conservation Status

Fauna conservation status were assessed using the rankings of the International Union for the Conservation of Nature (IUCN, 2022).

International Union for Conservation of Nature and Natural Resources (IUCN, 2022)

The International Union for Conservation of Nature and Natural Resources (IUCN) Red List of Threatened Species (2022) provides taxonomic, conservation status and distribution information on taxa that have been evaluated using the IUCN Red List Categories and Criteria (Appendix 1a). The main purpose of the IUCN Red List is to catalogue and highlight those taxa that are facing a higher risk of global extinction (i.e. those listed as Critically Endangered, Endangered and Vulnerable). The IUCN Red List also includes information on taxa that are categorized as Extinct or Extinct in the Wild; and taxa that cannot be evaluated because of insufficient information (Data Deficient); and on taxa that are either close to meeting the threatened thresholds or that would be threatened were it not for an ongoing taxon-specific conservation programme (i.e., Near Threatened) (http://www.redlist.org).

The following categories have been developed:

(1) EX (Extinct) - No reasonable doubt that the last individual has died
(2) EW (Extinct in the Wild) - Known only to survive in captivity or as a naturalized populations well outside its previous range
(3) CR (Critically Endangered) - The species is in imminent risk of extinction in the wild
(4) EN (Endangered) - The species is facing an extremely high risk of extinction in the wild
(5) VU (Vulnerable) - The species is facing a high risk of extinction in the wild
(6) NT (Near Threatened) - The species does not meet any of the criteria that would categorize it as risking extinction but it is likely to do so in the future
(7) LC (Least Concern) - There are no current identifiable risks to the species
(8) DD (Data Deficient) - There is inadequate information to make an assessment of the risks to this species

4.2 RESULTS

4.2.1 Fauna Abundances and Diversity

Generally, the HCV followed by the buffer supported the highest number of individuals and species (Table 6). In all cases the rubber plantation ranked lowest in species diversity.

Table 6: Fauna species diversity indices (Shannon_H) generated by PAST 2.17c

Management Zone	Mammals	Herpeto-fauna	Birds	Insects
HCV	3.08	1.82	3.70	3.68
Rubber	2.35	0.56	2.56	2.84
Buffer	1.78	0.00	2.29	2.51

Generally, the buffer and HCV yielded the highest number of individuals (Figure 9, Table 7) and species (Figure 10, Table 8). In all cases, lower numbers and species were recorded in the rubber plantation.

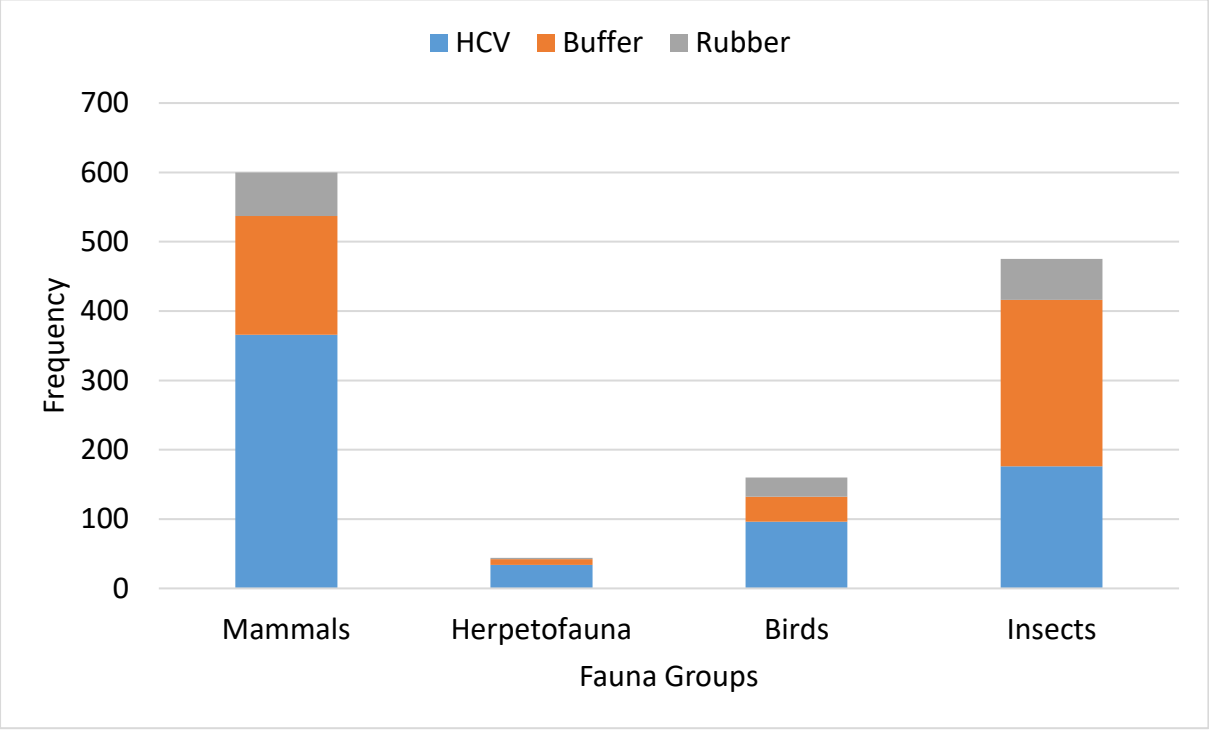

Figure 9: Total number of individuals/signs recorded in the various management zones

Table 7: Total number of individuals/signs recorded in the various management zones

Fauna Group	HCV	Buffer	Rubber
Mammals	366	171	63
Herpetofauna	34	8	2
Birds	96	36	28
Insects	176	240	59

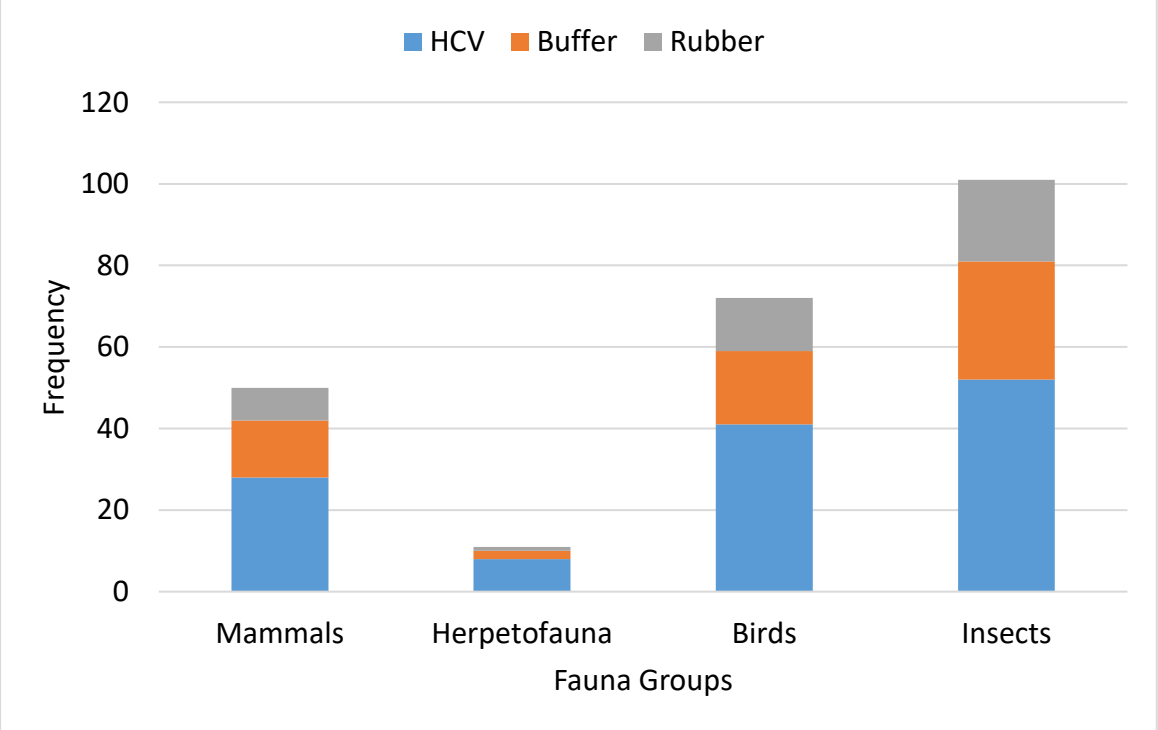

Figure 10: Total number of species recorded in the various management zones

Table 8: Total number of species recorded in the various management zones

Fauna Group	HCV	Buffer	Rubber
Mammals	28	14	8
Herpetofauna	8	2	1
Birds	41	18	13
Insects	52	29	20

Mammals

Four main mammal taxonomic groups (primates, rodents, carnivores and ungulates), representing 16 Families, 27 Genera, and 28 Species were confirmed in the project area during the survey (Figure 11, Appendix 12).

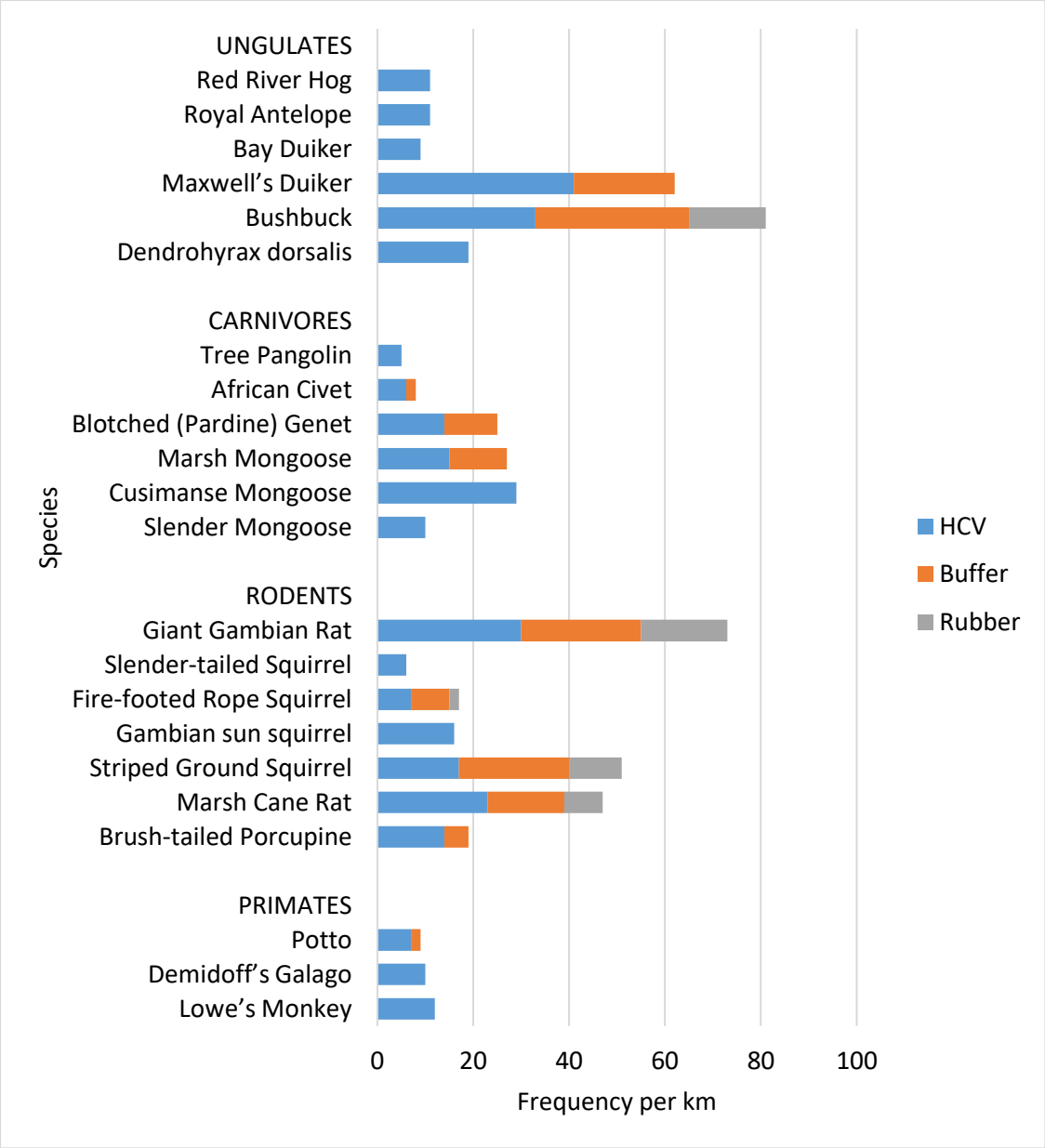

Figure 11: Abundance of mammal signs recorded in the study area

The HCV area ranked highest with a record of 28 mammal species, followed by the buffer area (14) and rubber (8) (Table 8). A total of 600 terrestrial mammal signs were recorded: 366 signs in the HCV area, 171 signs in the buffer and 63 signs in the rubber plantation.

