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Effect of Mining on the Diversity of Invertebrate in Peri-Urban Dar es Salaam

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ABSTRACT

This paper pertains to address the effects of mining activities on the diversity of invertebrates in three mining sites of Wazo, Bunju and Kitonga in peri-urban Dar es Salaam. Each site was divided into two areas: the mined area and the adjacent unmined area. In each of the two areas, three sampling plots were established and collection of invertebrates was carried out using three methods: pitfall traps, timed hand collecting, and sweep nets.

A total of 4,448 specimens comprising 360 species were captured. Of these, 1,149 specimens (156 species) came from Wazo, 1,011specimens (156 species) from Bunju and 2,288 specimens (197 species) from Kitonga. There were significant difference in abundance between the sites and between mined vs unmined areas at each site, with the highest abundance at Kitonga. Within-site there was higher abundance in unmined areas at Wazo and Bunju, while at Kitonga the mined area had a higher abundance of invertebrates compared to surrounding unmined area. Species richness were higher in the unmined areas and Kitonga, the younger site had higher richness compared to Bunju and Wazo.

Invertebrate diversity was higher at Wazo and Bunju in unmined areas than mined areas, while at Kitonga mined and unmined areas did not differ in diversity. It is concluded that mining activities had negative effects on invertebrate diversity. Recommendations are given on actions that need to be taken.

Key words: *Invertebrates, Peri-urban, Diversity, Mining*

INTRODUCTION

Mining is the extraction of the geological materials from earth. In Tanzania, mining is an important activity which contributes 2.3% of the National GDP[10] and the economic welfare of the people involved. Mining materials in the country includes minerals (gold, diamond, copper, nickel, cobalt, coal) and gemstones (Tanzanite), industrial raw materials (limestone, soda ash and phosphate), and construction materials (sand, stones and gravel) which are found in abundance in geographically diverse regions of the country.

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In Dar es Salaam, mining activity involves extraction of limestone, dimension stones, construction aggregates, sands and gravels for building purpose. It is conducted at large and small scales in which they operate as open cast mining; this may completely eliminate existing vegetation, displaces or destroys fauna and habitat, degrades air quality and to some extent permanently changes the land topography of an area.

Invertebrate in mining areas

Invertebrates are the largest and most diverse fauna group on earth and have a significant role to play in different ecosystems[7]. These organisms provide provision, regulating and supporting services within an ecosystem. Because of their ecological functions and services they provide; it is crucial to know their status and how diverse these organisms are in different ecosystem. The matter allows one to estimate how effectively the diversity of invertebrates has been compromised in each area. On the other hand measuring the effect of mining duration to invertebrate diversity was done. Area mined from 1990's back was considered as old mining areas and the areas mined from 2000's to date was considered as the young mined areas in this study. In this case Wazo site was an old mining area, the mining of the limestone started since 1959[11], and Bunju and Kitonga were new mined areas in which mining operation started since 2000s and both areas mining activities were still operation.

Peri-urban areas and invertebrates

Peri-urban are areas of transition or interaction zone, where urban and rural activities are put together, and landscape features are subject to rapid modifications, induced by human activities[5]. They experience immediate impacts of land demands from urban growth and pollution. These regions are far more environmentally unstable than either urban or rural settings[5], because of the pressure from urban. Although the area supports invertebrates and acts as a refuge from urban pressure, diversity of invertebrates in peri-urban mining area in Dar es Salaam is not known. Active mining and post mining areas in peripheral areas can be a home for useful organisms which escape the pressure from city centre. Also these areas can harbour harmful invertebrates which may act as vector of diseases like malaria, elephantiasis and bilharzias or they are of negative important to human health and properties.

The present study was carried out to determine the effect of disturbance caused by mining activities on the diversity of invertebrates in selected peri-urban sites around Dar es Salaam.

MATERIAL AND METHOD

The study was conducted in three mining areas (two of around age and one older) at periphery of Dar es salaam. First area was a limestone mining area (wazo hill quarry), the oldest quarry located approximately 25km from city centre with rich rock material extends for about 3.3km. Second a stone and aggregate mining area (mawela) located 30km from city centre with mining area extended to about 1.15km. Third, a sand mining area (kitonga) located approximately 28km from the city centre

Invertebrates Sampling and Handling

Three sampling protocols were employed; pitfall traps, hand collections and sweep nets in all three sites in mined and unmined areas. Sampling was carried out on December, 2013. For pitfall traps were six transects (3 on mined and 3 on unmined) of 100m long randomly selected with 10 pitfall of I litre plastic container positioned 10m apart with 4% formaldehyde in. Samples were collected daily for three days.

