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ORIGINAL RESEARCH PAPER

Influence of public road proximity on ground-dwelling insect communities

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ABSTRACT: Ecological studies on road's impact on wildlife have concentrated on vertebrates although less is known of their effects on invertebrates. The current study presents public road influences on species richness, abundance, and diversity of ground dwelling insects in Arusha National Park in Tanzania. Values from pitfall traps data were generally higher in core habitat than road verge. Nine species were only found in road verge and twenty eight species found only in core habitat. Results also show significant differences p<=0.01 in species richness, abundances and diversity of ground-dwelling insects, between road verge and core habitat with greater values for core area, where soil acidity was low and cation exchange capacity was high. Results suggest that high soil pH, relative to low soil pH, provides good conditions for different insects species. These findings provide evidence on the effect of public roads on distribution of wildlife communities in protected area and hence call for proper road design and management of established roads in protected areas.

KEYWORDS: *Core area habitat; Fragmentation: Road resources; Road verge; Species distribution*

INTRODUCTION

Background information of the study

Habitat fragmentation is one of the leading threats to biological diversity worldwide, along with biological invasions and over-exploitation (Franklin *et al.,* 2002; Geneletti, 2008). Habitat fragmentation involves outright destruction of a habitat, along with alteration, degradation, and fragmentation of large areas into smaller patches (Beazley *et al*., 2004; Kideghesho *et al*., 2006). Habitat fragmentation,in turn, creates landscapes of distorted habitats different from those to which species have adapted over evolutionary time (Donaldson and Bennett, 2004; Spellerberg, 2007). Some documented adverse effects of habitat fragmentation to species and populations include changes in the availability of type and quality of food and cover, increase in predation rates, competition and nest parasitism (Forman, 2000; Underhill and Angold, 2000) . Of all the known causes, roads constitute a major contributor to terrestrial habitat fragmentation through dividing large landscapes into smaller patches and converting interior habitats into edge habitats (Rusak, 2003; Ree *et al*., 2015; Watson, 2005). "In the context of roads, research has so far largely considered the effect of roads up on individual and species; this leaves major questions over our understanding of the impact of roads on biodiversity at the population and community level" (Roedenbeck *et al*., 2007). Most studies investigating the effect of road on animals have concentrated on vertebrates, for instance Beazley *et*

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al., 2004 on moose, Eigenbrod and Hecnar (2009) on anuran, Fuentes-Montemayor et al., (2009) on small mammals and Kioko et al. (2015) as well as Ontario Road Ecology Group and Toronto Zoo (2010) on different vertebrate taxa. However, the ecological consequences of roads on invertebrate remain relatively unknown (Munoz et al., 2014). This paper presents findings from a study aimed at understanding how roads alter community composition of ground-dwelling insects on road side habitats in Arusha National Park. The paper describes how insect species richness, abundance, and diversity vary as one moves from the roadside to core area habitat in Arusha National Park and how soil and vegetation alteration may influence ground-dwelling insects proximal to the road.

The study has been carried out in 2016 at Arusha National Park, (Tanzania) which is located in Arusha region, in northern Tanzania.

MATERIALS AND METHODS

Study area description

Data for this study were collected in May 2016 from Arusha National Park (ANAPA) (Fig. 1) that covers an area of 552 km² and located between longitudes 36^0 45' and 36 ^{0} 56' East and latitudes 03^0 12' and 03^0 18' South (Maleko et al., 2012; TANAPA, 2004). As part of a larger regional ecosystem of mount Meru – Kilimanjaro – Amboseli, ANAPA lies along the eastern edge of the Great Rift Valley (KWS and TAWIRI, 2010). The climate in ANAPA varies with altitude, generally experiencing bimodal rainfall, with short rains from November to December and long rains from mid March to late May. January and February are the hottest months although temperature rarely exceed 27^0 C, while June to August is the cold season but with midday temperatures not below 15 ^{0}C (ANAPA, 2004).

