

The butterfly community assemblage of Mowire Quarry Site in the forest agroecological zone of Ghana: Response of indicator biodiversity to ongoing quarry operations.

Sampson Addae¹, Sampson Addae², Michael Osae³, Danilo Harms⁴, Jones Quartey¹, Roger Sigismund Anderson¹, and Ben Aikins¹

¹University of Ghana

²Affiliation not available

³Biotechnology and Nuclear Agriculture Research Institute, Ghana Atomic Energy Commission.

⁴Universität Hamburg

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Abstract

Quarry operations cause serious environmental impact on invertebrate communities and contribute negatively to habitat destruction and the species they promote but very little is still known about the response of butterflies to such disturbances in western Africa. The current study provides data from a baseline survey of butterflies at Mowire quarry site in the agroecological zone of Ghana and investigates the effects of ongoing quarry operations on butterfly diversity. Specifically quarry operations were assessed on species abundance and richness. A total of 417 individual butterflies belonging to 67 species from 5 families was recorded in three zones. High relative abundance in the Eastern Zone (EZ) (N = 329) and high species richness (S = 55) may be due to increased flowering plants diversity which contain sweet nectar which attracts and support rich butterfly abundance. Low species richness (S = 22) and relative abundance (N= 41) in the Western Zone (WZ), and Northern Zone (NZ) (S = 21) and low relative abundance (N= 47), was corroborated with low plant diversity. Our results shows that, the EZ received less negative impact from the quarry operations but the operations negatively affected WZ and NZ. More generally our study indicates that state institutions should ensure mandatory environmental impact assessment reports from the quarry companies.

Introduction

Resource extraction through mining, lumbering, and quarry operations contribute to the economic lifeblood of many countries in Sub-Sahara Africa. Quarry operations are a major source of livelihood in the Mowire community, with a growing demand for limestone has led to the establishment of different scales of quarry companies in the district. Quarry operations have serious environmental impact on invertebrate communities and contribute negatively to habitat destruction and the species they promote. (Lameed, 2010). One of the greatest adverse environmental effect of quarry operation is the loss of species diversity (Anand, 2006). Insect biodiversity tends to provide clearer outcomes on ecological consequences of human-induced disturbance (Husseini, Abubakar, & Nasare, 2019). Arthropods are useful bio indicators of environmental modifications caused by anthropogenic disturbance such as pollution, habitat fragmentation, loss of habitat and early warnings of ecological change. Butterflies provide information on the health of ecosystem through species presence-absence and abundance data, hence they are used as bio indicator to monitor changes in habitat condition in the environment (Weisser & Siemann, 2008). The level of land degradation caused by stone quarry in Ghana has put forth questions as to whether or not the activity should be allowed to

continue (Nartey, Nanor, & Klake, 2012). Changes in landscape affect invertebrates more significantly and rapidly compared to other taxa. One of the greatest adverse environmental effect of quarry operations is the harm to biodiversity (Eta, Idiku, & Dan, 2019). Diversity and abundance of butterfly species can be used to assess the impact of anthropogenic activities on landscape changes, rapid biodiversity assessment, monitoring degraded land and managed ecosystem (Gandhi, Patel, & Padate, 2017). This study provides a baseline survey of butterfly abundance, diversity and species richness between three zones on the Mowire quarry site. Specifically the study sought to: i) to use butterflies as indicator species to assess the relationship between quarry operations and insect diversity in the quarry operational area. : ii) to assess the relationship between quarry operations and butterfly diversity and abundance between three zones of the quarry site. The Mowire Quarry site is perfect for carrying out this study due to the continuous quarry operations in the area and the large concession it holds.

