ECOLOGICAL STUDIES
FOR THE FORM GHANA AGRO-FORESTRY PROJECT IN
TAIN II FOREST RESERVE, GHANA

FORM GHANA

Prepared By

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PREFACE

This report describes the baseline biodiversity survey findings in Form Ghana compartments in Tain II Forest Reserve, Brong Ahafo Region, Ghana in November 2012. The team constituted the consultant William Oduro and eight technicians (experts in four major taxonomic groups) from the Department of Wildlife and Range Management in the *Kwame Nkrumah University of Science and Technology* (KNUST), Ghana.

The study formed an integral part of an overall project to restore and monitor biodiversity in degraded areas in Tain II Forest Reserve and was under the auspices of Form Ghana with major cooperation from the *Ghana Forestry Commission* (FC). The team also investigated the presence of species of special conservation interest and assess the possible impacts of teak plantation development activities on wildlife. The aim of the project is in line with the Forest Stewardship Certification Standards and also meets the social and environmental requirements for sustainable forest management in Ghana.

Plate 1: A section of the biodiversity field team pose for the camera before fieldwork

SUMMARY

Form Ghana aims at large-scale reforestation of degraded forest reserves in Ghana while conserving and restoring natural, riparian forest. The current study was conducted in November 2012 and aimed at providing baseline biodiversity information that can be used as a basis for monitoring and evaluation of teak plantation development activities in Tain II Forest Reserve. The line transect technique was used to sample animal signs to estimate their density and distribution. Detailed vegetation and visual habitat assessments were also conducted on the transect walks.

Four main vegetation types were identified and classified as forest, teak plantation, farmlands and degraded areas. Degraded areas (73%) constituted the major vegetation type followed by forest (5%) whilst teak plantation (13%) and farmlands (9%) formed the least vegetation types. Four medium to large mammal taxonomic groups, representing 13 Families, 17 Genera, and 18 Species were confirmed in the study area. Forest vegetation ranked highest with a record of 18 species, followed by teak plantation (8), farmland (8) and then degraded areas (3). Majority of animal signs (68%) consisting mostly of ungulates (35%), carnivores (18%) and reptiles (15%) were spotted in the forest vegetation type (Jacobs' Preference Index: 0.87) compared to the other vegetation types (0.38). Comparative analysis confirmed little overlap in species composition between the two land-use categories (Jaccard Similarity Index: 0.34). There was no record of primate activity. The White-throated Bee-eater, Black-winged Bishop, Red-eyed Dove, Common Bulbul, Zitting Cisticola, Viellot's black Weaver and Grey-backed Cameroptera, were the most recorded and widespread bird species. Fourteen frog species consisting of 62 individuals were identified in contrast to only four species of terrestrial small mammals.

Regression analysis showed that four variables; distance to water sources, number of hunting signs, length of forest in an area and distance from forest roads were most important in determining the distribution of mammals in the study area. Length of forest applies year-round whilst water availability and hunting intensity may change seasonally. The magnitude of road avoidance increased with local hunting pressure. Forest clearance

for farming, hunting activity, timber felling, charcoal production, seasonal fires and activities of Fulani herdsmen were identified on-going threats to wildlife habitat in the study area.

SECTION ONE

1.0 INTRODUCTION

The Strategic Environmental Assessment report of the Ghana Poverty Reduction Strategy has identified loss of biodiversity and forest cover as key areas of environmental concern. The Tain II Forest Reserve located in Berekum District, Ghana has been recognized as a highly degraded forest. To support Ghana in sustainable forest management, Form Ghana (Form) is spearheading private international funding to develop forest plantation in the reserve, which previously hosted some of the last significant tropical rainforest fragments of the Upper Guinea Forest Ecosystem.

This will be a viable approach to sustainable forest management that also brings brings economic value to the investor. Form Ghana is determined to develop the project to meet Forest Stewardship Certification standards and thus also meet social and environmental requirements for sustainable forest management in Ghana.

In pursuance of this goal, the ecology of the project site has to be assessed. The proposed assessment consists of the following activities:

- Processing existing data of the available studies recently conducted in the area
- Ecological survey, fieldwork in Ghana and data processing

The main purpose of the ecological studies is to gather information on the existing flora and fauna in the Tain II Forest Reserve. The results of the study will be incorporated in the management documentation. The general objectives for the assessment are to:

(i) Develop a baseline of the ecology of the area
(ii) Investigate the presence of species of special conservation interest
(iii) Integrate environmental components in management decisions at the earliest stages of the programme

SECTION TWO

2.0 STUDY AREA

The study was conducted in Tain II Forest Reserve (Figure 1: 7° 35"N; 2° 30"W), which has an area of 509.2km². The reserve lies within the fire zone subtype of the dry semi-deciduous forest. It has a bi-modal rainfall pattern with a major and minor peak in June and October respectively. The main dry season is from November to March and there is a second dry spell in August. The mean annual rainfall is 1200mm and the maximum and minimum annual temperature for 26 years were 23.6°C and 26°C (Orgle, 1994). Relative humidity in the dry season ranges from 100% at night to 30% near midday when the harmattan is strongest.

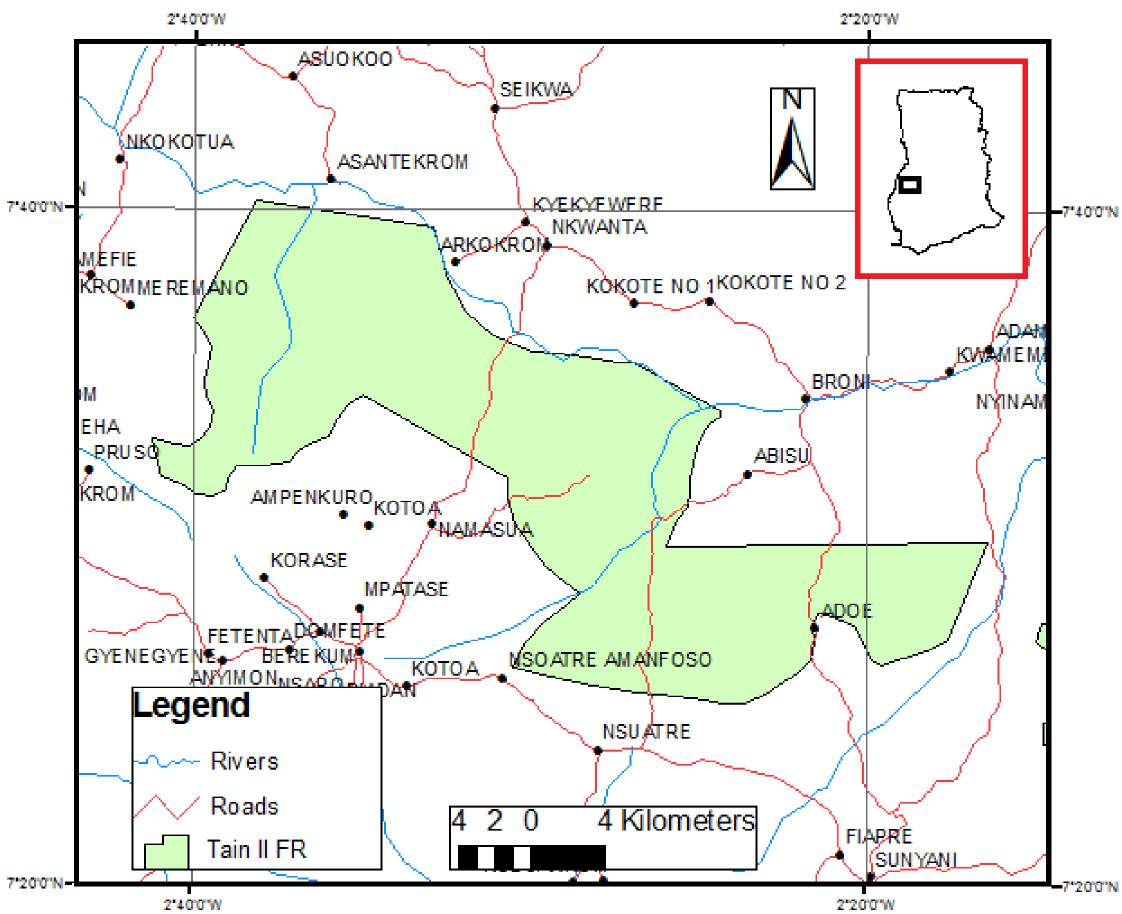

Figure 1: Map of Tain II Forest Reserve showing surrounding communities and towns. The inset map shows the location of Tain II Forest Reserve in mid-western Ghana.

The reserve has been extensively burnt and logged and with variable severity. This makes it possible to categorize four main vegetation types (forest, teak plantation, farmland and degraded areas) based on the effect of different levels of degradation on the forest. Forest vegetation constituted natural forest fragments in little stages of human disturbances classified as slightly disturbed and moderately disturbed. Slightly disturbed forests had continuous upper canopy whilst moderately disturbed forests had broken canopy with little undergrowth. Teak plantation represented areas with monocultures of teak whilst farmland constituted fallowed areas and sites actively used for the cultivation of a variety of food crops including maize and cassava. Degraded areas represented severely disturbed forest vegetation with virtually no trees constituting mostly grassland with several grass species and thickets of *Chromolaena odorata*. These areas also served as active cattle grasslands for Fulani herdsmen.

SECTION THREE

3.0 METHODOLOGY

3.1 Reconnaissance

We undertook a two-day reconnaissance (recce) exercise in the first week of November 2012 in the environs of Tain II FR to assess important landmarks, predict logistical problems and test operational procedures including accuracy of maps.

Plate 2: Linking from Asuokokoo to Asantekrom

3.2 Distribution of transects

Using GIS applications, a grid consisting of cells, each 1-km of length or breadth was superimposed on a map of Tain II FR showing the Form Ghana compartments (Figure 2).

One hundred and twenty transects of length 1km each were systematically distributed within the various compartments based on the number or cluster of compartments found at a particular place. The intersections of the grid formed the likely beginning for each transect. Thus, 100 transects were distributed in the biggest cluster (constituting about 100 compartments) located in north-west of study area (Figure 2). The remaining twenty transects were distributed equally in the two smaller clusters located in northeast and south of study area, conforming to a *systematic segmented line transect* design. All transects were orientated northwards as a rule of thumb (Norton-Griffiths 1978).

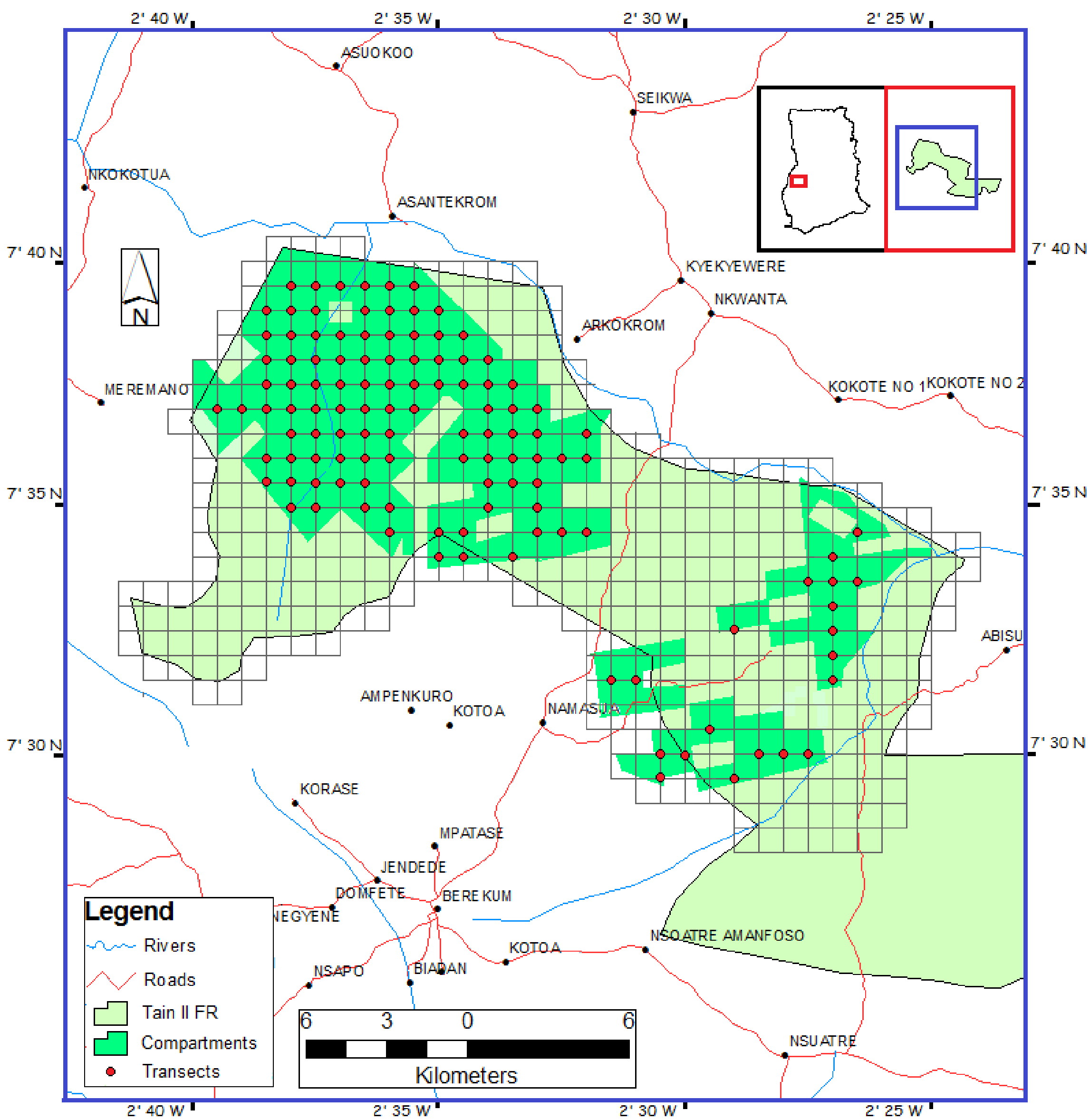

Figure 2: Map of Tain II Forest Reserve showing distribution of compartments and transects.

