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Determination Of Effect Of Land Use On Distribution And Abundance Of Ground Dwelling Macro Invertebrates In Kirimiri Forest In Embu County, Kenya

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Abstract: Ground dwelling macro invertebrates are essential for soil functions and other significant ecological process such as nutrient cycling. The distribution and ecological role of crawling macro invertebrates may be influenced by anthropogenic factors. Human factors such as deforestation and agricultural activities that destroy the habitat pose great threat for the survival of macro invertebrates. Most of the natural ecosystems including forests in Kenya have been encroached, segmented and reduced in size by the rapidly growing population. However, studies on the impact of such destructive activities on the abundance and distribution of ground dwelling macro invertebrates are limited. Thus, there exist information gap on macro invertebrate composition and their distribution in different ecosystem and habitat segments in Kenya. Such studies are necessary in generating knowledge and creating wholesome understanding to facilitate policy making, habitat management and conservation of crawling macro invertebrates. Based on the above highlights, this study was conducted to determine the effect of land use on the distribution and abundance of ground dwelling macro invertebrate in Kirimiri forest in Embu County, Kenya between January and April 2016. The Napier grass plantation, Tea plantation and indigenous intact forest were evaluated for their macro invertebrates. In every habitat studied, crawling macro invertebrates were caught using the pit fall traps set in 50 m by 50 m grid subdivided into six rows at equidistance gap of 8 m. The pit holes comprised of 60 (250 ml capacity) clear plastic containers filled with 30 ml mixture of ethanol and liquid soap. Macro invertebrates were identified using their morphometric features and then stored in 70 % Ethanol for further laboratory identification at the National museums of Kenya headquarter in Nairobi, Kenya. The data collected was analyzed using Scientific Analysis System (SAS) version 9.4 and significance means separated using Least Significance Difference (SLD). The indigenous intact forest recorded the highest mean of macro invertebrates with family of Polydesmidae being the most abundant (mean=17.33). Tea plantation had the second largest mean (4.59) of macro invertebrates, and the family Gryllidae was the most abundant group with mean of 12.667. Napier grass plantation had a mean of 3.94 and the family Platydesmidae was the most abundant group (mean=12.833). The disparity in abundance and distribution of terrestrial macro invertebrate observed in this study may have resulted from micro climate and microenvironment shift influenced by human activity along and within the forest.

Keywords: Macro invertebrates, Habitat effect, Kirimiri forest, Embu County, Kenya

