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Habitat Preference and Distribution of Crickets (Orthoptera; Gryllidae) in Western Kenya

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Abstract
Information for identifying biodiversity hotspots for species conservation involves the estimation of species abundance, distribution and habitat preference. Adult crickets were sampled from four Agro ecological zones (AEZ) in Western Kenya during the months of June 2020 to January 2021 and identified morphologically. Thirteen descriptive variables associated with topography, water, and greenness, were used to create a habitat distribution model. Akaike information criteria (AIC) was applied to estimate the habitat preference for each cricket species. A total of 3535 crickets were recovered, comprising 3335 insects belonging to 6 identified species and 200 others. *Gryllus bimaculatus* had the highest relative abundance of 28.43% while *Brachytrupes membranaceus* recorded the least abundance of 4.67%. The diversity indices showed that natural vegetation had the highest diversity index (H'= 0.361) and dorminance (D = 0.194). Areas with human settlement had the least diversity index and dominance (H'= 0.231) and (d = 0.010) respectively. The results indicate that the cricket species can be classified into three groups, Group I (*Acheta domesticus*, and *Diestrammena asynamora*) which preferred areas near settlement, Group II (*Scapsipedus icipe*, *Gryllus bimaculatus*, and *Brachytrupes membranaceus*) that preferred fields and grasses and Group III (*Gryllotalpa africana*) that preferred wet lands. This study concludes that the most preferred habitats are natural vegetation, areas near water bodies, having high shelter density and away from human settlement. Conservation management targeting habitats for this edible insect should form part of integrated species conservation measures focusing especially on the biodiversity hotspots.
Keywords: Abundance, Crickets, Diversity, Distribution, Habitat preference
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1.0 Introduction
Natural habitats for crickets continue to shrink and fragment due to multiplicity of natural phenomena as well as ever-increasing anthropogenic pressures (Ayieko *et al*., 2010; Hutcheson and Jones, 1999). Edible insects are in critical demographic crisis by loss of habitat due to expanding and developing human populations (Angela, 2006). With the decreasing size of cricket habitat and increasing fragmentation, it has become essential to determine the diversity and abundance of these species and develop species-specific habitat suitability models (Kavishe, 2016; Ward and Lariviere, 2004). Habitat selection is an important part of organism's life history pattern (Lui, 2009). Preservation of species requires a complete knowledge of their spatial requirements (Kavishe, 2016; Khadijah *et al*., 2013). Habitat evaluation is the assessment of the suitability of land or water as habitat for specific species (De Leeuw and Albritch, 1996; Pereira and Itami, 1991). There is therefore need for a model to predict the suitability of land in a given particular set of land conditions. Conservation biologists and managers need a range of both classical analyses and specific modern tools to face the increasing threats to biodiversity (De Leeuw and Albritch, 1996; Pereira and Itami, 1991).

Insects are closely associated with our lives and affect the welfare of humanity in diverse ways (Van Huis, 2013; Ayieko, 2012). At the same time, large numbers of insect species, including those not known to science, continue to become extinct from local habitats worldwide (Ayieko *et al.,* 2010). The diversity of insect species is a function of the environmental conditions (Bidau, 2014). The distribution of these insects depends on the suitability of their environment for development and survival. However, there is inadequate taxonomic and ecological knowledge of insects in Western Kenya since the distribution and abundance of many insect species in the country are unknown and their ecosystem services mostly assumed. The study was carried out to document the distribution, diversity and abundance of crickets in the counties of Busia and Siaya, in Western Kenya. This information will provide an understanding of the habitat preference of this edible insect in Western Kenya; information that is very critical for the ecological management of this noble insect.

2.0 MATERIALS AND METHODS

2.1 Study species

Crickets are distributed throughout tropical and temperate regions, except at latitudes above 55 º, with the greatest diversity being in the tropics (Martins, 2014; Jaganmohan *et al*., 2013;). They occur in varied habitats from grasslands, bushes, forests, mashes, beaches and caves (Resh and Carde 2009). They are omnivorous generalists that prefer tall grassland habitats (Chapman *et al*., 2013; Hardy *et al*., 1983). Crickets are mainly nocturnal and are known for loud persistent chirping song of males trying to attract females, although, some species are mute (Resh and Carde, 2009; Huber, 1989). The singing species have good hearing ability via the tympana on the tibiae of the front legs (Otte, 2007). Sometimes there are challenges in identifying cricket species due to phenotypic plasticity and morphological similarities.