As a basis for comparing flora and fauna relationships, each transect was associated with a vegetation plot. Thus, each vegetation plot was systematically placed in the middle and across a fauna-assessment transect (Norton-Griffiths 1978).

Determination of the survey transect system set-up was based on three basic requirements;

1. A length of transect long enough to cover animals with large territories and home ranges (ungulates, carnivores);
2. A transect system sufficiently fine-grained to determine the habitat preferences and density estimation of species with restricted range and small territories;
3. A length of transect long enough to include most vegetation and farm types typical of the study area.

3.3 Data Collection

3.3.1 Transect methods

It is impossible to count animals directly in the forest/farm/farm bush mosaic such as that of the study area because of the poor visibility. Hence, we conducted a sign count survey in November 2012, using the line transect method (Burnham *et al.*, 1980; Buckland *et al.*, 1993, 2001) adapted for forest conditions. Two survey teams of four technicians and led by a forest guard (line cutter) was maintained throughout the counts to ensure consistency in data collection procedures. The technicians consisted of experts in taxonomically well-known groups (mammal, herpeto-fauna, avifauna and vegetation) for ready identification of organisms.

We navigated with a compass and a GPS to reach the starting point of each transect. Once on the transect, all animal signs seen along the transect centre-line were recorded. The compass man directed the line cutter whilst all team members walked in line towards the line cutter, scrutinising 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.

3.3.2 Fauna Assessment

Large Mammals

Large mammal surveys comprised both direct and indirect methods (White and Edwards, 2001). All large mammals including their signs were included in the survey to make a complete species list for the area. Direct sightings, vocalizations, dung (scats and pellets) and tracks (trails) counts were recorded systematically along line transects and on ad hoc basis outside transects. For the most part, transect surveys began in the early hours of the morning but the major determinant of the duration of a survey was the type of vegetation and the availability of animal signs. Mammal signs recorded on transects were used to generate a species list.

Small Mammals

Only live-trapping methods were used for small mammals. Fifty Sherman live traps were used simultaneously. Trap lines were set along trails, hauling roads and selected transects, in various habitat types. Traps were placed either randomly or at fixed intervals of 25m on each side of roads, paths and cut lines. Majority of traps were placed on the ground, lightly covered with leaves, bark etc., whereas some were placed on fallen trees or lianas. Others were set close to heaped brushwood, network of aerial roots, holes in the ground or hollow trees. Traps were baited with peanut butter. Trap sites were indicated by ribbons made of orange nylon rope fixed at eye height on twigs. Voucher specimen were collected and preserved as wet specimens in 70% ethanol and later identified at the Faculty of Renewable Natural Resources museum.

Avifauna

Shorter transects (10 1-km transects in each vegetation type) were used to survey the avifauna of the area. Transects were located near makeshift camps in the forest along existing tracks and. Transects were walked between the hours of 06:00 to 10:00 and 15:00 to 18:00 daily avoiding the afternoons during which period soaring temperatures were experienced and almost impossible to detect birds All birds detected both visually and vocally and also while walking normal line transects were identified and recorded. Additionally, mist netting was employed to capture the shy and cryptic understory bird species that are difficult to record during the transect walks.

Calls of unfamiliar birds were recorded and later identified from master-tapes of forest birds. When walking through an area, notes were kept on high-density sites. Particular attention was paid to species of special interest, notably Upper Guinea endemics, rare or threatened species and key or unusual species.

Herpetofauna

Herpetofauna surveys comprised both direct and indirect methods. Species were recorded systematically along line transects and on ad hoc basis outside transects. Suitable habitats and refuges for reptiles were also visited and surveyed for different species. A combination of both visual and acoustic encounter survey techniques were used to detect and record frogs. All individuals sighted were captured marked and released. Each site was visited for 10 times over the survey period. Voucher specimen were collected and preserved as wet specimens in 70% ethanol and later identified at the Faculty of Renewable Natural Resources museum.

3.4 Flora Assessment

Sample plots were laid at the mid-point (500m) of each transect. Plots were of 50m by 50m dimensions for forest vegetation and 20m by 20m for any other vegetation type.

Each of these plots was associated with a 5m by 5m and 2m by 2m plot for more detailed assessment of saplings (woody plants of DBH range 3-5cm), seedlings (DBH range less than 3cm) and grass species. The sample plots were demarcated with the help of ranging poles, a prismatic compass and a linear measuring tape. The transect line passed through the middle of the plot to facilitate movement through the plot.

An enumeration team was made up of a tree spotter and a recorder. Moving clock-wisely, all trees (DBH range more than 5cm) were identified, recorded and diameter at breast height (DBH) and height measured and recorded. The average height of vegetation was also estimated at the middle of each plot. Nomenclature of tree species followed Hawthorne and Jongkind, (2006) and Hawthorne and Ntim Gyakari, (2006)

3.5 Factors Affecting Fauna Abundance

The following notes were made each time an animal sign was recorded: the distance along the transect, measured by the GPS and the vegetation type in the area. Other notes were made on ecological and human factors that might explain the distribution of animals including distance to water sources (ponds, rivers, streams) and number of human signs (farming, hunting activity and roads). Table 1 shows the variables recorded for each transect.

Table 1: List of the variables recorded for each transect.

Variable	Description of variable
X1	Date that the transect was walked
X2	Number and types of animal signs
X3	Number of hunting activity (empty cartridges, wire snares, etc)
X4	Distance to roads
X5	Distance to water sources
X6	Length of vegetation type traversed on transect (km)

3.6 Data Analysis

3.6.1 Fauna Assessment

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

A software; EstimateSWin800 Version 8.0.0 (Colewell, 2006) was used to determine species diversity and richness in the various vegetation types. Habitat preferences of the various mammal species were assessed based on Jacobs' Preference Index (Jacobs, 1974). Comparative analysis to show species composition similarity between vegetation types was done using Jaccard Similarity Index (Southwood and Henderson, 2000). Where appropriate, simple descriptive statistics was used and results presented in the form of graphs, tables and charts for easy observation and understanding.

3.6.2 Flora Assessment

Tree density and relative density were estimated as:

$$\text{Tree density} = \frac{\text{Total number of trees in all plots}}{\text{Total sampled area}}$$

$$\text{Relative density} = \frac{\text{Number of a particular species}}{\text{Total number of species}}$$

3.6.3 Factors affecting fauna distribution

Regression analyses were used to assess the factors that influence fauna distribution in the study area. In this case, the statistics package StatView 5.0.1 was used. The goal was to build mathematical models that described the distribution of animal species.

As the response variable, the number of animal signs recorded on transects are typical count data: they are not normally distributed and they consists of integers, positive numbers and sometimes there are many zeroes. Therefore, variables were statistically normalised before analysing.

3.7 Water Quality Analysis

Water samples were taken into well-sealed plastic containers from various waterbodies (rivers) in six locations (Figure 3) and analyzed to assess impact of the environment on the habitat. Water quality parameters that were measured were: (1) pH, (2) Turbidity (NTU), (3) Dissolved Oxygen (m/l), (4) Conductivity (µs/cm) and (5) Nitrate levels (m/l). Measurements and analysis were carried out by a specialist at the Faculty of Renewable Natural Resources, KNUST.

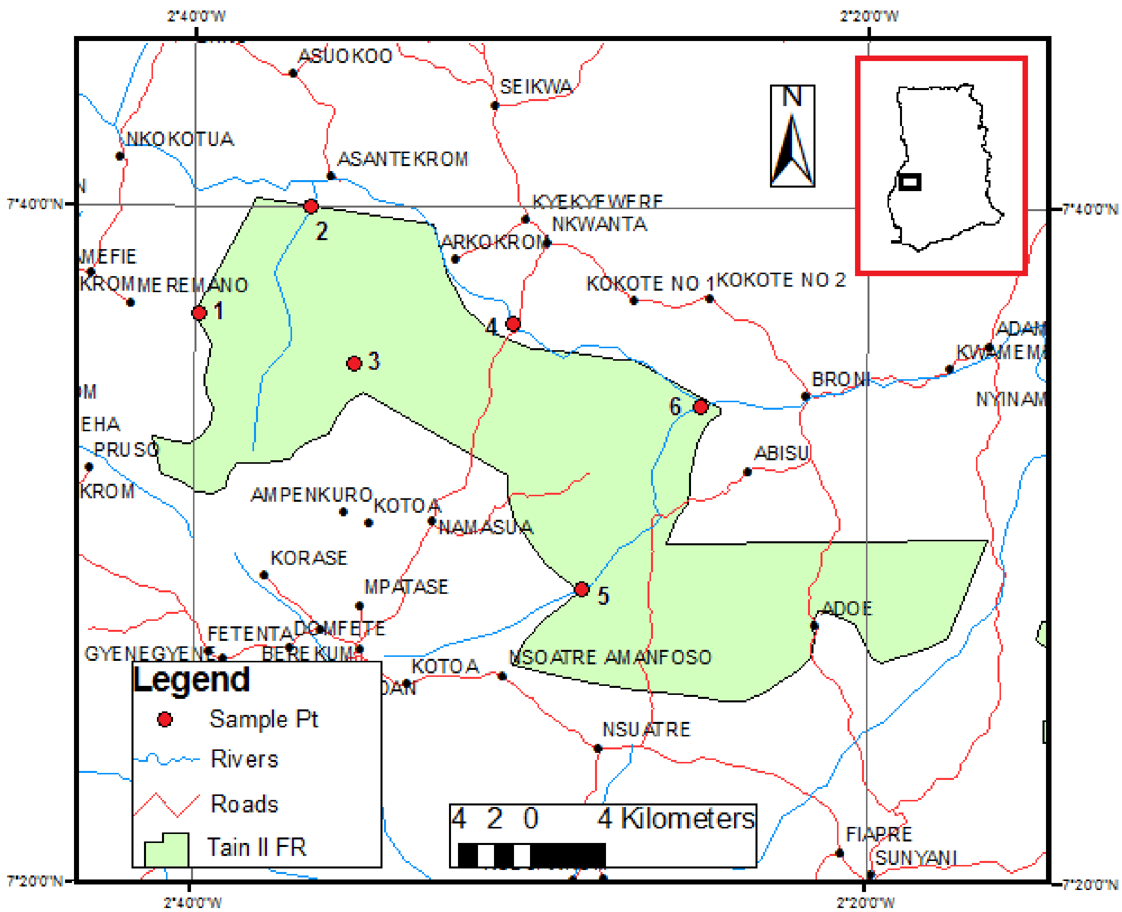

Figure 3: Distribution of water quality sample points

SECTION FOUR

4.0 RESULTS

4.1 Main vegetation types surveyed

Four main vegetation types were identified and classified as forest, teak plantation, farmlands and degraded areas (Table 2). Forest vegetation represented natural forests with little human disturbance. Tree basal area (Hédl *et al*., 2009; DBH>10cm) ranged from 30 - 20 m^2/ha in slightly disturbed areas to 19 – 10 m^2/ha in moderately disturbed areas. Teak plantation represented areas with monocultures of teak whilst farmlands were actively cultivated areas including fallowed areas used for the production of a variety of food crops including maize and cassava. Degraded areas represented highly disturbed forests and grasslands with thickets of *Chromolaena odorata* and isolated trees (basal area of less than 10 m^2/ha). These areas also served as active Fulani cattle grasslands and were constantly razed by fires in the dry season.