Rodents constituted the largest group of mammals (13 species) whiles primates were restricted to three species (Figure 11). Bushbuck (*Tragelaphus scriptus*), Giant Gambian Rat (*Cricetomys gambiensis*), Striped Ground Squirrel (*Euxerus erythropus*) and Marsh Cane Rat (*Thryonomys swinderianus*) were the most widespread species, occurring in all three management zones (Figure 11). More than sixty percent (60%) of the species were recorded in the HCV. Small mammal group constituted rodents (6 species). The shrew (*Crocidura flavescens*) was the most abundant small mammal (Figure 12). Very rare mammal species included the Vulnerable Tree Pangolin [Pholidota (*Phataginus tricuspis*)].

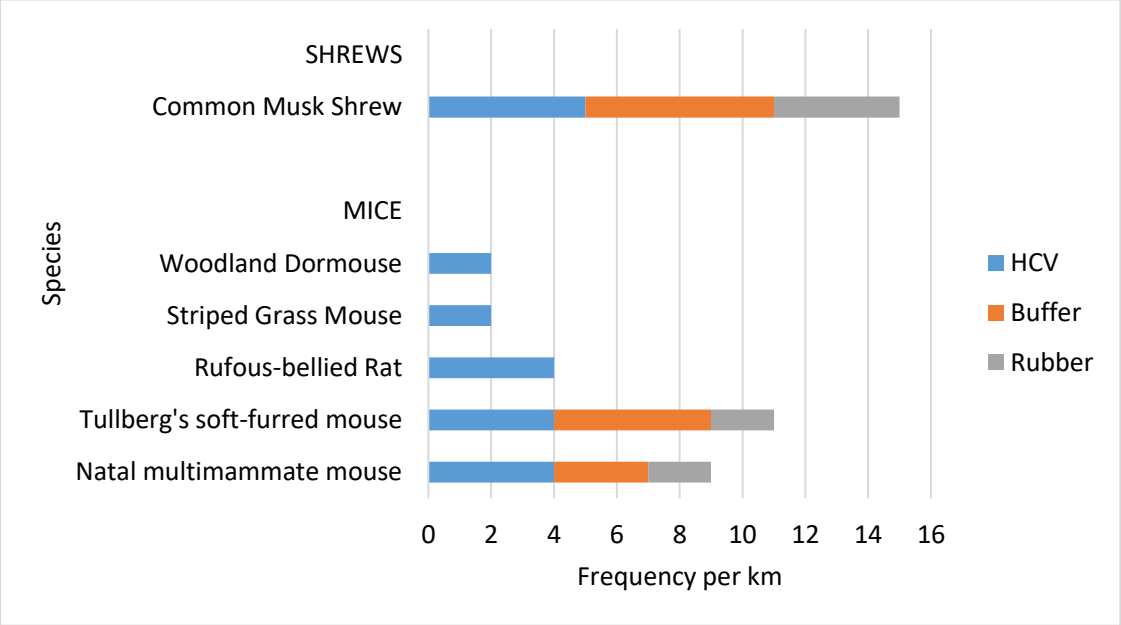

Figure 12: Abundance of mammal signs recorded in the study area

Herpetofauna

Two main herpetofauna taxonomic groups (amphibians and reptiles), representing 8 Families, 9 Genera, and 11 Species were recorded (Figure 13, Appendix 13). The HCV ranked highest with a record of 8 herpetofauna species, followed by the buffer (2) and rubber (1). A total of 44 herpetofauna were captured and recorded: 34 individuals in the HCV, 8 in the buffer and 2 in the rubber plantation.

Amphibians constituted the largest group (6 species) whiles reptiles constituted five species. More than seventy percent (73%) of the species were recorded in the HCV. The forest cobra (*Naja melanoleuca*) was the most widespread herptile, occurring in all three management zones (Figure 13). All amphibians were generally scarce and restricted to the HCV.

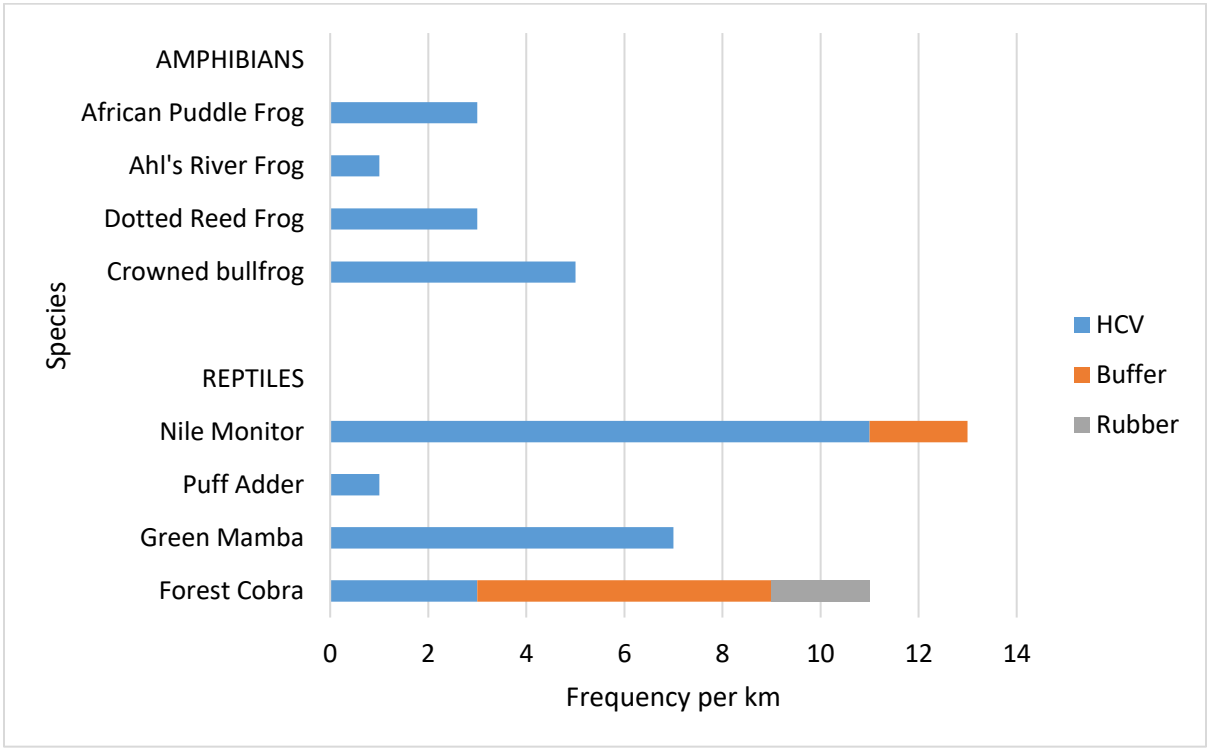

Figure 13: Abundance of herpetofauna signs recorded in the study area

Birds

Sixty-four (64) Species, from 52 Genera and 21 Families were recorded (Figure 14, Appendix 14). The HCV ranked highest with a record of 41 bird species, followed by the buffer (18 species) and rubber plantation (13 species). A total of 384 bird signs were recorded: 272 signs in the buffer, 69 signs in the HCV and 43 signs in the rubber plantation.

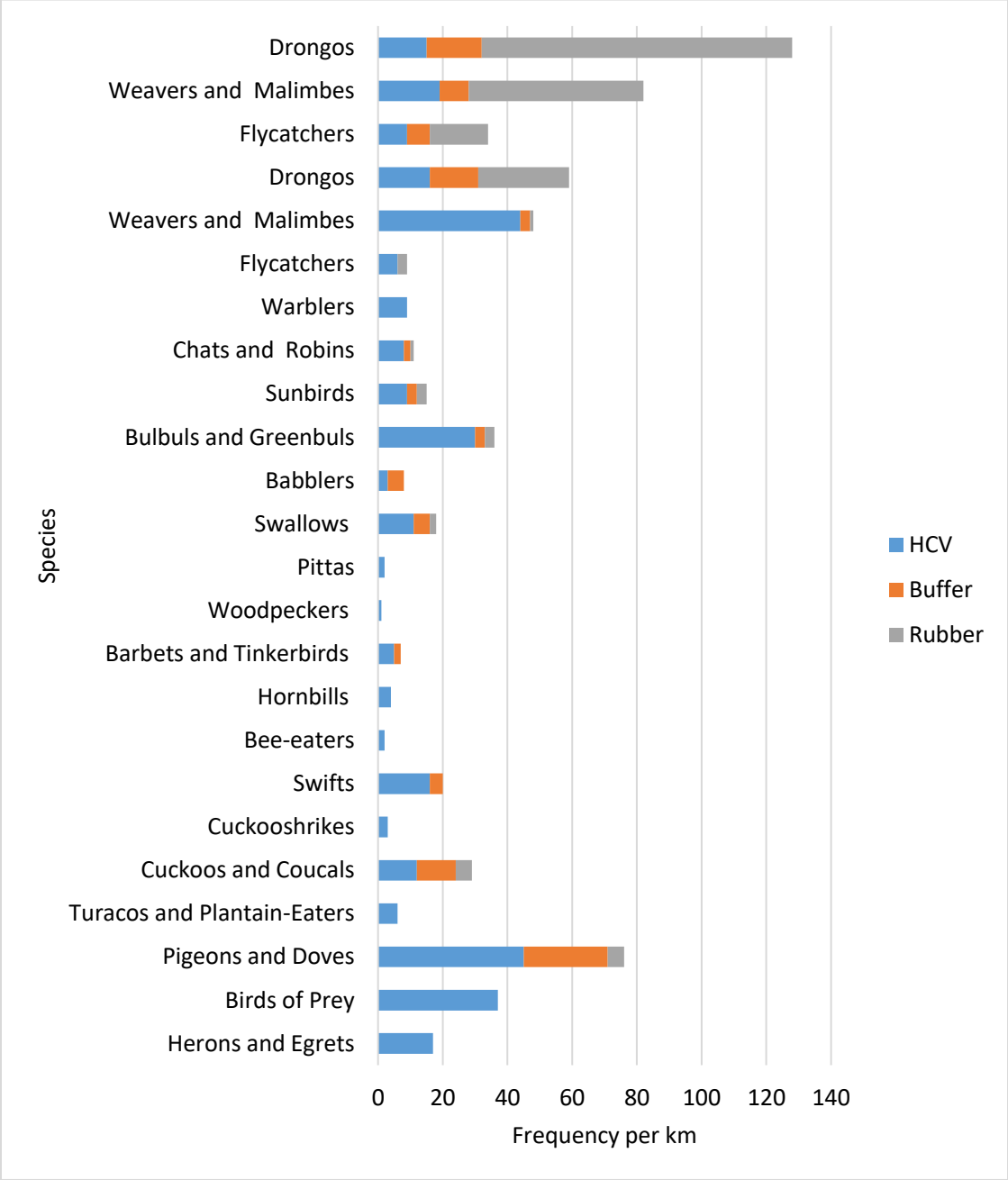

Figure 14: Abundance of bird signs recorded in the study area

Over 40% of the species recorded belong to the Families Accipitridae, Columbidae, Apodidae, Ploceidae and Pycnonotidae (Appendix 14). The Senegal Coucal (*Centropus senegalensis*) (relative abundance of 7.4%) was the most abundant bird species.

Insects

Three insect taxonomic groups (butterflies, dragonflies and damselflies), representing 12 Families, 47 Genera, and 81 Species were confirmed (Figure 15, Appendices 15).