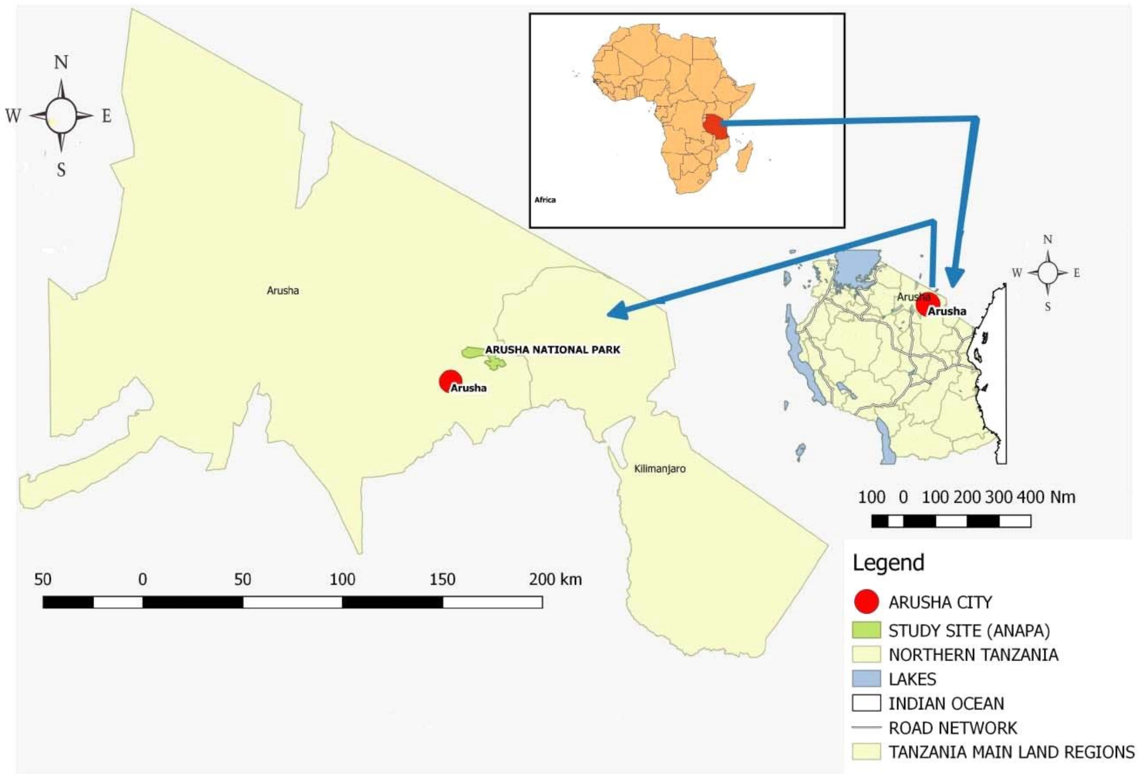

Fig. 1: ANAPA, Maps showing the location of Arusha National Park

Insects, soil and vegetation sampling layout

Insect trapping involved 60 plots randomly located within the road verge and core area i.e. within 100 m from the road after Sutherland (2006). The standard unit of trapping effort was 30 plots operated over a period of 3 days as recommended by McGavin (2007). Road verges had 30 plots as recommended by Zar (2010), with 15 plots located on left and right side of the road each. Plots were positioned parallel to the road as recommended by Marques *et al.* (2009).

The layout in the core area was modified so that only 30 traps were located on one side of the road, due to river proximity to the road and rocky nature of the landscape. The road verge plots started 3 to 5m from the road while in the core area, the same ranged from 80m to 100m depending on accessibility (Delgado *et al*., 2013).

Each plot had a 2 × 2m section within which four containers (i.e. unbaited pitfalls) were placed. Containers were laid from each angle of a plot after Rotholz and Mandelik (2013). Holes were dug using a trowel and plastic containers placed into the ground so that the rims were at the same or slightly below the level of the ground. Similar containers to those in Yi *et al*. (2012), measuring about 15cm in diameter and 5cm deep were used. There was preservative solution inside each trap (washing detergent/Omo), to arrest decay and prevent invertebrates from eating each other (McGavin, 2007).