Table 2: Main vegetation types surveyed

Main vegetation types and constituent vegetation
Forest
Natural relatively undisturbed forests including riverine/gallery forests
Teak Plantation
Teak monocultures at various stages of development and management
Farmland
Actively cultivated areas (maize, cassava, vegetables, etc) including fallowed areas
Degraded Areas
Highly disturbed forests, grasslands, chromolaena stands, bare soil, etc

4.2 Percent vegetation type

Figure 4 shows the pooled percent habitat data on vegetation type for the study area. Degraded areas (73%) constituted the major vegetation type followed by teak plantation (13%) and farmlands (9%) whilst natural forest (5%) formed the least vegetation types.

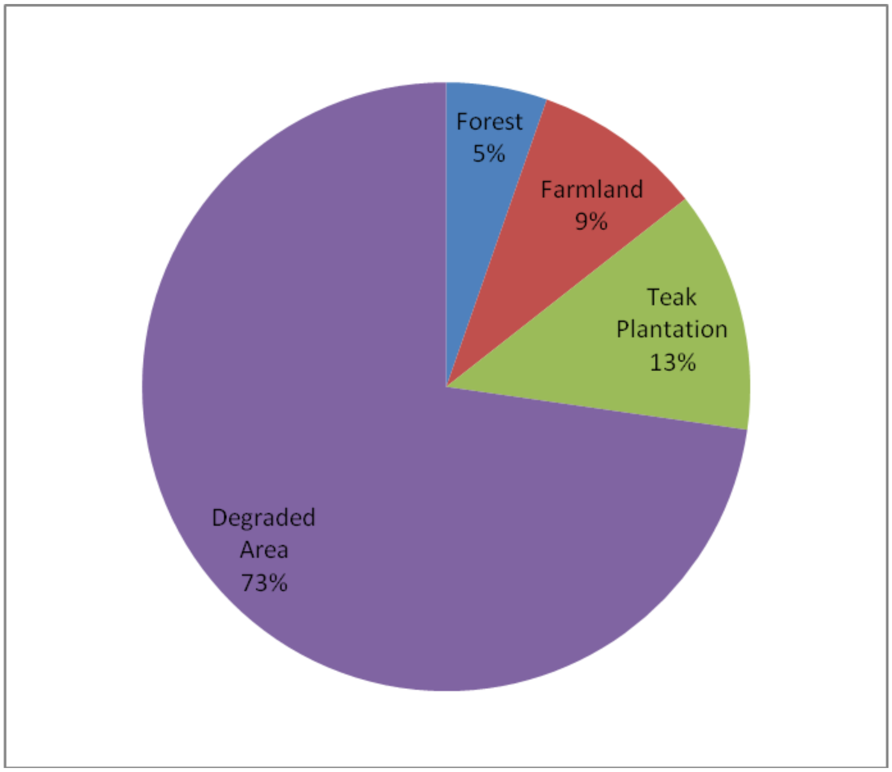

Figure 4: Percent vegetation types found on transects in the study area

Generally, forest patches were recorded along the main waterbodies, especially along the Tain River and its tributaries. These forests generally existed as riverine forests and occurred along the the northern and western fringes of the reserve. There were also smaller forest fragments dotted within the central portions of the reserve. There was no clear pattern in the distribution of degraded areas and teak plantation however; farmland was recorded mostly towards the fringes of the reserve. Although the percentage of actively farmed land for food crops varied across the study area, fallowed areas (farm bush) were more or less evenly distributed.

4.3 Floristic Diversity

Flora representing 24 Families, 52 Genera, and 61 Species were confirmed in the study area during the survey (Appendix 2). *Tectona grandis* (teak) was concentrated in isolated local plantations but ranked highest in abundance with relative density of 59.60%. This was followed by *Ficus exasperata* with relative density of 5.67, then *Albizia adianthifolia* (3.61), *Cola gigantea* (2.28), *Antiaris toxicaria* (1.47), *Holarrhena floribunda* (1.18), *Newbouldia leavis* (1.10) and then 1.03 each for *Aningeria altissima*, *Trema orientalis*, *Morus mesozygia* and *Albizia ferruginea*. Very rare species included *Mareya micrantha*, *Piptadeniastrum africanum* and *Mucana pruriensis* with relative abundance lower than 0.10.

4.3.1 DBH Class Distribution

There are fewer young individuals than mature trees in the population and the relation of DBH classes to number of individuals does not follow an exponential model closely (Figure 5). There are very few trees bigger than 40 cm DBH and none over 60 cm DBH.

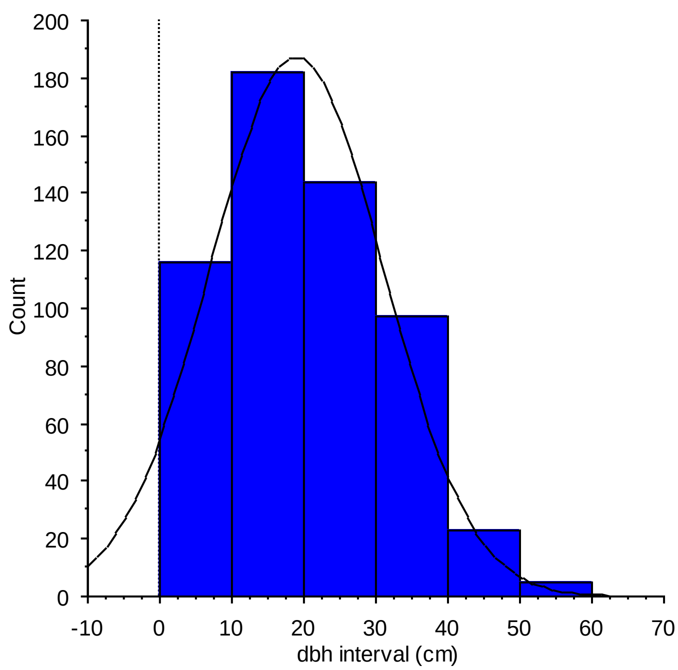

Figure 5: Size (DBH) class distribution of trees recorded in sample plots

4.3.2 Vegetation Height Class Distribution

The mean height class distributions of the four main vegetation types recorded in the various plots are shown in Figure 6.

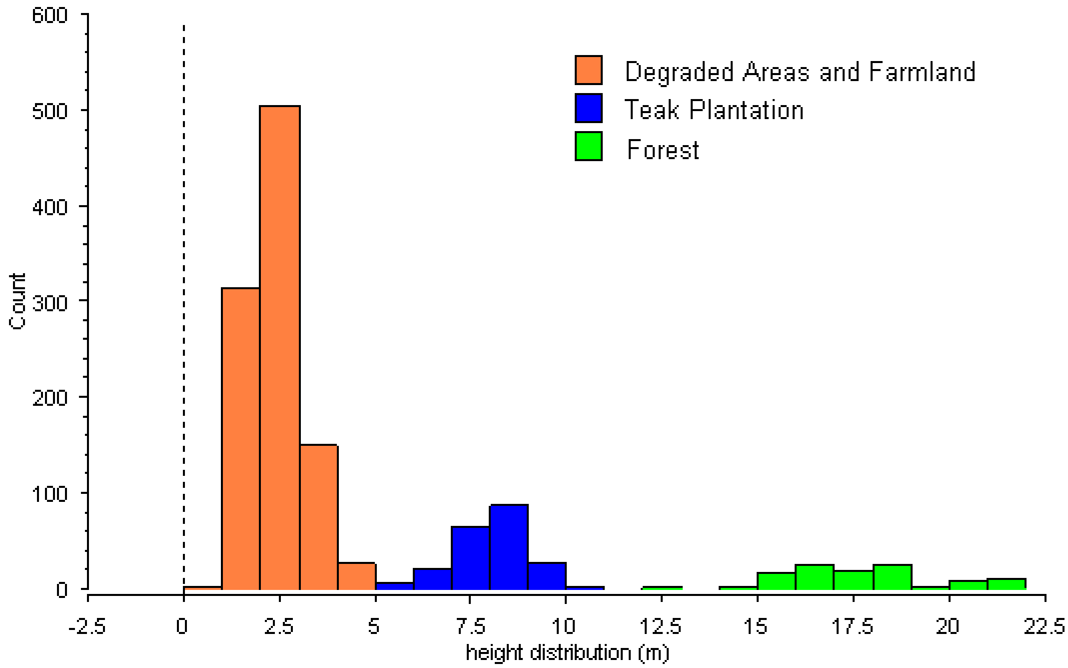

Figure 6: Vegetation height class distribution recorded in sample plots

There seems to be some similarity between the height class distributions recorded in degraded areas and farmland, teak planatation and forest. Generally, the younger and older individuals in all vegetation types were few and the size classes did not have the "normal" logarithmic representation (Richards 1998). No tree exceeded a height class of (>22.50m). In addition, forest trees had species of which individuals of less than 12.50m were almost absent. In comparison, most teak trees ranged in height of between 7m to 9m. In the case of degraded areas and farmland, there were few bare areas of vegetation height (<1.0m) and virtually no areas with vegetation higher than 5.0m. The height class range of (1.0m - 5.0m) represented most grassland, thickets and farms.

4.4 Diversity of Medium to Large Mammals

Four taxonomic groups, representing 13 Families, 17 Genera, and 18 Species were confirmed in the study area during the survey (Appendix 3). Forest vegetation ranked highest with a record of 18 species, followed by farmland (11), teak plantation (9) and then degraded areas (9).

Our sampling effort was more than the optimum sampling effort of about 100 transects required to determine the entire range of species in the study area (Figure 7).

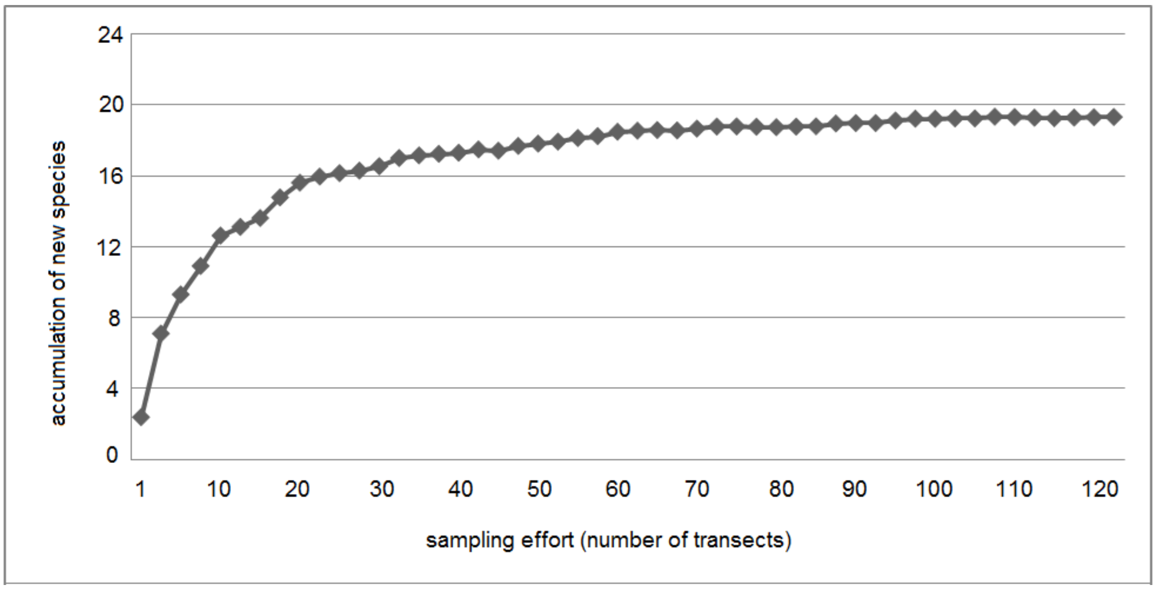

Figure 7: Species accumulation curve with sampling effort

The species accumulation curve flattened out approximately from the 100th transect onwards, suggesting that most species had been confirmed at that sampling intensity and that continuing sampling possibly resulted in no new species.

Forest vegetation was found to be richest and most diverse in terms of species when various richness and diversity indices were applied to the data (Table 3). Comparably, these indices were low in the farmland, degraded areas and teak plantation.

