Seasonal Dynamics of Carabid Beetles (Coleoptera : Carabidae) in Areas with Anthropogenic Disturbance. The Case of Uzungwa Scarp Nature Forest

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Abstract

Seasonal variation in diversity and community composition of ground beetles was investigated in the Uzungwa Scarp Nature Forest Reserve (USNFR), Tanzania. Carabid beetles were collected using three methods, namely pitfall traps, active day search and active night searching. Sampling of ground beetles was carried out in three seasons: dry season, wet season, and end of dry season in 2016, 2018 and 2019. Results showed that the diversity of ground beetles was highest during the wet season (Shannon-Wiener $H' = 2.19$) and lowest at the end of the dry season ($H' = 1.83$). The difference was statistically significant when comparing the end of dry season against the wet season, and between wet and dry season ($t = 5.85$ and 4.88, respectively, $p < 0.05$). Species richness was highest during the wet season and the difference was statistically significant among the three seasons ($\chi^2 = 13.46, p < 0.05$). Abundance was highest during the wet season, with mean number of carabid beetles $1.256 \pm 0.08$ per sample, and lowest at the end of dry season ($0.48 \pm 0.05$ individuals per sample). Kruskal-Wallis test revealed that the difference in abundance among the three seasons was statistically significant ($H = 128.3, p < 0.05$). Bray-Curtis similarity index showed low similarity in community composition among all three seasons. We conclude that ground beetles communities in anthropogenically disturbed areas vary with season, therefore to have a comprehensive sampling of ground beetles, sampling should cover at least one-year involving different seasons of the year.

Introduction

The distribution of arthropods may vary due to changes in climatic conditions and availability of resources such as food which may affect their diversity and composition (Chilima and Leather 2001, Leite et al. 2005). Different groups of arthropods have their highest abundance during different times of the year (Smythe 1983, Nummelin and Nshubemuki 1998). This seasonal variation is observed in many tropical regions due to well-defined dry and wet seasons (Leite et al. 2006, Hamer et al. 2005).

In carabid beetles, seasonality has been recorded to influence abundance, breeding periods, dormancy and larval development (Lovei and Sunderland 1996, Vennila and Rajagopal 2003). Also, factors such as prey availability and competition have been related to the seasonal variation of carabid beetles (Symondson et al. 2002, Currie et al. 1996). On the other side, carabid beetles have been reported to show flexibility in seasonal cycles especially in disturbed habitats, allowing them to reproduce at different periods of the year (Ranio 2013).

Carabid beetles play many ecological roles in ecosystems as seed predators and generalist predators, potential bioindicators but also they are very abundant (Kromp 1999, Nelson 2001), also they are potential biocontrol agent in agroforest ecosystems (Honek et al. 2007).

Anthropogenic disturbances such as fuel wood collection, trampling, fire, logging for both timber and building pole and hunting are very common in many forest including the Uzungwa Scarp Nature Forest Reserve due to high dependance of the people around the reserve on forest to sustain their lives (.........).
These activities may affect the carabid beetles because they may equally affect factors such as prey availability, dormancy period and competition. Available studies consider a single form of disturbance such as fire (……..), forest clearance (……..) conversion of natural forest for agriculture(………..), El-nino (Ariza et al 2021) in relation to seasonality. Studies in tropical ecosystems which considers multiple anthropogenic activities at a time are scarce.

The scarcity of studies also been evidenced in the Eastern Arc Mountains (EAM) where carabid beetles are only known in few localities include and very little is known about their ecology and seasonality. The available studies includes; Nyundo and Yaro 2007b on assessment of methods for sampling carabidae in montane forest, and Belousov and Nyundo 2013 on the description of new species from Udzungwa Mountain National Park (UMNP). Within the USFNR in particular, studies by Zilihona and Numelin 2000 and Zilihona et al. 2004 assessed the impact of construction of the Kihansi gorge on coleopterans, Mwambala et al. 2019 investigated the correlation between ground beetles and soil organic carbon. None of the above studies addressed seasonal variation in diversity and community composition of carabid beetles. Therefore, the aim of this study is to fill this gap.