Chemical analysis of soil samples to find out the differences in soil properties between road verge samples and core area. One soil sample (0–20 cm deep) was collected at each plot following recommendations by Lotfalian *et al*. (2012). The chemical properties tested for soil samples include pH level and Cations Exchange Capacity (CEC) for Sodium, Calcium, Potassium, and Magnesium. The sampling procedures followed soil sampling standards as recommended by EPA (2014). Furthermore, in each plot dominant plant species were identified and recorded to species level, and the height of vegetation was measured and recorded after Lotfalian *et al*. (2012).

Data management and analysis

Data on insects were analyzed for species richness, abundance per species and species diversity per zone proximally to the road (Buckland *et al*., 2005). Patterns of composition and diversity of plant and insect communities of the habitats along the road verge and at the core areas were analysed .Shannon index of diversity was employed because it assumes equal representation of populations (Boduszek, 2010; Colwell, 2009; Mason *et al*., 2013). Two groups i.e. road verge insects composition and core area habitat insects' composition were tested by t- test at 95% confidence level using Microsoft Excel 2007Analysis Tool Pak. The mean score for variables i.e. abundance, species richness and diversity were tested (Boduszek, 2010). The aim of the test was to show whether the mean score of a population on the road verge ($\mu 1$) differ from that at the core area ($\mu 2$) (Gardener, 2012; Borden, 2010).

RESULTS AND DISCUSSION

Species richness of ground dwelling insects in road verge and core area

A total of 745 ground dwelling insects of 60 species were trapped. Out of the 60 species, 23 (38%) were common between road verge and core area habitat, 28 (47%) were found only in core area habitat, and only 9 (15%) in road verge sites (Fig. 2).

Simple species richness per plot was used to draw a graph of variation in species richness among the plots located in road verge and core area as (Fig. 3).The mean number of species per plot for road verge was 4 and core area habitat was 6.

Fig. 3 illustrates the higher species richness found at the core area plots when compared to that found at the road verge. A two tailed sample t- Test assuming Unequal Variances for number of species showed significant difference in species richness between core area habitat plots and road verge plots (p = 0.00057).

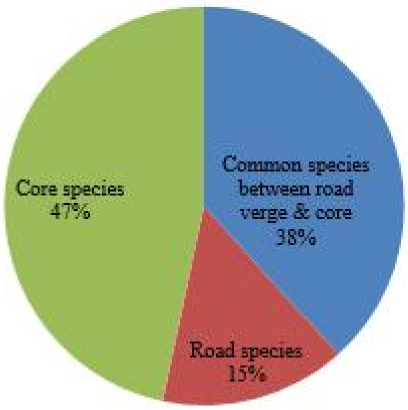

Fig. 2: Distribution of insect species found at the study sites.

Ground dwelling insects abundances in road verge and core area habitat

In this histogram the data on ground-dwelling insects abundance in individual plots from road verge site is represented side-by-side with the data from the core area, ilustrating the difference between the two study sites. Specifically, six of the core area habitat plots (e.g. 30,29,28,23 and 15) contributed the highest abundance of individuals accounting for 37.72% of the total. T- test for abundance of ground-dwelling insect indicated strong significant difference between plot abundances in road verge and core area habitat plots (p = 0.0026). The most abundant species in road verge was African thief ant, while harvester ant was the most abundant one in the core area.

