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Morphological Identification of Edible Termites (Isoptera) in Luanda Sub-County, Kenya

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Abstract

Termites are social insects that live in colonies underground. Globally, there are 3000 termite species, of which 39% are found in Africa. Termites are used as food and livestock feed in most communities of the world. In Kenya, termites are consumed by many communities, especially in the western region. Termite species diversity across different parts of the Luanda sub-county was established as there are many edible and non-edible species in the area. This study assessed the species diversity of termites in Luanda sub-county, and characterized them morphologically. Termites were sampled in Luanda sub-county using the line transect method. The collected termites were preserved in tubes containing 70% Ethanol. The preserved samples were taken to the National Museums of Kenya for morphological identification up to species level. Species richness of each habitat was analyzed for diversity (Shannon-Wiener) index and Shannon index by using Vegan package version 1.16 - 32 in R. The differences in species composition and diversity of termites were analyzed using one-way ANOVA. Morphological identification recorded seven species, namely, *Macrotermes herus*, *Macrotermes spp1*, *Macrotermes sp1*, *Pseudocanthotermes grandiceps*, *Macrotermes bellicosus*, *Macrotermes spp2* and *Pseudocanthotermes militaris.* The results of this study showed that the Shannon diversity index **H** was 0.3606 while Simpson index **D** was 0.20644, which implied a high species diversity of termites in Luanda sub-county a leading producer of edible termites in Kenya.

Keywords

Termite, Morphological, Species, Diversity

1. Introduction

There are around 3000 species of termites in 280 genera that have been described worldwide, and about 39% of the total termite species are found in Africa [1]. Identification of termites is crucial to understanding their distribution and abundance [2] and their relationship to climate change and food security. Termites have important functional and ecological roles in Africa and the world. However, a few species are pests, while 99% of the more than 2000 termite species offer beneficial ecosystem services. Despite their importance, termites are largely understudied, and most ecological research in tropical ecosystems concentrates on mound building termites, while comparatively little is known about hypogeal termite species [3]. The taxonomy of African termites is challenging, and many new species are yet to be described [4]. Termites have excellent nutritional qualities, proximate composition indicates that termites all species of termites have low shelf-life, and a good source of crude protein of 45.85% [5], and other micro- and macro-nutrients. Consumption of termites should thus be encouraged in Africa and the rest of the world. Termites have a low phytic acid value and hydrocyanide value, which implies that they are harmless [6].

According to [7] the scientific classification of termites follows the pattern: Kingdom: Animalia Phylum: Arthropoda Class: Insecta Subclass: Pterygota Infraclass: Neoptera Superorder: Dictyoptera Order: Isoptera. Generally, termites are classified into 280 genera and over 2600 species within seven families and 14 subfamilies. [8] [9] further stated that isopteran are phylogenetically categorised into lower termites (Mastotermitidae, Kalotermitidae, Hodotermitidae, Termopsidae, Rhinotermitidae and Serritermitidae) and the higher termites (Termitidae).

There are many termite species across the world, [10] documented that termites are classified into nine families namely, Termitidae which is notably the largest family, that consists 14 subfamilies, 280 genera and over 2600 species identified in the world. In his work [11] found out that there are approximately 175 species of termites from 42 genera and three families (Kalotermitidae, Rhinotermitidae and Termitidae) all originating from Peninsular Malaysia. In a research conducted in India, [12] identified termites of the genus *Odontotermes* sp. The most abundant species was *Odontotermes feae*, *Odontotermes obesus*, and *Odontotermes feoides.* In Northern Africa: termite species diversity is low thus has less than 15 species. This is due to the arid and semi-arid conditions as reported by [13]. In East Africa, it was found that less than 143 termite species were present in the habitats. In Djibouti, Eritrea, Ethiopia, Somalia and Sudan to the North, and Malawi, Mozambique, Zambia and Zimbabwe and South Africa, Southern Africa accounted for more than 165 species. Despite the numerous efforts to identify termites, the taxonomy of African termites is challenging, as new species have not been characterized [14]. Predation on termites by wild animals such as snakes and birds also play a significant role in reducing the populations of termite [15].