**Materials and Methods**

The study was conducted in the USNFR (Fig. 1), part of the Udzungwa Mountains located in the southernmost area of the Eastern Arc Mountains of Tanzania and Kenya. Data was collected in November – December 2016, July – August 2018 and March – April 2019. According to TMA, these months mark the end of dry season, end of the wet season and mid-wet season, respectively. Sampling of ground beetles was carried out using three methods, namely, night active search, active search during the day and pitfall traps. The methods were selected to obtain complete information on all ground beetles diversity in the study area, as recommendations from other studies (for example Greenslade 1968, Nyundo and Yaro 2007a, Nyundo and Yarro 2007b). Geographical position and altitude of each site were recorded using a Garmin 60 GPS.

A total of twelve sampling sites were established (Fig. 1). At each site, 38 pitfall traps were installed (sunk into the ground with their rim level with the surface) at a distance of 10 meters apart to avoid ‘digging inn’ effect (Digweed et al. 1995). Square pieces of plywood were fixed above each trap using metal spikes to avoid rainwater in the traps during the rainy season. Pitfall traps were made of plastic containers (12 cm top diameter, 15 cm depth) which were installed in the ground and were half filled with propylene glycol (a preservative liquid). Traps were checked after one week and each trap constituted a sample. Active searching during the day involved searching for ground beetles in all possible hiding places encountered on the ground such as under logs, dead tree barks, rotting logs and in leaf litter. Using a sifter of 0.5 cm wire mesh size, sifting of dry leaf litter for carabids was done. Leaf litter was scooped onto a 1 m² white cloth and carabid beetles were collected by hand or forceps. Similar activities explained in active searching during the day were employed in the third method, night active search, except that this took place between 1900 and 23.30 hrs. Each collector was equipped with a three-battery headlamp to facilitate searching. Sampling for one hour constituted a sample. In all three methods, collected carabid
beetles were immediately transferred to labeled plastic containers containing 75% alcohol. Specimens collected by all the methods were transported to the University of Dar es Salaam, Department of Zoology and Wildlife Conservation laboratory for sorting and identification.

Data analysis

Ground beetles were identified following Basilewsky (1953), internet sources and voucher specimens available at Zoology and Wildlife Museum of the University of Dar es Salaam. Identification was made to species level whenever possible, while difficulties cases were identified to genus or subfamily level, then assigned a morphospecies code. Observed species richness (sobs) and estimated total species richness (using Chao’s (1987) estimator) were computed using the statistical software EstimateS version 6.0b1 (Colwell 2000). Chao2 is the best estimator of species richness, with a low and consistent bias (Walther and Morand 1998, Nyundo 2002).

Species diversity for each season was computed using Shannon-Wienner index and the level of significance was tested using diversity t-test. The differences in abundance between the three seasons were tested using Kruskal-Wallis test, while pairwise comparison between seasons was carried out using Mann-Whitney test. Bray-curtis similarity index was used to gauge the similarity in community composition among the three seasons. All statistical analyses were carried out using PAST software Version 3 (Hammer 2018).

Results

General results

The species accumulation curves using Chao 2 and Sobs showed that sampling effort was sufficient to represent species richness of the study sites for all the sampling periods (Fig. 2–4). This implies that, even if more samples were to be taken, there would be no significant increase in the number of new species obtained. During the wet season (2019) and end of wet season (2018), sampling effort reached saturation earlier when compared to end of dry season (2016).

Seasonal variation in carabid beetles abundance, species richness and diversity

A total of 2,024 individuals of carabid beetles represented by 41 species were collected during three collection seasons namely end of dry season (November-December 2016), end of wet season (July-August 2018) and wet season (March-April 2019). The mean number of carabid beetles per sample was highest in wet season and lowest at the end of dry season. The respective mean number of beetles (with standard deviations) were $1.256 \pm 0.08$, $0.598 \pm 0.06$ and $0.48 \pm 0.05$ beetles per sample for the wet season, end of wet season, and end of dry season. Kruskal-Wallis test showed that the differences were statistically significant ($H = 128.3, p < < 0.05$). Pair-wise comparison using Mann-Whitney revealed that
comparing between end wet and end dry, the difference was not statistically significant difference ($p > 0.05$), while comparing between end wet and wet season the difference was statistically significant ($p < 0.05$). Likewise,

Species richness of carabid beetles was highest during the wet season (41 species) and lowest at the end of the dry season (16 species). At the end of the wet season species richness was intermediate (21 species) (Fig. 5). The difference of species richness between seasons was statistically significant ($\chi^2 = 13.46$, $p < 0.05$). More than half of the collected species were encountered during wet season (55.88%), followed by end of wet season (24%) and the lowest contribution was from the end of dry season (20.12%). Some species were encountered in all three seasons of data collection in varying proportions, while others were collected in two seasons and others in one season only.