I. Introduction

Macro-invertebrates are organisms that are visible by naked eye and lack the spine. Examples of macro- invertebrates include flatworms, crayfish, snails, clams and insects, such as dragonflies [1]. Invertebrates may be grouped as aquatic invertebrates [2] [3], wetland invertebrates [4] [5] or terrestrial macro-invertebrates. These invertebrates are significant component of biodiversity in any ecosystem in terms of functionality [1] [2] [6] [7]. Ecosystem biodiversity loss may compromise important process of communities' such as efficient resource acquisition, biomass production, decomposing, and nutrient recycling thus affecting ecosystem stability [8] [9] [10]. Numerous studies have been done on aquatic macro invertebrates. Jackson and Reder [2] studied freshwater macroinvertebrates in the United States of America in relation to their frequency, lifespan and ecological significance. Mabid et al. [10] studied the distribution and diversity of the aquatic macroinvertebrates assemblages in semi-arid areas within the Eastern Cape Karoo in South Africa and reported on the macroinvertebrates which included Notonectids, copepods and Gastropod molluscs occupying wetlands.Variation in macroinvertebrates was associated with water turbidity, pH and altitude [10]. Studies on aquatic macro invertebrates have also been reported in Heilongjiang province Northern China [5], Mexico [11], Antarctica [12], Southeast Alaska [13] and, Tanzania [14]. In Kenya, Abongo et al. [15] studied aquatic macroinvertebrates in Nyando river catchment areas. Additional studies of macro invertebrates in Kenya have been at Moiben river [16] Mara Basin [17] and in Lake Victoria [18]. Evidently, there exist scanty information on the terrestrial as compared to aquatic macroinvertebrates despite their ecological significance [19] [4]. Terrestrial crawling macro invertebrates are very important in the soil functions and to the human life [20]. Nonetheless, hundreds of these organisms are fast becoming extinct worldwide [21]. Due to knowledge gap that exists on macro invertebrates [22], studies' aiming at generating knowledge on abundance, evenness and their distribution is necessary. Further studies on effect of habitat change on distribution of terrestrial macro invertebrate are fundamental. Significance of enhanced study on macro-invertebrates is justified by rapid habitat loss globally [22]. Habitat loss has been hastened by anthropogenic activities like the real estate development, agricultural practices such as fertilizer and herbicides application and uncontrolled harvesting of forest resources [23]. Habitat destruction goes against expected human responsibility of conserving the biodiversity for efficient ecosystem function [24]. Though the Rio Janeiro 1992 Convention on Biological Diversity require member states such as Kenya to document their fauna and flora to enhance biodiversity conservation [25] most of Kenyan fauna of most habitat particularly macro invertebrates in many forests remains largely un-documented. The current study was conducted to generate knowledge on the effect of land use on composition, distribution and abundance of macro invertebrates in Kirimiri forest in Embu County in Kenya. Our data does not build on any previous information of the study area but compares the findings to other studies done elsewhere in the world. We hypothesize that there was no significant difference in the number of macro invertebrates across Napier grass plantation, tea plantation and in indigenous forest areas of Kirimiri Forest in Embu County.

II. Methods

Study Area

Kirimiri forest is located in the Mukuuri locality of Runyenjes, Embu County in Kenya (Figure 1). It covers an area of about 800 acres and it is recognized as an ecologically sensitive site in Africa by International Union for Conservation of Nature [26]. There are a variety of rare indigenous and medicinal trees and animals that are threatened by deforestation and disturbance. Its' Centre lies at the latitudes of S 000 25' 22.30" and longitude of E 37^o 32' 41.42"and it has an elevation of 5454 feet above sea level at the hilltop. The elevations within the homesteads where Napier grass plantation takes place is at the height of 4939 feet, a longitude of S 00025.640` and a latitude of E 037033.038`. At the edges where the Tea plantations takes place the elevations are at 5038 feet above sea level, a longitude of S 00025.655` and a latitude of E 037033.002`. The predominant languages spoken are Kiembu, Kiswahili and English. The hill is culturally famous as a hideout for Mau Mau fighters including Embu's most venerated fighter General KubuKubu. The total population of Runyenjes is 142,360. The area receives a bimodal rainfall with two distinct rainy seasons. The long rains (March- June) while short rains in (October-December). Rainfall quantity received varies with altitude averaging from 640 mm and in some areas to as high as 1495 mm per annum. The temperature ranges 12^0C in July to a maximum of 30^0C in March with a mean of 21^0C as mentioned in Ogolla et al. [26]. There are three major types of vegetation around this region: Intact forest, Tea plantations and the Napier grass plantation. The forest appears not to have experienced any fire disasters. The soil in the forest is composed of dead organic matter and thus very soft in nature.

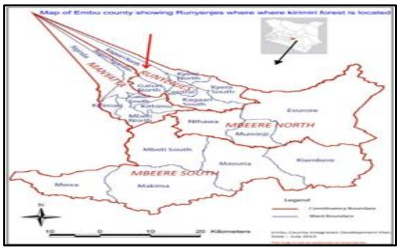

Figure 1: Map of Embu County showing the study site

Sampling Procedure

Sampling was done between January and April 2016. Six parallel line transects separated by 8 m gap were made in a 50 x 50 sampling grid across the study site. Ten pitfall stations were established a long individual transects at equidistance gap of 4.6 m that totaled to 60 pitfalls for every study site and 180 for the whole study. Each pitfall trap consisted of a transparent plastic bowl of diameter 6 cm and 8 cm depth, buried to its' rim in soil and partly filled with a mixture of soap and 30 ml 70 % Ethanol in accordance with Pekár [27]. Ethanol served as a preservative while the soap ensured that the macro invertebrates remained afloat by enhancing surface tension of the preservative. Traps were set at 8 am and checked on the following day at 8 am.