Species diversity is assessed using Simpson and Shannon indices Simpson's

Diversity Index is a measure of diversity which takes into account the number of species present, as well as the relative abundance of each species. As species richness and evenness increase, so diversity increases. In a study by [16] documented that there were two species of termites in the study area in Pakistan. The Simpson diversity scale was 48% while Shannon scale was 97%. On the other hand, the species richness was 0.5917. In a study done in Indonesia [17] documented that the lowest termite species richness was 62.5%. According to [18] [19], termite species differ in their morphology and ecology, including colony size, nesting, feeding, grooming, swarming and reproductive behaviour. Accurate identification of termite species and information on their distribution are key in developing environmentally and sustainable pest control strategies. According to [20], termite identification, especially, Coptotermes species is very challenging as the morphological identification of this species cannot provide detailed taxonomic status. The overdependence on the soldier morphological features presents a major challenge to species taxonomy because of the intraspecific variation in morphological characters in soldiers thus molecular identification are needed to give clear information.

[21] documented that over 4300 samples of termite were used in the studies in Thailand. Termites were identified using morphological features of soldiers. The characteristics used in the identification of termite genera were the shape and size of head, fontanelle, labrum, clypeus, mandible and pronotum. Additionally, to mandible characteristics, the location of teeth and number of antennae were also used. Measurements were generally taken in ethanol-preserved specimens which were dissected out and placed on the petri-dishes. [22] in their research documented that eight species of termite noted in the study area belonged to the family *Termitidae*. The dominance of the genus *Macrotermes* could be due to their character as generalist feeders that eat organic material. *M. bellicosus* was dominant in fresh grasslands while *M. subhyalinus* which existed in both fresh grassland and dry wood unlike *Macrotermes spp1* which was collected on the ground *Odontotermes spp1*, *Macrotermes spp1* and *Pseudocanthotermes spp1* were identified as crop pests.

2. Materials and Methods

2.1. Study Site

Luanda sub-county is located 0˚30'34˚35"E it has a population of 134,202 (2019 Census) who occupy an area of 1200 km^2. The climate is mainly tropical with variations due to altitude. Luanda Sub-County is mainly warm with mean temperature of 21˚C and wet most of the year. The dorminant soil type is sandy loam which is a mixture of clay and sand soil. The soil is usually fertile, well drained, moderate moisture retention capabilities and varied particle size.

2.2. Economic Activities and Food Security

The main economic activity is farming, majorly, sugarcane and maize on large scale. Some farmers practice small scale farming by growing soybeans, cassava, beans, tea, millet and sorghum. Dairy farming is also practiced, specifically, zero grazing. The staple diet of the region is maize. Due to diversified farming, the study area is averagely food secure. In addition to the food crops, farmers in Luanda sub-County of western region also consume a variety of edible insects such as crickets, Locusts, Caterpillars and termites.

2.3. Sampling of Soldier Termites to Determine the Species Composition

The termites were sampled from farms in the study site. This is because they have high prevalence of termites. The habitats t sampled were grasslands, forests, farms and hills. Sampling was done in the agroecological zones as per soil map of Vihiga County.

2.4. Determination of Species Composition of Solder Termites in Each Habitat

The solder and worker termites were sampled as they come out from their nests in large numbers and are easily visible. One belt transect was conducted in each habitat. A transect 100 m long and 2 m wide and divided into 20 successive quadrate sections of 5 m × 2 m were used. Termites were collected in whole sections by searching all potential microhabitats including wood, leaf litter, and surface soil down to 10 - 15 cm deep, visible nests, and galleries up to the height of 2 m in trees nearby mounds. Sampling was done from the lowland areas near Maseno up to the highlands in Emmatsi. There were ten sampling points in each study area.

Solder termites, and workers were sampled in a grid, 20 cm below the ground, and 1 meter on trees. Each grid was thoroughly searched for any termite mud trails, tree trunk, fallen tree trunks, rotting vegetation, and termite mounds. The solder termites were hand sorted according to different castes and kept in tubes containing 70% alcohol then taken to the laboratory for identification. Information on the GPRS of the sampled site was recorded this and the procedure was repeated in grasslands, forested area and hilly sites.