Shannon-Wiener diversity index revealed that, the diversity of carabid beetles in the USNFR was highest in wet season ($H = 2.19$) and lowest in end of dry season ($H = 1.66$), while the end of wet season was intermediate ($H = 1.83$) (Fig. 6). Dominance was highest in dry season (0.4) and lowest in wet season (0.21). Pair wise comparison of species diversity using diversity t-test revealed that between end wet an end dry season, the different was not statistically significant ($t = 1.71$, $p > 0.05$). A notable statistical significance different between end dry and wet season and end wet and dry season was obtained (respectively, $t = 5.85$ and $4.88$, $p < 0.05$).

In all seasons *Galeritiola procera* was the most abundant species contributing about 42.79% of the collected individuals, among the *G. procera* 48.49% were collected in wet season, while 28.41% only were encountered during the end of dry season and 23.09% encountered during end of wet season. The four most dominant species in wet season were *Galeritiola procera* (20.75%) followed by *Sphaerodes* sp 18 (14.23%), *Tefflus* sp (3.4%) and *Mamboicus* sp (2.71%). In end of wet season the four most dominant species included *Galeritiola procera* (9.88%) followed by *Abacetus* sp 39 (7.46%), *Metagonum mboko* (1.73%) and *Mamboicus* sp (0.94%). While in end of dry season *G. procera* (12.15%), *Mamboicus* sp (0.94%), *Morion* sp 1 and *Metagonum* sp 2 (0.69%) were the most dominant.

Twelve species of carabid beetles were encountered only during wet season. These were *Abacetus* sp 39, *Thyreopterus* sp 2, *Egadroma* sp 2, *Morion* sp 66, *Sphaerodes* sp, *Typhloscaris* sp, *Metagonum* sp 3, *Tyronia* sp, *Tyronia* sp 2, *Mamboicus* sp 1, *Pterostichinae* sp 2 and *Abacetus* sp 2. One species *Abacetus* sp 5 was encountered only at the end of wet season and no species were exclusively encountered at the end of dry season. Species encountered in end of dry season were also encountered in wet season and end of wet season in a varying proportions. Four species *Pterostichus* sp, *Tyronia* sp 2, *Mamboicus* sp 1 and *Tyronia* sp 1 were represented by singletons (0.05%). Bray-Curtis similarity index showed a low similarity in community composition of the collected carabid beetles between end wet and end dry season (0.21), end dry and wet season (0.19) and end wet and wet (0.26).

**Discussion**
The present study revealed significant influence of season in diversity and community composition of ground beetles. Higher diversity (in terms of abundance, species richness, and Shannon index) of carabid beetles was observed during wet season when compared to end dry and end of wet season. The difference between seasons was statistically significant. The results are in agreement with several studies, including Tanaka and Tanaka (1982), Pearson and Derr (1986), Hill (1993), Seymour and Jones (2000) and Maveety et al. (2014). Contrary to the present study Nyundo (2002), reported high relative abundance in dry season.

The peak abundance of carabid beetle species varied notably with season, also it was noted that some peaked in one season while some peaked in all three seasons. For example *G. procera* was abundant throughout the three seasons. Species such as *Tefflus*, *Sphaerodes*, *Mamboicus*, *Anchomenina* sp and *Megalonyinchus* sp peaked in wet season. *Morion* sp 1, *Morion* sp 2, *Metagonum* sp 2, *Thyropterinus limbatus*, and *Metagonus* sp 3 peaked in end of the dry season, while *Abacetus* sp 15, *Abacetus* sp 39, and *Thyropterinus* sp 2 peaked in end of the wet season. It is likely that some species of carabid beetles are limited to wet season and others can be encountered throughout the year due to the fact that carabid beetles vary in their level of tolerance to dry/ moist condition and individual optimal temperature and moisture requirement differs (Thiele 1977). Similar observations were noted in other studies such as Kadar and Szentkiralyi (1997), Ranio (2013) and Knapp et al. (2019) who reported variation in peaking season for different species of carabid beetles.