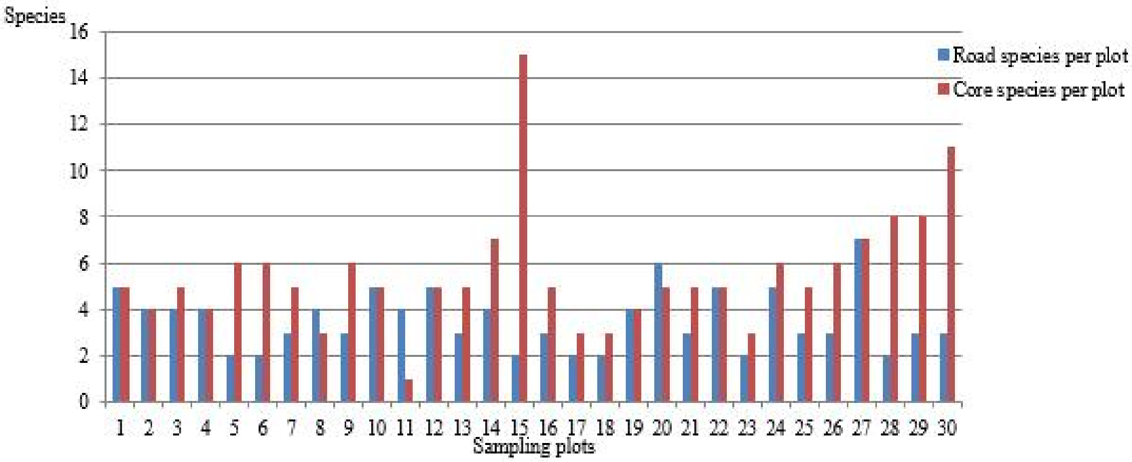

Fig. 3: Variation of insect species richness at each plot from the road verge (red) and from the core area (blue)

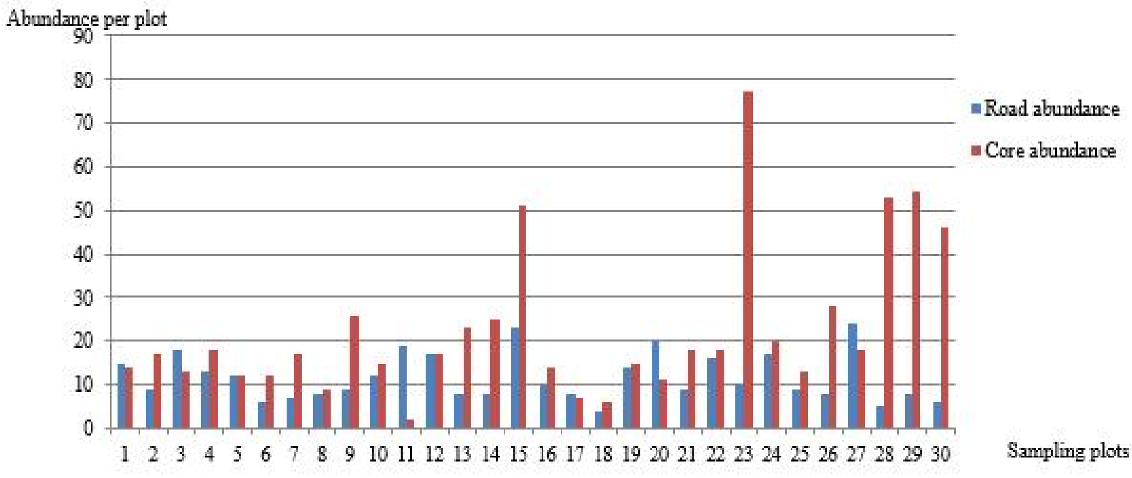

Fig. 4: Ground dwelling insect abundance at the plots of the core area (red) is higher than the abundance at the plots from the road verge site (blue)

Shannon index of diversity

The pattern of species diversities obtained at the road verge study site in compairison to that of the core area study site is ilustrated in Fig. 5. The respective statistical analysis are summarised in Table 1.

Overall, the core area habitat had a higher diversity per plot (i.e. >= 1.5) than the road verge plots (i.e. >= 0.3). Statistical tests for diversity showed significant differences between the plots in road verge and core area habitat (p = 0.0097).

The value followed format X ± S.E. Where; X – Mean and S.E – Standard error; Zone – refers to plots located along the road at the same distance from the road, i.e. for instance all plots that will be located at 5m from the road will form a single zone.