Materials and Methods

Study Area

The research was conducted in Mowire near Kodie in the Ashanti Region of Ghana. An area lying between Latitude: 6° 48' 21.38" (6.8347°) north and Longitude: 1° 38' 25.43" (1.7172°) west with an elevation of 280m in the Afigya Kwabre District (Fig 1). Average temperatures ranged between 25.0 °C between July and August and 28.0 °C from March to April with an average annual rainfall of 1400 mm (Bannerman *et al* .,2013). The district experiences relatively high humidity ranging from 90% to 98% in the rainy season and drops to below 75% in the dry season (Bannerman *et al* .,2013). The district has a current population density of 397.3 persons per square kilometer with increasing demand of land for residential purposes whiles available land for agriculture and natural vegetation has been depleted. The forest vegetation has been degraded by lumbering, settlement development and agriculture. Part of the forest has been disturbed by various human activities such as farming, logging and quarry operations. The economy of the district is mainly agrarian employing about 61% of the total workforce. K.K quarry and Brosa Mineral Resource Limited are located at Mowire Township about (6km) away from Kodie on the Offinso highway. These two companies mine within the enclave of the quarry located in the town periphery. The quarry operation has existed and been active for the past fourteen years. Stone quarry is the main activity engaged by the two quarry companies. The stones are crushed into relatively small pieces of gravel-sized particles which are transported by heavy duty vehicles daily. Blasting of rocks are done every Tuesday and Friday. KK Quarry company take their turn to blast on Tuesdays whiles Brosa Mineral Resource blast on Fridays. The site was positioned on a radial map with three cardinal points Northern Zone (NZ), Eastern Zone (EZ) and Western Zones (WZ) (Figure1). Significant quarrying activities are undertaken on the (EZ) of the quarry operational which consist mainly of a secondary forest (dense canopy with a lot of undergrowth and sweet nectar plants) stretching along to the Northern part of the quarry. The EZ had the rock cracker which was a compact, cost-effective and transportable piece of machinery used to split, break stones and rock blocks, to reduce rocks and to split reinforced concrete. Crushing of stones into small pieces of rocks were done here. The rock cracker works almost every day for 24 hours generating a lot of noise and small volumes of dust to the adjoining environment. The (WZ) has two secondary forest (degraded with less canopy) patches as well as a sacred grove. The zone has a vast land which has been degraded by a lot of flying rocks from the quarry operations. Dust moves in this direction after every blast of the quarry which was done every Tuesday and Friday. The (NZ) comprises of a secondary forest and a settlement forming a large community and experiences a lot of land vibrations as a result of heavy vehicles which transport rock particles from the quarry site. The study was carried out between the months of August 2018 and February 2019, which spanned within dry and wet season.

Sampling Method and species identification

Sampling was carried out using a combination of aerial/butterfly net, random walk and count and Charaxes trap. Direct count of individuals were recorded along all the three zones and random walk sampling involving two individuals were employed during each visit throughout the sampling period. Four Charaxes traps (90cm in height), meant to attract alcohol-loving species or those attracted to fermenting fruits were set randomly

(200m apart) to avoid bias in each zone during the sampling period (Figure1). Aerial/butterfly net was also used to capture butterflies, especially those which were not easily identifiable in flight. The net was swung swiftly around butterflies in flight. The Charaxes traps were retrieved every six days between 7:00am and 10:00am for catches and reset throughout the sampling period, complementing it with random walk and count in each zone. Trapped butterflies were killed by pinching the thorax gently, but firmly and placed in labelled envelopes for morphological identification in the lab. Butterflies were identified to species level with reference to the collection at the Entomology Museum at Department of Animal Biology and Conservation Science, University of Ghana. Floral density and diversity in each zone was visually identified and counted.

Data Analysis

Statistical analysis on species richness, species abundance, evenness, species diversity and habitat similarities or differences in all the zones were examined and computed. Data from all the zones were pooled to obtain total diversity of insects for the entire study site and sampling period. Three diversity indices were computed using PRIMER 6 & PERMANOVA+ to compare data from all three zones. These were preferred because they allowed for qualitative assessment of sites by comparing their diversity indices (Chao *et al.*, 2005) which were treated for biodiversity assessment (Marshall *et al.*, 2006). Diversity indices (Margalef index, Shannon-index, Simpson index and Evenness) were calculated and compared between all three zones.

1. Species richness (Margalef): $d = (S - 1) / \log(N)$ - This is a measure of the number of species present, making some allowance for the number of individuals.
2. Pielou's evenness: $J = \frac{H'}{\ln(S)}$ - this is a measure of equitability, a measure of how evenly the individuals are distributed among the different species
3. Shannon-Wiener index: $H = - \sum p_i \ln(p_i)$ - incorporates both species richness and equitability components.
4. Simpson index (D): It is influenced by dominant species (Measures dominance and evenness).

n_i = the number of individual species in the sample, $\sum n_i = N$. p_i = the proportion of individual species in the sample, $p_i = n_i / N$. S = the number of species in the sample, N = the total number of individuals in the sample.