Other studies have reported variation in arthropod abundance with season contrary to the present study. Some had reported that arthropod abundance peaked toward the end of dry season in Australia, Costarica, and Peru (Struhsaker 1998). Novotny and Basset (1996) reported high abundance of Auchenorryncha in early wet season. In Kibale forest, Uganda Nummelin (1989) reported high arthropod abundance toward the end of wet season, equally Nummelin and Nshubemuki (1998) reported a similar pattern in Uluguru Mountains in Tanzania. They explained their results by postulating a lag-time in the build-up of the abundance, with peak abundance occurring 2-3 months after peak rainfall. It is likely that, studies that consider arthropods or insects lump together organisms, thus masking the variation in phenology of different species which may show a complex depiction when analyzed at a finer scale.

Equally present results corroborate with other studies in the rain forest which reported differences in abundance and diversity of insects (Hill, 1993; Seymour and Jones, 2000; Tylianakis et al. 2005) and of beetles (DeVries and Walla 2001) in rain forest in different seasons. On the other hand, the present results are not in agreement with results by Hill et al. (2003), who reported reduced number of insects during the wet season.

Among the three seasons, there might be great variation in soil moisture and temperature, this is due to the fact that, wet season in tropics, including Tanzania, is associated with long period of rainfall and warmer temperatures. End of dry season was associated with long sunny periods, while end of wet season was associated with occasional short rain and cold weather. These seasons might have created variations in soil moisture and temperature making the wet season favorable for carabid beetles. The two
aspects have been reported by several studies as responsible for fluctuation of abundance and species richness of carabid beetles (Lovei and Sunderland 1996; Yu et al. 2006; Fidan and Sirin 2016). The cold weather in end of wet season is not favorable for reproduction in carabid beetles. Studies such as Sotherton (1985) and Lovei and Sunderland (1996) have noted that some carabid beetles hibernate in the forest during unfavorable climatic conditions associated with changes in temperature and soil moisture.

Bray-Curtis similarity index showed low similarity between different seasons, indicating that there were great variations in species encountered among the three seasons and species turnover was very high. The high species turnover from one season to another implies that the total species pool is greater than can be established by one season of sampling. This means that relying on data from single time scale of sampling may lead to under/overestimations of number of species and irrational judgement of diversity between habitats in general (Roubic, 2001; Summerville and Crist 2005). Similar to the present study, Lucky et al. (2002) reported high species turnover of carabid beetles between sampling seasons in western Amazonian rain forest. Therefore, this study has shown that sampling carabid beetles in different seasons is important in understanding their ecology and plan appropriate conservation and monitoring strategies.

Conclusions

The results in this work have revealed seasonal variation in ground beetles diversity and community composition. Despite the presence of anthropogenic disturbances, phenology of ground beetles is apparently unaffected this might be related to a set of traits (e.g diapause) possessed by ground beetles that show adaptation to harsh conditions created by disturbances (Ariza et al 2021). It also appears that disturbance and season might hinder ground beetles availability. From these findings, we advise that, for a comprehensive data collection on ground beetles in disturbed areas, one-year period of data collection covering different months is recommended. Understanding important traits that help ground beetles to withstand disturbances is very crucial in tropics, especially given other threats such as climate change are also acting.

Declarations

Aknowlegement

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Declaration of Interest

The authors declares that there is no conflict of interest in any aspect.
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Figure 1

The map of the USFNR, showing the study sites in which data collection was carried out.
Figure 2

**Figure 2-4**: Species cumulative curve for carabid beetles. 2= end of dry season 2016, 3= end of wet season 2018, 4= wet season 2019
Figure 3

Figure 5: Species richness of carabid beetles in different seasons

Figure 4
Figure 6: Shannon-Wiener index for three seasons.