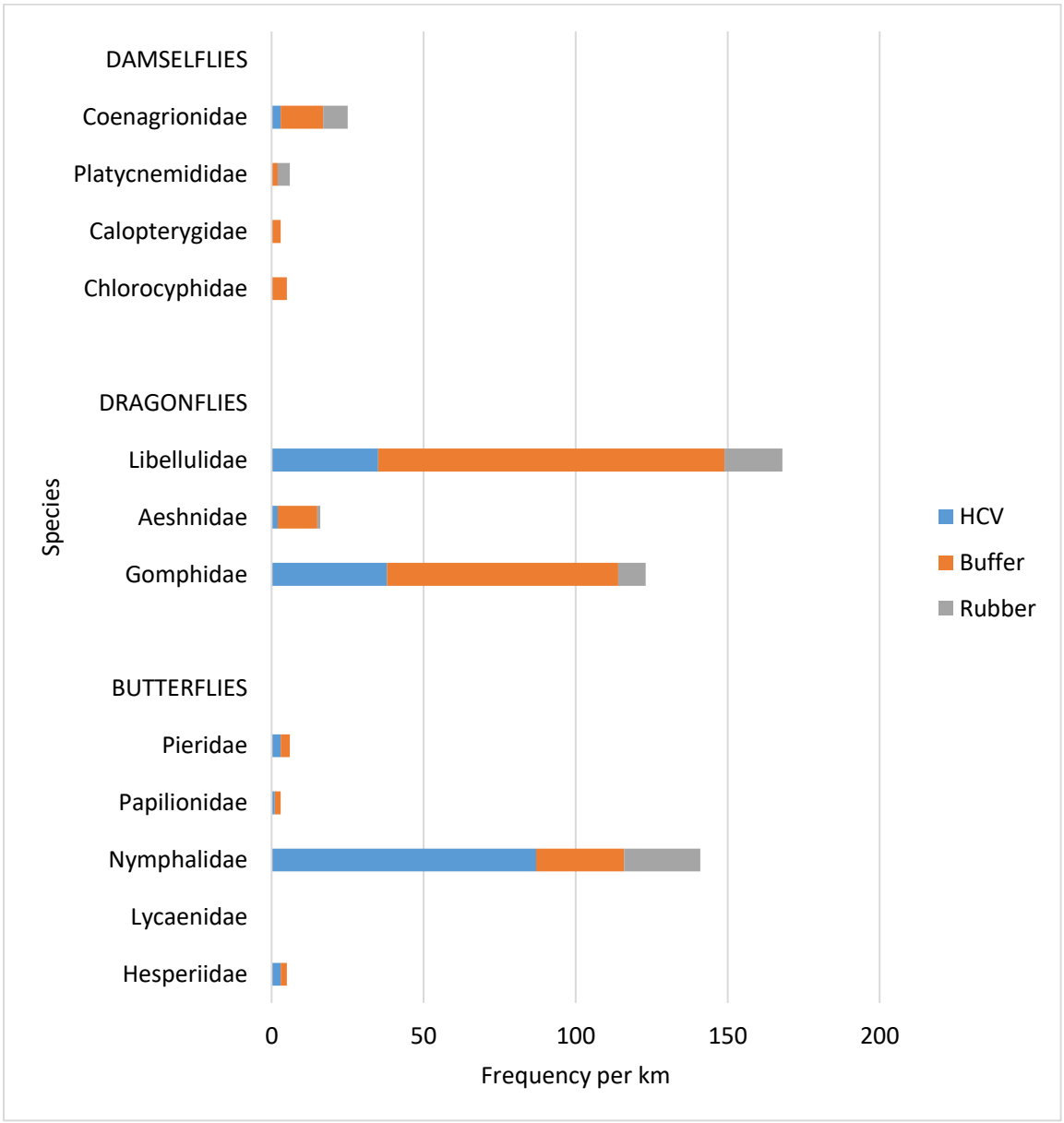

Figure 15: Abundance of insects recorded in the study area

A total of 475 individual insects were recorded: 176 individuals in the HCV, 240 individuals in the buffer and 59 individuals in the rubber plantation. However, the HCV ranked highest with a record of 52 species of insects, followed by the buffer (29) and rubber (20).

Butterflies constituted the largest group (64 species) whiles dragonflies and damselflies were restricted to 11 and 6 species respectively. Odonate members of the Family Libellulidae and Gomphidae were the most recorded species, occurring in all the land use types. On the other hand, the butterfly Family, Nymphalidae comprised the most widespread species, occurring in all three management zones (Figure 15).

4.2.2 Fauna Population Trends

Most fauna populations and species abundances exhibited significant population fluctuations from 2015 to 2022 (Figure 16 and 17).

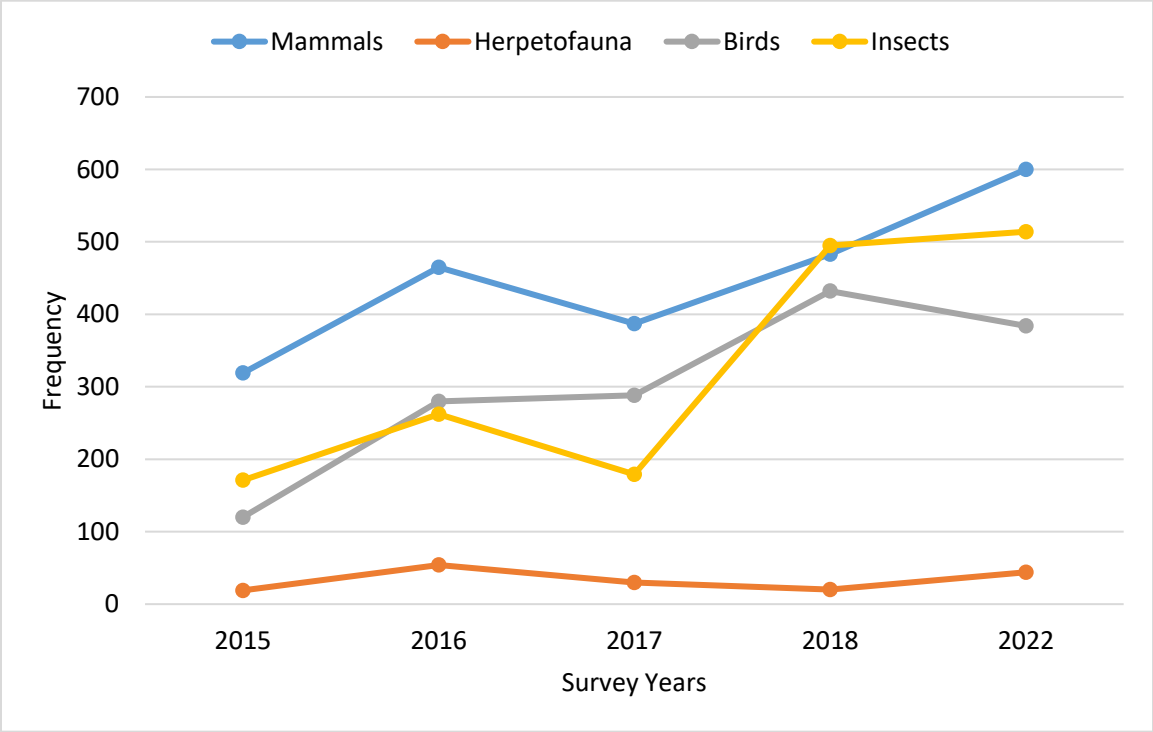

Figure 16: Comparison of fauna sign abundances from 2015 to 2022

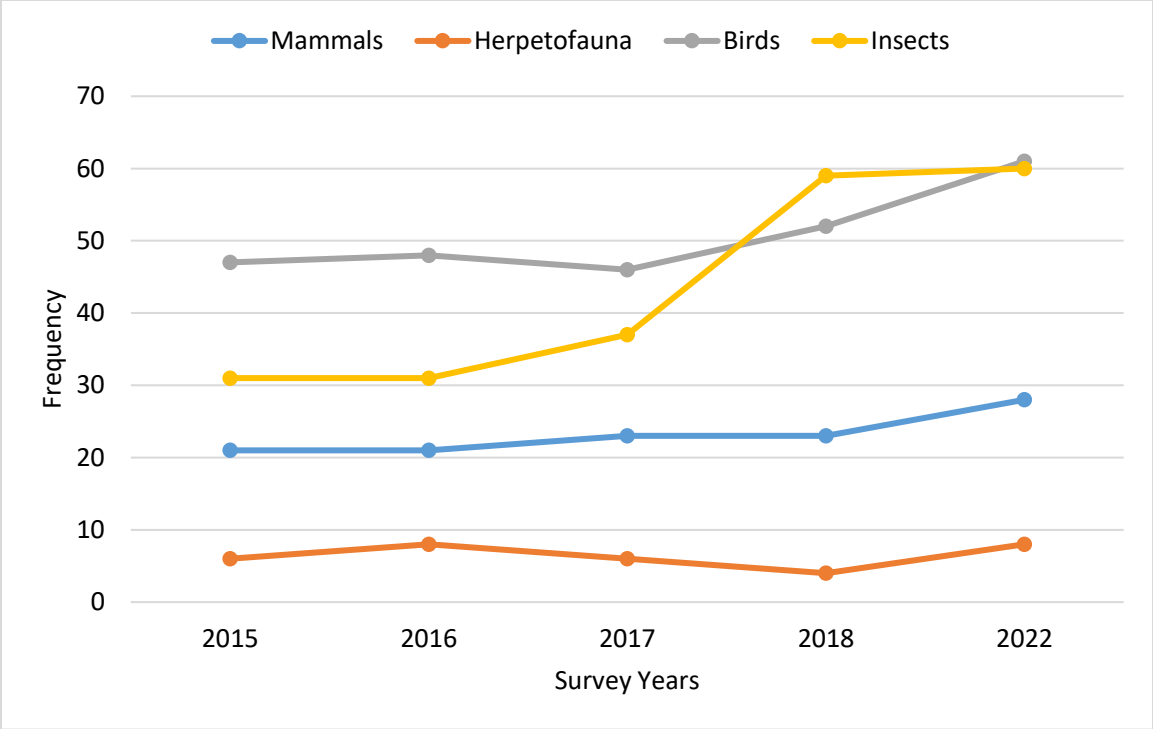

Figure 17: Comparison of fauna species abundances from 2015 to 2022

Most notably, population trends of mammals, herpetofauna, birds and insects all declined around 2017. The reason for this decline in all these fauna groups is not readily known but can be attributed to very heavy rains experienced during the survey which could have hampered visibility. After 2017, most of the fauna populations including species increased again, except herpetofauna which continued to decline both in populations and species types. Insects were the fauna groups that were able to recover most quickly in terms of both population levels and species types. At 2022 mammals, insects and birds had reached their highest population levels and species abundances. Comparatively, mammals occurred in highest population levels whiles birds occurred at highest species types.

4.2.3 Species of Conservation Interest

Recorded mammalian species of conservation interest on the IUCN Red List of Threatened Species (2022) include one carnivore (Tree Pangolin; *Phataginus tricuspis*; Endangered)

and two primates (Lowe's Mona Monkey; *Cercopithercus lowei*; Vulnerable and Bossman's Potto; *Perodicticus potto*; Near Threatened). These species are also listed in Appendix II of CITES (species that are not necessarily threatened with extinction but may become so unless trade is closely controlled). The African Civet (*Civettictis civetta*) is also listed in Appendix III of CITES (trade in these species is only permitted with an appropriate export permit and a certificate of origin from the member country). Locally, all primates and the tree pangolin are of special conservation importance in Ghana and are listed in Schedule 1 of the Ghana Wildlife Conservation Regulations (1995). Tullberg's soft furred mouse (*Proamys tullbergi*) is endemic to West Africa.

Most of the birds recorded were either forest fringe species or birds of degraded forests. Apart from the hooded vulture (*Necrosyrtes monachus*) which is Critically Endangered, none of the recorded birds are of special conservation importance on the IUCN List of Threatened Species 2022 or CITES schedules. 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).

None of the insects or herpetofauna species are of any significant conservation concern on the IUCN Red List of Threatened Species (2022). However, the Nile Monitor is listed in Appendix II of CITES (species that are not necessarily threatened with extinction but may become so unless trade is closely controlled) and protected in Ghana.