Results and Discussion

Relative abundance of butterflies in all the three zones

A total of 417 individuals belonging to 68 species from 5 families were collected from all the three zones. (Table 1). The main families included Nymphalidae (45 species, 106 individuals), Papilionidae (2 species, 21 individuals), Pieridae (14 species, 123 individuals), Hesperidae (4 species, 17 individuals) and Lycaenidae (3 species, 150 individuals). At the family level Papilionidae and Hesperidae had the lowest number of individuals while Lycaenidae had the highest number of individuals (Table 1).

Diversity indices of butterflies in all the three zones

The eastern zone (EZ) was the most diverse site for butterflies, with the highest relative abundance of individuals ($N = 329$) and the highest species richness ($S = 55$), which was corroborated with the highest Margalef index ($d = 9.317$) with a Shannon Weiner index ($H' = 2.616$) (Table 2). Two families Lycaenidae and Pieridae had the highest relative abundance of individuals (42.9% and 30.7%) (Table 1).

The western zone (WZ) had low species richness ($S = 22$) and the lowest relative abundance of individuals ($N = 41$) with the highest Shannon Weiner index ($H' = 2.807$) corroborated by the highest Pielou evenness ($J' = 0.908$) (Table 2). Family Nymphalidae accounted for 61% of all the butterflies recorded in this zone (Table 1).

The Northern zone (NZ) had the lowest species richness ($S = 21$) as well as low relative abundance of individuals ($N = 47$) corroborated by the lowest Margalef index ($d = 5.195$) with a Shannon Weiner index ($H' = 2.696$) (Table 2). Family Pieridae and Nymphalidae had the highest relative abundance of individuals (34.0%) and (32.0%) respectfully for all the butterflies recorded in this zone.

Relative abundance of plant species in all the zones

A total of 386 individuals belonging to 25 genera were identified across all the three zones for the sampling period. The Eastern zone had highest relative abundance of individuals ($N = 175$) followed by the Western zone ($N = 111$) and the least from the Northern zone ($N = 100$).

Diversity indices of plant species in all the three zones

The eastern zone (EZ) had the highest relative abundance individuals ($N = 175$) and the highest richness ($S = 16$). The western zone (WZ) had low richness ($S = 13$) and the highest Shannon Weiner index ($H' = 2.241$) (Table 4). The Northern zone (NZ) had the lowest richness ($S = 13$) and the lowest relative abundance of individuals ($N = 100$) (Table 4).

Butterfly similarity index

This shows the similarity between the Eastern and Northern zone at 39.81% and similarity between Eastern, Western and Northern Zone at 27.74 %. From the dendrogram all the Zones are dissimilar since their percentages fall below 50% with Western and Northern Zones being more dissimilar.

The highest relative abundance ($N = 329$) and species richness (55 species, 5 families) of butterflies in the (EZ) may be attributed to the presence of large undisturbed secondary forest which serves as a refuge for butterfly species. This was in consonance with work done by Tudor *et al.* (2004) which suggest that vegetation structure is important for butterfly assemblage as a site for mating and thermoregulation. This correlated positively with the highest abundance of tree species (175) and tree diversity (2.17292) in the EZ. This conforms to work done by Wala *et al.* (2012) which suggests that diverse nature of plant species in forest ecosystem attract butterflies for foraging and reproductive purposes, which could result in higher species richness and abundance.

Low species richness ($S = 22$) and the lowest relative abundance ($N = 41$) of butterflies in WZ could be attributed to the movement of dust particles towards the zone after every blast of the quarry. This is in agreement with work done by Mabogunje (2008) who suggested that, quarrying carries the potential of destroying habitats and the species they support. Dust and vibrations from heavy vehicles that transport quarry products in the NZ could possibly have caused the decline in butterfly relative abundance ($N = 47$) and species richness ($S = 21$). This support work done by Nisic (2018), who indicated that quarry operations negatively affects the environment in a variety of ways during exploration, blasting, transportation and disposal of waste rocks.