Data Collection

Trapped macro invertebrates were collected by sieving the content of the trap and picking by forceps. The specimen collected were stored in vials containing 70% ethanol preservative and the vial labeled as per the station transect and collection date.

Data Analysis

The data on the Macro invertebrate's abundance obtained were analyzed using Scientific Analysis System (SAS) version 9.4 and the significance means were separated using least significance difference (LSD).

III. Results

1. Major Grouping of Macro Invertebrates in Kirimiri Forest

The forest recorded the highest number of functional groups having 7 decomposers, 5 herbivores, 6 omnivores and 5 predators. The Napier plantation had had the least number of functional groups having 1 decomposer, 2 herbivores, 3 omnivores and 1 predator (Figure 2). The last habitat type was the tea plantation, which had 4 decomposers, 3 herbivores, 4 omnivores and 2 predators

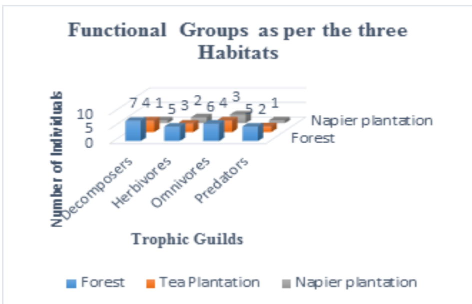

Figure 2: Functional groups as per the three Habitats

2. Macroinvertebrate Family Variation in Tea, Forest and Napier grass plantation

Habitat type had significant effect on distribution of macro-invertebrates (α=0.05). Means of Gryllidae spp was significantly different (p=0.05; F=0.026) across the three habitats. However, Gryllidae spp mean in the forest and Napier plantation was not significantly different. The mean of Jullidae spp across the three habitats was significantly different (p=0.05; F=0.037). However, there was no significant difference of mean in Tea and the Forest habitats. The mean of Platydesmidae spp across the three habits were significantly different (p=0.05; F=0.003) but its' mean in Forest and Napier did not differ significantly. Though the mean of Polydesmidae spp were significantly different (p=0.05; F=0.0084), the mean were not significantly different in Tea and Napier plantations (Table 1). There was no significant differences in the mean of Lycosidae (p=0.05; F=0.986), Ellobiidae (p=0.05; F=0.966), Carabidae (p=0.05; F=0.992) among other families across the three habitats (Table 1). In tea plantation, the most dominant macro invertebrates was Gryllidae spp with mean of 12.667 followed by Lullidae spp (10.167) and Jullidae spp (9.50). The least observed macro invertebrates in tea plantation was Formicidae with mean of 1.668 as compared to Forest (3.333) and then Napier (4.0). The second and third dorminant families in the tea plantation were Lycosidae spp (2.0) and Gnaphosidae spp (2.50) respectively. The difference between the highest and the lowest macroinvertebrate mean is 10.999 in tea plantation. In the forest, the dominant macro invertebrate was Polydesmidae spp with a mean of 17.33 as compared to Tea (9.333) and then Napier (3.667). Polydesmidae spp was the most observed family followed by the Crangonyctidae spp (16.0) and Platydesmidae spp with mean of 14.16. The least observed macro invertebrates in the forest were Curculionidae spp with the mean of 1.33 followed by Lycosidae spp (2.167) and Ellobiidae spp (3.0). In the Napier grass, the dominant macro invertebrate was Platydesmidae spp with mean of (12.833) as compared to Forest (14.167) and then Tea (2.333). The second and third dominant species in the Napier plantation were Crangonyctidae spp (8.0) and Termitidae spp (5.833) respectively. Apidae spp was the least observed macro invertebrate in the Napier plantation with the mean of 0.33 followed by Geomatridae spp with mean of 1.00 and Curculionidae spp with the mean of 1.833. In the tea plantation (mean=4.59) only Gryllidae spp, Termitidae spp, Jullidae spp, Lullidae spp, Lymantriidae spp, Polydesmidae spp, Arthoracophoridae spp, Crangonyctidae spp and Apidae spp had their means above the overall mean. Forest had overall mean of 6.33, Termitidae spp, Jullidae spp, Lullidae spp, Lymantriidae spp, Platydesmidae spp, Polydesmidae spp, Gnaphosidae spp and Crangonyctidae spp had their means above the overall mean. Formicidae, Arthoracophoridae, Arionidae, Scarabaeidae, Nitulidae, Curculionidae, Caribidae, Nymphalidae, Crangonyctidae, Tubificidae, and Polyxenidae appeared in the three habitats (Tea, Forest and Napier) with no significant mean differences [α=0.05](Table1)