Comparison of dominant plant species

Seven dominant plant species were identified on the road verge. These species are *Acacia xanthophlea*, *Crotalaria barkae*, *Solanum incanum*, *Dodonaea viscosa*, *Juniperus procera*, *Penisetum clandestenum* and *Crassocephalum vitellinum*. Fig. 6 below illustrate occupancy frequency of seven species in two sites.

From Fig. 6, three species i.e. *C. vitellinum,C.barkae* and *P. clandenistenum* were only found in road verge, while *S. incunum* occupied less area in road verge compare to core area where it was abundant. A t-test for occupancy frequency of the species showed no significant difference for the dominant species occupancy between the road verge and core area habitat (p = 0.52).

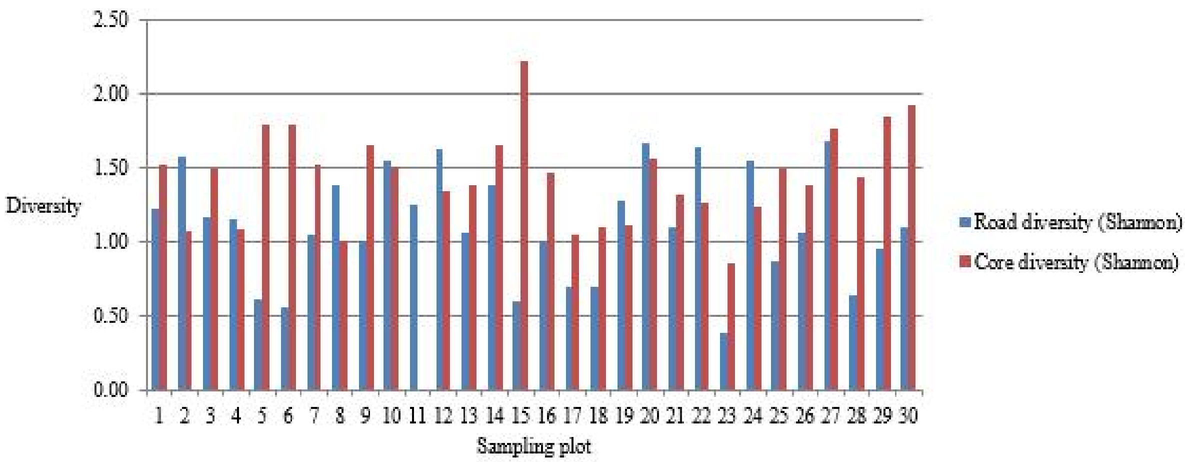

Fig. 5: Representation of ground-dwelling insects diversity at individual plots from road verge study site (blue) in comparison to those from the core area study site (red)

Table 1: Community composition variation

Attribute	Species richness (S)	Abundance (A)	Diversity (D)
Road verge zone	4±0.24	11.62± 1.01	1.12 ± 0.07
Core area zone	6±0.47	22.59 ± 3.20	1.39 ± 0.07
P - value	0.00057	0.0026	0.0097