2.2 Study area

The study was carried out in Busia and Siaya counties of Western Kenya, which extends between 34° 00E and 36° 30E as well as 0° N and 30° S (Jaetzold *et al*., 2006). The region is a biodiversity sanctuary and one of the prime habitats of edible cricket species in its distribution range in Africa, but developments in agriculture, industry and urban centers have affected its distribution in the region (UNCCD, 2001). The study area has a mean annual rainfall of 1280 mm usually occurring from March to November (Okungu *et al*., 2005). The highlands however, receive more than 2400 mm of rainfall, from March to May and from July to September (Adger, 2006). Temperatures range from a minimum of 10 ^{0}C and a maximum of 40 ^{0}C, with an expected increase of 2 ^{0}C to 2.5 ^{0}C in maximum and minimum temperatures by 2020 (Adger, 2006; UNFCC, 2006). With increasing climate vulnerabilities, the maximum and minimum temperatures are projected to further increase by 3.5 ^{0}C to 4 ^{0}C in more than half of the area by 2030 (UNEP, 2009; UNFCC, 2006).

The landscape in this region consists of a mosaic of farmland land (36 %), grassland (26 %), forest (24 %), scattered settlement and small towns (6 %), lakes and water ways (5 %), and a small proportion of other land use types (3 %) (Swallo *et al*., 2002; UNCCD, 2001).

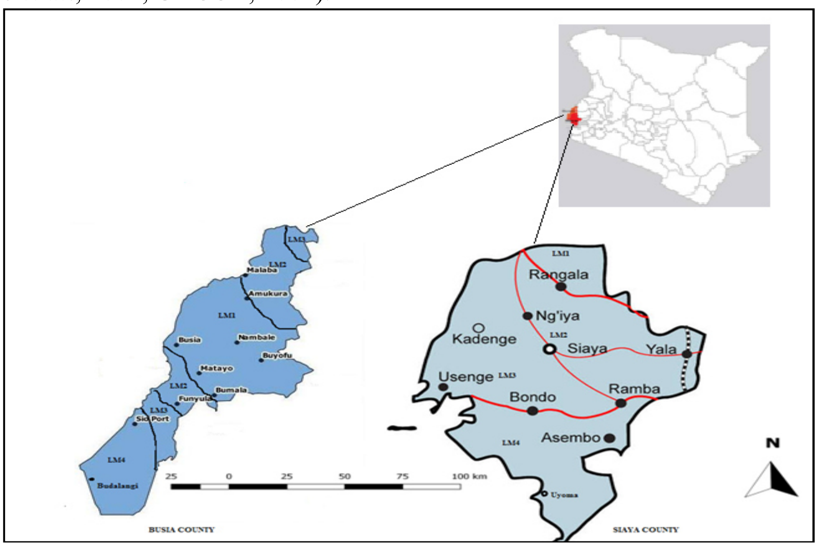

Figure 1: Map of Busia and Siaya Counties in Western Kenya

2.3 Factors defining the habitat choice of crickets

Various inferences illustrating how environmental factors control the distribution of species form the basis of habitat models (Kwon *et al.*, 2015). In this study various environmental factors were examined for habitat modeling (Grillet *et al*., 2010). Habitat components studied for the model were food, shelter and water. The presence of vegetation cover in forests, grasslands and shrub lands contain food, shelter and oviposition subtrates (Collinge *et al.*, 2003). Farmlands and areas adjacent to water sources equally have these habitat characteristics (Kwon *et al.*, 2015; Khadijah *et al*., 2013). Elevation, slope and aspect are topographic components which were

incorporated since they indicate the magnitude of radiant energy that contributes to habitat conditions for organisms (Lassau *et al*., 2005; Wolters, 2003). Topographic factors were gotten from digital topographic maps drawn to a scale of 1:5000. The digital elevation model was then converted into slope, relief and wetness (Kwon *et al.*, 2015). Anthropogenic factors threaten species existence through habitat loss and fragmentation (Wolters 2003). Water is essential in the life of any living organism therefore the presence of a water body affects the distribution of species. In this study, the distance from existing water bodies was used to explain the choice of each species to distances from water.
Table 1 shows thirteen environmental variables used in the study to determine their effects on habitat selection by cricket.

Table 1: The variables used to predict habitat and distribution of crickets

S/No.	Variables	Description of each variable	Data type
1	AEZ	Agro ecological zones (LM1, LM2, LM3, LM4)	continous
2	Land use	Forests, grasslands, farmlands, wetland, settlement	continous
3	Ground cover	Presence of shelter	Continous
4	Slope	% Slope	continous
5	Northness	Northness	continous
6	Vegetation height	Height of the vegetation in m	continous
7	Canopy closure	Measure of ground vegetation cover	continous
8	Normalized difference vegetation index (NDVI)	Using Landsat enhanced thematic mapper (ETM) to measure different levels of greenness of vegetation	Continous
9	Distance from water body	Distance from water in m	Continous
10	Distance from roads	Distance from roads in m	Continous
11	Distance from settlement	Distance from settlement in m	Continous
12	Distance from farms	Distance from farms in m	Continous
13	Wetness	Degree of wetness	continous

2.4 Cricket sampling and identification

Data on cricket abundance and distribution was collected through insect sampling and diversity analyses (Adetundan and Olusola, 2013). A field survey was conducted in the region to assess the diversity and abundance of cricket species. The sampling was carried out after every two weeks for six months using pitfall traps, sweep nets and hand collection. The pitfall traps were set in 3 replicates, 50 m apart in 3 different locations having similar environmental characteristics.