Table 1: Mean Separation Table

Invertebrate Family	Tea	Forest	Nappier	Means	Lsd	F	MSE
Gryllidae	12.667^{a}	3.500^{b}	4.1667^{b}	6.778	6.950	0.026	29.19
Termitidae	5.167^{a}	7.500^{a}	5.833^{a}	6.167	4.836	0.561	5.541
Cantharidae	4.167^{a}	4.333^{a}	5.500^{a}	4.667	7.128	0.901	4.760
Jullidae	9.500^{a}	11.33^{a}	3.333^{b}	8.056	6.123	0.037	4.335
Lullidae	10.167^{a}	8.333^{ab}	3.833^{ab}	7.444	5.576	0.075	5.098
Lymantriidae	7.333^{a}	6.833^{a}	2.167^{a}	5.444	6.558	0.204	2.993
Saturnidae	3.000^{a}	4.333^{a}	2.333^{a}	3.222	3.850	0.522	3.463
Platydesmidae	2.333^{b}	14.16^{a}	12.833^{a}	9.778	4.454	0.003	5.946
Polydesmidae	9.333^{b}	17.33^{a}	3.667^{b}	10.111	7.649	0.0084	35.36
Pyralidae	2.833^{a}	4.167^{a}	2.167^{a}	3.056	3.990	0.544	7.122
Geomatridae	3.0^{ab}	5.167^{a}	1.0^{b}	3.056	3.131	0.043	5.095
Ariolimacidae	3.833^{a}	4.0^{a}	5.0^{a}	4.278	4.936	0.852	15.20
Formicidae	1.668^{a}	3.333^{a}	4.0^{a}	3.000	5.220	0.606	24.49
Arthoracophoridae	5.167^{a}	6.167^{a}	5.0^{a}	5.444	4.936	0.852	5.433
Arionidae	3.0^{a}	4.667^{a}	2.833^{a}	3.500	3.923	0.537	8.722
Scarabaeidae	3.167^{a}	4.667^{a}	4.333^{a}	4.056	5.176	0.799	18.06
Nitulidae	2.667^{a}	3.0^{a}	2.50^{a}	2.722	3.513	0.949	2.933
Curculionidae	2.833^{a}	1.333^{a}	1.833^{a}	2.0	2.313	0.375	4.489
Caribidae	3.667^{a}	4.333^{a}	2.333^{a}	3.444	3.719	0.450	4.433
Nymphalidae	4.333^{a}	5.333^{a}	4.50^{a}	4.722	5.703	0.917	3.122
Gnaphosidae	2.50^{b}	6.50^{a}	0.667^{b}	3.222	2.675	0.002	3.759
Crangonyctidae	7.333^{a}	16.0^{a}	8.0^{a}	10.444	8.676	0.091	4.918
Tubificidae	3.50^{a}	4.833^{a}	4.333^{a}	4.222	6.327	0.875	3.411
Lycosidae	2.0^{a}	2.167^{a}	2.333^{a}	2.167	4.388	0.986	3.692
Polyxenidae	2.333^{a}	4.0^{a}	4.167^{a}	3.50	4.75	0.646	2.079
Carabidae	3.167^{a}	3.50^{a}	3.50^{a}	3.389	6.554	0.992	5.488
Ellobiidae	3.333^{a}	3.0^{a}	3.833^{a}	3.3889	7.060	0.966	3.877
Apidae	5.167^{ab}	6.0^{a}	0.333^{b}	3.833	4.988	0.061	9.622
TOTAL MEAN	4.59	6.33	3.94				