Table 3: Richness and diversity indices generated for vegetation types

	Richness index		Diversity indices			
Vegetation Type	Bootstrap mean	Bootstrap SD	Shannon mean	Shannon SD	Simpson mean	Simpson SD
Forest	104.23	3.78	4.21	0.11	88.10	1.28
Teak Plantation	33.46	7.18	3.14	0.22	47.92	3.80
Farmland	85.77	22.30	4.08	0.24	73.72	17.46
Degraded Ares	53.32	12.44	3.72	0.26	68.89	10.23

NB: SD is standard deviation

Rodents were widespread in the study area with grasscutters and brush-tailed porcupines representing the most abundant species (Figure 8, Appendix 3). Giant rats and ground squirrels were however restricted in abundance and distribution.

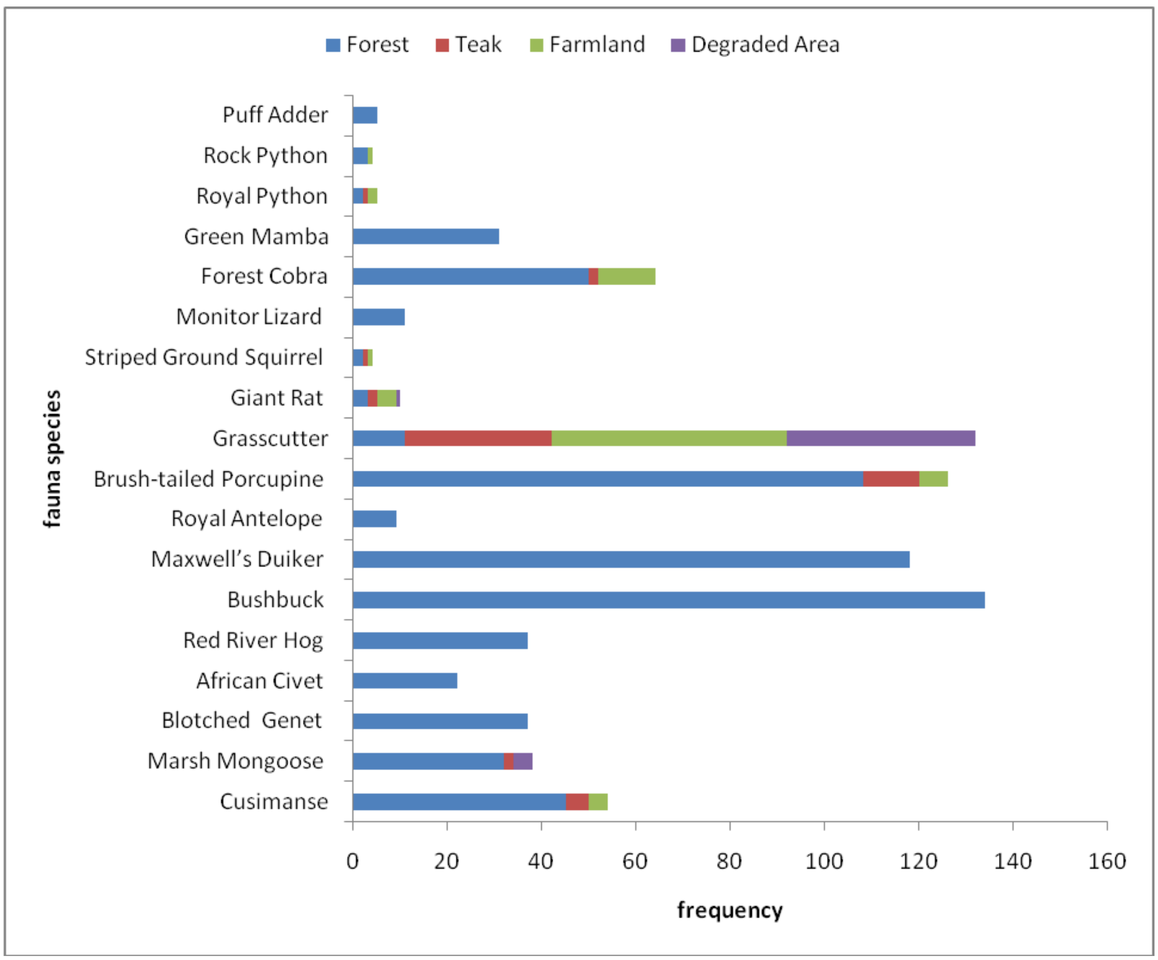

Figure 8: Abundance of animal signs recorded in the study area

Common carnivores were mongooses, civets and genets. Although, these species occurred in lower densities, they were largely restricted to forest vegetation with highest densities occurring in the riverine vegetation. Bushbucks were the most abundant ungulate followed by Maxwell's duiker whilst red river hogs and royal antelopes were comparably restricted to just a handful of sites. Apart from the forest cobra and green mamba, the activities of reptiles including the Nile monitor were among the least recorded (< 0.50 signs per km) animal signs.

No direct recordings of primate activity were made throughout the study. Nevertheless, a few hunters interviewed confirmed the presence of Demidoff's galago and Bossman's potto in a few sites, particularly in some of the forested vegetation.

Plate 3: Approaching a riverine forest

4.5 Density of Medium to Large Mammals

Eight hundred and forty-seven animal signs were recorded on 120 km transects (average encounter rate = 7.1 animal signs per km): 509 in forest vegetation, then farmland (148), degraded areas (132) and then teak plantation (58) (Appendix 3). Animal densities were significantly different (Kruskal-Wallis Test: H=31.335, d.f. = 3, $P<0.01$) between vegetation types.

Majority of animal signs (62%) consisting mostly of ungulates (73%), carnivores (21%) and reptiles (6%) were spotted in forest vegetation type (Jacobs' Preference Index: 0.83) (Figure 9) where canopy foliage gaps and density in the understorey stratum were lowest. In contrast, fewer (38%) animal signs were recorded in the remaining three vegetation types (Jacobs' Preference Index: 0.40) where canopy openness and understorey foliage density was greatest. Comparative analysis confirmed little overlap in species composition between the two land-use categories (Jaccard Similarity Index: 0.37).

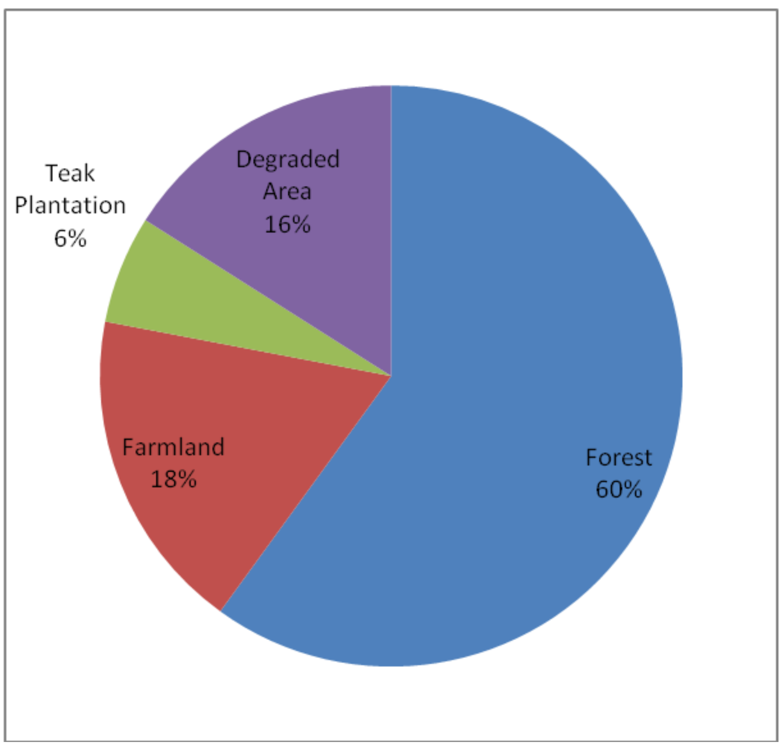

Figure 9: Percent encounter rate of animal signs in relation to vegetation types found on transects in the study area

Forests provided the highest encounter rates for most species; however, the activities of cane rats (commonly called grasscutters) were particularly recorded in farmlands and degraded areas compared to teak plantations. There was no significant difference in sign abundance between farmlands and degraded areas (Kruskal-Wallis Test: H=1.203, d.f. = 2, P>0.05). Ungulates and carnivores showed marked differences (H=31.054, d.f. = 5, P<0.01) in sign densities between forest sites and other vegetation types whilst there were no significant difference (H=9.137, d.f. = 5, P>0.05) for reptiles and rodents.

4.6 Avifauna, Small Mammals and Amphibians

4.6.1 Avifauna

Sixty (60) species, belonging to 23 genera and 22 Families were recorded on transects (Figure 4; Appendix 4). More than 10% of the species recorded belongs to the family Ploceidae. Other families included Muscicapiidae, Pycnonotidae and Columbidae with a record of 8% species each. The White-throated Bee-eater (relative abundance of 13.861), Black-winged Bishop (7.129), Red-eyed Dove (5.743), Common Bulbul (4.752), Zitting Cisticola (4.752), Viellot's black Weaver (3.960) and Grey-backed Cameroptera (3.960), were the most recorded and widespread bird species. The Families Alcedinidae and Accipitridae accounted for about less than 1% of the specimen recorded and produced the least number of species. Most bird species were recorded in the forest vegetation (38), followed by degraded areas (33), teak plantations (21) and then farmlands (19) (Figure 10).

White-throated Bee-eater recorded the highest number of individuals in the survey but was not recorded in teak plantations, possibly because of the low diversity of insects compared to other vegetation types (Larsen, 2005). The activity of the Family Accipitridae known to be birds of prey was much recorded on the degraded areas more than the forest interior. They presumably make frequent flights to the open areas due to improved visibility and as carnivores recorded their highest numbers in the grasslands.

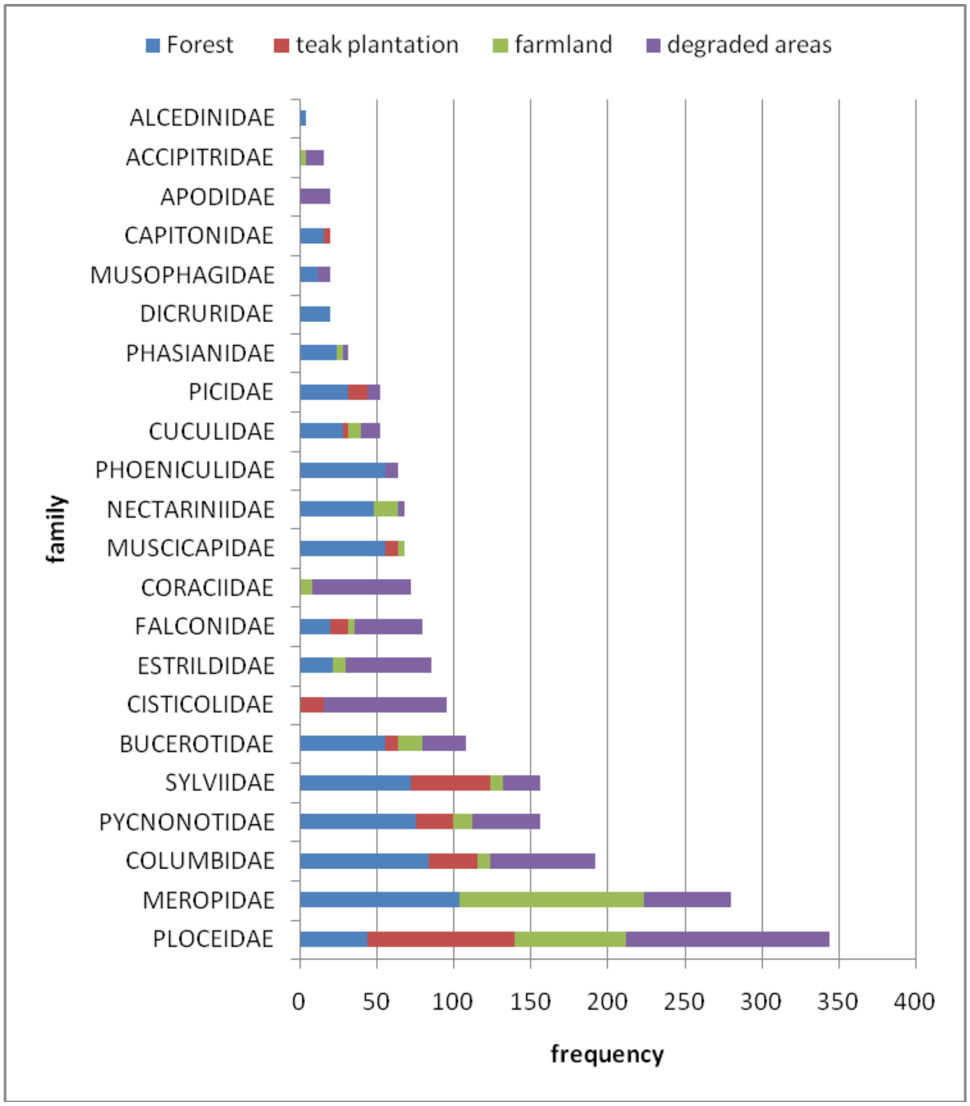

Figure 10: Abundance of bird family groups recorded in the various vegetation types

The mist net sampling protocol yielded four species (Red-collared Widowbird, Grey-headed Sparrow, Black headed Weaver and Collared Sunbird) that were not recorded on transects. It is worth mentioning that the transect and mist net sampling protocols recorded a different species on each sampling day. This is a good indication that the Tain II Forest Reserve may still hold an impressive number of birds.