A double cup design of pitfall trap with a length of 11cm and 10 cm wide was used in which a hole is dug and two containers placed in the hole and soil is packed around it to the level of the rim of the inner container (Sabu and Shiju, 2010). The trap, containing granulated sugar and bread crumbs in a 1 x 1 km grid across the study area, was set up from which a sum of adult crickets were recovered. The inner cup is a removable container that allow for setting and servicing of the trap (Nyundo and Yarro, 2007). The outer cup keeps the hole from back filling with soil. An elevated wooden tripod stand (5 cm above the ground level) was placed over the pitfall to keep off water, falling debris and small rodents (Nyundo and Yarro, 2007;). House crickets were collected using sweep nets.

The study area has four agro ecological zones (AEZ), Lower midland 1 (LM1), Lower midland 2 (LM2), lower midland 3 (LM3) and lower midland 4 (LM4). Sampling was done in 12 locations selected randomly as representatives of the four different AEZ in the county of Busia and 12 locations in Siaya county (Islam, 2018). For analysis of habitat preference, each location was clustered based on land use characteristics (Natural vegetation, agricultural land, wet land and settlement) totaling 96 sites and data on insect population recorded along the diagonals of each selected field. After identifying natural vegetations in lower midlands 1 (LM1) as the areas with the highest insect populations, the six locations of LM1, were further clustered based on nine environmental variables (Normalized difference vegetation index, distances from water, road, settlement and farms, vegetation height, presence of shelter, canopy closure and slope) and data on insect population recorded.
Table 2 shows 24 surveyed sites (12 in Busia county and 12 in Siaya county) with their GPS coordinates.

Table 2: Survey Sites in Busia County and their GPS Coordinates

	Code	**AEZ**	**Location**	**Coordinates** **Latitudes**	**Longitudes**
1	BS1	LM1	Alupe KALRO	0.4959	34.1331
2	BS2	LM1	Busia Youth Polytechnic	0.4518	34.1217
3	BS3	LM1	Butula Boys	0.3426	34.3341
4	BS4	LM2	Amukura health centre	0.5706	34.2719
5	BS5	LM2	Malaba town	0.6346	34.2756
6	BS6	LM2	Lukolis Dispensary	0.6086	34.2084
7	BS7	LM3	Kolanya Boys	0.7099	34.4004
8	BS8	LM3	Nangina mission hospital	0.2763	34.1017
9	BS9	LM3	Angurai Chiefs Camp	0.7123	34.3477
10	BS10	LM4	Bunyala Catholic	0.0939	33.9756
11	BS11	LM4	Bumbe Technical	0.1721	33.9955
12	BS12	LM4	Port Victoria forest station	0.0961	33.9781

Survey Sites in the Siaya County and their GPS Coordinates

	Code	**AEZ**	**Location**	**Coordinates** **Latitude**	**Longitude**
13	SY1	LM1	Yala St. Marys	0.0967	34.5314
14	SY2	LM1	Rangala School	0.1526	34.3296
15	SY3	LM1	Sigomere School	0.2018	34.3546
16	SY4	LM2	Ukwala Boys	0.1954	34.1894
17	SY5	LM2	Siaya ATC	0.0626	34.2878
18	SY6	LM2	Boro Trading Centre	0.0860	34.235
19	SY7	LM3	Kadenge Yala Swamp	0.0270	34.1810
20	SY8	LM3	JOOUST	0.0939	34.2586
21	SY9	LM3	Ajigo Dispensary	0.3538	34.5652
22	SY10	LM4	Usigu Health Centre	0.0605	34.0929
23	SY11	LM4	Naya Dispensary	0.3837	34.2834
24	SY12	LM4	Nyamonye School	0.0483	34.1385

Insects recovered were wet preserved in 70% ethanol mixed with a few drops of glycerin inside glass vials. Representative samples were taken to the Insect laboratory of Egerton university (EU), Kenya for identification. The genera of the specimens were identified using the available keys and confirmed by recognized specialists (Sharkey, 2007; Choate, 2011). A habitat suitability model for crickets was prepared using the primary and secondary sources of data (Aslam, 2009; Wolters, 2003).