*Means followed by the same latter rows are not significantly different
*LSD= Least Significance Difference, MSE = Mean Square Errors, F= F-value

3. The Overall Variation of Macro Invertebrates Species in Kirimiri Forest

The macro invertebrate spp abundance in Kirimiri forest varied from one family to the next. The most abundant macro invertebrate family was Thiaridae with an abundance of 7.73 %, the second was Polydesmidae (7.48%) and third was Platydesmidae (7.24%). The least abundant family was Curculionidae (1.48%), followed by Lycosidae (1.60%) and third was Nitulidae (2.02). The difference between the most and the least abundant macro invertebrate families in Kirimiri forest was 6.25 percent. Percentage abundance of the macro invertebrate families collected and the total number of individuals are shown below.

$$\text{Abundance (\%)} = \frac{Individuals\ No.collected\ per\ family}{Total\ \ No.of\ individuals\ collected\ in\ all\ the\ families} x100$$

Table 2: Table showing Oval macro-invertebrate Family Abundance in Kirimiri Forest

Table 2: Percentage abundance of Macroinvertebrates in the three Habitats Invertebrate Family	Number of individuals	Percentage (%)
Gryllidae	122	5.00
Termitidae	111	4.56
Cantharidae	84	3.45
Jullidae	145	5.96
Lullidae	134	5.51
Lymantriidae	98	4.03
Saturnidae	58	2.39
Platydesmidae	176	7.24
Polydesmidae	182	7.48
Geometridae	55	2.26
Pyralidae	55	2.26
Ammodesmidae	77	3.17
Formicidae	54	2.22
Arthoracophoridae	98	4.03
Arionidae	63	2.59
Scarabaeidae	73	3.00
Nitulidae	49	2.02
Curculionidae	36	1.48
Caribidae	62	2.55
Lumbricidae	85	3.50
Gnaphosidae	58	2.39
Thiaridae	188	7.73
Tubificidae	76	3.13
Lycosidae	39	1.60
Aeshnidae	63	2.59
Limacidae	61	2.51
Ellobiidae	61	2.51
Apiidae	69	2.84
TOTAL	2432	100

