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Diversity and Abundance of Grasshopper and Locust Species in Nakuru County, Kenya

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ABSTRACT

This study evaluated the diversity, distribution and abundance of grasshoppers and locusts in three ecological zones of Nakuru County, Kenya. A total of 456 individuals belonging to Acrididae family (93.4% with 16 species) and Pyrgomorphidae family (6.6% with 2 species) were recorded. *Ailopus thalassinus* was the most abundant (27.4%) and distributed species. There were 5 dominant and 3 rare species (in zone II only). Abundance was highest in zone II (47%) and lowest in zone IV (24.3%) but was not significantly different ($p > 0.05$) among the zones. Species diversity and abundance were highly correlated ($r = 0.99$, d.f. = 2, $p<0.05$). Zone II and III, and Zone II and IV had highest species similarity (Jaccard and Sørensens similarity indices), while zone III and IV had the lowest. Zone II had the highest diversity (2.45), while zone III and IV had the lowest (1.37 and 1.30, respectively) at $t=0.04$ (Shannon-Wiener indices). Species were distributed more equitably (evenness) in zone II than the rest (Renyi diversity). Different areas in zone II had higher diversity (Shannon-Wiener), than those in zone III and IV at $t=0.0012$ and $t=0.0003$. Therefore, ecological zones affect species abundance and diversity and their conservation is threatened, thus forestry to improve biodiversity conservation should be encouraged.

Key words: Acrididae; Caelifera; Ecological zones; Nakuru County; Orthoptera

INTRODUCTION

Grasshoppers and locusts in the suborder Caelifera, order Orthoptera are one of the most diverse and ecologically important insects found in the grasslands (Latchininsky *et al*., 2011). They are known to be crop pests especially species like *Schistocerca gregaria*, *Locusta migratoria migratorioides*, *Anacridium* spp., *Nomadacris septemfasciata, Zonocerus elegans, Zonocerus variegatus, Phymateus viridipes* and *Phymateus saxosus* (Meynard *et al*., 2017). Their defoliation mode reduces the photosynthetic area of the leaves and their ability to aggregate facilitates mass feeding and hence, more crop destruction (Skaf *et al*., 1990; Safi, 2017; Lomer *et al.,* 2001). Moreover, some species of locusts and grasshoppers are used as human food such as *Sphenarium purpurascens*, *Oxya hyla hyla* and *Acanthacris ruficornis.* From literature, they are good sources of amino acids, fatty acids, crude carbohydrates, fibre and ash (Ghosh *et al*., 2016) .

Caeliferans also play some part in recycling of plant nutrients where in their absence; much would be bound up in dead plant tissue, insoluble and unavailable for plant uptake. Through passage of the plant materials in their digestive system, the enzymes and microorganisms break them down into smaller pieces which hasten the degradation of cellulose and other materials which are then released into the environment as fecal matter. When their fecal matter is degraded, it releases nutrients into the soil thereby favoring new plant growth (Cease *et al.,* 2015; Culliney, 2013). Caeliferans are also important elements in trophic food webs as they represent first order consumers where they convert plant tissue into animal proteins which serve as food for vertebrate animals and therefore facilitating their survival and reproductive efficiency which contributes to their abundance to some extent.

Various studies have shown that Acrididae family is the most common Caeliferan worldwide. For instance, it's found in Turkey (Sirin *et al*., 2010); in India (Arya *et al.,* 2015; Kumar & Usmani, 2014); in Sudan (Ibrahim *et al.*, 2015); in Pakistan (Samejo *et al*., 2016; Hussain *et al*., 2017); in Palestine (Abusarhan, 2017), in USA (Ullah Mohammed, 2012); in Malaysia (Tan & Kamaruddin, 2014) and in Europe (Hochkrich *et al.,* 2016). This can be attributed to the polyphagous mode of feeding, which means they are able to obtain food from a wide variety of plants.