4.6.2 Small Mammals

In total, individuals of four species of terrestrial small mammals were captured (Table 4). Due to the small numbers of captures, it was impossible to make realistic comparison between sites. Nevertheless, most rodent species seemed to favour forest vegetation.

Table 4: Small mammal sign densities per km recorded in the various vegetation types

Species	Forest	Teak Plantation	Farmland	Degraded Areas
Soricomorpha				
Crocidura grandiceps	1	0	0	1
Rodentia				
Proamys tullbergi	4	0	2	0
Mastomys natalensis	5	1	3	0
Lophuromys sikapusi	2	1	2	0
Total specimen	12	2	7	1
Total species	4	2	3	1

Both Tullberg's soft furred mouse (*Proamys tullbergi*) and the shrew *Crocidura gradiceps* are endemic to West Africa. The latter is ranked on the red list as Near Threatened (IUCN, 2012).

4.6.3 Amphibians

Fourteen frog species consisting of 62 individuals were found during the study in Tain II FR (Appendix 5). Amphibians were generally difficult to encounter in the study area and individuals encountered represented a variety of habitats including savanna, forest, or grassland vegetation types. It is expected that when the canopy in the teak plantation closes with time, a shift in species is likely to occur. Hence more closed canopy species will thrive as teak stands mature.

4.7 Factors Affecting Mammal Distribution

The distance to water sources, number of hunting signs, length of forest and distance from roads had the most significant effect on the density of mammals in the study area (Table 5). Length of farmland, degraded area and teak plantation did not appear to influence mammals density.

Table 5: Spearman rank correlation coefficients (r_s) between mammal sign density (pooled data) and a suite of human/ecological variables recorded on transects. Sample size is 120 transects.

Description of variable	r_s	P
Length of forest (km)	0.963	< 0.01
Distance from roads (km)	0.673	< 0.01
Distance to water sources (km)	- 0.844	> 0.01
Number of hunting signs	- 0.835	> 0.01
Length of farmland (km)	- 0.213	> 0.05 NS
Length of teak plantation (km)	- 0.075	> 0.05 NS
Length of degraded area (km)	- 0.125	> 0.05 NS

Each potential predictive variable (Table 6) was regressed against the individual species sign densities. However, there were no significant relationships at that level, hence, the data was further analysed by pooling the sign data for all the mammals recorded. For this level of analysis, all mammals signs were combined per transect and related to each of the potential predictive variables.

Length of forest was the strongest predictor of mammals density (r^2=0.931, P<0.01) when expressed as a polynomial (Figure 11). The regression model indicated that mammal density generally increased steadily with increasing length of forests.

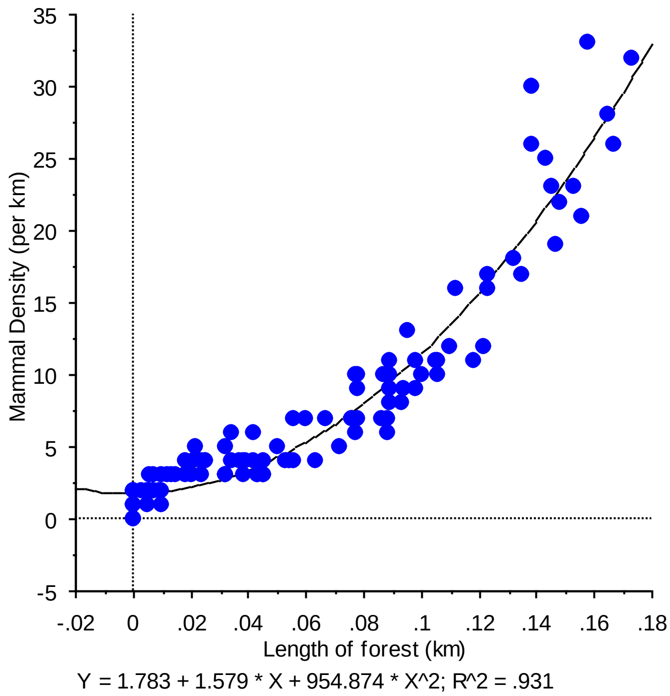

Figure 11: Relationship between pooled sign density and length of forest

Highest numbers of fauna species are found at maximum intensities of forest vegetation where tree cover is abundant. This positive relationship between mammal density and changing forest cover is consistent with the productivity hypothesis (Gaston, 2005).

The second step was to regress each of the other potential predictive variables in turn against the pooled sign data. The number of hunting signs in an area emerged as the second most important variable (r^2=0.806, P<0.01) determining mammal density in polynomial model (Figure 12).

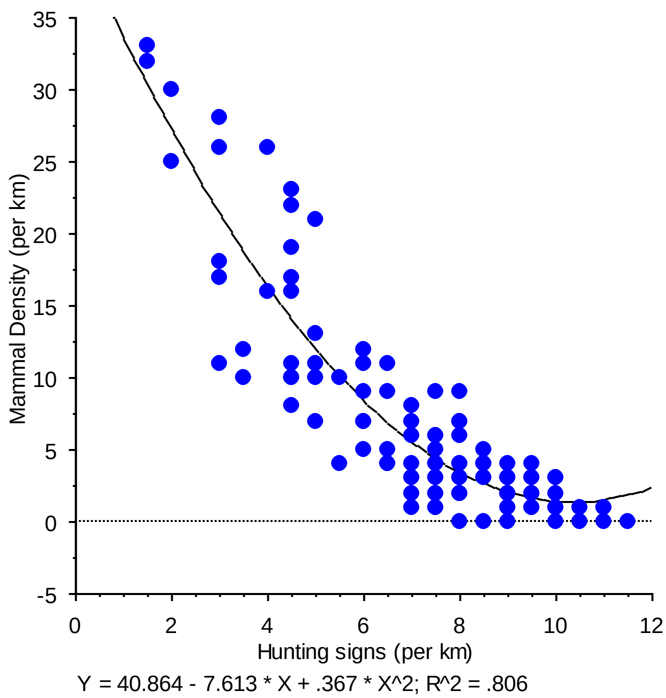

Figure 12: Relationship between pooled sign density and hunting signs per km

The regression model generally showed decreasing mammal density with increasing hunting activity. Lowest numbers of mammals are found at maximum intensities of hunting activity where wildlife persecution is highest. This negative relationship between mammal abundance and increasing human influence is consistent with the the ecosystem-stress hypothesis (Rapport *et al.*, 1985).

Signs of hunting were relatively low in the study area surveyed. One hundred and eighty (180) indices of hunting activity were encountered on 120 km of transects combined (average of 1.5 signs per transect). These consisted mostly of rat hunting activities (51%) (Figure 13). Other indices were; wire snares (27%) and empty cartridges cases (22%). No gunshots were heard throughout the survey. Most of the hunting signs were found in forest vegetation (52%) and farmland (31%). The rest were found in teak plantation (13%) and degraded areas (4%).

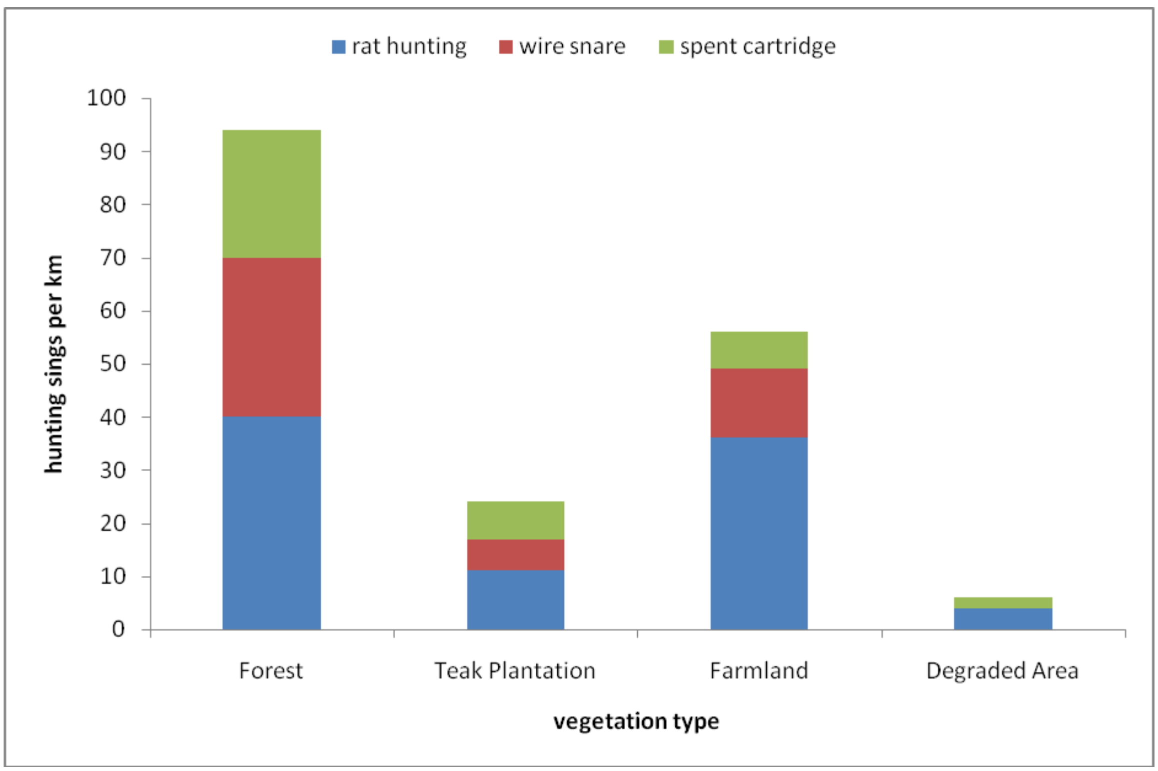

Figure 13: Abundance of hunting signs recorded in the four main vegetation types

Proximity to roads then emerged as the third most important variable (r^2=0.723, P<0.01) influencing mammal density, again in polynomial model (Figure 14). The regression model indicated that mammal density generally increased steadily with increasing distance from forest roads.

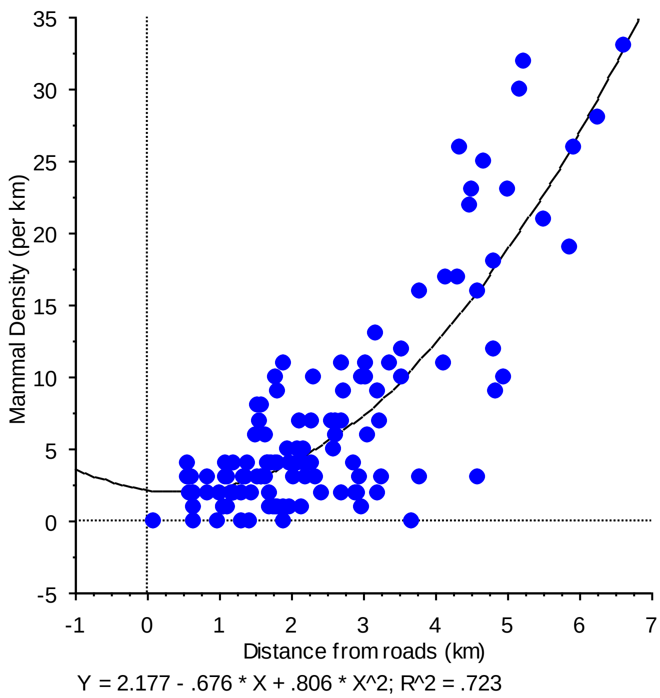

Figure 14 Relationship between pooled sign density and distance from roads

Highest density of mammals are found at maximum distance from forest roads where vehicular noise and human disturbance is lowest. This positive relationship between mammal density and changing distance from forest roads is consistent with the productivity hypothesis (Gaston, 2005).