Invertebrates that were not active on the surface were collected by timed hand collection. This was done randomly for 30 minutes in the interval of 5min in mined and unmined areas in three days consecutively. Any invertebrates which were visually observed in the substrates like logs, stones and at the surface were collected by hand (using forceps and gloves as needed).

Invertebrates on herbaceous vegetation and flying ones were collected using the sweep nets. The sweeping were conducted randomly in the sites of mined and unmined each for 30minutes in three days consecutive.

Data were sorted, identified by using different identification keys[21,10,18,6,15], classified and analysed to determine the species abundance, richness, diversity and similarities. Kruskal-wallis analysis was used for hypothesis testing to see the difference in abundance between the sites. Mann-Whitney test was used to test the different between the mined and unmined sites and for pair-wise comparison for Hypothesis testing. Probabilities for statistical test was two tailed with 95% degree of confidence i.e. $\alpha = 0.05$. Statistical package employed for species diversity was Species Diversity and Richness (SDR) IV and Diversity Index used was Margalef Diversity index. Solow[20], randomization test were used to compare the significant different in diversity between sites. Similarity of invertebrates was calculated by S$_{ø}$rensen index.

RESULTS AND DISCUSSION

A total of 360 invertebrate species were collected with a total number of 4,448 individual specimens captured in all three sites. The minimum number of invertebrates collected from the traps was 0 while the maximum number obtained was 127. Species with the highest abundance was *Camponotus solenopsis* (Hymenoptera: Formicidae) with a total of 1,225 individuals. The average abundance was 14.49 individuals per sample with a standard deviation of 18.89. The total invertebrates taxa collected were 24 orders with Coleoptera, Lepidoptera and Hemiptera having high representatives of the species. The highest abundance came from Hymenoptera (Formicidae), Orthoptera and Coleoptera.

Impact of Mining on Abundance of Invertebrates

The abundance was 1,149, 1,011 and 2,288 for Wazo, Bunju and Kitonga respectively with the mean of 11.27±0.81, 9.91±0.57 and 22.43±3.07 individuals per samples. Based on Kruskal Wallis test the difference between abundance of invertebrates at the three sites was significant (Kruskal Wallis H = 22.701, p=1.177E-5). Pair wise comparison of the abundance by Mann Whitney U Test shows abundance at Kitonga was significantly higher compared to Bunju (Mann Whitney U=3,325.5, P=8.35E-6) and Wazo (U=6,745.5,P=0.0002), while Wazo and Bunju sites (U=4,858, P=0.413) show no significant difference in abundance.

Abundance between levels of disturbance

Unmined sites had a total abundance of 1,881 with a mean of 12.29 and mined sites had a total abundance of 2,567 with a mean of 16.778. The difference in abundance between mined and unmined sites was not significant (Mann Whitney U = 12,055 with p = 0.650). Omitting fire ants of the family Formicidae which had extremely high abundance at Kitonga with a total of 124 individuals in unmined and 1,101 in mined areas. The abundances were 1,757 and 1,466 in unmined and mined sites respectively. By omitting Fire ants the unmined areas had significantly higher numbers of individuals than mined areas (Mann Whitney U = 9,703, p = 0.009).

At Wazo the abundances of invertebrates between unmined and mined areas had a mean of 13.34 and 9.216 respectively. The difference was significant (Mann-Whitney U = 702, p < 0.005). At Bunju the abundances of invertebrate had a mean of 8.5 and 11.314 in unmined and mined areas respectively. The difference was significant (U = 1,743, p = 0.003). While Kitonga had a mean of 15.059 and 29.804 in unmined and mined areas respectively (U = 1,705.5, p = 0.0007) (Figure 3.2). The abundance at Kitonga was statistically significant with the Mined areas having higher abundance than unmined areas. However, when fire ants were excluded unmined area shows significant higher abundance compared to unmined area (U = 855, p = 0.003).