IV. Discussion

Decomposers were the leading functional group in the forest, as compared to the Napier plantation and Tea farm. We did not find any similar study to compare these results. The results may be explained by shift in habitat parameters such as moisture, temperature and nutrients which in total affect distribution of organisms across habitats [28] [29]. The high abundance of decomposers in the forest that has mixed vegetation may be attributed to the difference in soil vegetation covers that influence forest's environment such as conducive temperature and nutrient composition [29] [30] [31][36]. This is different from the Napier and Tea plantation with single dorminant plantation. Gryllidae was the most abundant family in the tea plantation. These results are similar to Alexander and Otte [32] which reported that Gryllidae are the most abundant family in plantations. This may be explained by the fact that Gryllidae family such as crickets feed on both vegetation matter and other insects unlike others which depends on decomposed materials. This result is different from report by Graham et al. [33] that observed Formicidae as the most abundant in the undisturbed and also moderately disturbed areas of the forest. Polydesmidae recorded the highest abundance in the forest areas. The dominance of this macro invertebrate in the forest may be as a result of less habitat disturbance and high moisture content in the forest [34] [36] [36]. Curculionidae was the least abundant macro invertebrate in the forest. These results are different from that of Bouchard et al. [37] which reported Curculionidae as most abundant family in the forest. The difference in the observation may be attributed to variation in forest's diversity. Certain macro-invertebrates including Termitidae, Cantharidae, Saturnidae, Ellobiidae and Lycosidae were captured across all habitats in almost equal frequency in our study indicating that they were habitat non-specific. Thus, these habitat nonspecific macro invertebrates could cross and inhabit intact forest, tea plantation as well as Napier plantation. Physiologically, such organisms are able to survive, since they regulate or tolerate harsh non-conducive habitat changes such as reduced food source, water loss and niche heterogeneity [38] [39]. Abundance of Termitidae family in tea plantation may be explained by the fact that they tend to live in colonies and mainly feed on stem and leaves which they decompose [39] [40]. The highest observed macro invertebrate in the forest was Polydesmidae followed by Crangonyctidae and Platydesmidae. These results differ from those of Gichana et al. [17]. The reason for the difference may be due to difference in study sites that vary in their micro climate parameters [31]. Molluscs were abundant in the forest. The finding corroborates with those of Oke and Chokor [41]. According to Göltenboth and Widmann [31], Molluscs such as snails are sensitive to habitat change and therefore they dominate intact forest with conducive environment. Thus, lower number of molluscs observed in the Tea and Napier plantation as a result of monoculture and a sign of disturbance [41]. In Napier plantation, the most observed macro invertebrate was Platydesmidae followed by Crangonyctidae and thirdly Termitidae. We did not find any related study. The abundance of Platydesmidae in the plantations may be linked to the abundance of leaf litter and quality of the soil [42]. The lowest observed macroinvertebrate was Apidae followed by Formiciade and finally Gnaphosidae. These results differ from those of Sekiranda et al. [18]. The lower abundance of Apidae can be attributed to the monoculture nature of Napier farm since Apidae family is reported to do well in a polyculture plantation [43]. The highest macro invertebrates were the Thiaridae followed by Polydesmidae and finally the Platydesmidae. We did not find any similar studies relating to our finding. According to Cortes et al. [11] families that are abundant in deciduous and tropical forest are key ecosystem engineers. In some parts of the tea plantations near the forest, there was a high amount of macro-invertebrates which may be due to declined light intensity and other abiotic extremes [44][34] [36]. It is plausible to argue that the macro invertebrates species observed in the tea and Napier grass plantation may comprise of communities adapted to thrive in the modified conditions such as that created by monoculture plantation. Overall, the forest had the highest abundance, followed by tea plantation and lastly the Napier grass plantation. The number of macro invertebrates differed significantly within the three habitats. Our findings are in line with those reported by McBrayer et al., [30] and Villalobos et al. [45] which suggested that highest abundance in terms of communities occurs in the forest habitat. Forest fragmentation may cause 'edge effect', which in the long run may be imposed onto the existing flora and fauna [44]. In general, Thiaridae had the highest abundance across the three habitats followed by Polydesmidae and then Platydesmidae. These findings are different from those of Stuhl [47] and Ukam et al. [48]. Curculionidae was the least abundant macro invertebrate across the three habitats followed by Lycosidae and then finally Nitulidae. Curculionidae was the least abundant family. Nitulidae were also less in abundance. These results are different from Stuhl [47] that reported that Nitulidae were the most abundant family in a study.

V. Conclusion

Distribution and amount of ground dwelling macro invertebrates were affected by land use. Disparities in ground dwelling macro invertebrate's distribution in the three different habitats points to the negative effects caused by human activities into the soil. Continued practice of these activities may end up having a negative effect on the environment hence causing ecological imbalance and reduced functions of macro invertebrates onto the soil such as aeration.

VI. Acknowledgement

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