Proximity to waterbodies also emerged as the fourth most important variable (r^2=0.699, P<0.01) influencing mammal density, again in polynomial model (Figure 15). The regression model generally showed decreasing mammal density with increasing distance to waterbodies. Lowest numbers of mammals are found at maximum distance from waterbodies where habitat condition may be unsuitable. This negative relationship between mammal abundance and increasing unsuitable influence is consistent with the the ecosystem-stress hypothesis (Rapport *et al*., 1985).

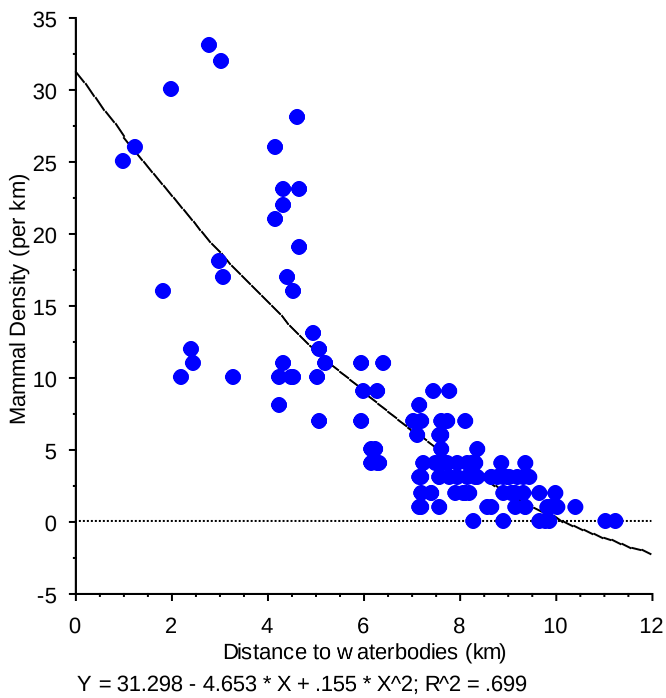

Figure 15: Relationship between pooled sign density and distance to water sources

These models allow us to predict the density of mammal signs in an area given the number of available variables recorded in a particular area. Such changes in mammal community structure can have potentially broad effects on forest ecosystems via alterations in predation, herbivory, and seed dispersal.

Roads had significant negative impacts on mammal species, presumably as a result of increased hunting activity near roads (r^2=0.488, P<0.01) (Figure 16). Highest levels of hunting activity occurred close (less than 3 km) to roads and *vice versa*.

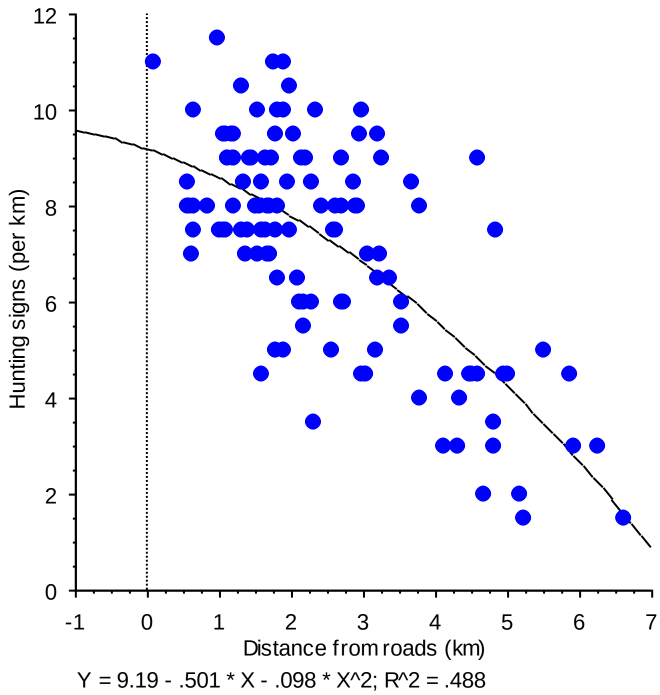

Figure 16: Relationship between hunting activity and distance from roads

4.8 Water Quality Analysis

Forest degradation in Tain II FR is very extensive and most riverine forests have been affected. Water quality analyses on waterbodies indicate low quality of parameters such as pH, turbidity, dissolved oxygen (DO), conductivity and nitrate content (Table 6).

The proximity of contaminant sources to most water bodies is an issue of concern. Most settlements in the north and northwest of Tain II FR are close to the Tain River and its main tributaries. In many cases the team observed rubbish disposal sites, charcoal production sites, farming activities including irrigating and the activities of Fulani herdsmen close to these waterbodies. Hence, the inflow of artificial fertilizer (23:15, 15:15, urea, sulphate of ammonia) and pesticides which most farmers depend on are a potential source of contamination to the water bodies. These potentially degrade biodiversity in general and pose serious threats to the communities that directly depend on the waterbodies for survival.

Table 6: Water quality indicator measurements

Parameter	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
PH	6.70	6.77	6.81	6.74	6.74	6.75
Turbidity (NTU)	5. 87	1.21	2.22	5.64	6.12	5.76
Dissolved Oxygen/(m/l)	1.23	5.66	6.23	2.11	2.41	1.43
Conductivity (µs/cm)	99.00	52.00	48.00	120.00	98.00	112.00
Nitrate (m/l)	23.20	21.30	21.10	24.20	23.40	26.40

4.9 Other human activities

Logging for timber, charcoal production and clearing of forests for new farms were a common threat in the study area. Illegal chain- sawing and charcoal production activities for instance, were relatively higher in riverine forests along the Tain River, especially in the western portions of Tain Forest Reserve towards Meremano. The activities of Fulani herdsmen and their cattle were also encountered in the southern sections of the reserve in the Kotaa area. However, these activities are perceived by locals to be less destructive compared to logging and clearing of forests, cattle grazing sites were frequently sighted close to streams and waterbodies thus polluting them. Furthermore, grazing areas did not have a positive influence on mammal density.

Plate 4: The activities of Fulani herdsmen and their cattle

SECTION FIVE

5.0 DISCUSSION

Although it is difficult to count animals accurately in the forest/farm bush mosaic that exist in the study area, the results of this survey indicate that censusing these species by sign counts can provide an indication of abundance for comparison of trends in future surveys. The use of sign counts for elusive species may be useful as an index of abundance (Koster and Hart, 1988) and a cheap and simple method for detecting trends in wildlife population numbers. Furthermore, the line transects method (Buckland *et al*., 1993) is very well suited for mammal sign surveys.

Ungulates including some antelope species are adapted to secondary or colonising forests, thereby persisting or increasing (Struhsaker and Oates, 1995) and do not appear to have suffered to the same extent as primates or larger carnivores due to hunting and commercial logging activities. Most antelope populations are assessed as stable or increasing in Ghanaian forests (Table 6-3; IUCN/SSC, 1996). Species such as bushbucks, Maxwell's duikers and royal antelopes may also be favoured by the opening of mature forest and an increase in secondary growth. In addition, most antelopes, especially duikers, can probably withstand hunting pressure to a greater degree than the more susceptible primate species. Nevertheless, hunting activities might have reduced the large ungulate populations in comparison to past levels of abundance.

The generally low record of reptile signs and particularly of amphibians in the study area corresponds well to conditions that exist in degraded habitats that are often plagued by frequent raging forest fires and excessively high human pressure.

5.1 Summary of status of key wildlife species

1. Primates: Primates were until in the recent decade common and widespread in Tain II Forest Reserve. While the total range in other protected areas may be still extensive, loss of range and habitat as result of fires, rapidly increasing human populations, agriculture and hunting activities in the study area might have confined the remaining animals to vestigial isolated populations. Based on field interviews, we have classified primates to be generally rare in the study area. The activities of prosimians like Demidoff's galago (*Galagoides demidoff*) and potto (*Perodicticus potto*) may be comparatively higher in some forest vegetation. Both species are classified as Least Concern in the IUCN Red List (IUCN, 2012).

2. Carnivores: The most prominent carnivores were mongooses (*Crossarchus obscurus*, *Atilax paludinosus*), followed by genets (*Genetta* sp.) and then civets (*Civettictis civetta*). Relatively uncommon within the study area, all these species are vigorously hunted. The civets and mongooses are especially vulnerable to hunting dogs, which may pose a threat in most localities. On the other hand, tree pangolins (*Phataginus spp.*) and most large carnivores including leopards (*Panthera pardus*) may be locally extinct.

3. Bushbuck (*Tragelaphus scriptus*): The bushbuck's ability to withstand heavy hunting pressure and adapt to secondary vegetation and human-dominated landscapes has enabled it to persist locally in suitable habitats throughout Ghana (IUCN/SSC, 1996). Bushbucks are relatively common and occurred in most of the study area in appreciable numbers.

4. Maxwell's Duiker (*Cephalophus maxwelli*): This species withstands heavy offtake by hunters and remain common throughout its range in southwestern and central Ghana, including areas of primary moist lowland forest, secondary vegetation, dense thickets and farm bush (Wilson, 1994). It was however uncommon in the study area and has probably been affected by the destruction of primary forests.

5. Black Duiker (*Cephalophus niger*): The black duiker remains widespread and common in protected areas, where it is found in primary and secondary forest. However, it does not appear to have adapted well in the study area and to existing hunting regimes. Overall, it was rare and generally not represented in the study area.

6. Bay Duiker (*Cephalophus dorsalis*): The Bay duiker remains common in the forests of southwestern Ghana, but also does not appear to tolerate hunting pressures or adapt well to disturbed forest, thickets, farm bush and has become very rare outside protected areas (Wilson, 1994). It has disappeared from many of the marginal parts of its range, including most of the study area. Its distribution may be more limited than black duikers.

7. Royal Antelope (*Neotragus pygmaeus*): A species of the southwestern forest zone and outlying forest patches, including secondary vegetation, the royal antelope may still occur widely. However, it was difficult to record the signs of this very small, secretive antelope. Its signs were rare but information gathered from interviews projected a thriving population.

8. Red river hog (*Potamochoerus porcus*): Wherever forests have disappeared, this species becomes scarce and it is now rare outside protected areas in Ghana. A few individuals may occur in the riverine forests around the Tain River but might have disappeared from the remaining vegetation types.

9. Rodents: Common rodents whose activities were spotted throughout the study area were Brush-tailed Porcupines (*Antherurus africanus*) and Cane Rats (*Thryonomys swinderianus*). Squirrels (*Euxerus erythropus*) and Giant Rats (*Cricetomys emini*) were however rare. There was no record of the activities of Pel's Anomalure (*Anumalurus peli*) and African Giant squirrel (*Protoxerus stangeri*).

5.2 Factors Affecting Distribution of Mammals

Four variables emerged as determinants of mammal distribution in the study area. Analysis of mammal sign distribution indicated that water availability accounted for a large proportion of the variation in animal numbers. Danquah, (2007) has reported a positive correlation between mammal abundance and number of water sources in Bia and in most cases, scarcity of water in an area and animals' affinity to water becomes the central theme for such distribution. Water will have a seasonal effect on animals with a stronger influence in the dry season (Danquah, 2007).

Areas around most water bodies (rivers, ponds, swamps, etc.) were associated with very thick riverine vegetation (forest) which was very difficult to traverse and hence likely to be avoided by most hunters. Therefore, whilst the pools of water provide water for the animals in general, the type of vegetation existing in such areas offered refuge and protection. The length of forest in an area therefore comes as no surprise as the most important variable in determining mammal distribution and densities. This implies that maintenance of adequate forest fragments within the study area may be a viable approach to improving biodiversity levels in a sustainable forest management that also brings economic value to Form Ghana. Similarly, Barnes *et al*. (1995) suggested that the occurrence of secondary patches within forests creates a more favourable habitat that far outweighs the negative effects of loss of mature fruiting trees. Holbech (1996), Wilkie & Finn (1990) and Wilkie (1989) have also shown the importance of secondary patches in forest habitat mosaics as good environments for maintaining high game production and diversity even under relatively high hunting pressures.

Mammal density was also significantly affected by hunting activity. Almost all the remaining forest patches which should have provided refuge for animals had comparably higher hunting intensity than the other vegetation types. Unfortunately, few sites in the study area still have reasonable forest cover to serve as animal habitat. Gradual loss of forest cover and wildlife due to increasing human activities may be an inevitable consequence for the area if an immediate conservation strategy is not implemented.

Though hunting activity in the study area seem relatively low, it is important to note that it is still high compared to 0.44 and 0.76 activities per km recorded within Ankasa and Bia respectively (Danquah, 2007) or in the Kakum Conservation Area (0.63 activities per km; ARG 2004). Form Ghana should endeavour to reduce hunting activity in the area because unlike in the other protected areas, Tain II FR is without wildlife guard posts, hence less patrolled to safeguard animal security.