Abundance within levels of disturbance

Abundances of mined sites were 470, 577 and 1,520 for Wazo, Bunju and Kitonga respectively. Kruskal Wallis test, H = 26.529 has a p < 0.05 showed a significant differences in abundance within the mined level, (Wazo vs Bunju Utest = 1,716 P=0.005, Wazo Vs Kitonga UTest = 1,982 p=0.000001, Bunju Vs Kitonga Utest = 784 p=0.001)

Unmined areas had the abundance of 679, 434 and 768 for Wazo, Bunju and Kitonga respectively. The invertebrate abundance in the unmined areas were significant (Kruskal Wallis, H = 20.61, p < 0.05). Pair wise comparison for difference in invertebrate abundance shows that Wazo had higher invertebrate abundance than Bunju (UTest =678 P=0.1E-7) and Kitonga had higher abundance than Bunju (UTest = 757 P= 0.1E-7)

Effect of Mining on Species Richness

From the total 360spp collected Kitonga had higher invertebrate species richness (197spp) than Bunju (156spp) and Wazo (156spp). Total percent of invertebrate species in all three mined sites was 59.9 and in unmined area 71.9 out of 360 invertebrate species sampled. Unmined areas had higher invertebrate species richness than mined area. In the mined areas, Kitonga had a higher species richness of 101 spp, followed by Bunju 92 spp and Wazo 78 spp.

Effect of mining on invertebrate diversity

Diversity between sites

Magdalef D index (D) at Wazo area was D = 22, Bunju D = 22.4 and Kitonga D = 25.34. Randomization test by Solow[20],was used to test for the differences in diversity between Wazo, Bunju and Kitonga. (Difference between indices (Delta) = 0.406792, p = 0.8196 for Bunju Vs Wazo, Delta = 3.34, p = 0.987 for Wazo Vs Kitonga, and Delta = 2.934, p = 0.999 for Kitonga Vs Bunju). There were no significant differences in invertebrate diversities between the three study sites.

Species diversity between levels (mined and unmined)

The diversity were (Margalef D index = 25.99 for mined and 34.22 for unmined). There was a significant difference in invertebrate diversity between the levels Delta= 8.234, p < 0.05) unmined having higher diversity than mined.

Diversity within sites

Wazo Unmined D=17.64, mined D=12.51 for Bunju Unmined was D=18.61,mined D=14.31 and Kitonga Unmined D=19.72 and mined D=13.65. Wazo (Delta Value =5.12157 p=0.022) and Bunju (delta value=4.29378 p=0.0327) show a significant difference between their invertebrate diversities. Unmined areas had higher diversity than mined areas. In each case Kitonga invertebrate diversity showed no significant difference between the mined and unmined (Delta Value = 6.06852, p=0.2302).

Coefficient of species similarity

Similarities between species in the three sites were less than 50%. Comparison of the similarity of species between sites using Sorensen coefficient (S_s) were; (S_s = 0.487 for Wazo and Bunju; S_s=0.346 for Wazo and Kitonga and 0.368 for Bunju and Kitonga). Wazo and Bunju species were more similar than species found at Kitonga as seen in Figure 3.6

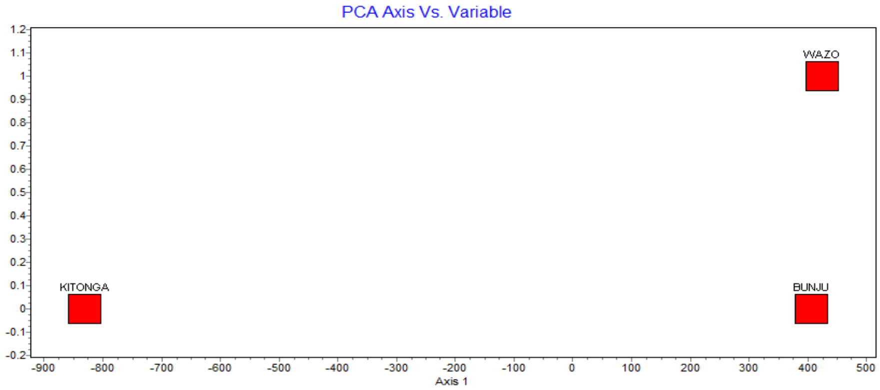

Fig. 3.6: Relationship between samples and species of Wazo, Bunju and Kitonga

Mine and unmined levels in all sites had 60% species of invertebrates in common. Comparing individual levels at each site between mined and unmined areas, invertebrate similarities were less than 50%. (S_s = 0.4089 for Wazo; 0.485 for Bunju and 0.309 for Kitonga).