Conclusion

Loss of suitable or quality habitats negatively affect the distribution and abundance of butterflies in the quarry enclave. The quarry operations had little effect on the diversity, abundance and richness of butterflies in the EZ and retained a suitable environment for insect diversity. However the quarry operations negatively affected WZ and NZ resulting in the lowest abundance of individuals and species richness. It is recommended that interventions to prevent biodiversity habitat loss in and around the quarry operational site should focus on policies that ensure and enforce the establishment of a dust control mechanism system in the extractive industry.

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Data Availability Statement : The data that support the findings of this study are available at <https://doi.org/10.5061/dryad.0vt4b8gxb>.

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Figures:

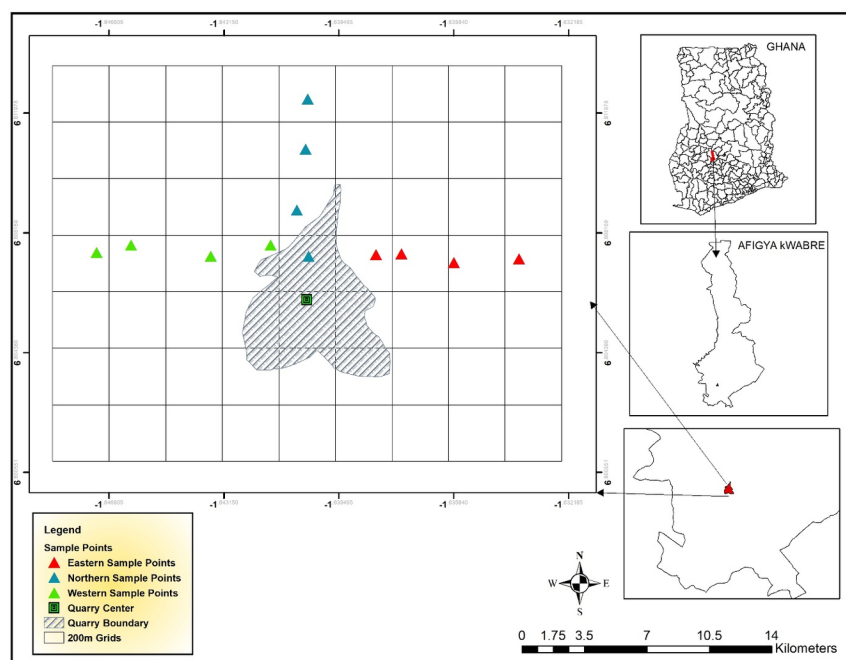


Figure 1: A map showing all the sampling points in all the three zones (**Source:** Addae, 2019)

Butterfly similarity index

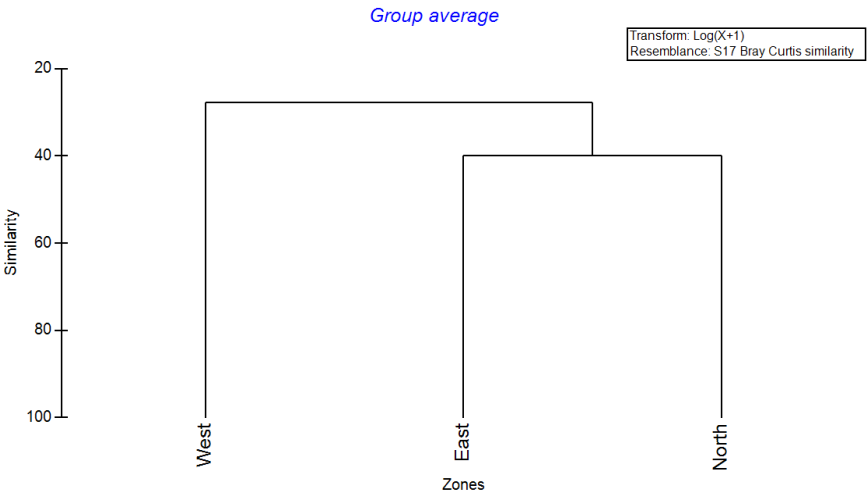


Figure 2: Dendrogram showing similarities of butterflies in the different zones

Table 1: Relative abundance (%) of butterfly families recorded in all three zones.