The most dominant Caeliferan species varies from location to location. For instance, *Chorthippus dubius* dominates Qilian mountains in Northwestern China (Sun *et al.*, 2015), *Abisares depressus* in Lake Baringo, Kenya (Mungai *et al.*, 1995), *Spathosterrium pygmaeum* in Calabar Metropolis, southern Nigeria (Oku *et al*., 2011), *Aiolopus thalassinus* in Al-Tebbin region, South Cairo, Egypt (Soliman *et al*., 2016), *Dichroplus elongatus* in Pampas, Argentina (Cigliano *et al*., 2000), *Xenocatantops karyni* in Western Himalayas,

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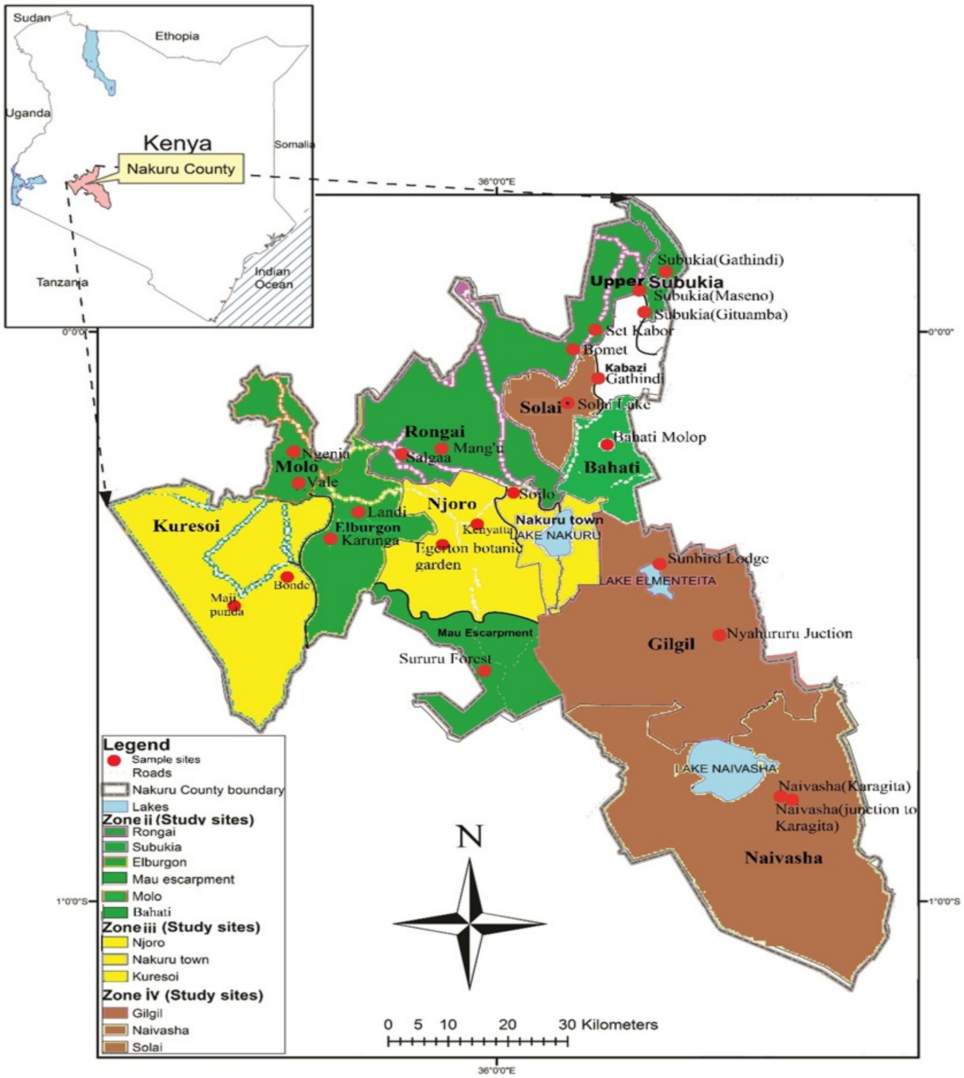

Figure 1. Map showing randomly selected sampling sites in Nakuru County, Kenya according to Ecological Zones.

India (Arya *et al.*, 2015), *Hieroglyphus banian* in Uttar Pradesh, India (Akhtar *et al*., 2012) and *Phlaeoba antennata* in Fraser's hill, Peninsular Malaysia (Tan and Kamaruddin, 2014).