WATER QUALITY
ASSESSMENT

5.0 WATER QUALITY ASSESSMENT

5.1 METHODOLOGY

5.1.1 Selection of Sampling Points

Six water sampling points were selected. Three were systematically located on the Huni River at upstream, mid-stream and downstream (Plots 1-3) whiles the other three were randomly located on selected streams within the concession (Plots 4-6) (Figure 18).

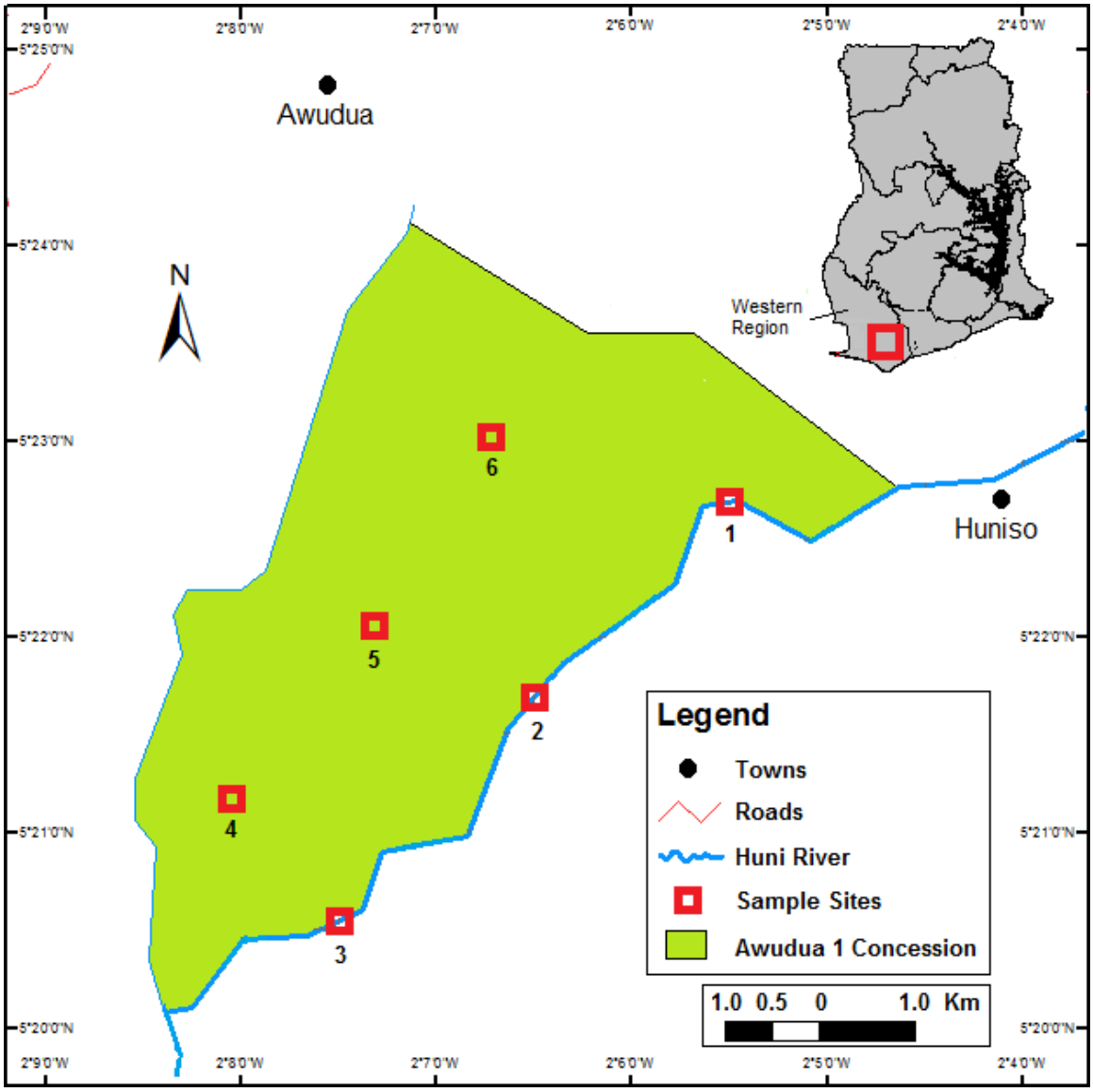

Figure 18: Locations of sampling sites in the Awudua 1 Rubber Concession

The Ankobra River was not included in the sampling because of the presence of illegal small-scale miners whose activities could drastically influence the results of the study.

5.1.2 Sample Collection

All water samples were taken directly from the Huni River and streams, which also serve as habitats for aquatic organisms and water sources for fringe communities. Pre-washed 200 mL plastic bottles were used to collect water sample for the water quality analysis. Sample containers were labeled on the field using appropriate codes and water samples were temporary stored in an ice packed cooler and transported. Sealed sample bottles were placed in a dark environment at a constant temperature range of 4–10°C to avoid any contamination and the effects of light and temperature. Water samples collected were analyzed for parameters such as pH, conductivity, total dissolved solids (TDS), alkalinity, nitrate, ammonia and phosphate using multi-meter probes (Model: Horiba U-51 and Model: HACH 2100 P). All laboratory analyses of the samples were conducted at KNUST, Kumasi, according to the "Standard Methods for the Examination of Water and Wastewater" of the American Public Health Association, 1995 edition.

5.2 RESULTS

5.2.1 Channel Descriptions and Locations

The river/streambeds for all the sampling sites ranged from rocky to gravel and sandy substrates (Table 9). In general, the vegetation around the waterbodies were mostly in good condition.

Table 9: GPS locations and descriptions of sampling sites in the Awudua 1 Rubber Concession

ID	Site	Description	GPS Coordinates N	W
1	Upstream	Rocky substrate with cobbles. Riverbed vegetation is in good condition.	05.22.660	-002.05.500
2	Middle	Gravel substrate. Riverbed vegetation is in fairly good condition.	05.20.500	-002.07.500
3	Downstream	Rocky substrate with small boulders. Riverbed vegetation is in good condition.	05.21.660	-002.06.500
4	8 J (Plantation)	Sandy bedload. Streambed vegetation is in good condition.	05.21.000	-002.08.000
5	11 G (Plantation)	Gravel substrate. Streambed vegetation is in good condition.	05.22.000	-002.07.330
6	Plantation	Sandy bedload. Streambed vegetation is in good condition.	05.23.000	-002.06.660

5.2.2 Channel Morphometrics

Flow rates were generally high in the River Huni compared to within the plantation (Table 12). The colour of the rivers/streams were mostly clear. Generally, the banks of these waterbodies were bordered with remnant riparian vegetation along most sections with just a few sections composed of invasive and opportunistic weed, herb and shrub species. Substrate composition was variable, ranging from muddy to gravel and rocky.

Table 10: Morphometrics of sampling sites of waterbodies

ID	Site	Flow rate (m/s)	Width (m)	Depth (m)	Substrate	Colour
1	Upstream	13	4.8	0.6	Rocky	Clear
2	Middle	17	7.5	2.1	Gravel	Clear
3	Downstream	16	11.3	3.2	Rocky	Clear
4	8 J (Plantation)	8	2.1	0.5	Sandy	Clear
5	11 G (Plantation)	7	3.2	0.6	Gravel	Clear
6	Plantation	7	2.6	0.4	Sandy	Clear

5.2.3 Water Quality Analysis

Apart from the recorded pH values and some of the alkalinity values, all the other values for the analyzed surface water quality parameters were found to be within the safe limits as set by the World Health Organization (WHO, 2017) (Table 11).

Table 11: Summary of surface water parameters recorded in the study

Site	pH	Conductivity µS/cm	TDS mg/L	Alkalinity mg/L	Nitrate mg/L	Ammonia mg/L	Phosphate mg/L
Upstream	6.63	35.4	27.25	22	0.209	<0.05	0.16
Downstream	6.76	37.3	29.25	24	0.211	<0.05	0.19
Middle	6.64	36.6	27.32	26	0.219	<0.05	0.21
8 J (Plantation)	6.22	30.0	23.26	21	0.173	<0.05	0.31
11 G (Plantation)	6.24	32.1	23.42	18	0.142	<0.05	0.23
Plantation	6.36	31.6	22.48	19	0.128	<0.05	0.21
RANGES							
Maximum	6.36	37.3	29.25	26	0.219	0	0.31
Minimum	6.14	30.0	22.48	18	0.128	0	0.16
Mean	6.23	33.8	25.50	22	0.180	0	0.22
WHO range	6.5 - 8.5	50 - 1500	0 - 1000	20 – 300	0 – 10	0 – 0.50	N/A

Physical Parameters

The pH for the water samples ranged from 6.14 to 6.36, below the WHO limits (6.5 to 8.5) for potable water. The mean value (6.23) was much lower than the mean (6.65) recorded in 2017 for the same waterbodies. Streams within the concession had lower pH values than water from the Huni River. These recorded low pH values, indicating high acidity could be due to a decrease in the use of inorganic fertilizers and pesticides in the

plantation thus reducing chemical discharges and surface run-offs into the waterbodies. Low quantities of chemical substances might have altered the acid-base equilibria and resulted in an increased acid capacity and generally low alkalinity values.

Conductivity ranged from 30 µS/cm to 37.3 µS/cm, below the WHO limits (50 - 1500 µS/cm) for potable water. The mean value (33.8 µS/cm) was very much lower than the mean (126.8) recorded in 2017. The generally low conductivity recorded can also be attributed to a decrease in chemical discharges and surface run-offs into the waterbodies which might have decreased the concentration of ions.

TDS values ranged from 22.48 mg/L to 29.25 mg/L and the mean value (25.50 mg/L) was lower than the mean (39.9 mg/L) recorded in 2017. These values are very low when compared to the WHO limits of 0 – 1000 mg/L for potable water, hence, water colour was generally clear at all sampling sites. The generally low turbidity coupled with low colour characteristics in the waterbodies, is an indication of good water quality even in the rainy season when most rivers and streams are flooded.

Chemical Parameters

Values for Nitrate (0.128-0.219 mg/L), Ammonia (0.00-0.00 mg/L) and Phosphate (0.16-0.31 mg/L) were very low and insignificant when compared with the WHO permissible limits. Their very low levels once again suggest a decrease in the application of chemicals in the concession and the subsequent decrease in surface run-offs into the waterbodies.

6.0 GENERAL DISCUSSION

The HCV occupies a critical position and contributes significantly to the abundance and distribution of species within the Awudua I Rubber Concession. Forty-seven (47) tree species have been identified. The concession also supports the most abundant and diversity of wildlife with up to 230 fauna species identified compared to the 86 identified in 2018. This observation of about 200% increase in the overall number of species recorded in the concession is however mainly due to an increase in insect species. The buffer area was associated with the most abundant and diverse insect life. The abundance of insects in the concession firstly, indicates a very good chemical regulation and management regime which is commendable. Secondly, the beneficial importance of insects in pollination services in the plantation cannot be overemphasized. Insects transport pollen to plants that are a good distance from each other, hence ensuring a good mixing of genes. Plants including rubber, benefit from this increase in genetic diversity. Research have indicated that pollen, stuck to a butterfly's long tongue, stays fresh for a good time and ensures this valuable pollination at a distance. Furthermore, a number of flowers are completely dependent on butterflies and odonates for pollination.

There was a general increase in the number of species recorded in 2022 compared to what were recorded in 2018. For instance, 28 mammal, 64 bird, 10 reptile and 81 insect species were recorded in 2022 whilst 24 mammal, 53 bird, 14 herpetofauna and 67 insect species were recorded in 2018. This increase may be mainly due to the abundance and variety of available food and shelter sources emanating from the diversity of land use types in the area that provides security for wildlife. The herpetofauna of the study area may seem not very impressive because of the lower record of species in 2022. However, the relative lower record of herpetofauna signs and particularly of amphibians in the study area corresponds well to established low densities in plantation habitats. Many of the species recorded within the study area are considered to be habitat generalists, capable of surviving in both mature forest and degraded and highly fragmented habitat.