2.5. Morphological Identification of Termites

The collected termites were examined at National museums of Kenya under real-time imaging dissecting microscope. Identification of termites was based on description from [23] and [24]. The identification was done up to species level. The features included head length, width, and height, pronotum and mesonotum length and width, body length, shape and segment number of antennae, mandible length, distance among marginal tooth, of mandibles, tibla length, femur length, segment number of tarsi, tibia and spur, labrum, fontanelle, width and length, postmentum length and width, and nasus length. The termite species were sorted in each habitat and labelled.

3. Results

3.1. Identification of Termite Species in Luanda Sub-County

Soldier termites were identified morphologically at the National Museums of Kenya and the species listed below were identified in the 47 sites within Luanda sub-county which lies on coordinates, 0.0692˚N, 34.6525˚E (source: Vihiga county GIS laboratory) (Tables 1-7).

Table 1. Table showing *Pseudocanthotermes militaris* and site where it was collected.

Site code	Name	Species richness	s.d	Longitude	Latitude	Species
19	Mulwanda	5.95014	0.68727	34.63194 E 34˚37'54.978"	0.04083 N 0˚2'26.067"	*Pseudocanthhotermes militaris*
21	Ilonje	6.09741	0.66292	34.5800 E 34˚34'47.982"	0.04827 N 0˚2'53.664"	*Pseudocanthtermes militaris*
24	Elukunza	6.28064	0.62274	34.63622 E 34˚38'10.314"	0.04009 N 0˚2'24.318"	*Pseudocanthotermes militaris*
26	Ebiba	6.38323	0.59425	34.60236 E 34˚37'39.485"	0.04128 N 0˚2'24.386"	*Pseudocanthotermes militaris*
37	Ebukanga 2	6.77241	0.41882	34.59143 E 34˚35'52.321"	0.09946 N 0˚5'55.512"	*Pseudocanthotermes militaris*
43	Ekwanda 2	6.91440	0.27865	34.56234 E 34˚34'26.125"	0.0347 S 0˚1'17.269"	*Pseudocanthotermes militaris*

Table 2. Table showing *Pseudocanthotermes grandicepes* and site where it was collected.

code	site	species richness	s.d	longitude	latitude	species
18	Esibakala	5.86704	0.69846	34.6333 E 34˚37'59.988"	0.03935 N 0˚2'22.104"	*Pseudocanthotermes grandicepes*
15	Esianda	5.56884	0.72625	34.62626 E 34˚37'34.482"	0.04427 N 0˚2'52.464"	*Pseudocanthotermes grandicepes*
12	Ibubi	5.16922	0.73911	34.6333 E 34˚37'59.988"	0.03935 N 0˚2'22.104"	*Pseudocanthotermes grandicepes*

Table 3. Table showing sites *Macrotermes bellicosus* and site where it was collected.

Code	Site	Species Richnesss.	s.d	Longitude	Latitude	Species
30	Mwikunga 2	6.55318	0.53450	34.61007 E 34˚37'42.783"	0.01562 N 0˚1'27.434"	*Macrotermes bellicosus*
31	Maseno 3	6.58971	0.51904	34.6027 E 34˚36'9.702"	0.00312 N 0˚0'11.208"	*Macrotermes bellicosus*
33	Maseno 4	6.65694	0.48736	34.60213 E 34˚36'7.662"	0.00709 N 0˚0'25.5"	*Macrotermes bellicosus*
22	Esalwa	6.16296	0.64994	34.6333 E 34˚37'59.988"	0.03935 N 0˚2'22.104"	*Macrotermes bellicosus*

Continued

45	Ebukanga 1	6.95745	0.20185	34.6012 E 34˚35'34.402"	0.09980 N 0˚5'56.589"	*Macrotermes bellicosus*
41	Essumba	6.86987	0.33442	34.5124 E 34˚34'32.246"	0.05278 N 0˚3'26.154"	*Macrotermes bellicosus*
14	Emmaloba	5.44908	0.73278	34.56514 E 34˚33'54.498"	0.02802 S 0˚1'40.854"	*Macrotermes bellicosus*
13	Maseno 2	5.31655	0.73727	34.60175 E 34˚36'6.306"	0.00597 N 0˚0'21.498"	*Macrotermes bellicosus*
48	Khwiliba	5.54328	0.72156	34.57106 E 34˚34'52.828"	0.01122 S 0˚0'40.398"	*Macrotermes bellicosus*

Table 4. Table showing *Macrotermes herus* and site where it was collected.

