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Impacts of Gas Flaring on Soil Fauna Biodiversity and Community Structure across a Flare-Distance Gradient at Agbada, Niger Delta, Nigeria

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ABSTRACT

Gas flaring can alter terrestrial environmental conditions, but soil-fauna responses may not follow a simple distance gradient. This study assessed soil-fauna abundance, taxonomic composition and biodiversity at Agbada Flow Station, Rivers State, Nigeria, using four distance-referenced stations: 500 m (A), 3 km (B), 5 km (C) and >5 km (D; external reference). Three replicate plots were sampled at each station at 0–15 cm and 15–30 cm soil depths, and fauna were extracted using a modified Berlese–Tullgren funnel. A total of 127 individuals representing 24 taxa and four major groups were recorded. Station A had the highest abundance (65 individuals; mean 21.67 plot^{-1}), whereas Station B had the lowest (5; mean 1.67 plot^{-1}). Station C had the highest taxonomic richness (S = 14), Shannon–Wiener diversity (H′ = 2.21) and Margalef richness (d = 3.60). One-way ANOVA showed a significant difference in mean abundance among stations, $F(3,8) = 4.816$, $p = 0.0335$. Tukey HSD identified a significant difference between A and B (adjusted $p = 0.028$), while all other pairwise comparisons were not significant. The results did not support a simple monotonic distance-response pattern. Instead, abundance and biodiversity displayed different spatial patterns, with high abundance at the closest station but greater taxonomic richness and diversity at 5 km. These findings indicate heterogeneous soil-fauna responses and support the use of multiple community and biodiversity measures alongside abundance when assessing ecological conditions in gas-flaring landscapes.

Keywords: gas flaring; soil fauna; biodiversity; soil microarthropods; Niger Delta; ecological disturbance; bioindicators

1. INTRODUCTION

Gas flaring is a persistent environmental pressure associated with petroleum production because combustion releases heat and combustion products into the surrounding atmosphere and terrestrial environment. In the Niger Delta, gas flaring has long been associated with environmental degradation and changes in terrestrial and aquatic resources (Ologunorisa, 2001; Seiyaboh & Izah, 2017; Adeoye, 2022). The ecological significance of flaring extends beyond atmospheric emissions because thermal and depositional effects may interact with existing soil and habitat conditions. Flare-associated environments may also contain combustion-derived contaminants. Studies of Nigerian oil-producing environments have reported spatial variation in environmental conditions around flare locations, while recent work has documented polycyclic aromatic hydrocarbons in soils around gas-flaring points in the Niger Delta (Adeoye, 2022; Odali et al., 2024). Such evidence provides a basis for considering below-ground biological responses alongside conventional physicochemical assessments. Soil fauna are important

components of terrestrial ecosystems because they contribute to decomposition, nutrient cycling and soil structure. Their abundance and community composition can respond to environmental stress, making soil fauna useful complementary indicators of soil condition (Menta & Remelli, 2020). Airborne pollutants can affect soil fauna directly or indirectly through changes in habitat conditions, food resources and other soil processes (Rusek & Marshall, 2000). Responses may differ among taxa and therefore may be expressed not only as changes in total abundance but also as changes in richness, dominance and evenness.

Land use is another important consideration when interpreting soil-fauna patterns. Soil-fauna abundance and richness can be altered by land-use conversion and associated changes in vegetation and habitat conditions (Chiappero et al., 2024). Consequently, a spatial comparison based on distance from a flare should not automatically be interpreted as a pure pollution gradient where stations also differ in vegetation, land use and other local environmental characteristics. Despite the ecological importance of soil fauna, comparatively little field-based research has examined how soil-fauna communities vary across gas-flaring distance categories in the Niger Delta. The present study addressed this gap at Agbada Flow Station using a distance-referenced design. The study determined soil-fauna abundance and taxonomic composition across four stations, evaluated biodiversity using richness, Shannon–Wiener, Simpson, evenness and Margalef measures, and tested whether mean abundance differed significantly among stations. The analysis was designed to assess spatial variation without presupposing a simple monotonic distance-response relationship.