Bush meat is an important source of protein for the local population and observations on the ground indicated that animals were still hunted with snares and shotguns. Also, the activities of small-scale miners in the nearby River Ankobra are a key source of disturbance to wildlife habitat in the HCV area. An examination of these human activities including hunting within the study area suggested that distance to the Ankobra River boundaries accounted for a large proportion of variation in their distribution. In particular, hunting and 'galamsey' activity increased towards the Ankobra River. For that matter, fauna abundance was observed to be lower on the immediate peripheries of the Ankobra River.

The carbon stock assessment was conducted in the HCV area mainly because of its importance as a wildlife habitat and its significant contribution to tree diversity. The HCV represented about 15% of the total area of the concession. The carbon sequestration potential of the HCV was relatively high and therefore supports the existing efforts to conserve the area. Based on this, GREL management should continue to prioritize its conservation since its existence is important in the mitigation of greenhouse gas (GHG) emission. Possible vegetation types within the concession that are potential HCVs include sensitive vegetation and riparian vegetation fringing waterbodies. Such places have high carbon sequestration potential and are also known to habour significant levels of biodiversity and should be conserved.

In terms of water quality of the concession's waterbodies, the recorded values of pH, conductivity, TDS and alkalinity were lower than their values recorded in 2017. All the chemical parameters including nitrate, ammonia and phosphate levels were also very low. The low pH values coupled with the low conductivity, indicates a high acid content of the concession's waterbodies and possibly the soil. This observation could be due to a decrease in the use of inorganic fertilizers and pesticides in the plantation thus reducing chemical discharges and surface run-offs into the waterbodies. Low quantities of chemical

substances might have altered the acid-base equilibria and decreased the concentration of ions. This might have resulted in an increased acid capacity and the generally low alkalinity values. The generally low turbidity coupled with the clear water colour of the waterbodies, is an indication of good water quality even in the rainy season when the survey was conducted.

With the exception of conductivity and pH, all the other water quality parameters were within the safe limits set by the WHO and local standards based on GSB and GWC guideline values for water consumption. The conductivity of water is a measure of the concentration of dissolved salts in water, hence low conductivity is an indicator of chemically unpolluted conditions. Consuming water with low TDS by a healthy person alone cannot have unhealthy effects. Also, water with high conductivity does not necessarily pose a risk to human health, but it can cause corrosion in industrial equipment or plumbing systems, scale build-up, mineral-like taste in drinking water, and issues with dissolved solid concentration in agriculture. A pH level is a measurement of acid-base equilibrium, and that number can indicate whether a substance is acidic or basic. The pH scale ranges from 0-14 with levels less than 7 considered acidic, levels greater than 7 considered alkaline, and a pH of 7 considered neutral. Nevertheless, water with a pH level between 6 and 8.5 is safe to drink because it is neither acidic or alkaline enough to be dangerous to the human body. Water with a pH of less than 6 can be corrosive and filled with toxic metals. Water with a pH of higher than 8.5 can be hard, which poses less of a health risk than acidic water but can taste bad and leave scale deposits on dishes, sinks and more. The above observations suggest that plantation activities by GREL in the Awudua 1 Rubber Concession is having minimal effects on the water quality in the environment hence, water from rivers and streams flowing from the concession to downstream community users may be generally fit for domestic use.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

7.1.1 Conservation Interests

Recorded tree species of conservation interest on the IUCN Red List of Threatened Species (2022) include two Near Threatened species (*Chrysophyllum albidum* and *Daniellia ogea*) and three Vulnerable species (*Heritiera utilis*, *Nesorgodonia papavifera* and *Pterygota macrocarpa*). Mammalian species of conservation interest constituted the Tree Pangolin; *Phataginus tricuspis* (Endangered), Lowe's Mona Monkey; *Cercopithercus lowei* (Vulnerable), Bossman's Potto; *Perodicticus potto* (Near Threatened) and one bird species (Hooded Vulture; *Necrosyrtes monachus* - Critically Endangered). Fortunately, GREL has set aside the HCV and buffer areas as 'no go' areas for wildlife conservation, where wildlife management is incorporated into existing land use. Its continued protection and conservation will have long-term significant and positive implications for a wide range of wildlife.

The carbon sequestration potential of the HCV was relatively high and therefore supports the existing efforts to conserve the area. Based on this, GREL management should continue to prioritize its conservation since its existence is important in the mitigation of greenhouse gas (GHG) emission.

Generally, all the figures of the water quality parameters, with the exception of pH were within the safe limits set by the WHO and local standards based on GSB and GWC guideline values. This suggests that plantation activities by GREL in the Awudua 1 Rubber Concession is having minimal effects on the water quality in the environment. Based on these observations and the WHO safe limit standards, water from rivers and streams flowing from the concession to downstream community users may be generally fit for domestic use.

7.1.2 Wildlife Trends

The HCV and buffer areas seems to be doing well in terms of protecting wildlife in the Awudua 1 Rubber Conservation. Majority (72%) of species were persistent across the 4-year monitoring period, suggesting that GREL is conducting wildlife-friendly plantation activities. Only very few of the confirmed species representing only 4% of the overall total were not verified in recent surveys. It is readily not very clear what could be the cause of this observation but it is likely that species affected could be very rare or extremely shy species that may still be present but difficult to sight regularly. GREL should invest in more discrete methods of detecting wildlife including cameras to improve upon detectability of very rare species. The good news is that whiles a rather small percentage of species might have been missed in recent surveys, a relatively bigger percentage of new species (22%) have been currently confirmed in recent surveys as new species in the concession. Results indicate that most fauna densities and diversity have actually increased over the 4-year study period.

7.2 RECOMMENDATIONS

7.2.1 Regulating Human Activities

The tree pangolin (*Phataginus tricuspis*) is an uncommon species in Africa and threatened by habitat loss. It has been recorded in the rainforests of Western and parts of West Central Region of Africa from Guinea, Côte d'Ivoire, Ghana, W Nigeria, and possibly Cameroon. Its habitat is primary rainforest, hence GREL should endeavour to protect the established HCV areas and minimize human activities close to the area. One may accept the inevitability of the presence of local hunters in the plantation; nevertheless, more effort should be channeled into salvaging the situation now, in order to reduce deterioration of the status of wildlife in the future. Agreements should be made with the 'galamsey' operators to conduct their activities in specified areas which can be monitored.

7.2.2 Buffer Creation

In delineating additional buffers, GREL should also ensure strict adherence to a minimum of 30m buffer to rivers and streams in order to safeguard their integrity. This could be expanded if necessary and should be given priority in tree planting exercises. Creating and subsequently expanding intensively managed refuges within the plantation forms the basis of establishing internal wildlife corridors within the larger landscape and is an effective way of curtailing illegal forest clearing activities, whilst enhancing landscape connectivity (Harvey *et al*., 2006).

7.2.3 Butterfly/Odonate Sanctuary Establishment

The buffer areas could offer something that is perhaps unique to Ghana and only comparable to the Bobri Butterfly Sanctuary in the Ashanti Region of Ghana. There are many tourists and researchers who would delight in the opportunity to spot and study butterflies and odonates in the area. Camp-sites could be established close to buffer areas for both research and tourist intentions. GREL could restrict the number of tourists entering the plantation at any one time to avoid over-crowding. If this tourist and research experience is well managed, it could form the central feature on which to base conservation publicity for GREL. This innovation itself is an opportunity that stands GREL in good stead to enjoy support from many sides, especially government, ecologists and NGOs.

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APPENDICES

Appendix 1: Characteristics of tree species in Plot 1

Species	DBH (cm)	Height (m)	Wood Density	AGB	Carbon Stock	C (Mg)
Cola nitida	21.65	9.4	0.5	109.96	54.98	0.05
Carapa procera	21.65	8.3	0.6	116.51	58.26	0.06
Funtumia elastica	27.37	8.9	0.42	139.88	69.94	0.07
Napoleonaea vogelii	20.12	7.9	0.57	91.00	45.50	0.05
Berlinia confusa	62.20	23.4	0.57	2576.67	1288.34	1.29
Elaes guineensis	32.85	13.8	0.5	371.82	185.91	0.19
Carapa procera	25.15	9.2	0.6	174.31	87.15	0.09
Elaes guineensis	31.19	12.7	0.5	308.56	154.28	0.15
Carapa procera	28.33	9.6	0.6	230.85	115.42	0.12
Zanthoxylum gilletii	38.20	9.4	0.5	342.44	171.22	0.17
Diospyros gabonensis	27.06	8.8	0.5	160.85	80.42	0.08
Berlinia confusa	39.47	16.3	0.57	722.81	361.41	0.36
Rinorea oblongifolia	17.25	6.9	0.5	51.28	25.64	0.03
Carapa procera	25.15	9.6	0.6	181.88	90.94	0.09
Carapa procera	34.06	13.2	0.6	458.79	229.39	0.23
Carapa procera	27.06	6.5	0.6	142.57	71.28	0.07
Elaes guineensis	35.01	115	0.5	3520.25	1760.12	1.76
Dacryodes klaineana	29.60	7.5	0.57	187.08	93.54	0.09
Heritiera utilis	53.29	15.5	0.5	1098.83	549.42	0.55
Carapa procera	20.50	7.6	0.6	95.69	47.84	0.05
Diospyros gabonensis	41.38	10.5	0.57	511.76	255.88	0.26
Turreanthus africanus	22.09	8.5	0.49	101.50	50.75	0.05
Margaritaria descoidea	21.07	8.2	0.72	130.91	65.46	0.07

Carapa procera	11.27	4.5	0.6	17.12	8.56	0.01
Cola nitida	15.92	5	0.5	31.62	15.81	0.02
Berlinia confusa	43.61	17.2	0.5	816.69	408.35	0.41
Vitex ferruguinea	13.75	9	0.55	46.74	23.37	0.02
Xylopia aethiopica	25.46	12	0.57	221.49	110.75	0.11
						6.48

Appendix 2: Characteristics of tree species in Plot 2

Species	DBH (cm)	Height (m)	Wood Density	AGB	Carbon Stock	C (Mg)
Xylopia aethiopica	35.969	12	0.57	441.91	220.95	0.22
Cordia millenii	18.653	7	0.34	41.35	20.68	0.02
Carapa procera	11.1408	4	0.59	14.63	7.31	0.01
Cola nitida	19.0986	6.5	0.5	59.20	29.60	0.03
Chrysophyllum subnudum	23.8732	15	0.57	243.34	121.67	0.12
Pterygota macrocarpa	14.6423	7	0.58	43.47	21.73	0.02
Chrysophyllum subnudum	49.9747	13	0.57	924.14	462.07	0.46
Chrysophyllum subnudum	19.7352	11.5	0.57	127.49	63.74	0.06
Funtumia elastica	24.1916	13	0.45	170.96	85.48	0.09
Carapa procera	28.9662	9.5	0.59	234.84	117.42	0.12
Cola lateritia	12.6051	8	0.7	44.43	22.22	0.02
Cordia millenii	26.547	13	0.34	155.55	77.78	0.08
Cola nitida	15.2789	4.5	0.5	26.23	13.11	0.01
Macaranga barteri	27.9476	15	0.4	234.02	117.01	0.12
Rinorea oblongifolia	28.3296	10	0.5	200.39	100.19	0.10
Cordia millenii	14.9606	5	0.34	19.00	9.50	0.01
Chrysophyllum subnudum	30.0485	13	0.57	334.10	167.05	0.17
						1.66

Appendix 3: Characteristics of tree species in Plot 3

Species	DBH (cm)	Height (m)	Wood Density	AGB	Carbon Stock	C (Mg)
Petersianthus macrocarpus	55.32	14	0.5	1069.84	534.92	0.53
Macaranga barteri	13.94	11	0.4	42.71	21.35	0.02
Macaranga barteri	20.44	13	0.4	108.44	54.22	0.05
Macaranga barteri	17.38	13	0.4	78.43	39.22	0.04
Hannoa klaineana	38.52	11	0.51	415.58	207.79	0.21
Macaranga barteri	12.73	8.5	0.4	27.52	13.76	0.01
Carapa procera	34.38	7	0.59	243.73	121.87	0.12
Cola gigantea	27.37	9	0.46	154.92	77.46	0.08
Napoleonea vogelii	12.99	4	0.57	19.20	9.60	0.01
Carapa procera	21.14	6.5	0.59	85.55	42.78	0.04
Cola nitida	12.73	5	0.5	20.24	10.12	0.01
Cola millenii	18.27	7	0.34	39.68	19.84	0.02
Elaeis guineensis	18.53	7	0.5	59.98	29.99	0.03
Cola gigantea	25.34	8	0.46	117.98	58.99	0.06
Cordia millenii	24.64	8.5	0.34	87.60	43.80	0.04
Cordia millenii	18.27	7	0.34	39.68	19.84	0.02
Lannea welwitschii	34.89	8	0.45	218.80	109.40	0.11
Cordia millenii	16.74	5	0.34	23.80	11.90	0.01
Carapa procera	20.56	3.5	0.59	43.60	21.80	0.02
Cola nitida	15.85	5.5	0.5	34.51	17.25	0.02
						1.47