Caeliferan diversity and distribution is influenced by both biotic and abiotic factors. Abiotic factors include temperature, with high temperatures resulting to increased metabolism while low temperatures results to reduced metabolism and therefore mortality. High rainfall results to physical damage of both immature and mature ones while increased water availability in the soils results in water laden plant tissues which makes it difficult to consume enough nutrients. It also provides high relative humidity which favours fungal growth. Low rainfall, however, results to little vegetation. Biotic factors include predators (insects, mammals, birds and reptiles), parasitoids (Coleopteran, Hymenopteran and Dipteran), and pathogens (viruses, fungi, protozoa and nematodes) (Lockwood, 2008). Plant diversity provides a variety of food due to their phytophagous nature as well as provision of microhabitats (Haddad *et al.*, 2001).

Despite their usefulness as already illustrated, very little is known about the diversity, the relative abundance as well as the distribution of Caeliferans in Africa more so in Kenya. The need for diversity studies therefore cannot be over-emphasized as this would provide information on the different species that exist in a particular ecosystem in the country, the relative abundance as well as the distribution of individuals. It's clear that such knowledge would provide an indicator of the ecosystem quality as the number of Caeliferans relates positively to other organisms present especially those preying on them.

This study aimed to gather data on the diversity, the distribution and influence of locusts and grasshoppers on the 3 ecological zones in Nakuru County, Kenya. The data collected will serve as a foundation for further investigations into the potential of locusts and grass hoppers as food for man and feed for animals in Kenya, an area that has been touted to be of great potential.

MATERIALS AND METHODS

Study area

The study was carried out in Nakuru County which lies in the Great Rift Valley and covers an area of 7,495.1km^2 (Figure 1). It is located between longitude $35^{0}28'$W and $35^{0}36'$E; latitude $0^{0}13'$N and $1^{0}10'$S. It has bimodal rainfall pattern with short rains falling between October to December while long rains fall between March and May. The temperature averages 29.3^{0}C between December and March while June and July are the coldest months averaging 12^{0}C. Nakuru County is classified into three ecological zones (II, III and IV). Zone II has Upper Subukia, Rongai, Molo, Elburgon and Mau escarpment and is found at elevation of between 1980-2700 m above sea level. It receives rainfall ranging between 1200 - 2600mm per annum and has volcanic and Latosolic soils. Zone III has Nakuru town, Njoro and Kuresoi and is found at elevation of 900-1800 m above sea level. It receives rainfall ranging between 950 and 1500 mm per annum and has Latosolic soils. Zone IV constitutes Solai, Gilgil and Naivasha and its elevation ranges between 900 -1800 m above sea level. It receives rainfall ranging between 500-1000mm per annum and has Alluvial and Locustine deposits (Jätzold & Kutsch, 1982). This area is inhabited by people of diverse ethnicity and nationality whose major economic activity is agriculture with maize and wheat being the major crops while in livestock farming, dairy is the main product.

Sample Collection

Insect sampling was done between 9 am and 2 pm. This is because in the morning they were less active and capturing was easy and as the day progresses, they become active and therefore easy to notice. However, they later retreat to hideouts due to the hot temperatures making it hard to find them. Sampling included the different habitats across the ecological zones where sampling methods included searching them in the grasses and shrubs which were followed by capturing using a sweep net or by hands. Every sampling point was geo-located with a GPS, then the GIS points recorded and then used to plot the points sampled in each ecological zone.

The collected specimens were transferred to a 500 ml Kilner jar, containing a cotton wool soaked with 6.9% diethyl ether concentration for killing. Those with different features were selected, counted and their representatives pinned using size three entomological pins. They were then placed in an insect box of 30cm length, 30cm width and 3 inches' height, which was fitted with one naphthalene crystal at each corner for preservation. The samples were then transported to the National Museum of Kenya for taxonomic identification (Marino-Perez & Song, 2018).