CODE	Name	Species richness	s.d	Longitude	Latitude	Species
4	Ekwanda	2.98703	0.47022	34.57178 E 34˚34'18.426"	0.02261 S 0˚1'21.396"	*Macrotermes herus*
5	Maseno 1	3.42188	0.55501	34.60248 E 34˚36'8.97"	0.00748 N 0˚0'26.94"	*Macrotermes herus*
6	Emmunwa	3.78888	0.61898	34.61972 E 34˚37'11.208"	0.023925 N 0˚1'26.118"	*Macrotermes herus*
7	Emmatsi	4.10279	0.66523	34.61411 E 34˚36'50.898"	0.00436 N 0˚0'15.684"	*Macrotermes herus*
9	Emabungo	4.61137	0.71833	34.60926 E 34˚36'33.69"	0.00083 N 0˚0'3.282"	*Macrotermes herus*
10	Eliang'oma	4.81994	0.73102	34.63891 E 34˚38'20.088"	0.02558 N 0˚1'32.088"	*Macrotermes herus*
16	Emmabwi	5.67750	0.71816	34.58273 E 34˚34'57.666"	0.09307 N 0˚5'35.052"	*Macrotermes herus*
17	Emusenjeli	5.77650	0.70881	34.64576E 34˚38'44.736"	0.04178 N 0˚2'30.024"	*Macrotermes herus*
23	Asiongo	6.22388	0.63653	34.60520 E 34˚36'78.432"	0.00324 N 0˚0'18.241"	*Macrotermes herus*
25	Emutsa	6.33364	0.60864	34.60613 E 34˚36'22.452"	0.02418 N 0˚1'27.042"	*Macrotermes herus*
32	Ebusiratsi 2	6.62424	0.50335	34.6120 E 34˚37'62.927"	0.05989 N 0˚3'39.256"	*Macrotermes herus*
34	Ebusiratsi 1	6.68796	0.47102	34.62829 E 34˚37'41.808"	0.05866 N 0˚3'31.241"	*Macrotermes herus*
35	Emwatsi	6.71746	0.45424	34.57604 E 34˚34'47.244"	0.007560 N 0˚4'32.364"	*Macrotermes herus*
38	Esibila hill	6.79814	0.39983	34.5813 E 34˚34'47.244"	0.06144 N 0˚3'41.178"	*Macrotermes herus*
39	Emukhuya	6.82288	0.37967	34.62588 E 34˚37'33.182"	0.02243 N 0˚1'20.736"	*Macrotermes herus*
40	Esibila down hill	6.84675	0.35802	34.5946 E 34˚34'48.350"	0.06300 N 0˚3'42.190"	*Macrotermes herus*
44	Waluka	6.93605	0.24408	34.64212 E 34˚38'31.65"	0.02248 N 0˚1'20.94"	*Macrotermes herus*
47	Ebukolo	7.000	0.23243	34.58730 E 34˚34'38.658"	0.006255 N 0˚4'48.126"	*Macrotermes herus*

Table 5. Table showing sites *Macrotermes spp1* and site where it was collected.

code	Site	Species richness	s.d	Latitude	Longitude	Species
28	Ebulako	6.47339	0.56479	34.61169 E 34˚36'42.078"	0.00194 N 0˚0'6.978"	*Macrotermes spp1*

Table 6. Table showing *Macrotermes sp1* and site where it was collected.