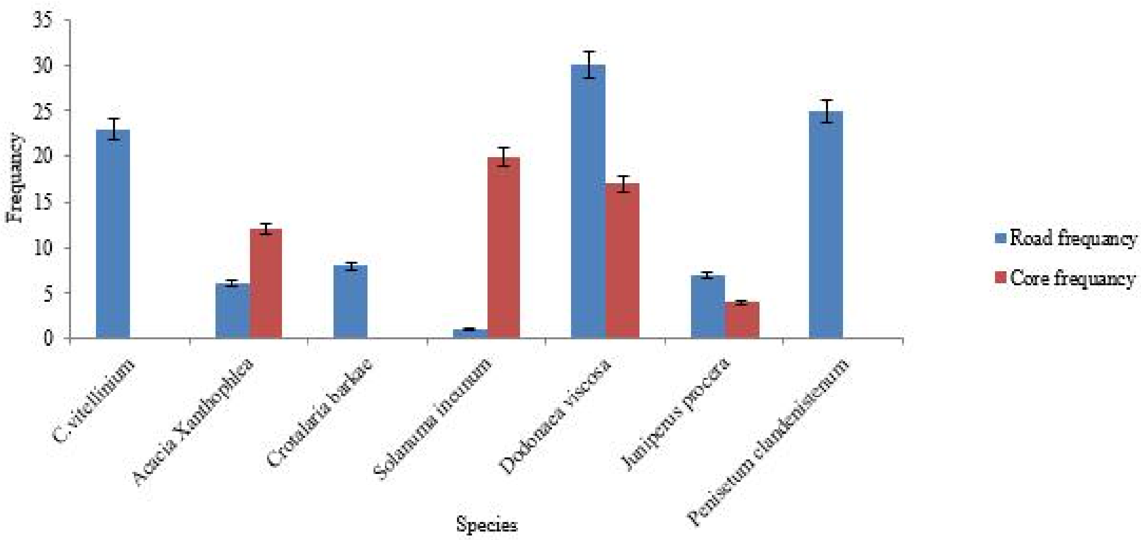

Fig. 6: Variation of common (dominant)plant species across the two study sites

Soil properties in road verge and core area

The results from chemical analysis of soil samples collected indicated a CEC gradient with increases from the road verge to core area habitat (Fig. 7).

From Fig. 8, pH influence insects' richness, diversity and abundance. Where the alkaline level was relatively higher, the road verge had lower species richness, abundances and diversity values than the core area of the park where soils were less alkaline. Furthermore, the CEC increases from road verge to core area also correlated positively with insect species richness, abundance, and diversity.

Ground-dwelling insect abundance, distribution, and diversity

Five most dominant insect species i.e. *Drosophila* spp, *Dycinetus morator*, *Sarcophaga spp*, *Anoplolepis spp* and *Afreumenes aethiopicus* accounted for about 60.17% of total individuals caught. Abundances for each dominant species was twice as larger in the core area than in the road verge. This suggests that, for these species,the core area and road verge acted as the source and sink habitat, respectively . Only nine species were found in road verge and not in the core area habitats. These were the *Danaus chrysippus*, *Agrotis iplsilon*, *Staphylu sceos*, *Solenopsis molesta*, *Hydrophilus spp*, *Cephonodes hylas virescens*, *Locust spp*, *Orthosoma brunneum* and *Hemistigma albipunta*. Furthermore, *Hemistigma albipunta* was trapped in road verge only. The fact that the area was riverside, these results imply the habitat for *Hemistigma albipunta* may have been disturbed by road activities.

The observed low species diversity in the road verge in comparison to core area habitat concur with those of USFWS (2011) which found an index of road density to be negatively correlated with diversity of macro invertebrates. These results therefore support an alternative hypothesis of the study and reject the null hypothesis in that significant variation exists between road verge species richness, abundances and diversities and that of core area habitat. Thus, public roads have significant influence on species richness, abundances and diversities of ground dwelling insect in Arusha National Park.

Plant species distribution and its influence on ground-dwelling insects

Plants on road verge grow rapidly with ample light and with moisture from road drainage. In reality, management often includes regular mowing, which slows woody-plant invasion (Alexander and Forman, 1998; Skorka *et al*., 2013). This practice is quite different to what was observed in this study in Arusha National Park, where wood plants are maintained along the road through mowing 3 times a year. This is a little contrary to earlier reports reviewed by Alexander and Forman (1998) whereby cutting and removing roadside vegetation twice a year, compared with less frequent mowing, resulted in more species of insect. The mowing regime is especially important for insects such as meadow butterflies and moths, where different species go through stages of their annual cycles at different time. The results also showed no significant variation of dominant plants species between road verge area and core area habitat. Usually, distribution of vegetation is good proxy for insect distribution pattern (Mike *et al*., 2004), based on the current results, it seems a slight variation of plants may contribute to significant variation of insects distribution in two sites.