2. MATERIALS AND METHODS

2.1 Study area and sampling design

The study was conducted around Agbada Flow Station in Rivers State, Nigeria, with the soil-fauna sampling component centred on Agbada 2, the larger of the two Agbada facilities. Four distance-referenced stations were used: Station A at 500 m from the flare, Station B at 3 km, Station C at 5 km and Station D beyond 5 km. Station D was treated as an external reference condition rather than a pristine control. Stations A and C were located in farmland with vegetation, whereas Stations B and D were residential areas with no or little vegetation. Three sampling plots were established at each station. At each plot, soil was collected at 0–15 cm and 15–30 cm depths, giving six samples per station and 24 samples in total. The design provided a spatial framework for comparing soil-fauna communities across increasing distances from the flare while recognizing the differing habitat contexts of the stations.

2.2 Soil sampling, extraction and identification

Soil samples were collected using an 8.5-cm-diameter bucket soil auger. Samples were processed in the Environmental Entomology Research Laboratory, Department of Animal and Environmental Biology, University of Port Harcourt. A locally fabricated modified Berlese–Tullgren funnel extractor was used to drive soil fauna from the samples into collection containers containing 70% ethanol. Extraction proceeded for seven days. Extracted organisms were sorted under a dissecting microscope and identified morphologically to the lowest practicable taxonomic level using available identification keys. The recovered fauna were grouped principally into Cryptostigmata, Mesostigmata, Collembola and Insecta.

2.3 Assessment of soil-fauna biodiversity

Total abundance, relative abundance, taxonomic richness (S), Shannon–Wiener diversity (H′), Simpson's dominance (D), Simpson's diversity (1 − D), Pielou's evenness (J) and Margalef's richness (d) were calculated for each station. The indices were selected to provide complementary information on numerical abundance, taxonomic richness, diversity, dominance and distributional evenness (Magurran, 2004; Pielou, 1966; Shannon, 1948; Simpson, 1949).

$p_i = n_i / N$

$H' = -\Sigma_{i=1}^{s} p_i \ln(p_i)$

$D = \Sigma_{i=1}^{s} p_i^2$

Simpson diversity = 1 − D

$J = H' / ln(S)$

$d = (S - 1) / ln(N)$

where p_i is the proportional abundance of taxon i, n_i is the number of individuals in taxon i, N is the total number of individuals and S is the number of taxa recorded at the station.

2.4 Statistical analysis

For inferential analysis, the two depth counts within each plot were combined to obtain one plot-level abundance value because the inferential comparison was defined at the plot/station level rather than as a test of depth effects, producing three replicate observations per station: A = 33, 18 and 14; B = 1, 4 and 0; C = 8, 12 and 17; and D = 15, 0 and 5. A one-way analysis of variance (ANOVA) tested the null hypothesis that mean abundance was equal across the four stations. Where the omnibus test was significant, Tukey's Honestly Significant Difference (HSD) test was used for pairwise comparisons. Statistical significance was evaluated at $\alpha = 0.05$.

3. RESULTS

3.1 Soil-fauna abundance and taxonomic composition

A total of 127 individuals representing 24 taxa were recorded across the four stations. Station A recorded 65 individuals, followed by Station C (37), Station D (20) and Station B (5). Mean plot-level abundance was highest at A (21.67 individuals plot^{-1}), followed by C (12.33), D (6.67) and B (1.67). The observed abundance pattern was therefore A > C > D > B and was non-monotonic with distance, as shown in Table 1.

Table 1. Plot-level soil-fauna abundance used for station comparison.