Even in the sparsely populated study area, roads had a strong negative impact on the local abundance of fauna. Roads could be a far more formidable barrier to strictly arboreal species, including primates. Virtually none of the roads we encountered had overhead canopy connections that would permit road-crossing movements by the strictly arboreal species. Moreover, the inhibitory effects of roads on movements of larger animals will surely increase both as human activity and local hunting pressure rise (Peres, 2000; Fa *et al*., 2005) (Figure 16) and as road width increases. Since the general impact of roads on fauna is linked to local hunting pressure, we expect the magnitude of road avoidance by animals to generally decrease with increase and effective regulation of illegal human activities in the study area by Form Ghana. We had expected that the length of farmlands and degraded areas would emerge as an important variable. Although, its effect was not significant on animal distribution, Barnes *et al*. (1995) showed a much greater influence.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

6.1.1 Biodiversity Priority Hotspots

Important features in the study area are water bodies, forest patches, riverine vegetation and swamps. These habitats were found to be richest in biological abundance and diversity. Fortunately, these features are generally protected through various legislations and considered “no go areas” hence legally; communities cannot grow any crop there.

6.1.2 Threats

It is evident that the abundance of animal species within the study area is partly determined by human activities. Wildlife habitat (forest) continues to be converted to farmlands in most sites. Very little forest remains in other places, particularly around the Tain River. In the Meremano and Kotaa/Nemesua areas, the remaining forest is especially threatened from encroaching teak plantations and activities of charcoal burners. The tragedy of the situation is that while struggling to feed their families, farmers are creating the conditions that deter animals therefore; the study area is increasingly at risk of losing its wildlife.

While hunting should be regulated in the area, enforcing this regulation is difficult due to already set precedents and strong community reliance on forest resources for economic activities especially NTFP gathering. One may accept the inevitability of the activities of hunters in the study area; nevertheless, it may be possible to take measures to reduce the risk. If nothing is done now to salvage the situation, the status of wildlife within the study area is likely to deteriorate in the future.

Chromolaena odorata an invasive weed (commonly called Acheampong) was identified as a threat to wildlife habitat. A C*hromolaena* dominated landscape is mostly less diverse. Most animals do not feed on it; however, it may serve as cover for them.

6.1.3 Animal Densities

Animal densities were generally low, except for a few ungulates and other opportunistic species like rodents whose activities were relatively widespread. Most carnivores were confined to the forested areas within the study area. No activity of key animals like primates and large mammals was encountered in study area indicating a possibility of local extinction.

6.2 RECOMMENDATIONS

The duration of the study was short. Hence, some aspects of seasonality on habitat usage in the study area as well as the phenomenon of habitat factors need further investigations. In addition, much work entails convincing some members of the local populace to agree to regulate forest clearing and hunting activities. The following short and long-term management strategies have been discussed in this light.

6.2.1 Regulating Human Activities

The long-term viability of Tain II FR will depend on earning the goodwill of all community members. Form Ghana may need to be creative in its attempt to control human activities in the study area because some community members have come to rely upon such reserves for economic activities especially farming and NTFP gathering. Education on the importance of the reserve and existence of the water bodies and the factors which affect this existence should be intensified. High migrant settlement and activity in the area may pose a challenge to management. Thus full government backing at the local and national level for this type of effort would ensure its success.

6.2.2 Intensively Managed Refuges

With the establishment of the severe negative effect on the water bodies due to anthropogenic activities, it is recommended that immediate remedial actions; re vegetation using native plant species, reconstruction of river pathways, and shading be under taken. There is the need to establish intensively managed wildlife refuges within these areas, where absolutely no roads or human activity occurs. Riverine vegetation, swamps and habitat around ponds and rivers should be given precedence because of the high biodiversity that exist in those places and the prohibitive farming and hunting prospects associated with them. Such refuges, when identified, need to be expanded and linked-up in order to safeguard their integrity and should be priority in tree planting exercises. Creating and subsequently expanding intensively managed refuges within the study area may be an effective way of curtailing unregulated hunting and forest clearing activities whilst improving habitat to allow wildlife numbers to increase.

6.2.3 Enrichment planting of trees

Whilst focusing on the rehabilitation of riverine forests (30 to 60 meters around rivers), further research should consider the species composition, structure and functions of the trees to be considered for enrichment planting. The trees should serve as a source of attraction of fauna. Hence, it is also important to have detailed information on the diet of the major fauna in the study area.

6.2.4 Wildlife density and distribution

It is strongly recommended to conduct the same kind of research in both seasons. This will allow seasonal comparison of wildlife distribution to give an insight into their habitat usage. Again, habitat factors that affect them seasonally will be known. This information is vital for their complete conservation and management.

6.2.5 Wildlife monitoring

Inventory information obtained by the consultants and indeed the entire document is strength of FORM Ghana in undertaking the plantation initiative. Hence, monitoring animal densities and distribution should be done regularly to assess the effectiveness of Form Ghana plantation activities on animal populations. One design will consist of a number of trails that could be systematically established to cover both high and low animal density zones. Each trail could be sampled twice per year. Ideally, this kind of sampling should be done continuously and at the same time of day. It will be one way of ensuring that at least animals are monitored on regular basis. Along each trail, counts would be made of the number of encounters with animals and their signs.

6.2.6 Potential of Plantation Activities

The importance of forest patches in plantation mosaics provides a good environment for maintaining high game production and diversity even under relatively high hunting pressures. Consequently, the relationship between length of forest and animal densities itself is an opportunity that stands the company in good stead to enjoy support from many sides, especially government, ecologists and land owners. Additionally, Government policy support for plantation as a strategy for recovery of degraded forest is a source of strength for FORM Ghana.

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APPENDICES

Appendix 1: List of the members of the faunal survey team

Team Composition

William Oduro	(Consultant) Team Leader	KNUST, Ghana
Emmanuel Danquah	Technician	KNUST, Ghana
Mac E. Nutsuakor	Technician	KNUST, Ghana
Joseph Owusu	Technician	KNUST, Ghana
Nana Owusu Ansah	Technician	FC, Ghana
Nicholas Boamah	Technician	FC, Ghana
Albert Kyereh-Diabor	Technician	FC, Ghana
Bature Ali	Technician	Accra, Ghana
Gilbert Osei	Technician	Kumasi, Ghana
Edward Akwasi Addae	Driver	KNUST, Ghana
Hafiz Iddrisu	Driver	Kumasi, Ghana
Kofi Owusu Gyan	Labourer	Berekum, Ghana
Alex Nketia Mensah	Labourer	Berekum, Ghana

Appendix 2: Density of flora species in the study area

Family/Scientific Name	Local Name	Life Form	Density (trees/ha)	Relative Density	Local Status
ASTERACEAE (COMPOSITEAE)					
Chromolaena odorata	Acheampong	Herb	19%	>100	Widespread
ANACARDIACEAE					
Anacardium occidentale	Cashew	Tree	12	0.22	Rare
BIGNONIACEAE					
Newbouldia leavis	Sesamasa	Tree	60	1.10	Uncommon
Spathodea campanulata	Kuokuonisuo	Tree	20	0.37	Rare
COMBRETACEAE					
Terminalia avicennoides	Petrii	Tree	20	0.37	Rare
Terminalia glaucascens	Ongo	Tree	8	0.15	Rare
Terminalia superba	Ofram	Tree	8	0.15	Rare
Anogeissus lerocarpus	Kane	Tree	40	0.74	Rare
CAESALPINIOIDEAE					
Afzelia africana	Paopao	Tree	12	0.22	Rare
EUPHORBIACEAE					
Alchornea cordifolia	Gyama	Shrub	16	0.29	Rare
Mallotus oppositifolius	Satadua	Shrub	28	0.52	Rare
Mareya micrantha	Odubrafo	Tree	4	0.07	Rare
Margaritaria discoidea	Pepea	Tree	44	0.81	Rare
Ricinodendron heudelotii	Wama	Tree	32	0.59	Rare
FABACEAE (LEGUMINOSAE-MIM)					
Albizia adianthifolia	Pampena	Tree	196	3.61	Abundant
Albizia ferruginea	Ewiemfo Samina	Tree	56	1.03	Uncommon
Albizia zygia	Okro	Tree	44	0.81	Rare
Centrosema plumieri	Centrosema	Herb	5%	>100	Widespread
Griffonia simplicifolia	Kagya	Shrub	32	0.59	Rare
Erythrophleum suaveolens	Potrodom	Tree	36	0.66	Rare
LEGUMINOSAE-CAES.					
Anthonotha macrophylla	Totoro	Tree	28	0.52	Rare
LEGUMINOSAE-MIM					
Piptadeniastrum africanum	Dahoma	Tree	4	0.07	Rare
Senna siamea	Cassia	Tree	32	0.59	Rare
Tetrapleura tetraptera	Prekese	Tree	24	0.44	Rare

LEGUMINOSAE-PAP					
Dalbergia hostilis	Wota	Tree	20	0.37	Rare
Milletia zechiana		Shrub	44	0.81	Rare
Millethia rhodantha	Tetetoa	Shrub	44	0.81	Rare
Mucana pruriensis	Apea	Shrub	4	0.07	Rare
MALVACEAE(BOMBACACEAE)					
Ceiba pentandra	Onyina	Tree	24	0.44	Rare
Bombax brevicuspe	Onyina Koben	Tree	40	0.74	Rare
Bombax buonopozense	Akonkodie	Tree	24	0.44	Rare
MALVACEAE (STERCULIACEAE)					
Cola gigantea	Watapuo	Tree	124	2.28	Common
Cola milleuii	Ananse Dodewa	Shrub	36	0.66	Rare
Mansonia altissima	Oprono	Tree	8	0.15	Rare
Sterculia rhinopetala	Wawabima	Tree	8	0.15	Rare
Sterculia tracagantha	Sofo/Foto	Tree	36	0.66	Rare
Triplochiton scleroxylon	Wawa	Tree	40	0.74	Rare
MELIACEAE					
Khaya anthotheca	White Mahogany	Tree	16	0.29	Rare
Trichilia prieureana	Kakadikro	Tree	20	0.37	Rare
MORACEAE					
Antiaris toxicaria	Kyenkyen	Tree	80	1.47	Uncommon
Ficus anomani	Odoma	Tree	24	0.44	Rare
Ficus capensis	Kotre Amforo	Tree	20	0.37	Rare
Ficus exasperata	Nyankyere	Tree	308	5.67	Widespread
Morus mesozygia	Wonton	Tree	56	1.03	Uncommon
Milicia excelsa	Odum	Tree	40	0.74	Rare
PALMAE					
Elais guineense	Abe	Tree	44	0.81	Rare
POACEAE					
Pennisetum purpureum	Elephant grass	Grass	26%	>100	Widespread
Pannicum maximum	Guinea grass	Grass	40%	>100	Widespread
SAPINDACEAE					
Blighia sapida	Akyee	Tree	40	0.74	Rare
Lecaniodiscus cupanioides	Dwendwera	Shrub	20	0.37	Rare
Paullinia pinnata	Toatin	Herb	28	0.52	Rare
ULMACEAE					
Celtis mildbraedii	Esafufuo	Tree	16	0.29	Rare
Trema orientalis	Sesea	Tree	56	1.03	Uncommon

SAPOTACEAE					
Aningeria altissima	Asamfinanini	Shrub	56	1.03	Uncommon
Chrysophyllum delevoyi	Akasaa	Tree	16	0.29	Rare
GENTIANACEAE					
Anthocleista vogelii	Bontodie	Tree	36	0.66	Rare
APOCYNACEAE					
Holarrhena floribunda	Sese	Tree	64	1.18	Uncommon
RUBIACEAE					
Morinda lucida	Konkroma	Tree	12	0.22	Rare
Nauclea latifolia	Sresokusia	Shrub	16	0.29	Rare
CECROPIACEAE					
Myrianthus arboreus	Nyankuma	Tree	20	0.37	Rare
VERBENACEAE					
Tectona grandis	Teak	Tree	3240	59.60	Widespread
Number of Species	61				

Relative Density: 0.00-0.99 (rare); 1.00-1.99 (uncommon); 2.00-2.99 (common); 3.00-3.99 (abundant); =>4.00 (widespread)

NB: Density for herbs and grasses are estimated in percentages and hence, have not been included in the relative density calculations

Appendix 3: Mean animal encounter rates per km for the main vegetation types in study area