Table 3 shows the characteristics of the four agro ecological zones based on altitude in (m), mean annual temperature in ^{0}C and average annual rainfall in mm

Table 3: Characteristics of the four Agro ecological zones (AEZ)

AEZ	**Altitude in (m)**	**Mean annual Temperature in ^{0}C**	**Average annual rainfall in mm**
LM1	122-1440	21.0 - 22.2	1650 -2000
LM2	1200-1350	21.4 -22.3	1420 – 1650
LM3	1140-1500	21.0 – 22.7	1100 – 1420
LM4	1135-1200	22.3 -22.7	900 – 1200

2.5 Data analysis

The following biodiversity indices were computed using Past3 software; (Hill *et al*., 2005).

1.Shannon weaver index. (H) (Shannon and weaver, 1963).

2. Pielou's evenness index (E) (Diserud and Ø degaard, 2007, Pielou, 1966).

3. Simpson index (D) (Crane and Baker, 2011; Simpson, 1949).

Difference in species occurrence was tested using analysis of variance (ANOVA). A generalized linear model with a binomial distribution of the response variable and logit link function was used for analysis (Pinheiro *et al*., 2018; Box *et al*., 2005). Linear mixed effect (LME) models were used to determine the environmental variables that best explained the changes in population density of **crickets** along an altitudinal gradient in the study area. All possible models were constructed based on sets of sampled environmental variables, and evaluation was done using Akaike Information Criterion (AIC) (Akaike, 1974). The best model was selected, and its statistical significance determined. All the analyses were performed in the R environment (R - Core Team 2017; R - Studio team, 2016).

3.0 RESULTS

3.1 Relative abundance of crickets across different habitats

Table 4 shows the diversity and abundance of insect species recovered in the selected habitats. A total of 3535 insects were recorded, comprising 3335 insects belonging to 6 identified crickets species and 200 others. The largest number of insect species was recovered from natural vegetation, areas near water bodies and with shelter. The least were recovered from the open field. Natural vegetation had the highest species population percentage of (44.07 %) followed by wetlands with (27.51%), agricultural lands with 18.39 % and the lowest in settlement at 10.03 %. The diversity indices shows that natural vegetation and wetlands had the highest diversity index (H'= 0.361 and 0.355) respectively and dominance index of 0.194 and 0.076 respectively. Settlement had the least (H'= 0.231) and (D = 0.010).

Table 4: Relative abundance of cricket species across four land use types

	Relative abundance (%)	Simpsons index (D)	Shannon Index (H^l)	Evenness (E^1)
Natural vegetation	44.07	0.194	0.361	0.049
Wetlands	27.51	0.076	0.355	0.052
Agricultural lands	18.39	0.034	0.311	0.048
Settlement	10.03	0.010	0.231	0.039

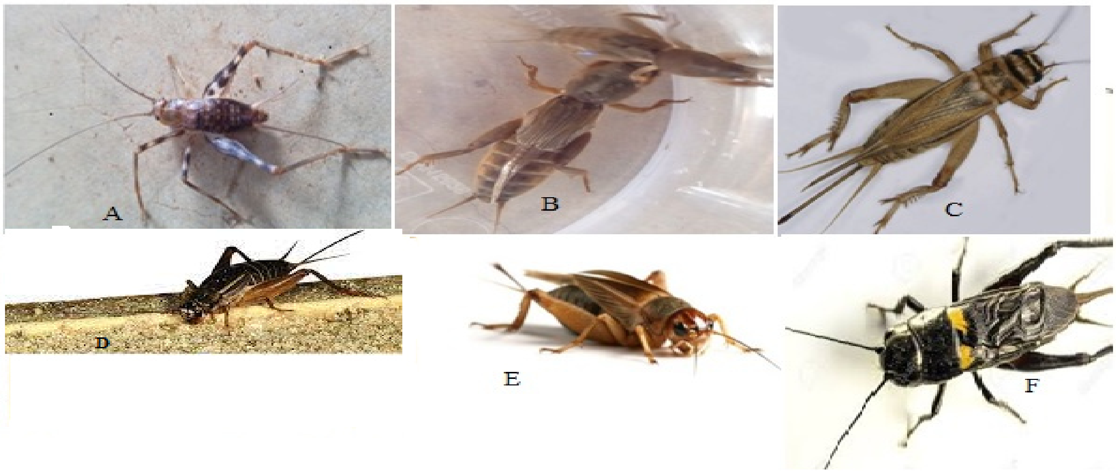

Figure 2: Cricket species sampled during the study
A= *Diestrammena asynamora, B= Gryllotalpa africana, C= Acheta domesticus, D= Scapsipedus icipe, E = Brachytrupes membranaceus, F= Gryllus bimaculatus.*