Code	Site	Species richness	s.d	Longitude	Latitude	Species
2	Mwikunga	1.82239	0.24459	34.62037 E 34˚37'13.236"	0.02418 N 0˚1'27.042"	*Macrotermes sp1*
3	Esibuye 1	2.46364	0.36405	34.63854 E 34˚38'18.336"	0.08564 N 0˚5'8.004"	*Macrotermes sp1*
27	Esiamatete	6.42972	0.57963	34.59099 E 34˚35'27.738"	0.1113 N 0˚6'40.686"	*Macrotermes sp1*
29	Murram	6.51447	0.54974	34.62862 E 34˚37'41.73"	0.04084 N 0˚2'27.73"	*Macrotermes sp1*
36	Enyahera	6.74556	0.43689	34.4216 E 34˚34'49.632"	0.05287 N 0˚3'45.728"	*Macrotermes sp1*
42	Essongolo	6.89238	0.30828	34.6332 E 34˚37'59.97"	0.03962 N 0˚2'22.65"	*Macrotermes sp1*
`46	Mukhunzulu	6.97872	0.14430	34.6023 E 34˚35'38.137"	0.1267 N 0˚6'52.462"	*Macrotermes sp1*
11	Esibuye 2	5.00467	0.73742	34.63954 E 34˚38'28.176"	0.09524 N 0˚2'22.104"	*Macrotermes sp1*

Table 7. Table showing *Macrotermes spp2* and site where it was collected.

code	site	species richness	s.d	longitude	latitude	species
1	Itabalia	5.86704	0.69846	34.6333 E 34˚37'59.988"	0.03735 N 0˚2'52.104"	*Macrotermes spp2*
8	Ebukanga3	5.56884	0.72625	34.58623 E 34˚37'35.382"	0.09424 N 0˚5'52.463"	*Macrotermes spp2*

3.2. Photographs for Morphological Identification of Termites (Figures 1-7)

Figure 1. photograph showing *Macrotermes bellicosus*.

Figure 2. Photograph showing *Macrotermes herus*.

Figure 3. Photograph of *Macrotermes sp1*.

Figure 4. Photograph of *Macrotermes spp2*.

Figure 5. Photograph of *Psudocanthotermes grandiceps*.

Figure 6. Photograph of *Pseudocanthotermes militaris*.

Figure 7. Photograph showing *Macrotermes spp1*.

3.3. Species Diversity of Termites in Luanda Sub-County

Soldier and worker termites were sampled in Luanda sub-County, in 47 sites. The Shannon diversity index was **H** = 0.3606685, while Simpson index was **D** = 0.2064429.

3.4. Species Richness

The total number of species identified in Luanda sub-county was 7 and the species accumulation curve is shown in **Figure 8** showing the abundance of species in the 47 sites.

3.5. Analysis of Variance of Termite Species

The results from ANOVA show that the difference between soldiers and workers was significant at $p < 0.05$ (**Table 8**).

Comparison between the number of soldiers and workers.

Post hoc test was done to show that there was no significant difference between the number of soldiers and workers (**Figure 9**, **Table 9**).

Different letters indicate significant differences (the least significant difference at 5%).

3.6. Comparison between Different Termite Species

A total of 7 species were identified out of which six species had no significant difference (a) while there was significant difference in *Macrotermes spp1* (a b) (Table 10).

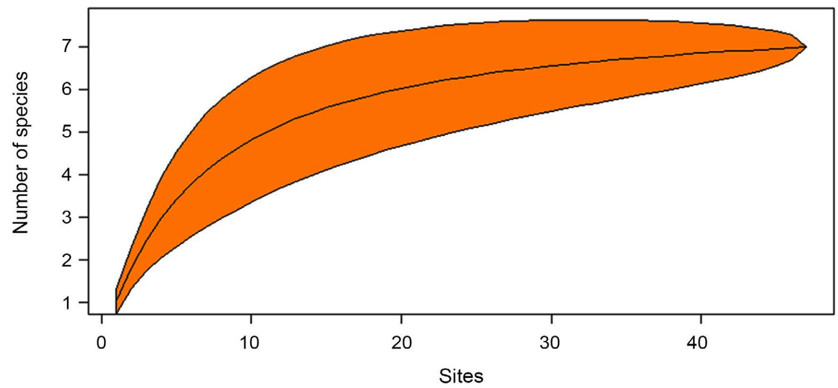

Figure 8. The species accumulation curve for species diversity data of termites in Luanda using the exact method.