Appendix 4: Characteristics of tree species in Plot 4

Species	DBH (cm)	Height (m)	Wood Density	AGB	Carbon Stock	C (Mg)
Hannoa klaineana	68.12	15	0.51	1772.59	886.30	0.89
Strombosia glaucescens	35.97	16	0.8	826.96	413.48	0.41
Strombosia glaucescens	32.21	15.5	0.8	642.54	321.27	0.32
Daniellia ogea	25.81	15	0.4	199.67	99.83	0.10
Manilkara obovata	21.45	16	0.78	286.85	143.42	0.14
Berlina confusa	15.28	14	0.57	93.03	46.51	0.05
Cola nitida	23.87	7	0.5	99.61	49.81	0.05
Strombosia glaucescens	14.32	13	0.8	106.56	53.28	0.05
Cola nitida	14.90	7	0.5	38.79	19.39	0.02
Garcinia cola	13.81	6	0.57	32.59	16.30	0.02
Chrysophyllum subnudum	17.51	14	0.57	122.14	61.07	0.06
Chrysophyllum subnudum	28.90	14	0.57	332.89	166.44	0.17
Heritiera utilis	63.03	14	0.56	1555.13	777.56	0.78
Manilkara obovata	37.18	16	0.78	861.43	430.71	0.43
Chrysophyllum albidum	38.52	16	0.56	663.74	331.87	0.33
Carapa procera	13.50	6	0.6	32.75	16.37	0.02
Chrysophyllum albidum	13.69	7	0.56	36.67	18.34	0.02
Berlinia tomentella	19.74	7	0.58	78.96	39.48	0.04
Diospyros cooperi	14.01	6	0.82	48.19	24.10	0.02
Berlinia tomentella	15.34	6	0.58	40.91	20.45	0.02
Berlinia confusa	55.51	14	0.57	1228.05	614.02	0.61
Daniellia ogea	22.03	13	0.4	125.99	62.99	0.06
Diospyros cooperi	13.05	7	0.82	48.82	24.41	0.02
Berlinia tomentella	13.31	8	0.58	41.02	20.51	0.02
Diospyros cooperi	11.78	3	0.82	17.04	8.52	0.01

Tabernaemontana africanus	16.23	6	0.49	38.69	19.35	0.02
Heritiera utilis	38.20	15	0.56	612.01	306.01	0.31
Millettia rhodanta	10.82	8	0.72	33.69	16.84	0.02
Strombosia glaucescens	13.62	7	0.8	51.90	25.95	0.03
Heritiera utilis	29.60	13	0.56	318.58	159.29	0.16
						1.28

Appendix 5: Characteristics of tree species in Plot 5

Species	DBH (cm)	Height (m)	Wood Density	AGB	Carbon Stock	C (Mg)
Strombosia glaucescens	31.67	14.9	0.8	597.09	298.55	0.30
Millettia rhodanta	11.46	8	0.72	37.77	18.89	0.02
Daniellia ogea	23.43	13	0.4	142.52	71.26	0.07
Manilkara obovata	20.85	16	0.78	270.90	135.45	0.14
Berlina confusa	16.23	14	0.57	105.02	52.51	0.05
Cola nitida	21.96	6	0.5	72.27	36.13	0.04
Strombosia glaucescens	15.60	14	0.8	136.06	68.03	0.07
Cola nitida	11.71	5	0.5	17.13	8.56	0.01
Garcinia cola	13.50	6	0.57	31.11	15.55	0.02
Chrysophyllum subnudum	17.51	13	0.57	113.41	56.71	0.06
Chrysophyllum subnudum	29.86	15	0.57	380.62	190.31	0.19
Heritiera utilis	59.52	13	0.56	1288.05	644.03	0.64
Manilkara obovata	39.06	17	0.78	1010.07	505.04	0.51
Chrysophyllum albidum	37.56	15	0.56	591.78	295.89	0.30
Berlinia tomentella	15.66	6	0.58	42.62	21.31	0.02
Berlinia confusa	55.51	15	0.57	1315.77	657.88	0.66
Daniellia ogea	21.71	12	0.4	112.96	56.48	0.06
Diospyros cooperi	13.69	7	0.82	53.70	26.85	0.03
Berlinia tomentella	13.34	7	0.58	36.06	18.03	0.02
Diospyros cooperi	12.10	3	0.82	17.97	8.99	0.01
Tabernaemontana africanus	18.78	7	0.5	61.64	30.82	0.03
Heritiera utilis	36.92	14	0.56	533.77	266.88	0.27
Millettia rhodanta	12.41	8	0.72	44.33	22.16	0.02
Heritiera utilis	30.88	14	0.56	373.23	186.62	0.19
						1.59

Appendix 6: Characteristics of tree species in Plot 6

Species	DBH (cm)	Height (m)	Wood Density	AGB	Carbon Stock	C (Mg)
Dacryodes klaineana	58.95	11	0.7	1336.26	668.13	0.67
Synsepalum ntimii	13.69	5	0.5	23.39	11.69	0.01
Carapa procera	21.65	7	0.59	96.62	48.31	0.05
Synsepalum ntimii	17.83	5	0.5	39.67	19.83	0.02
Carapa procera	26.10	9	0.59	180.65	90.33	0.09
Chrysophyllum subnudum	33.74	14	0.57	453.66	226.83	0.23
Chrysophyllum subnudum	29.60	14	0.57	349.21	174.61	0.17
Berlinia tomentella	31.89	16	0.58	471.41	235.71	0.24
Chrysophyllum subnudum	38.20	15	0.57	622.94	311.47	0.31
Diospyros cooperi	11.78	12	0.82	68.16	34.08	0.03
						1.82

Appendix 7: Characteristics of tree species in Plot 7

Species	DBH (cm)	Height (m)	Wood Density	AGB	Carbon Stock	C (Mg)
Carapa procera	15.85	5.5	0.59	40.72	20.36	0.02
Berlinia tomentella	30.88	13	0.58	358.95	179.48	0.18
Cola nitida	14.64	3	0.5	16.06	8.03	0.01
Heritiera utilis	18.78	9.5	0.56	93.70	46.85	0.05
Amphimas pterocarpioides	27.44	13.5	0.63	319.75	159.87	0.16
Cola nitida	14.32	6	0.5	30.74	15.37	0.02
Cola nitida	14.58	4	0.5	21.23	10.61	0.01
Chrysophyllum subnudum	35.65	9	0.57	325.59	162.80	0.16
Chrysophyllum subnudum	41.89	10	0.57	499.47	249.73	0.25
Diospyros sanza-minika	11.33	13	0.57	47.52	23.76	0.02
Berlinia confusa	20.05	13	0.57	148.81	74.40	0.07
Cola nitida	24.64	6	0.5	90.93	45.47	0.05
Scottellia klaineana	19.42	10	0.5	94.13	47.07	0.05
Hannoa klaineana	43.61	15	0.51	726.48	363.24	0.36
						1.41

Appendix 8: Characteristics of tree species in Plot 8

Species	DBH (cm)	Height (m)	Wood Density	AGB	Carbon Stock	C (Mg)
Chrysophyllum subnudum	25.27	13	0.57	236.36	118.18	0.12
Chrysophyllum subnudum	47.75	14	0.57	908.46	454.23	0.45
Berlinia confusa	33.42	14	0.57	445.14	222.57	0.22
Manilkara obovata	21.84	9	0.78	167.15	83.57	0.08
Synsepalum ntimii	12.16	5	0.5	18.46	9.23	0.01
Cola nitida	18.72	6	0.5	52.48	26.24	0.03
Cola nitida	24.19	7	0.5	102.29	51.14	0.05
						0.97

Appendix 9: Characteristics of tree species in Plot 9

Species	DBH (cm)	Height (m)	Wood Density	AGB	Carbon Stock	C (Mg)
Hannoa klaineana	35.97	16	0.51	527.19	263.59	0.26
Heritiera utilis	51.76	15	0.56	1123.67	561.84	0.56
Mannilkara obovata	39.15	18	0.78	1074.72	537.36	0.54
Carapa procera	44.25	8	0.59	461.41	230.71	0.23
Guarea cedrata	14.64	8	0.48	41.11	20.56	0.02
Dacryodes klaineana	15.92	6.5	0.7	57.55	28.78	0.03
Garcinia cola	19.86	5	0.57	56.15	28.07	0.03
Napoleonaea vogelii	11.14	4	0.57	14.13	7.07	0.01
Chrysophyllum subnudum	21.77	13	0.57	175.41	87.70	0.09
Scaphopetalum amoenum	12.10	4	0.5	14.61	7.31	0.01
Allanblackia parviflora	17.25	9	0.63	84.28	42.14	0.04
Chrysophyllum subnudum	12.10	10	0.57	41.64	20.82	0.02
Garcinia cola	13.37	4	0.57	20.35	10.17	0.01
						1.85

Appendix 10: Characteristics of tree species in Plot 10

Species	DBH (cm)	Height (m)	Wood Density	AGB	Carbon Stock	C (Mg)
Hannoa klaineana	68.88	18	0.51	2175.09	1087.54	1.09
Strombosia glaucescens	15.79	6	0.8	59.75	29.87	0.03
Aidia genipiflora	10.12	4	0.78	15.96	7.98	0.01
Garcinia cola	11.40	4	0.57	14.78	7.39	0.01
Heritiera utilis	36.67	14	0.56	526.43	263.22	0.26
Funtumia africana	40.43	13	0.4	424.36	212.18	0.21
Cola nitida	15.28	8.5	0.5	49.54	24.77	0.02
Strombosia glaucescens	45.84	10	0.8	839.33	419.67	0.42
Carapa procera	43.29	7	0.59	386.50	193.25	0.19
Mannilkara obovata	14.96	9	0.78	78.46	39.23	0.04
Microdesmis puberula	13.88	5	0.5	24.05	12.02	0.01
Pycnanthus angolensis	36.61	14	0.4	374.72	187.36	0.19
Heritiera utilis	11.78	8	0.56	31.03	15.52	0.02
Diospyrus sanza-minika	23.87	13	0.57	210.89	105.45	0.11
Turreanthus africanus	53.29	11	0.5	779.82	389.91	0.39
Cola nitida	26.42	10	0.5	174.28	87.14	0.09
Funtumia africana	11.87	10	0.4	28.16	14.08	0.01
						3.10

Appendix 11: Characteristics of tree species in Plot 11

Species	DBH (cm)	Height (m)	Wood Density	AGB	Carbon Stock	C (Mg)
Hannoa klaineana	41.19	16	0.51	691.32	345.66	0.35
Nesorgodonia papavifera	32.47	16	0.65	547.46	273.73	0.27
Uapaca heudelotii	45.58	9	0.6	560.27	280.14	0.28
Mannilkara obovata	54.24	13	0.78	1489.69	744.85	0.74
Diospyros sanza-minika	10.25	7	0.57	20.93	10.47	0.01
Myrianthus lebericus	22.60	11.2	0.5	142.83	71.42	0.07
Mannilkara obovata	29.35	10.5	0.78	352.26	176.13	0.18
Strombosia glaucescens	10.12	5	0.8	20.47	10.23	0.01
Carapa procera	16.23	7	0.59	54.35	27.18	0.03
Garcinia cola	9.99	6	0.57	17.06	8.53	0.01
Heritiera utilis	23.43	12	0.56	184.18	92.09	0.09
Mannilkara obovata	42.78	13	0.78	926.74	463.37	0.46
Berlinia confusa	55.51	16	0.57	1403.48	701.74	0.70
Mannilkara obovata	49.27	10	0.78	945.71	472.85	0.47
Dacryodes klaineana	35.01	12.5	0.7	535.69	267.84	0.27
Carapa procera	14.96	8	0.59	52.75	26.38	0.03
Heritiera utilis	38.20	7	0.56	285.61	142.80	0.14
						4.12