Data Analysis

An overall measure of locust and grasshopper abundance at each site was estimated by summing the counts of all species. Species dominance (D) was determined according to a method by Buschini and Woiski (2008): D = (abundance of a species/total abundances recorded) × 100. If D was > 5%, the species was considered dominant, if 2.5% < D < 5%, the species was considered an accessory species/ species of intermediate abundance, and if D < 2.5%, the species was considered an incidental species. Rare species were the ones that had less than 5 individual grasshoppers or locusts and/ or sampled from only one ecological zone. The unique species were the ones occurring with one individual: singleton, or with two individuals: doubleton). Species diversity and distribution in different ecological zones that included Shannon-Wiener Diversity Index (H′) and Simpson's Dominance Index (D^{-1}) were calculated using PAST software. The Sørensen and Jaccard similarity indices were used to compare similarities among the zones (Munyuli, 2002). Comparison of species diversity among the zones was done using Shannon diversity *t*-test and ANOVA (one way) which were performed in SAS® software version 9.1. The correlation (Pearson's correlation) between species richness and abundance of grasshoppers and locusts in the different zones was calculated using Microsoft Excel 2010.

RESULTS

The families, subfamilies, genus and species of the grasshoppers and locusts collected are shown in Table 1. A total of 456 grasshopper and locust individuals were sampled across the three ecological zones. There were 5 dominant species, 6 species with intermediate dominance, 4 incidental species, and 3 rare species, while there were no unique species from all the ecological zones (Table 1). Acrididae family was the dominant (93.4% of total individuals recorded) with 6 subfamilies which amounted to 15 genera and 16 species. Pyrgomorphidae family had only one subfamily with two genera and two species and accounted for only 6.6% of the total individuals. Across the ecological zones, abundance was highest in zone II (47%), followed by zone III (28.7%), while zone IV had the least individuals (24.3%) (Table 1). However, the p-value corresponding to the F-statistic of one-way ANOVA was greater than 0.05, which suggested that the abundance of butterflies in the three zones were not significantly different.

Different grasshopper and locust species varied in abundance among the ecological zones. Overall, the most abundant/dominant species was *Ailopus thalassinus* (D = 27.4) which was also highly distributed in the three zones, followed by *Acrotylus blondeli* (D = 13.16), *Acrotylus patruelis* (D = 11.18), *Parasphena ngongensis* (D = 8.6), and *Coryphosima stenoptera* (D = 7. 23) (Table 1). For zone II, *Ailopus thalassinus* (D = 7.9 and *Acrotylus blondeli* (D = 5.9) were the dominant species (Table 1). The most abundant species in zone III were *Ailopus thalassinus* (D = 14.25) and *Parasphena ngongensis* (D = 7.9). Zone IV had only 4 species and *Acrotylus patruelis* was the most dominant (D = 9.2), followed by *Acrotylus blondeli* (D = 7.2) and *Ailopus thalassinus* (D = 5.3), while *Acanthacris ruficornis* was the least dominant with D = 2.6.

In general, grasshopper and locust diversity and abundance were well correlated (r = 0.99, d.f. = 2, $p<0.05$). The rare species were present only in Zone II (Table 1). The shared species statistics (Jaccard and Sørensens similarity coefficients) between pairs of the three ecological zones are provided in Table 2. Zone II and Zone III, and Zone II and Zone IV showed the highest similarity in grasshopper and locust species. On the other hand, zone III and zone IV had the lowest similarity in grasshopper and locust species (Table 2). The overall diversity index (Shannon-Wiener) was found to be 2.38. The diversity of locust among the ecological zones was significantly different at t=0.04. Zone II had the highest

Table 1. Distribution of locusts within the study area at family, sub-family and species level.