Family	Eastern	Western	Northern	Total
NYMPHALIDAE	66 (20.1%)	25 (61.0%)	15(32.0%)	106(25.4%)
PAPILIONIDAE	11 (3.3%)	1 (2.4%)	9 (19.1%)	21 (5.0%)
PIERIDAE	101 (30.7%)	6 (14.6%)	16 (34.0%)	123(29.5%)
HESPERIIDAE	10 (3.0%)	4 (9.8%)	3 (6.4%)	17 (4.1%)
LYCAENIDAE	141 (42.9%)	5 (12.2%)	4 (8.5%)	150(36.0%)
Total	329	41	47	417

Table 2: Diversity indices of butterflies recorded in all three zones.

Diversity index	Eastern	Western	Northern
H'	2.616	2.807	2.696
D	0.8218	0.9209	0.9072
J'	0.6529	0.908	0.8855
d	9.317	5.655	5.195
N	329	41	47
S	55	22	21

*Simpson index (D), Shannon-Weiner diversity index (H'), Pielou evenness (J'), Margalef (d), Number of individuals (N) and Number of species / species richness (S).

Species	East		West		North		Total
<i>Antiaris toxicaria</i>	4	(2.3%)	0	0	4	(2.3%)	8(2.1%)
<i>Albizia adianthifolia</i>	1	(0.6%)	0	0	9	(5.1%)	10(2.6%)
<i>Albizia zygia</i>	6	(3.4%)	0	0	2	(1.1%)	8(2.1%)
<i>Amphimas pterocarpoides</i>	<i>Amphimas pterocarpoides</i>	2	(1.1%)	0	0	0	2(0.5%)

Species	East		West		North		Total
<i>Baphia nitida</i>	30	(17.1%)	10	(9.0%)	0	0	40(10.4%)
<i>Baphia pubescens</i>	10	(5.7%)	3	(2.7%)	8	(4.6%)	21(5.4%)
<i>Blighia sapida</i>	1	(0.6%)	0	0	0	0	1(0.3)
<i>Ficus sur</i>	7	(4.0%)	0	0	0	0	7(1.8%)
<i>Ficus exasperata</i>	11	(6.3%)	11	(10.0%)	21	(12.0%)	43(11.1%)
<i>Margaritaria discoidea</i>	1	(0.6%)	22	(19.8%)	0	0	23(6.0%)
<i>Millettia zechiana</i>	9	(5.1%)	0	0	0	0	9(2.3%)
<i>Morinda lucida</i>	5	2.857143	17	(15.3%)	3	(1.7%)	25(6.5%)
<i>Newbouldia laevis</i>	0	0	0	0	6	(3.4%)	6(1.6%)
<i>Broussonetia papyrifera</i>	6	(3.4%)	18	(16.2%)	11	(6.3%)	35(9.05)
<i>Chromolaena odorata</i>	25	(14.3%)	0	0	0	0	25(6.5%)
<i>Elaeis guineensis</i>	55	(31.4%)	7	(6.3%)	16	(9.1%)	78(20.2%)
<i>Pseudospondias microcarpa</i>	2	(1.1%)	2	(1.8%)	0	0	4(1.0%)
<i>Leucaena leucocephala</i>	0	0	4	(3.6%)	0	0	4(1.0%)
<i>Spondias mombin</i>	0	0	2	(1.8%)	0	0	2(0.5%)
<i>Cocos nucifera</i>	0	0	0	0	10	(5.7%)	10(2.6%)
<i>Caragana arborescens</i>	0	0	0	0	4	(2.3%)	4(1.0%)
<i>Citrus medica</i>	0	0	12	(10.8%)	0	0	12(3.1%)
<i>Mangifera indica</i>	0	0	2	(1.8%)	4	(2.3%)	6(1.6%)
<i>Tectona grandis</i>	0	0	0	0	2	(1.1%)	2(0.5%)
<i>Alstonia boonei</i>	0	0	1	(1.0%)	0	0	1(0.3%)
Total	175		111		100		386

Table 3 . Relative abundance of plant species captured in all three zones for both seasons

Table 4 : Diversity indices of plant species for all the three zones.

Diversity index Eastern Western Northern

H' 2.173 2.241 1.992

N 175 111 100

S 16 13 13

* Shannon-Weiner diversity index (H'), Number of individuals (N) and Number of species / species richness (S).