DISCUSSION

Generally results from this study reveal that mining activities have negative effect on the abundance, richness and diversity of invertebrates. The unmined areas showed higher abundance, richness and diversity of invertebrates compared to mined areas. The recently mined sites had higher abundance than the older mined site.

Mining effects on the invertebrate diversity

Mining effects on Invertebrates abundance

The mined area has higher abundance which was highly contributed by one spp *Camponotus solenopsis* by 48% of all nimed area and 54% of mined area at Kitonga site than the unmined area. Removing *C. solenopsis* from the sample makes Unmined area to have higher abundance than mined area. The high abundance of *C. solenopsis* may be because of preference of ants for open habitat of warm sunny areas and their having a broad omnivorous diet[1].

Higher abundance in the unmined area may be due to the fact that most of the invertebrate species are herbivorous. Vegetation cover on the mined area was sparser this means less food for herbivorous invertebrates. Richer vegetation may also mean accumulation of plant matter that serves as nutrition for many invertebrates and also provide good physical environment. Open cast mining lead to the removal of vegetation and top soil layers, these results to loss of habitat diversity, ecological niches, food quality and protection from predator. Only generalist and adapted species will flourish in abundance in the mined areas. These results are also supported by other similar studies which show that mining activities had influence in the abundance of invertebrates. In Nongtrail Limestone, India it was found that butterfly and soil fauna were in highest abundance at the buffer zone compared to the core mining zone, the density of the soil fauna were 277 individual m^{-2} in the buffer zone and only 47individuals m^{-2} in the core mining area[2]. Possible reason from the author was that the unmined site had a rich organic soil and accumulation of leaf litters.

A similar research conducted by Novakova & Stastna[13]. on the Carabidae of an active limestone quarry of Mala dohoda, Czech Republic. The author collected a total of 37 species with abundance of 197 specimens, most specimens and species were captured from the plots at the edge of the quarry. The author postulated that the species of open habitat and generalist prevailed on the quarry edge. Study of Křížková *et al* [8],in the Czech Republic on the effect of active limestone mining on insects showed that mining activity affects the abundance of phytophagous insects which represent a significant percentage of the invertebrate group. The study points out that plant are consumed by members of some groups like Heteroptera, Hymenoptera and Lepidoptera larvae so high abundance will be in rich vegetation.

Mining effects on Invertebrate richness and diversity

Higher richness of invertebrates in the unmined areas may be attributed by sufficient and variety of food, water and better physical conditions than in the mined areas where the habitat was highly disturbed and the vegetation removed. This is supported by Niemela *et al.*[12], who suggested that cleared habitat needs more time for species to establish in high numbers in recently opened habitat after the disturbance.

A study conducted in Costa Rican Cloud Forest by Sheehan[19],comparing the richness, abundance and diversity of the leaf litter invertebrates across different levels of disturbance found that the invertebrate population, were much lower in richness, abundance and diversity in the pasture areas which were more disturbed than in the old growth and secondary growth forest with least disturbance. In a similar study conducted in

Usambara Chula *et al.*[4], found the species richness of aquatic macro-invertebrates to be higher in semi natural mined rivers compared to the rivers where active mining were taking place. According to the Intermediate Disturbance Hypothesis (IDH) the higher diversity and richness occurred at low level of disturbance due to competition hierarchy of species.

Results from the present study have revealed that disturbance caused by mining activities affect invertebrate richness negatively. This may be ascribed by abiotic and biotic species diversity hypotheses. Time stability hypothesis suggests that diversity is directly related to the length of time that an area of land has been around. Higher diversity and richness in unmined areas can also be explained by "the productivity hypothesis". Which says that more the energy there is in an area, the more biomass there will be in that area. More biomass supports greater species diversity. The mined sites had less biomass due to the clearing of the vegetation and top soil removal.