Common Name	Scientific Name	Forest	Teak Plantation	Farmland	Degraded Areas	Mean Encounter Rate	Relative Abundance	Local Status
CARNIVORES	*CARNIVORA*							
Mongooses	***Herpestidae***							
Cusimanse	*Crossarchus obscurus*	043	005	004	002	0.45	0.064	Rare
Marsh Mongoose	*Atilax paludinosus*	032	002	000	004	0.32	0.045	Rare
Genets and Civets	***Viverridae***							
Blotched Genet	*Genetta tigrina*	037	000	000	000	0.31	0.044	Rare
African Civet	*Civettictis civetta*	022	000	000	000	0.18	0.026	Rare
UNGULATES	*UNGULATA*							
EVEN-TOED UNGULATES	*ARTIODACTYLA*							
Pigs	***Suidae***							
Red River Hog	*Potamochoerus porcus*	037	000	000	000	0.31	0.044	Rare
Bovids	***Bovidae***							
Bushbuck	*Tragelaphus scriptus*	102	000	015	017	1.12	0.158	Common
Antelopes	***Antelopinae***							
Maxwell's Duiker	*Cephalophus maxwelli*	100	000	005	013	0.98	0.139	Uncommon
Royal Antelope	*Neotragus pygmaeus*	009	000	000	000	0.08	0.011	Rare

RODENTS	*RODENTIA*							
Porcupines	***Hystricidae***							
Brush-tailed Porcupine	*Antherurus africanus*	058	010	035	023	1.05	0.149	Common
Cane Rats	***Thryonomyidae***							
Grasscutter	*Thryonomys swinderianus*	004	031	050	047	1.10	0.156	Common
Pouched Rats	***Cricetomyinae***							
Giant Rat	*Cricetomys gambianus*	003	002	004	001	0.08	0.012	Rare
Squirrels	***Sciuridae***							
Striped Ground Squirrel	*Euxerus erythropus*	002	001	001	000	0.03	0.005	Rare
REPTILES	*REPTILIA*							
Varanus	***Varanidae***							
Monitor Lizard	*Varanus niloticus*	011	000	000	000	0.09	0.013	Rare
Cobras	**Elapidae**							
Forest Cobra	*Naja melanoleuca*	018	002	024	020	0.53	0.076	Uncommon
Green Mamba	*Dendroaspis viridis*	021	004	007	005	0.31	0.044	Rare
Pythons	**Pythonidae**							
Royal Python	*Python regius*	002	001	002	000	0.04	0.006	Rare
Rock Python	*Python sebae*	003	000	001	000	0.03	0.005	Rare
Adders	**Viperidae**							
Puff Adder	*Bitis arietans*	005	000	000	000	0.04	0.006	Rare
Number of species		18	09	11	09			

Mean Encounter Rate: 0.00-0.49 (rare); 0.50-0.99 (uncommon); 1.00-1.49 (common); 1.50-1.99 (abundant); =>2.00 (widespread)

Appendix 4: Mean bird encounter rates per km for the main vegetation types in study area

Common Name	Scientific Name	Forest	Teak Plantation	Farmland	Degraded Areas	Mean Encounter Rate	Relative Abundance	Local Status
HORNBILLS	*BUCEROTIDAE*							
African Pied Hornbill	*Tockus fasciatus*	028	008	008	020	1.60	3.168	Abundant
African Grey Hornbill	*Tockus nasutus*	028	000	008	008	1.10	2.178	Common
FRANCOLINS	*PHASIANIDAE*							
Ahanta Francolin	*Francolinus ahantensis*	024	000	004	004	0.80	1.584	Uncommon
KINGFISHERS	*ALCEDINIDAE*							
African Pygmy Kingfisher	*Ispidina picta*	004	000	000	000	0.10	0.198	Rare
ROLLERS	*CORACIIDAE*							
Blue-throated Roller	*Eurystomus gularis*	000	000	008	000	0.20	0.396	Rare
Broad-billed Roller	*Eurystomus glaucurus*	000	000	000	064	1.60	3.168	Abundant
DRONGOS	*DICRURIDAE*							
Fork-tailed Drongo	*Dicrurus adsimilis*	008	000	000	000	0.20	0.396	Rare
Shining Drongo	*Dicrurus atripennis*	012	000	000	000	0.80	1.584	Uncommon

WOODPECKERS	*PICIDAE*							
Fire-bellied Woodpecker	*Dendropicos pyrrhogaster*	016	000	000	008	0.60	1.118	Uncommon
Cardinal Woodpecker	*Dendropicos fuscescens*	016	012	000	000	0.70	1.386	Uncommon
FLYCATCHERS	*MUSCICAPIDAE*							
Black and White Flycatcher	*Ficedula hypoleuca*	008	000	000	000	0.20	0.396	Rare
Red-bellied Paradise Flycatcher	*Tersiphone rufiventer*	024	000	000	000	0.60	1.188	Uncommon
Paradise Flycatcher	*Tersphone viridis*	016	008	000	000	0.60	1.188	Uncommon
Northern Black Flycatcher	*Melaenornis edolioides*	008	000	000	000	0.20	0.396	Rare
Pale Flycatcher	*Bradornis pallidus*	000	000	004	000	0.10	0.198	Rare
BULBULS AND GREENBULS	*PYCNONOTIDAE*							
Common Bulbul	*Pycnonotus barbatus*	032	020	012	032	2.40	4.752	Widespread
Honeyguide Greenbull	*Baeopogon indicator*	004	000	000	000	0.10	0.198	Rare
Little Greenbul	*Andropadus virens*	016	004	000	004	0.60	1.188	Uncommon
Icterine Greenbul	*Phyllastrephus icterinus*	008	000	000	004	0.30	0.594	Rare
Grey-headed Bristlebill	*Bleda canicapilla*	016	000	000	004	0.50	0.990	Uncommon
Simple leaflove	*Chlorocichla simplex*	000	000	000	016	0.40	0.792	Rare
CUCKOOS AND COUCALS	*CUCULIDAE*							
Klaas Cuckoo	*Chrysococcyx klaas*	000	004	004	008	0.40	0.792	Rare
Senegal Coucal	*Centropus senegalensis*	012	000	000	004	0.40	0.792	Rare
Yellowbill	*Ceuthmochares aereus*	016	000	004	000	0.50	0.990	Uncommon

SUNBIRDS	*NECTARINIIDAE*							
Collared Sunbird	*Anthreptes collaris*	004	000	000	000	0.10	0.198	Rare
Copper Sunbird	*Cinnyris cupreus*	008	000	004	004	0.40	0.792	Rare
Little Green Sunbird	*Nectarinia seimundi*	012	000	000	000	0.30	0.594	Rare
Superb Sunbird	*Nectarinia superba*	024	000	012	000	0.90	1.782	Uncommon
BEE-EATERS	*MEROPIDAE*							
White-throated Bee-eater	*Merops albicollis*	104	000	120	056	7.00	13.861	Widespread
PIGEONS AND DOVES	*COLUMBIDAE*							
Green Fruit Pigeon	*Treron calva*	024	000	000	000	0.60	1.188	Uncommon
Blue-headed Wood Dove	*Turtur brehmeri*	000	000	000	004	0.10	0.198	Rare
Tambourine Dove	*Turtur tympanistria*	012	000	000	012	0.60	1.188	Uncommon
Laughing Dove	*Streptophelia senegalensis*	000	008	000	016	0.60	1.188	Uncommon
Red-eyed Dove	*Streptophelia decipens*	048	024	008	036	2.90	5.743	Widespread
TURACOS/PLANTAIN-EATERS	*MUSOPHAGIDAE*							
Green Turaco	*Tauraco persa*	012	000	000	008	0.50	0.990	Uncommon
BARBETS AND TINKERBIRDS	*CAPITONIDAE*							
Yellow-billed Barbet	*Trachyphonus purpuratus*	000	004	000	000	0.10	0.198	Rare
Red-rumped Tinkerbird	*Pogoniulus atroflavus*	016	000	000	000	0.40	0.792	Rare

WEAVERS AND MALIMBES	*PLOCEIDAE*							
Black headed Weaver	*Ploceus melanocephalus*	000	008	000	000	0.20	0.396	Rare
Viellot's black Weaver	*Ploceus nigerrimus*	000	040	000	040	2.00	3.960	Widespread
Black-winged Bishop	*Euplectes hordeaceus*	000	016	060	068	3.60	7.129	Widespread
Red-headed Bishop	*Anaplectes melanotis*	024	000	008	000	1.10	2.178	Common
Northern Red Bishop	*Euplectes franciscanus*	000	020	000	000	0.50	0.990	Uncommon
Pin-tailed Whydah	*Vidua macroura*	020	012	000	012	1.10	2.178	Common
Grey-headed Sparrow	*Passer griseus*	000	000	004	012	0.40	0.792	Rare
Red-collared Widowbird	*Euplectes ardens*	000	004	000	000	0.10	0.198	Rare
Yellow Mantled Widow Bird	*Euplectes macroura*	020	000	004	016	1.00	1.980	Common
WAXBILLS AND FINCHES	*ESTRILDIDAE*							
Lavender Fire-Finch	*Estrilda caerulescens*	006	000	000	000	0.20	0.297	Rare
Grey-crowned Negro-Finch	*Nigrita canicapilla*	016	000	000	008	0.60	1.188	Uncommon
Orange-cheeked Waxbill	*Estrilda melpoda*	000	000	008	024	0.80	1.584	Uncommon
Bronze Manikin	*Spermestes cucullata*	000	000	000	024	0.60	1.188	Uncommon
WARBLERS	*SYLVIIDAE*							
River Prinia	*Prinia fluviatilis*	032	012	000	000	1.10	2.178	Common
Olive-green Camaroptera	*Camaroptera chloronota*	024	008	000	000	0.80	1.584	Uncommon
Grey-backed Cameroptera	*Cameroptera brachyuran*	016	032	008	024	2.00	3.960	Widespread

SWIFTS	*APODIDAE*							
African Palm Swift	*Cypsiurus parvus*	000	000	000	020	0.50	0.990	Uncommon
WOOD-HOOPOES	*PHOENICULIDAE*							
Green Wood Hoopoe	*Phoeniculus purpureus*	024	000	000	008	0.80	1.584	Uncommon
Black scimitarbill	*Rhinopomastus aterrimus*	032	000	000	000	0.80	1.584	Uncommon
BIRDS OF PREY	*ACCIPITRIDAE*							
Yellow billed kite	*Milvus aegyptius*	000	000	004	012	0.40	0.792	Rare
CISTICOLIDS	*CISTICOLIDAE*							
Zitting Cisticola	*Cisticola juncidis*	000	016	000	080	2.40	4.752	Widespread
FALCONS	FALCONIDAE							
Grey Kestrel	*Falco ardosicicens*	000	004	000	012	0.40	0.792	Rare
TITS	*PARIDAE*							
White-shouldered Black Tit	*Parus guineensis*	000	004	000	000	0.10	0.198	Rare
Number of species	60	38	21	19	33			

Mean Encounter Rate: 0.00-0.49 (rare); 0.50-0.99 (uncommon); 1.00-1.49 (common); 1.50-1.99 (abundant); =>2.00 (widespread)

Appendix 5: Number and types of frog species recorded in the study area

	Scientific Name	Local Name	Status	Known Habitat	Number of Individuals
1	*Afrixalus dorsalis*	Striped Spiny Reed Frog	LC	Bushland	5
2	*Arthroleptis spp*	Crowned bullfrog	LC	Widespread	11
3	*Hoplobatrachus occipitalis.*		LC	Aquatic	4
4	*Hyperolius concolor*		LC	Bushland	2
5	*Hyperolius fusciventris*		LC	Unknown	1
6	*Hyperolius guttulatus*		LC	Swamps in forest	4
7	*Hyperolius nitidulus*		LC	Savanna	3
8	*Hyperolius picturatus*		LC	Forest	2
9	*Kassina senegalensis*	Senegal kassina	LC	Savanna	2
10	*Leptopelis spiritusnoctis*		LC	Forest	3
11	*Phrynobatrachus calcaratus*		LC	Widespread	6
12	*Phrynobatrachus gutturosus*		LC	Widespread	11
13	*Phrynobatrachus latifrons*		LC	Widespread	7
14	*Phrynobatrachus plicatus*		LC	Unknown	1
Total	14				62

Appendix 6a: Field data sheet - Fauna

Transect:		Date:	GPS Coordinate:	
Distance	Vegetation Type	Fauna Species	Type of Sign	Remarks

Appendix 6b: Field data sheet - Flora

Transect:		Date:	GPS Coordinate:		
Distance	Vegetation Type	50x50m / 20x20m		5x5m	2x2m
0 m					
100m					
200m					
300m					
400m					
500m					
600m					
700m					
800m					
900m					
1000m					