3.2 Effects of Agro ecological zone and topography

The mean number of cricket species showed significant differences (P- value= 0.00055, R^2 = 0.9327) among the four agro ecological zones (Table 5). Highest mean ranking was recorded in lower midland 1 (162.00), followed by lower midland 2 with mean ranking of 138.00, lower midland 3 with mean ranking of 120.71 and lowest in lower midland 4 with a mean ranking of 84.28. The presence of more species in lower midland 1 was due to favourable conditions for cricket survival such as the presence of more numbers of plant species as cricket's diet, shelter and breeding substrate. Lowest numbers in lower midland 4, regions bordering Lake Victoria were recorded in sites far off from the water body. There was no significant difference in slope and slope orientation with cricket species, although more species were recorded at a slope angle of 10.1 to 15% (Table 6). This indicated that the crickets prefer lower altitude but mostly in mid elevation. The cricket diversity decreases with increase in elevation. Across the habitats, *Gryllus bimaculatus* was the most abundant species (1005) followed by *Scapsipedus icipe*. (909) and *Gryllotalpa africana* (583) which was confined only to wetlands. *Diestrammena asynamora* recorded (367), *Acheta domesticus (*306) and the least number of species was recorded in *Brachytrupes membranaceus (165)*.

Table 5: Occurrence of cricket species across four agro ecological zones in Western Kenya

		Agro ecological zones(AEZ)				
Species	**English name**	**LM1**	**LM2**	**LM3**	**LM4**	**Total**
Gryllus bimaculatus	Two spotted cricket	315	276	239	175	1005
Scapsipedus Icipe	Scapsipedus icipe	292	251	223	143	909
Diestrammena asynamora	Spider cricket	112	104	89	62	367
Acheta domesticus	House cricket	101	82	70	53	306
Gryllotalpa africana	African mole cricket	179	163	145	96	583
Brachytrupes membranaceus	Giant cricket	56	43	37	29	165
Others		79	47	42	32	200
TOTAL		1134	966	845	590	**3535**
Mean		162.00	138.00	120.71	84.28	

Table 6: The effects of slope and slope orientation on the occurrence of six cricket species in Western Kenya

Species	*Gryllus bimaculatus*	*Scapsipedus icipe*	*Diestrammena asynamora*	*Acheta domesticus*	*Gryllotalpa africana*	*Brachytrupes membranaceus*
% Slope						
0 - 5	16	15	6	7	9	4
5.1 – 10	14	13	5	4	8	4
10.1 – 15	17	12	4	4	7	4
>15	10	9	4	4	7	4
Slope orientation						
Flat	15	13	7	8	6	5
North	9	8	7	8	4	4
East	10	11	6	5	7	6
South	11	12	4	4	7	4
West	23	19	9	8	6	6

3.3 Effects of Land useon the occurrence of crickets.

Number of species was significantly influenced by land use (p – value < 0.0001, $R^2 = 0.971$) (Table 7). Natural vegetation recorded the highest mean number of species (251.17) followed by wetlands with a mean number of 153.67, agricultural lands (100.00) and the least (51.00) was recorded in settlements. Wetlands showed higher number of Gryllotalpa species with fewer representation of the other species.

Table 7: Effects of land use type on the occurrence of six cricket species in Western Kenya

	Land use types				
Species	**Natural vegetation**	**Agricultural land**	**Settlement**	**Wetlands**	**Total**
Gryllus bimaculatus	613	225	35	228	1101
Scapsipedus icipe	555	217	33	218	1023
Diestrammena asynamora	56	42	96	20	214
Acheta domesticus	43	36	111	00	190
Gryllotalpa africana	127	70	23	424	644
Brachytrupes membranaceus	113	10	08	32	163
Total	1507	600	306	922	**3335**
Mean	251.17	100	51	153.67	
p-value < 0.001, R^2	*=0.9762*				

3.4 Effect of normalized difference vegetation index (NDVI)

Significant differences were recorded in places with different NDVI indices. The number of crickets and increase in NDVI showed a positive correlation. Higher species numbers (136) were recorded with NDVI > 50 % while lower values were recorded in places with NDVI < 25 % (p – value = < 0.001, $R^2 = 0.9762$) (Table 8).

Table 8: Effects of NDVI on the occurrence of six cricket species in Western Kenya

	% NDVI		
Species	**<25 %**	**25– 50%**	**>50**
Gryllus bimaculatus	19	36	41
Scapsipedus Icipe	18	30	37
Diestrammena asynamora	7	12	17
Acheta domesticus	6	10	12
Gryllotalpa robusta	5	10	13
Brachytrupes membranaceus	4	7	8
Total	**59**	**105**	**128**
Mean	**9.83**	**17.5**	**21.33**