Appendix 12: Mammal abundances in land use types and survey years

	Common Name	*Scientific Name*	IUCN	2022 HCV	2022 Buffer	2022 Rubber	2015	2016	2017	2018	Total
	MAMMALS	***MAMMALIA***									
	Primates	***Primates***									
	Monkeys	***Cercopithecoidea***									
1	Lowe's Monkey	*Cercopithecus lowei*	VU	12	0	0	0	0	8	8	28
	Prosimians	***Strepsirhini***									
2	Potto	*Perodicticus potto*	NT	7	2	0	0	12	3	8	32
3	Demidoff's Galago	*Galagoides demidovii*	LC	10	0	0	8	5	6	5	34
	Rodents	**Rodentia**									
	Squirrels	***Sciuridae***									
4	Striped Ground Squirrel	*Euxerus erythropus*	LC	17	23	11	17	52	44	47	211
5	Fire-footed Rope Squirrel	*Funisciurus pyrropus*	LC	7	8	2	5	14	13	12	61
6	Small Forest Squirrel	*Heliosciurus gambianu*	LC	16	0	0	5	10	11	14	56
7	Slender-tailed Squirrel	*Protoxerus aubinnii*	LC	6	0	0	0	0	0	0	6
	Porcupines	***Hystricidae***									
8	Brush-tailed Porcupine	*Antherurus africanus*	LC	14	5	0	28	19	11	7	84
	Cane-rats	***Thryonomyidae***									
9	Marsh Cane Rat	*Thryonomys swinderianus*	LC	23	16	8	46	58	25	42	218
	Pouched Rats	***Cricetomyinae***									
10	Giant Gambian Rat	*Cricetomys gambiensis*	LC	30	25	18	64	50	34	56	277
	Shrews	***Soricidae***									
11	Common Musk Shrew	*Crocidura flavescens*	LC	5	6	4	8	16	16	15	70
	Murid Mice	***Muridae***									
12	Multimammate Mouse	*Mastomys natalensis*	LC	4	3	2	6	8	6	9	38

13	Tullberg's Soft-furred Mouse	*Praomys tullbergi*	LC	4	5	2	6	5	7	7	36
14	Rufous-bellied Mouse	*Lophuromys sikapusi*	LC	4	0	0	4	0	0	0	8
	Dormice	***Gliridae***									
15	Striped Grass Mouse	*Lemniscomys barbarus*	LC	2	0	0	0	0	0	0	2
16	Common African Dormouse	*Graphiurus murinus*	LC	2	0	0	0	0	0	0	2
	Carnivores	***Carnivora***									
	Mongooses	***Herpestidae***									
17	Cusimanse	*Crossarchus obscurus*	LC	29	0	0	5	16	17	25	92
18	Marsh Mongoose	*Atilax paludinosus*	LC	15	12	0	8	16	15	20	86
19	Slender Mongoose	*Herpestes sanguineus*	LC	10	0	0	0	0	0	0	10
	Genets and Civets	***Viverridae***									
20	Blotched Genet	*Genetta tigrina*	LC	14	11	0	6	24	17	22	94
21	African Civet	*Civettictis civetta*	LC	6	2	0	2	3	13	6	32
	Pangolins	***Pholidota***									
22	Tree Pangolin	*Phataginus tricuspis*	EN	5	0	0	2	2	3	3	15
	Ungulates	***Ungulata***									
	Hyraxes	***Hyracoidea***									
23	Western Tree Hyrax	*Dendrohyrax dorsalis*	LC	19	0	0	12	18	15	18	82
	Bovids	***Bovidae***									
24	Bushbuck	*Tragelaphus scriptus*	LC	33	32	16	22	71	68	77	319
	Antelopes	***Antelopinae***									
25	Maxwell's Duiker	*Cephalophus maxwelli*	LC	41	21	0	48	52	43	58	263
26	Bay Duiker	*Cephalophus dorsalis*	LC	9	0	0	9	3	2	7	30
27	Royal Antelope	*Neotragus pygmaeus*	LC	11	0	0	8	11	7	9	46
	Pigs	***Suidae***									

28	Red River Hog	*Potamochoerus porcus*	LC	11	0	0	0	0	3	8	22
		Total number of signs		366	171	63	319	465	387	483	2254
		Total number of species		28	14	8	21	21	23	23	116

Appendix 13: Herpetofauna abundances in land use types and survey years

	Common Name	*Scientific Name*	IUCN	2022 HCV	2022 Buffer	2022 Rubber	2015	2016	2017	2018	Total
	HERPETOFAUNA										
	REPTILES	***REPTILIA***									
	Varanus	***Varanidae***									
1	Monitor Lizard	*Varanus niloticus*	LC	11	2	0	6	15	0	5	39
	Cobras	***Elapidae***									
2	Forest Cobra	*Naja melanoleuca*	LC	3	6	2	5	22	13	8	59
3	Green Mamba	*Dendroaspis viridis*	LC	7	0	0	2	6	7	3	25
	Pythons	***Pythonidae***									
4	Rock Python	*Python sebae*	LC	0	0	0	3	1	1	0	5
	Adders	***Viperidae***									
5	Puff Adder	*Bitis arietans*	LC	1	0	0	1	3	2	4	11
	AMPHIBIANS	***AMPHIBIA***									
	True Frogs	***Ranidae***									
6	Common frog	*Amnirana galamensis*		0	0	0	2	3	4	0	9
	Forked Tongue Frogs	***Dicroglossidae***									
7	Crowned bullfrog	*Hoplobatrachus occipitalis*	LC	5	0	0	0	0	0	0	5
	Bush Frogs	**Hyperoliidae**									
8	Dotted Reed Frog	*Hyperolius guttulatus*	LC	3	0	0	0	0	0	0	3
	Puddle Frogs	**Phrynobatrachidae**									
9	Savanna Puddle Frog	*Phrynobatrachus latifrons*	LC	1	0	0	0	0	0	0	1
10	African Puddle Frog	*Phrynobatrachus calcaratus*	LC	0	0	0	0	2	3	0	5
11	Guttural Puddle Frog	*Phrynobatrachus gutturosus*	LC	0	0	0	0	2	0	0	2
12	Ukami Reed Frog	*Hyperolus tornetis*	LC	3	0	0	0	0	0	1	4

Total number of signs	34	8	2	19	54	30	21	168
Total number of species	8	2	1	6	8	6	5	33

Appendix 14: Bird abundances in land use types and survey years

	Common Name	*Scientific Name*	IUCN	2022 HCV	2022 Buffer	2022 Rubber	2015	2016	2017	2018	Total
	BIRDS	***AVES***									
	Herons and Egrets	***Ardeidae***									
1	Cattle Egret	*Bubulcus ibis*	LC	0	0	0	0	0	14	10	24
2	Great White Egret	*Egretta alba*	LC	17	0	0	6	14	0	0	37
	Birds of Prey	***Accipitridae***									
3	Long-crested Eagle	*Lophaetus occipitalis*	LC	5	0	0	2	2	6	3	18
4	Western Little Sparrowhawk	*Accipiter erythropus*	LC	2	0	0	0	0	0	0	2
5	Black Sparrowhawk	*Accipiter melanoleucus*	LC	3	0	0	1	2	3	2	11
6	African Goshawk	*Accipiter tachiro*	LC	5	0	0	2	6	7	4	24
7	Black Kite	*Milvus migrans*	LC	14	0	0	3	4	4	10	35
8	African Hobby	*Falco cuvierii*	LC	3	0	0	4	5	6	4	22
9	Red-necked Buzzard	*Buteo auguralis*	LC	3	0	0	0	0	0	0	3
10	Hooded Vulture	*Necrosyrtes monachus*	CR	2	0	0	0	0	0	0	2
	Pigeons and Doves	***Columbidae***									
11	Green Fruit Pigeon	*Treron calva*	LC	5	0	0	4	11	12	11	43
12	Blue-headed Wood Dove	*Turtur brehmeri*	LC	5	0	0	2	6	7	3	23
13	Tambourine Dove	*Turtur tympanistria*	LC	14	4	0	1	6	6	2	33
14	Afep Pigeon	*Columba unicincta*	LC	3	11	0	3	10	11	33	71
15	Bronze-naped Pigeon	*Columba iriditorques*	LC	3	0	0	0	0	0	0	3
16	Red-eyed Dove	*Streptopelia semitorquata*	LC	15	11	5	0	0	0	27	58
	Turacos and Plantain-Eaters	***Musophagidae***									
17	Western Plantain-eater	*Crinifer piscator*	LC	6	0	0	0	0	0	0	6
	Cuckoos and Coucals	***Cuculidae***									
18	Klaas Cuckoo	*Chrysococcyx klaas*	LC	1	2	0	1	2	2	25	33

19	Yellowbill	*Ceuthmochares aereus*	LC	2	0	1	6	7	7	8	31
20	Senegal Coucal	*Centropus senegalensis*	LC	9	10	4	4	34	34	16	111
	Cuckooshrikes	***Campephagidae***									
21	Blue cukooshrike	*Coracina azurea*	LC	0	0	0	0	0	5	0	5
	Swifts	***Apodidae***									
22	Sabine's Spinetail	*Raphidura sabini*	LC	2	0	0	1	21	21	1	46
23	Mottled-throated Spinetail	*Telecanthura ussheri*	LC	2	2	0	2	4	4	2	16
24	Cassin's Spinetail	*Neafrapus cassini*	LC	2	0	0	0	0	0	0	2
25	Little African Swift	*Apus affinus*	LC	7	2	0	1	13	13	3	39
26	European Swift	*Apus apus*	LC	3	0	0	0	0	0	0	3
	Bee-eaters	***Meropidae***									
27	White throated Bee-eater	*Merops albicollis*	LC	2	0	0	0	0	0	0	2
	Hornbills	***Bucerotidae***									
28	White-crested Hornbill	*Tockus albocristatus*	LC	1	0	0	2	2	2	3	10
29	African Pied Hornbill	*Lophoceros fasciatus*	LC	3	0	0	2	2	2	9	18
	Barbets and Tinkerbirds	***Capitonidae***									
30	Naked-faced Barbet	*Gymnobucco calvus*	LC	2	2	0	2	3	3	3	15
31	Lemon-rumped Tinkerbird	*Pogoniulus bilineatus*	LC	1	0	0	2	6	6	2	17
32	Yellow-spotted Barbet	*Buccanodon duchaillui*	LC	2	0	0	1	2	2	1	8
	Woodpeckers	***Picidae***									
33	Gabon Woodpecker	*Dendropicos gabonensis*	LC	1	0	0	2	2	2	2	9
	Pittas	***Pittidae***									
34	African Pitta	*Pitta angolensis*	LC	2	0	0	5	5	5	10	27
	Swallows	***Hirundinidae***									
35	European Swallow	*Hirundo rustica*	LC	4	2	6	5	10	0	5	32
36	Lesser Striped Swallow	*Hirundo abyssinica*	LC	3	2	1	0	0	0	0	6
37	Norhtern Grey-headed sparrow	Passer *griseus*	LC	0	0	0	0	0	0	7	7