Variation in soil chemical properties

The fact that all soil samples from the road verge were found to be alkaline while at least sample one from the core area was acidic suggests that a larger proportion of the soils along the road may be alkaline in nature, while that of core area could be a mixture of alkaline and acidic soils. A change in pH can be very detrimental to floral communities adapted to either basic or acidic environments (Ahmed, 2014). These changes in pH in turn affect insects species since some are either not adapted to acidic or basic soil conditions. On the other hand, CEC increases as one moves from the road to core area habitat, suggest that humus level is probably low in the road verge compared to the core area habitat. This low CEC in road verge areas would also explain their observed higher soil acidity levels.

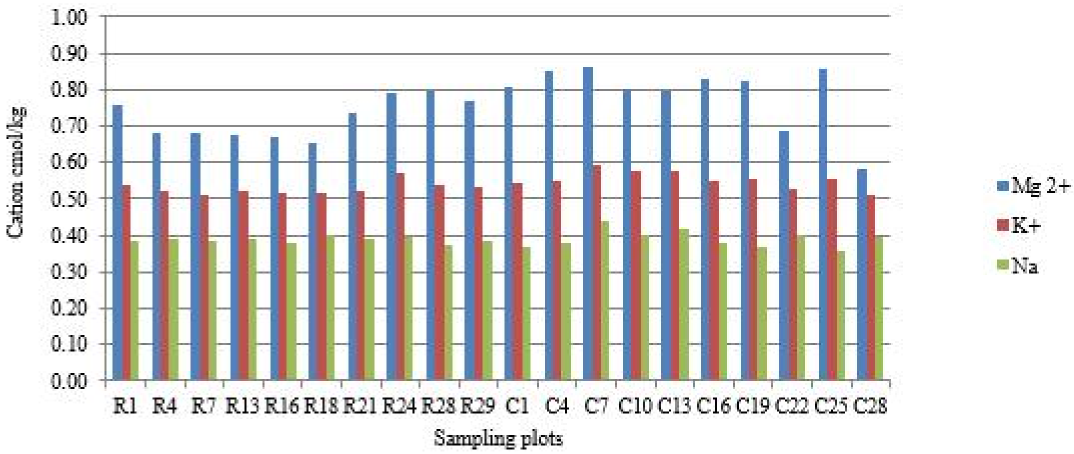

Fig. 7: Variation in cations exchange capacity for soils from the road verge and the core area habitat

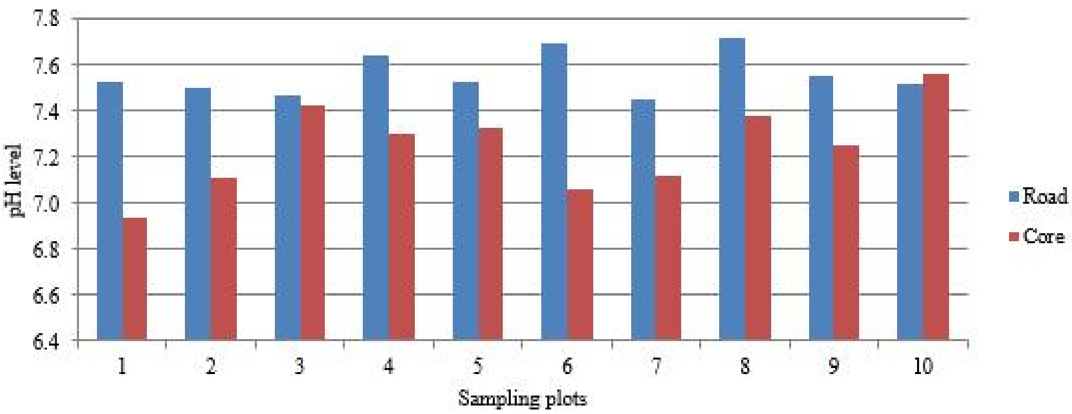

Fig. 8: Variation of soil pH level between road verge and core area plot

CONCLUSION

This study has revealed a significant difference in ground-dwelling insects species richness, abundance and diversities between road verge and core area habitat. There is a great need to establish key factor from road and traffic that are responsible for the influence seen in ground-dwelling insects.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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