***p-value* < 0.0001, R^2 = 0.971**

3.5 Effect of percentage ground cover and vegetation structure on the occurrence of crickets

There were significant differences ($p < 0.05$) in species with shelter density (p – value < 0.0001, R^2 = 0.9632) (Table 9). Higher shelter density in the forests, and other cricket habitats contributed to high species numbers because of the presence of dead logs, branches, and wood stump, a potential hideout for the crickets. The results of the analysis of the canopy cover on distribution of crickets showed higher species within the canopy cover ranging from 51% - 75% and 26 – 50%. The species numbers were lower in canopy cover of 0 - 25% than within the canopy cover ranging from 76% - 100%. Statistically, the correlation between the canopy cover and the number of crickets showed a positive relationship, *w*hich indicates that numbers of cricket species increases when crown cover increases up to 80%. Crickets mostly preferred within the crown cover between 51 – 75%, compared to the canopy cover of 25 – 50%. This is mainly because of the presence of adequate shelter within the canopy cover of 51 – 75%, with a relatively un-decomposed leaf litter layer and with a greater amount of dry dead sticks and branches (Table 10). However, the soil in the crown canopy between 76 -100% were observed to be moist with a thick layer of decomposing leaf litter where very little number of crickets were recovered.

Table 9: Effects of ground cover on the occurrence of six cricket species in Western Kenya

	% Ground Cover			
Species	**0 – 25**	**26– 50**	**51 - 75**	**76 -100**
Gryllus bimaculatus	10	19	32	29
Scapsipedus Icipe	8	17	29	25
Diestrammena asynamora	4	8	12	10
Acheta domesticus	4	6	10	8
Gryllotalpa africana	6	11	18	16
Brachytrupes membranaceus	4	4	7	5
Total	**36**	**65**	**108**	**93**
Mean	**6.00**	**10.83**	**18.00**	**15.50**

p-value < 0.000147, R^2=0.9632

Table 10: Effects of canopy closure on the occurrence of six cricket species in Western Kenya

	% Canopy Closure		
Species	**25 – 50**	**51-75**	**76 – 100**
Gryllus bimaculatus	17	21	15
Scapsipedus Icipe	15	19	13
Diestrammena asynamora	6	10	6
Acheta domesticus	5	11	5
Gryllotalpa africana	5	11	15
Brachytrupes membranaceus	4	11	9
Total	**52**	**83**	**63**
Mean	**8.67**	**13.83**	**10.5**

3.6 Effects of distance from water bodies, farms, roads and settlement

Areas near water bodies recorded significantly high species number compared to areas further away from water bodies. Significant differences were recorded in places far away from human activity (roads, p-value = 0.00000366, R^2= 0.9849; water, p-value = 0.0000349, R^2 = 0.9678; farm; p-value = 0.0005, R^2 = 0.9176; settlement, p-value = 0.0004664, R^2 = 0.9245) (Table 11). Places far away from human activities recorded more species than areas near farms, settlement and roads. The results shows that crickets preferred maximum inter-water distances of 0- 150 m with a mean of 36.50, followed by distance between 151- 500 m with a mean of 27.50, and lowest preference in habitats at a distance more than 500 m with a mean of 16.50 (Table 11). Areas near roads (0 – 150 m) recorded the lowest mean number of cricket species (9.83) where as sites at distances greater than 500m recorded the highest mean number of species (19.67). No significant differences were recorded with distances from farms, although higher mean species numbers (18.67) were recorded at distances far away from farms (> 500m) and lowest (16.33) at a distance of less than 150m. crickets preferred areas far away from human settlement. Highest mean (25) were recorded at a distance > 500m and lowest (10) at a distance < 150m.

Table 11: Effects of distance from water, roads, farms and settlement on the occurrence of six cricket species in Western Kenya

	Distance (m)		
	<150	151 - 500	>500
Species		**Distance from water**	
Gryllus bimaculatus	66	50	27
Scapsipedus icipe	59	47	25
Diestrammena asynamora	25	19	14
Acheta domesticus	19	16	16
Gryllotalpa africana	37	23	6
Brachytrupes membranaceus	13	10	11
Total	**219**	**165**	**99**
Mean	**36.50**	**27.50**	**16.50**
		Distance from roads	
Gryllus bimaculatus	19	29	39
Scapsipedus Icipe	18	25	35
Diestrammena asynamora	7	10	13
Acheta domesticus	6	8	12
Gryllotalpa africana	5	8	12
Brachytrupes membranaceus	4	6	7
Total	**59**	**86**	**118**
Mean	**9.83**	**14.33**	**19.67**
		Distance from farms	
Gryllus bimaculatus	32	35	38
Scapsipedus icipe	29	32	34
Diestrammena asynamora	12	13	13
Acheta domesticus	10	11	12
Gryllotalpa africana	8	8	8
Brachytrupes membranaceus	7	7	7
Total	**98**	**106**	**112**
Mean	**16.33**	**17.67**	**18.67**
		Distance from settlement	
Gryllus bimaculatus	20	32	42
Scapsipedus icipe	17	23	37
Diestrammena asynamora	8	12	14
Acheta domesticus	8	13	14
Gryllotalpa Africana	4	7	10
Brachytrupes membranaceus	3	5	6
Total	**60**	**92**	**123**
Mean	**10.00**	**15.33**	**20.5**