There are also some biotic factors which may influence higher species richness in the unmined than in the mined areas. These factors include heterogeneity hypothesis, competition and predation. Heterogeneity hypothesis suggests that the more spatially the community is the greater the species richness. The unmined areas had more heterogeneous habitat than the mined area. Study conducted in Canada by Saint-Germain *et al*.[17], showed that the ground beetle had significantly higher species richness in logged plots which were less disturbed than in the burned plots which were regarded as more disturbed habitats. Other study conducted by Barik [2].at Nongtrail Limestone mining found that the number of taxa of soil fauna was highest in the buffer zone than in the core mining area which may be because of the higher diversity of habitats and biomass in the buffer zone than in the core area.

Mining duration effects on invertebrate

Effect of mining duration on the abundance of invertebrates

Results from this study show that mining duration had a significant effect on the total abundance of invertebrates. This is shown by Kitonga site with a total abundance of 51% of all invertebrate collected. Ants may perhaps be a good successor in re-colonizing sand mined areas. Majer[9], studied the re-colonization of ants in sand mines at Stradbroke Island, Queensland and found that ant fauna on the older plots of mine had lower abundance and richness compared to the recently mined ones.

Wazo being an old mine site it had higher abundance compared to that of Bunju. This can be explained by the phenomenon of species area relationship. Larger areas accommodate more species than the small areas. Wazo being the larger mining area compared to Bunju, it is expected to have higher invertebrate abundance than Bunju.

A study conducted in South Moravia by Novakova & Stastna[14], on an old closed quarry and an active quarry showed that an a newly operated quarry had a higher abundance of carabid beetles compared to the old closed quarry. The explanation for higher abundance in the active quarry was the movement of carabid species from adjacent territory.

These findings are supported also by a study conducted at Moravia, Czech Republic by Benes *et al.*[3], which found that abundance of xerophilous and sedentary species of butterflies were higher in the young and actively operating quarry than in the old and abandoned quarry. The author explained that the young sites had higher heterogeneity of habitats which support large number of individuals compared to the old sites.

Effect of mining duration on the richness and diversity of invertebrate

Higher species richness at Kitonga may be explained by the disturbance hypothesis which states that as the frequency of disturbance increases the diversity of species increases because of the competition exclusion but when the frequency of disturbance is very high the diversity decreases because only good colonizers or highly tolerant species can persist. The disturbance caused by the mining activity at Kitonga was minimal compared to that at Bunju and Wazo as the site was opened for mining activity in 2009. According to the

Intermediate Disturbance hypothesis (IDH) high diversity occurs at the sites experiencing moderate levels of disturbance due to competition hierarchy of species. This could explain why species richness is higher in newly opened mine than in old operating mines.

From the present study Bunju site had the same species richness as Wazo, this may perhaps be due to the fact that Wazo has a large area which provide more food for different species than Bunju which is small in area. The phenomenon best described by Island Biogeography theory "The smaller the Island, the less the number of species" which also applies to terrestrial habitat. The positive relationship between habitat area and species richness is one of the few basic laws in ecology[16]. Factors influencing species area relationship may be the area itself, heterogeneity of habitat and sampling hypothesis.

Novakova & Stastna[14], conducted a similar research in South Moravia on the diversity of carabids in 2012 at two limestone qurries and found high diversity in active querry than in an old querry. The reason for high species richness in an active quarry was movement of species from the adjacent areas.

Similarity of species.

Wazo and Bunju species were more similar than species found at Kitonga. Wazo and Bunju geographically they are closer to each other in the North and Kitonga is in the South of the Dar es Salaam Region. Other reason for close similarity of Bunju and Wazo species may be the geological factor. The soil type of the two sites is rich in limestone materials which may determine the type and kind of vegetation found in the area.

The similarity of total invertebrates species found in mined and unmined areas were 60%. But at the site level the species similarity between unmined and mined areas were less than 50% with the Kitonga site having more dissimilarity of species between the levels. Less similarity of species between the mined and unmined areas may be because of habitat preference. Open habitat species will prefer the mined areas and at the edge of mining areas. At Kitonga only 31% of species found at the mined area were also found in the adjacent unmined area. This can be explained by the fact that when an area is first disturbed and vegetation removed it takes some time for species re-colonization and adaptation to the new area. These results show that the mining disturbance has effects on the variety of invertebrate species

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