Family	Sub-Family	Genus	Species	Zone_II	Zone III	Zone IV	Total individuals	Dominance (D)
Acrididae	Cyrtacanthacridinae	*Acanthacris*	*Acanthacris ruficornis*	6	3	12	21	4.6
	Cyrtacanthacridinae	*Cyrtacanthacris*	*Cyrtacanthacris tatarica*	0	9	0	9	2.0
	Cyrtacanthacridinae	*Ornithacris*	*Ornithacris pictula*	3	0	0	3	0.66
	Oedipodinae	*Aiolopus*	*Aiolopus thalassinus*	36	65	24	125	27.4
	Oedipodinae	*Acrotylus*	*Acrotylus patruelis*	9	0	42	51	11.18
	Oedipodinae	*Acrotylus*	*Acrotylus blondeli*	27	0	33	60	13.16
	Oedipodinae	*Trilophidia*	*Trilophidia conturbata*	21	0	0	21	4.6
	Oedipodinae	*Gastrimagus*	*Gastrimagus verticalis*	3	0	0	3	0.66
	Oedipodinae	*Sphingonotus*	*Sphingonotus turkanae*	12	0	0	12	2.60
	Oedipodinae	*Paracinema*	*Paracinema tricolor*	0	6	0	6	1.30
	Oedipodinae	*Heteropternis*	*Heteropternis couloniana*	3	0	0	3	0.66
	Gomphocerinae	*Rhaphotittha*	*Rhaphotittha nyuki*	18	0	0	18	3.93
	Eyprepocnemidinae	*Tylotropidius*	*Tylotropidius gracilipes*	7	0	0	7	1.52
	Acridinae	*Coryphosima*	*Coryphosima stenoptera*	21	12	0	33	7.23
	Catantopinae	*Pezocantantops*	*Pezocantantops impotens*	15	0	0	15	3.3
	Catantopinae	*Parasphena*	*Parasphena ngongensis*	3	36	0	39	8.6
Pyrgomorphidae	Pyrgomorphinae	*Pyrgomorpha*	*Pyrgomorpha conica*	9	0	0	9	2.0
	Pyrgomorphinae	*Chrotogonus*	*Chrotogonus hemipterus*	21	0	0	21	4.6
		Total		**214**	**131**	**111**	**456**	**100**

Table 2. Shared species between the ecological zones

	Zone II	Zone III	Zone IV
Zone II (S_J)		0.222	0.25
(S_S)		0.36	0.40
(SP)		4	4
Zone III(S_J)	-	-	0.25
(Ss)			0.4
(SP)			2

S_J, Jaccard similarity coefficient; S_S, Sörensens similarity coefficient; SP, shared species

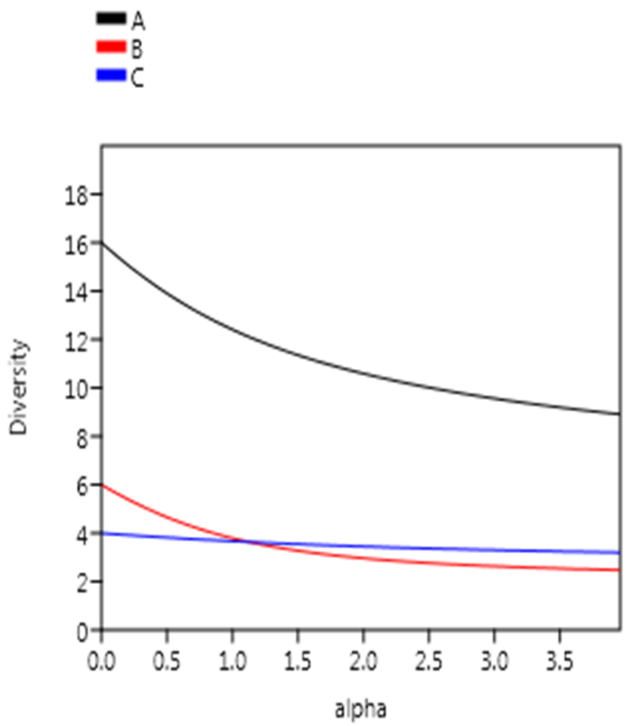

Figure 2. Rare species of locusts and grasshoppers collected from Nakuru County. 2a, Dominant species; 2b, rare species.

diversity index at 2.45 while zone III and IV had the lowest diversity index of 1.37 and 1.30, respectively. The Renyi indices of diversity (α-diversity) revealed that the number of grasshopper and locust individuals in zone II was not only higher, but the individuals in the zone were distributed more equitably (evenness) among the species (18 species). Zone III was second in evenness (6 species) and zone 4 was the least (4 species), however the interaction between zone III and zone IV indicates similar diversity and species distribution between the two zones (Figure 2).

Locust diversity and abundance among different areas within the ecological zones were found to be significantly different at t=0.0012 and t=0.0003 respectively (Table 3). Upper Subukia and Rongai areas, both in zone II, had the highest diversity indexes at 1.64 and 1.77 with lowest abundance indexes at 0.219 and 0.160 respectively. Mau escarpment, Nakuru town and Gilgil areas had the lowest diversity indexes at 0.00 with the highest abundance indexes at 1.00 each (Table 3).