3.7 Variables for the Model and Model Validation

Akaike Information Criterion (AIC) was used to examine the variables by means of backward stepwise selection at every step. Variables were removed step by step by finding out which model with remaining variables could be best explained by the lower AIC (Table 14). A smaller AIC indicates a better model; therefore, there is greater deviance explained for each environmental variable. The best combined variables was recorded. Variables chosen for each species showed higher area under the curve (AUC) values, demonstrating that each model explained the distribution of each species well. *Gryllus bimaculatus* had the highest Cross-Validated Area Under the Curve (cvAUC) indicating that the variables selected with higher cvAUC values had greater significance and explained the habitat preference for the species well (Table 15). Variables that remained after being removed by the backward stepwise selection were mostly related to habitat components (shelter density, AEZ, distance from bodies of water, NDVI and distance from farmland and human disturbances). These findings indicate that crickets responded positively to environmental factors associated with habitat components, while they shunned harsh conditions and disturbances resulting from anthropogenic factors.

Table 12: AIC values of the different Environmental Variables

Steps	Gryllus bimaculatus		Scapsipedus Icipe		Acheta domesticus		Gryllotalpa africana		Diestrammena asynamora		Brachytrupes membranaceus	
	Var	AIC	Var	AIC	Var	AIC	Var	AIC	Var	AIC	var	AIC
1	AEZ	103	AEZ	106	AEZ	113	AEZ	102	AEZ	109	AEZ	93
2	Land use	98	Land use	99	Land use	97	Land use	98	Land use	97	Land use	86
3	Ground cover	98	shelter density	94	shelter density	97	shelter density	87	shelter density	103	shelter density	84
4	D. water	109	D. water	110	D. water	123	D water	67	D. water	122	D. water	79
5	D. farms	101	D. farms	105	D. farms	122	D. farms	98	D. farms	116	D. farms	127
6	D. roads	125	D. roads	126	D. roads	131	D. roads	112	D. roads	126	D. roads	112
7	D. settlement	122	D. settlement	130	D. settlement	96	D. settlement	114	D. settlement	93	D. settlement	123
8	Wetness	106	Wetness	122	Wetness	116	wetness	86	Wetness	108	Wetness	102
9	Slope orientation	135	Slope orientation	133	Slope orientation	147	Slope orientation	141	Slope orientation	143	Slope orientation	144
10	Slope	125	Slope	122	Slope	143	Slope	143	Slope	148	Slope	144
11	NDVI	99	NDVI	97	NDVI	98	NDVI	95	NDVI	99	NDVI	87
12	Canopy cover	133	Veg. height	138	Veg. height	141	Veg. height	137	Veg. height	142	Veg. height	140
13	Litter depth	121	Litter depth	105	Litter depth	112	Litter depth	121	Litter depth	119	Litter depth	131

D.water = distance from water; D. farms = distance from farms; D. roads = distance from roads; D. settlement = distance from settlement

Table 13: Summary of the best combination of variables for model to predict presence of each cricket species.

Species	Selected Environmental Variables (order)	AUC	CvAUC
Gryllus bimaculatus	Land use, shelter density, NDVI, AEZ, distance from water, distance from farm	0.887±0.044	0.766±0.023
Scapsipedus icipe	Land use, shelter density, NDVI, AEZ, distance from water, distance from farm	0.845±0.048	0.737±0.016
Acheta domesticus	Land use, shelter density, NDVI, distance from settlement	0.772±0.032	0.689±0.028
Gryllotalpa africana	Land use, distance from water, distance from farms, wetness, shelter density, NDVI, AEZ.	0.885±0.054	0.761±0.043
Brachytrupes membranaceus	Land use, shelter density, NDVI, AEZ, distance from water, distance from farm, distance from road, distance from settlement	0.712±0.04	0.657±0.027
Diestrammena asynamora	Land use, shelter density, NDVI, AEZ, distance from water,	0.764±0.036	0.665±0.014