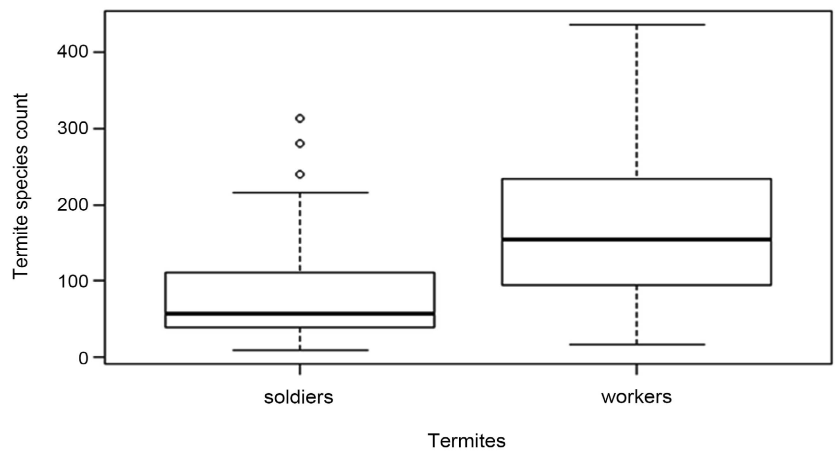

Figure 9. Boxplot of termite species count across the workers and soldiers.

Table 8. The analysis of variance table termite species.

Source of variation	DF	Sum of Squares	Mean Sum of Squares	F value	P value
Termite	1	205,905	205,905	30.503	3.34e−07***
Species	6	280,240	46,707	6.919	4.82e−06***
Residual	88	594,025	6750		

***indicates significance at 5%.

Table 9. Mean summary of the termites.

Termite	Mean ± SE
Workers	177.250 ± 10.52^{a}
Soldiers	84.625 ± 16.64^{b}

Note: Different letters are used in the table as supercripts there is no significant difference.

Table 10. Table showing mean termites of different species.

Termite species	mean
Macrotermes herus	192.63889[a]
Macrotermes spp1	140.50000[ab]
Macrotermes sp1	134.93750[b]
Pseudo militaris	92.75000[b]
Pseudo grandicepes	85.16667[b]
Macrotermes bellicosus	77.11111[b]
Macrotermes spp2	30.50000[b]

Note: Different letters are used in the table as supercripts there is no significant difference.

4. Discussion

4.1. Species Diversity of Termites in Luanda Sub-County

[25] in his work reported that there are many termite species in Africa, some have been poorly described due to lack of sufficient termite taxonomist. This study envisaged to identify termite species in Luanda sub-county in order to document on the species diversity of termites in the area. Termites were identified at the National Museums of Kenya; using termite identification keys as referred to by [26]. Specimens were identified to species level using soldier castes. Termite identification done on the termites collected in Luanda sub-county revealed that there were 7 species identified collected in 47 sites. The identified species include *M. herus* **Table 4**, *Macrotermes spp1* **Table 5**, *Macrotermes sp1* **Table 6**, *P. grandiceps* **Table 2**, *M. bellicosus* **Table 3**, *Macrotermes spp2* **Table 7** and *P. militaris* **Table 1**. Termites are widely distributed in tropical and sub-tropical savannas as elucidated by [27]. In western Kenya a number of species have also been identified and this illustrates the high species diversity of termites.

This study focused on 47 locations in Luanda sub, where soldier and worker termites were sampled, Shannon diversity index was **H** = 0.3606685, while Simpson index was **D** = 0.2064429, during the month of January to March, which is a dry season. This indicated a high species diversity of termites in Luanda sub-county. Out of the 47 sites there was seven termite species identified. *M. herus* had the largest species richness of 7.0 which was obtained at Ebukolo **Table 4** and **Table 10**. *Macrotermes sp1* had the lowest species richness among all the termites identified. The species richness was 1.8239 at Mwikunga.

Comparative studies on termite diversity conducted in West Islamabad, Pakistan by [28] revealed that Simpson and Shannon's diversity indices reflected that on Simpson's index, the overall diversity (D = 0.7034) was 70.34% and it was 99% in case of the Shannon scale. *Odontotermes horai* was the most dominant species with a value of 0.4332 on Simpson's index.