DISCUSSION

Grasshoppers and locusts' diversity was highest in zone II and lowest in zone IV. Zone II was found to have some areas with small forests, thickets of bamboo and grasslands while in zone IV, there were little regions of grasslands, but Aloe Vera and cactus dominant plants. Previous studies have shown that there is usually a positive correlation between species diversity and vegetation

Table 3. Shannon-Wiener Diversity Index and Simpsons' Abundance Index for locust in different areas within ecological zones in Nakuru, Kenya

Ecological zone	Area	Shannon-Wiener index	Simpsons' index
Zone II	Upper Subukia	1.64	0.219
	Rongai	1.77	0.160
	Molo	0.95	0.301
	Elburgon	1.24	0.400
	Mau Escarpment	0.00	1.000
Zone III	Njoro	1.24	0.301
	Kuresoi	0.99	0.389
	Nakuru Town	0.00	1.000
Zone IV	Naivasha	1.02	0.371
	Gilgil	0.00	1.000
	Solai	0.54	0.720

where diversity increases with an increase in vegetation structure. The various species of plants provides hideouts from predators and harsh environmental conditions like sun and rain which facilitates survival. It also provides a variety of food when considered that most Caeliferans are polyphagous. Furthermore, detritus from the dead plants attracts microorganisms like algae, fungi, detritus matter, humus, moss found on the ground which provides nutrient supplement to the Caeliferans and therefore more food variety which translates to an increase in population and consequent dispersal and distribution. This was lacking in zone IV, which explains the little diversity and distribution observed (Haddad *et al.,* 2001; Jinchao *et al*., 2011).

Acrididae family had the highest number with 16 species while Pyrgomorphidae family had the least number with two species. It was also found in the three ecological zones as compared to Pyrgomorphidae which was found in zone II only. Other studies also found family Acrididae as the most dominant as well as most distributed (Thakkar *et al*., 2015; Arya *et al*., 2015). Members of this family are graminivorous in nature and the grasslands found in the ecological zones means a wide variety of food as well as breeding grounds since they breed in short grasses and then the mature nymphs and adults migrate to the long grasses. They are able to colonize habitats with both monocot and dicots plants and therefore are able to colonize a wide range of habitats which explains their wide range of diversity and distribution. The latter's monophagous mode of feeding is limited to plants with secondary plant chemicals which means feed availability is limited which influences their survival and distribution (Jerath, 1968; Paulraj *et al*., 2009).

Aiolopus thalassinus was the most abundant and was found in the three ecological zones. Various factors contribute to this. They inhabit meadows habitat and in the ecological zones, there exists both wet and dry meadows which facilitated availability of food, hideouts and breeding grounds. They have no seasonal differences in hatching between males and females and therefore nymphs can be produced at all seasons which facilitates relative distribution of all developmental stages. They are migratory in nature which is enhanced by them being good fliers which means they may migrate to unusual habitat types from usual meadows where they lay eggs followed by hatching which contributes to their even distribution. In addition, migratory individuals are sometimes found in areas unsuitable for reproduction further contributing to their even distribution (Heifetz & Applebaum, 1995; Kristin *et al.,* 2007; Holusa *et al*., 2013).

The present study presented few numbers of grasshoppers and locusts compared to other studies. For instance, Mungai et al. (1995) studied a one kilometer transect in Lake Baringo area where they found two super families, two families, ten subfamilies and fifty-three genera which amounted to 70 species while this study found two super families, two families, two subfamilies and sixteen genera which amounted to 18 species. This can be attributed to reduced habitats due to massive development activities especially construction of buildings and factories, filling up the wetlands as well as agricultural intensification like plantations which use broad spectrum pesticides resulting to the death of plants and other small fauna which has symbiotic relationships with the Caeliferans. This has resulted to migration, inhibiting their seasonal distribution pattern or adapting to change their breeding season to any favourable condition (Dey & Hazra, 2003; Weiss *et al*., 2013). This study feels that what was portrayed was some of the Caeliferans that exists in the three ecological zones of Nakuru County but many remain undocumented. It therefore recommends that diversity and dominance studies of Caeliferans be done in all seasons as this will not just show the species that exist but also how different seasons affect their distribution.

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