4.0 DISCUSSION

The results showed that the cricket species in this study were primarily categorized into three groups. Group I (*Acheta domesticus and Diestrammena asynamora)* showed higher preference for all locations on settlements and had very different preferences for several environmental conditions. Jaganmohan *et al*., (2013) also indicated similar results in a previous research on urban domestic gardens in Bangalore. Specifically, these species did not appear to be sensitive to living close to buildings, and it showed a higher frequency in areas with higher building density (Bowling, 1955). Group II (Scapsipedus icipe, Gryllus bimaculatus and Brachytrupes membranaceus) preferred fields with tall grasses. *Gryllus bimaculatus and Scapsipedus icipe* simultaneously preferred lower elevation and mid elevation areas within the grasslands. The preference of *Gryllus bimaculatus and Scapsipedus icipe* for the grassland areas is due to cover resources for shelter. Chemura *et al*., (2018) reported similar results with *Henicus whellani chop* (Orthoptera: Stenopelmatidae) in South Eastern districts of Zimbabwe. G*ryllus bimaculatus* did not prefer to be close to buildings, although this species was not sensitive to higher densities of buildings (around 500 m^2/ha). Most species. appeared to depend on farmland and bodies of water and were often found occurring at places close to farmlands (<200) and bodies of water (<150). Hermann *et al*., 2012, in a study on drivers of specialist diversity reported that multiple factors are responsible for shaping the diversity and abundance of species. Group III (Gryllotalpa africana) preferred locations within the wetlands. Presence of water and general wetness were important and critical factors describing the preference of *Gryllotalpa Africana* for its habitat (Hermann *et al.,* 2012). Specifically, this species preferred areas close to farmland (0- 150 m) and bodies of water (0-150). Moreover, the probability of its occurrence increased as the Normalized difference vegetation index (NDVI) value increased in wetlands. Bidau, 2014 and Sultana *et al*., 2013, reported similar results showing that orthoptera diversity followed a specific pattern determined by the presence of food and shelter.

These findings indicate that regions with higher probability of occurrence for group I were distributed in almost all of the human settlement areas, while regions with higher probability of occurrence for Group II were sporadically distributed throughout the fields. Regions with higher probability for Group III were distributed throughout the wetlands and areas near water bodies. Furthermore, regions with a higher occurrence probability for species included in Group I were likely to be coincident with settlement boundaries, whereas regions for Group II were likely to be distributed in the grasslands. Regions for Group III were likely to be distributed in the wetlands and near streams. The occurrence probability for Group II was relatively higher (>0.6), while the probability for Group I did not exceed 0.3. Species in Group I tend to prefer to live anywhere in homes, regardless of environmental conditions. *Acheta* preferred fluctuant and concave topography for its living, and was often found at places not far from buildings and other artificial land uses. NDVI also explained the preference of *Brachytrupes membranaceus* for its habitat, with a positive response to greenness. *Brachytrupes membranaceus* was also shown to stay within a distance less than 500 m of water, although it was found everywhere, indicating that it was not dependent on this aspect. Roads did not significantly influence the occurrence of most recovered cricket species, although most were not found close to roads and showed slightly higher preference for areas further away from the roads. *Brachytrupes membranaceus* appeared everywhere without any dependence on aspect, but it showed a slightly higher occurrence on the western side of the mountain.

Similar findings were recorded by Adetundan and Olusola, (2013) and Basset *et al*., (2012) which, showed that the diversity and abundance of arthropods were influenced by vegetation types. Although some cricket species were not sensitive to the disturbance, most tended to avoid such disturbances (Chemura *et al*., (2018). *Acheta domesticus and Diestrammena asynamora* are general species that appeared not to be restricted by human disturbance (Bowling, 1955). Their requirements fluctuated but most preferred buildings as a cover resource to hide from predators. There were no clear data describing the preference of *Brachytrupes membranaceus* for its selected habitat. The results only indicated its preference for higher canopy cover and shelter. *Gryllotalpa africana* showed preference for wetness. Indeed, the results strongly indicated that *Gryllotalpa africana* preferred places near water and constantly moist and sufficient greenness. Such areas would be optimal for these organisms because they enable the species to protect itself from dessication while enabling easy access to food and oviposition sites (Belamkar and Jadesh, 2012).

5.0 CONCLUSION

Results obtained in this study indicate that environmental variables affected the abundance, diversity and distribution of cricket species. These findings demonstrate the importance and role of environmental factors in shaping the ecology of this insect species.

Acheta domesticus and *Diestrammena asynamora* were not sensitive to human disturbance, instead, they showed higher preference for the house habitat. Relatively large sized crickets such as *Brachytrupes membranaceus* had quite different strategies for their habitats. First, these large cricket species had the wider home range in forests and other tall trees so that they could get the flexibility to take their food within a safety according to the presence of their food and cover resources. Overall, these results indicate that *Gryllotalpa africana* was much more cautious and sensitive to anthropogenic land uses than other species.

Recommendations

- Cricket diversity in human occupied environment should be enhanced by continuous gardening and tree planting.
- Conservation of wetlands to preserve the endangered *Gryllotalpa africana.*
- Awareness creation of crickets as an important part of ecosystem and as source of food and feed
- The department of Natural Resource, Land and Environment in Western Kenya should provide conservation education to the communities so that the contribution of crickets to the ecosystem can be appreciated.

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