4.2. Termite Species Richness in Luanda Sub-County

Species richness was assessed in all the 47 collection sites and the results show that *P. militaris* had a high species richness of 6.9140 at Ekwanda 2 while Mulwanda had the lowest species richness 5.95014 **Table 1**. *M. bellicosus* on the other hand had highest species richness at Ebukanga 1 while lowest species richness at Maseno 2. *M. herus* was collected in 18 locations and Ebukolo had the highest species richness of 7.000 while Ekwanda had lowest species richness of 2.98703. Comparatively at Ekwanda *M. herus* had a lower species richness but on the other hand had highest species richness for *P. militaris*. From this results the two species do not coexist fully in their natural habitats.

Macrotermes sp1 had the lowest species richness among all the six species, at Mwikunga it had a species richness of 1.822. In a similar study [29] recorded that the lowest species richness of termites observed in the grassy savanna could mainly be explained by the annual disturbance. Fire behavior intensity, the rate of spread, flame height, residence time, and surface temperature is influenced by a wide range of variables such as fuel characteristics, burning season, and weather conditions. The mean summary of workers and soldiers indicated that there was a significant difference **Table 9** and **Figure 9**. Analysis of variance of the termite species shows that the difference between Soldier s and workers was significant at $p < 0.05$, **Table 8**.

The identified species based on body morphology include *M. herus* **Figure 2**, *Macrotermes spp1* **Figure 7**, *Macrotermes sp1* **Figure 3**, *P. grandiceps* **Figure 5**, *M. bellicosus* **Figure 1**, *Macrotermes spp2* **Figure 4** and *P. militaris* **Figure 6**. The species richness curve **Figure 8** showed a higher termite species richness in the study site. Most termite species belong to the family Macrotamatinae of which *Macrotermes herus* (25.56%) was the most abundant species in most sites in Luanda sub-county while *Macrotermes sp 1* was (4%). There was also no significant difference in the number of worker and soldiers collected in Luanda sub-county $p > 0.05$ **Table 9**. Termites are one of the soil macro fauna that have sensitivity to microhabitat variation as reported by [30]. Luanda sub-county has diverse features of termite habitats thus the presence of different species which contribute to food and feed for the local community. Luanda sub-county is characterized by farm forests. Grasslands, swamps, hilly terrain with rock outcrops. High species diversity was obtained in grassland mixed with trees habitat as they offered a ready feed source to the foraging termites. Termite sampling was done using the belt transect method which ensured that most locations were searched for the presence of termites. [31] in his study noted that although the geographical ranges of two Macrotermes species largely overlap, *Macrotermes michaelseni* prefer higher elevations. At Ebulako site *Macrotermes sp1* was predominantly found at 18% of all the termite species collected. Ebulako is found on latitude 34.61169 E 34˚36'42.078" and longitude 0.00194 N 0˚0'6.978". Ebulako is characterized by rock our crops hilly terrain and shrubs with little grass. [32] found out that weather conditions precipitated by climate change favour the increased emergence of insects specifically termites. Moisture and temperature play a significant role in insect ecology. Climate change influence insect population by influencing benthic fauna and its biodiversity that supports the insects. In Luanda sub-County a large proportion of termites were collected during the wet months unlike the dry months. During the wet months there was abundance of vegetation thus food source for the termites to forage.

In a similar study in Ethiopia [33] a total of over 16,000 termite individuals representing one family (Termitidae), two subfamilies, *i.e.*, Macrotermitinae and Termitinae, and five genera (Macrotermes, Odontotermes, Microtermes, Amitermes and Microcerotermes) were found. More Microtermes and Macrotermes termite individuals were found than on other genera. Microtermes and Macrotermes were more abundant. Shannon's diversity index and Simpson's index of diversity values appeared to be higher in the protected vegetation. The termite species identified are prevalent in Luanda sub-county due to presence of feed sources from plants which act as lures for termites to feed as described by [34].

4.3. Conclusion

This study addressed the gaps in the knowledge on edible termite species and their locations in Luanda sub-county. Having established the location and identities of edible termites will assist in the conservation efforts of the termites. Termites are used as food and feed in Luanda sub-county, therefore the knowledge on the species diversity in different habitats will inform termite harvesters on which areas to harvest.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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