	Babblers	***Timaliidae***									
38	Blackcap Illadopsis	*Illadopsis cleaveri*	LC	1	0	0	1	1	2	1	6
39	Rufous-winged Illadopsis	*Illadopsis rufescens*	LC	2	5	0	1	1	1	1	11
	Bulbuls and Greenbuls	***Pycnonotidae***									
40	Little Greenbul	*Andropadus virens*	LC	2	0	0	2	2	2	3	11
41	Slender-billed Greenbul	*Andropadus gracilirostris*	LC	2	0	0	4	5	5	7	23
42	Simple Leaf-love	*Chlorocichla simplex*	LC	2	1	3	3	6	6	3	24
43	Western Bearded Greenbul	*Criniger barbatus*	LC	1	0	0	3	3	3	6	16
44	Common Bulbul	*Pycnonotus barbatus*	LC	23	2	0	9	12	12	13	71
	Sunbirds	***Nectariniidae***									
45	Collared Sunbird	*Anthreptes collaris*	LC	1	0	0	2	6	6	5	20
46	Olive Sunbird	*Nectarinia olivacea*	LC	3	0	3	3	6	6	4	25
47	Olive-bellied Sunbird	*Nectarinia chloropygia*	LC	2	0	0	0	0	1	0	3
48	Superb Sunbird	*Nectarinia superba*	LC	3	3	0	4	5	5	4	24
	Chats and Robins	***Turdidae***									
49	Forest Robin	*Stiphrornis erythrothorax*	LC	5	2	1	2	2	0	2	14
50	Fire-crested Alethe	*Alethe diademata*	LC	2	0	0	1	1	0	1	5
51	Nightingale	*Luscinia megarhychos*	LC	1	0	0	1	1	0	1	4
	Warblers	***Sylviidae***									
52	Olivaceous Warbler	*Hippolais pallida*	LC	2	0	0	2	2	2	5	13
53	West African Prinia	*Prinia subflava*	LC	4	0	0	3	3	3	6	19
54	Olive-green Camaroptera	*Camaroptera chloronota*	LC	3	0	0	2	2	2	2	11
	Flycatchers	***Muscicapidae***									
55	Forest Flycatcher	*Fraseria ocreata*	LC	4	0	3	2	5	5	10	29
56	Olivaceous Flycatcher	*Muscicapa olivascens*	LC	2	0	0	1	4	6	8	21
	Weavers and Malimbes	***Ploceidae***									
57	Grey-headed Sparrow	*Passer griseus*	LC	7	0	1	1	9	10	1	29

58	Pin-tailed Whydah	*Vidua macroura*	LC	3	0	0	3	10	10	3	29
59	Village Weaver	*Ploceus cucullatus*	LC	21	3	0	0	0	0	19	43
60	Black-Necked weaver	*Ploceus nigricollis*	LC	6	0	0	0	0	0	22	28
61	Fire-crowned Bishop	*Euplectes hordeaceus*	LC	7	0	0	0	0	0	3	10
	Drongos	***Dicruridae***									
62	Fork-tailed Drongo	*Dicrurus adsimilis*	LC	3	2	8	1	1	2	10	27
63	Shining Drongo	*Dicrurus atripennis*	LC	4	3	4	1	1	4	41	58
64	Pied Crow	*Corvus albus*	LC	2	0	3	4	13	11	45	78
		Total number of signs		272	69	43	120	280	288	432	1504
		Total number of species		41	18	13	47	48	46	52	254

Appendix 15: Insect abundances in land use types and survey years

	Common Name	*Scientific Name*	IUCN	2022 HCV	2022 Buffer	2022 Rubber	2015	2016	2017	2018	Total
	INSECTS	***INSECTA***									
	BUTTERFLIES	***LEPIDOPTERA***									
	Skippers	**Hesperiidae**									
1	Giant Scarce Sprite	*Katreus johnstonii*	NE	0	0	0	3	9	4	0	16
2	Bouvier's Elfin	*Sarangesa bouvieri*	NE	0	0	0	19	25	21	0	65
3	Brigid's Elfin	*Sarangesa brigida*	NE	0	0	0	6	9	4	0	19
4	African giant skipper	*Pyrrhochalcia iphis*	NE	3	2	0	0	0	5	1	11
	G-winged Butterflies	***Lycaenidae***									
5	Western Aslaug	*Aslauga marginalis*	NE	0	0	0	14	15	11	0	40
6	Smoky Bean Cupid	*Euchrysops malathana*	NE	0	0	0	9	13	8	0	30
7	Yellow Liptena	*Liptena xanthostola*	NE	0	0	0	4	9	7	0	20
	Brush-footed Butterflies	***Nymphalidae***									
8	Elegant Acraea	*Acraea egina*	NE	0	0	0	1	2	1	0	4
9	African Castor	*Ariadne enotrea*	NE	3	0	0	0	0	0	1	4
10	Dark Palm Forester	*Bebearia mardania*	NE	0	0	0	1	4	2	0	7
11	Beautiful Forester	*Bebearia sophus*	NE	2	0	3	1	2	1	1	10
12	Black Forester	*Bebearia abesa*	NE	2	0	0	0	0	0	1	3
13	Common Palm Forester	*Bebearia cocalia*	NE	1	3	0	0	0	0	1	5
14	Light Bush Brown	*Bicyclus dorothea*	NE	3	0	0	12	14	8	7	44
15	Anal-patch Bush Brown	*Bicyclus analis*	NE	3	0	0	0	0	0	1	4
16	West White-tipped Bush Brown	*Bicyclus abnormis*	NE	2	0	3	0	0	0	0	5
17	Small Black Bush Brown	*Bicyclus buea*	NE	3	3	0	0	0	0	3	9
18	Funeral Bush Brown	*Bicyclus funebris*	NE	2	2	0	0	0	0	0	4
19	Black Bush Brown	*Bicyclus martius*	NE	1	0	0	0	0	0	1	2

20	Dark Vulgar Bush Brown	*Bicyclus sandace*	NE	3	0	1	0	0	0	18	22
21	White-tipped Bush Brown	*Bicyclus sylvicolus*	NE	2	1	0	0	0	0	1	4
22	Grey Bush Brown	*Bicyclus taenias*	NE	2	0	0	0	0	0	3	5
23	Velvet Bush Brown	*Bicyclus istaris*	NE	0	0	0	18	21	16	0	55
24	Vulgar Bush Brown	*Bicyclus vulgaris*	NE	3	2	0	20	21	15	2	63
25	Common Joker	*Byblia anvatara*	NE	2	0	0	0	0	0	2	4
26	Common Pathfinder	*Catuna crithea*	NE	1	0	1	0	0	0	1	3
27	Blue-spotted Charaxes	*Charaxes ameliae*	NE	2	0	0	0	0	0	1	3
28	Two-spot Blue Charaxes	*Charaxes bipunctatus*	NE	2	0	2	0	0	3	1	8
29	Western Red Charaxes	*Charaxes cynthia*	NE	2	1	0	0	0	0	1	4
30	Doubleday's Untailed Charaxes	*Charaxes doubleday*	NE	1	0	0	0	0	0	1	2
31	Lesser Blue Charaxes	*Charaxes numenes*	NE	1	2	0	0	0	0	1	4
32	Small Flame-bordered Charaxes	*Charaxes anticlea*	NE	0	0	0	2	0	1	0	3
33	Bamboo Charaxes	*Charaxes boueti*	NE	2	0	0	7	7	2	1	19
34	White-barred Emperor	*Charaxes brutus*	NE	0	0	0	4	6	3	0	13
35	Lesser Blue-Spotted Charaxes	*Charaxes etesipe*	NE	3	2	3	1	5	2	1	17
36	Green Charaxes	*Charaxes eupale*	NE	4	0	0	1	2	2	1	10
37	Common Red Charaxes	*Charaxes lucretius*	NE	4	0	2	4	6	1	1	18
38	Common Blue Charaxes	*Charaxes tiridates*	NE	2	0	0	1	3	3	6	15
39	Yellow Glider	*Cymothoe egesta*	NE	3	2	0	2	5	2	1	15
40	Plain Tiger	*Danaus chrysippus*	NE	2	2	3	0	0	0	8	15
41	African palmfly	*Elymniopsis bammakoo*	NE	2	0	0	0	0	0	12	14
42	Ceres Forester	*Euphaedra ceres*	NE	1	0	2	0	0	0	1	4
43	Modest Themis Forester	*Euphaedra modesta*	NE	3	0	0	0	0	1	1	5
44	Velvet Ceres forester	*Euphaedra velutina*	NE	2	0	3	0	0	0	1	6
45	Common Forest Queen	*Euxanthe eurinome*	NE	1	3	0	3	4	1	1	13
46	Western Hallelesis	*Hallelesis halyma*	NE	2	2	0	0	0	0	15	19

47	Guineafowl butterfly	*Hamanumida daedalus*	NE	4	2	2	0	0	0	1	9
48	Danaid Eggfly	*Hypolimnas misippus*	NE	0	0	0	0	5	2	0	7
49	Soldier Commodore	*Junonia terea*	NE	0	0	0	2	5	2	0	9
50	Common Evening Brown	*Melanitis leda*	NE	3	0	0	0	0	0	1	4
51	Violet-eyed Evening Brown	*Melanitis libya*	NE	4	2	0	0	0	3	3	12
52	White-Banded Palla	*Palla decius*	NE	5	1	2	3	6	2	1	20
53	False Diadem	*Pseudacraea lucretia*	NE	2	0	0	0	0	0	1	3
	Swallow-tail Butterflies	***Papilionidae***									
54	Broad-banded Green Swallowtail	*Papilio chrapkowskoides*	NE	0	0	0	3	7	4	0	14
55	Citrus Swallowtail	*Papilio demodocus*	NE	0	0	0	6	8	2	0	16
56	Green-banded Swallowtail	*Papilio nireus*	NE	0	0	0	3	11	5	0	19
57	Mocker Swallowtail	*Papilio dardanus*	NE	1	2	0	0	0	2	1	6
	Spotted Butterflies	**Pieridae**									
58	Calypso Caper White	*Belenois calypso*	NE	3	3	0	0	0	0	1	7
59	African Common White	*Belenois creona*	NE	0	0	0	7	9	11	0	27
60	Common Vagrant	*Catopsilia florella*	NE	0	0	0	9	11	14	0	34
61	Desjardin's Grass Yellow	*Eurema desjardinsii*	NE	0	0	0	3	9	3	0	15
62	Chloris Dotted Border	*Mylothris chloris*	NE	0	0	0	1	5	3	0	9
63	Large Vagrant	*Nepheronia argia*	NE	2	0	3	0	0	0	2	7
64	Blue Vagrant	*Nepheronia thalassina*	NE	0	0	0	1	4	2	0	7
	DRAGONFLIES	***ANISOPTERA***									
	Clubtail Dragonflies	***Gomphidae***									
65	Common Clubtail	*Ictinogomphus rapx*	NE	12	23	6	*	*	*	35	76
66	Common Tigertail	*Ictinogomphus ferox*	NE	26	38	3	*	*	*	62	129
67	Common Thorntail	*Ceratogomphus pictus*	NE	0	15	0	*	*	*	15	30
	Hawkers	***Aeshnidae***									

68	Blue Emperor	*Anax imperator*	NE	2	13	1	*	*	*	9	25
	Skimmers	***Libellulidae***									
69	Jones' Forestwatcher	*Notiothemis jonesi*	NE	0	4	0	*	*	*	4	8
70	Piedspot	*Hemistigma albipuncta*	NE	3	22	0	*	*	*	14	39
71	Red-veined Dropwing	*Trithemis arteriosa*	NE	0	11	0	*	*	*	23	34
72	Julia Skimmer	*Orthetrum julia*	NE	3	9	7	*	*	*	25	44
73	Banded Groundling	*Brachythemis leucosticta*	NE	12	18	4	*	*	*	30	64
74	Yellow-veined Widow	*Palpopleura jucunda*	NE	9	34	6	*	*	*	102	151
75	Wandering Glider	*Pantala flavescens*	NE	8	16	2	*	*	*	32	58
	DAMSELFLIES	***ZYGOPTERA***									
	Jewels	***Chlorocyphidae***									
76	Dancing Jewel	*Platycypha caligata*	NE	0	0	0	*	*	*	3	3
	Broad-winged Damselflies	***Calopterygidae***									
77	Damoiselles	*Calopteryx virgo*	NE	0	0	0	*	*	*	5	5
	White-legged Damselflies	**Platycnemididae**									
78	Featherlegs	*Platycnemis*	NE	0	0	0	*	*	*	9	9
	Narrow-winged Damselflies	***Coenagrionidae***									
79	Common Pond Damsel	*Ceriagron glabrum*	NE	0	0	0	*	*	*	12	12
80	Painted Sprite	*Pseudagrion hageni*	NE	0	0	0	*	*	*	2	2
81	Swamp Bluet	*Africallagma glaucum*	NE	0	0	0	*	*	*	3	3
		Total number of signs		176	240	59	171	262	179	495	1582
		Total number of species		52	29	20	31	31	37	59	212

Plate 2: The Endangered Tree Pangolin (*Phataginus tricuspis*; IUCN Red List, 2022).