Station	Distance	Plot 1	Plot 2	Plot 3	Total	Mean
A	500m	33	18	14	65	21.67
B	3km	1	4	0	5	1.67
C	5km	8	12	17	37	12.3
D	>5km	15	0	5	20	6.67

Relative abundance also varied among stations. Collembola represented 50.8% of individuals at A, while Cryptostigmata was dominant at C (43.2%). Mesostigmata and Insecta each contributed 40.0% at B, reflecting the very small sample size at that station. At D, Collembola and Insecta each contributed 35.0%. At Station A, *Cryptophagus sp* (21 individuals) and *Archogozetes magnus* (16 individuals) together accounted for 37 of the 65 individuals (56.9%), indicating strong numerical concentration in a limited number of taxa.

3.2 Biodiversity indices

Biodiversity metrics showed a different pattern from total abundance. The station-level biodiversity indices are presented in Table 2. Station C recorded the highest taxonomic richness (S = 14), Shannon–Wiener diversity (H′ = 2.21), Simpson's diversity (1 − D = 0.85) and Margalef richness (d = 3.60). Station A recorded lower richness and diversity despite having the highest total abundance, while Station B had

the lowest abundance and richness but the highest evenness (J = 0.96). Station D recorded high evenness (J = 0.93) and intermediate Shannon–Wiener diversity (H′ = 1.94).

Table 2. Biodiversity indices by sampling station.

Parameter	A (500m)	B (3km)	C (5km)	D (>5km)
Total abundance (N)	65	5	37	20
Taxonomic Richness (S)	8	4	14	8
Shanon-Wiener H’	1.71	1.33	2.21	1.94
Simpson Dominance (D)	0.22	0.28	0.15	0.16
Simpson Diversity (1-D)	0.78	0.72	0.85	0.84
Pielou evenness (J)	0.82	0.96	0.84	0.93
Margalef richness (d)	1.68	1.86	3.60	2.34

3.3 Statistical difference in abundance

One-way ANOVA demonstrated a significant difference in mean plot-level soil-fauna abundance among the four sampling stations, $F(3,8) = 4.816$, $p = 0.0335$. The null hypothesis of equal mean abundance was therefore rejected at the 5% significance level. The ANOVA summary is presented in Table 3.

Table 3. One-way ANOVA of plot-level soil-fauna abundance.

Source	SS	df	MS	F	p
Between stations	662.250	3	220.750	4.816	0.0335
Within stations	366.667	8	45.833		
Total	1,028.917	11			

Tukey's HSD showed that the significant pairwise difference was between A and B (adjusted $p = 0.0280$; mean difference = 20.00 individuals plot^{-1}). Comparisons of A–C ($p = 0.3883$), A–D ($p = 0.0997$), B–C ($p = 0.2890$), B–D ($p = 0.8031$) and C–D ($p = 0.7404$) were not significant. The complete pairwise comparisons are presented in Table 4.

Table 4. Tukey HSD pairwise comparisons among sampling stations.

Comparison	Mean difference	Adjusted p	Decision
A – B	20.00	0.0280	Significant
A – C	9.33	0.3883	Not significant
A – D	15.00	0.0997	Not significant
B – C	- 10.65	0.2890	Not significant
B – D	- 5.00	0.8031	Not significant
C – D	5.67	0.7404	Not significant

4. DISCUSSION

4.1 Variation in soil-fauna abundance across flare-distance stations

The central finding of this study is that soil-fauna abundance differed significantly among the four stations but did not follow a simple monotonic distance-response pattern. The highest abundance occurred at 500 m, the station nearest the flare, whereas the lowest occurred at 3 km. Thus, the data do not support the assumption that abundance necessarily increases progressively with distance from the flare.

The spatial variability observed here is consistent with the broader understanding that environmental pressures associated with petroleum production can interact with local soil and habitat conditions (Ologunorisa, 2001; Adeoye, 2022). However, the present observational design does not permit the significant station effect to be interpreted as proof of a causal gas-flaring effect.

4.2 Biodiversity structure and the difference between abundance and diversity

The high abundance at Station A was accompanied by comparatively modest taxonomic richness and diversity. This indicates that numerical abundance was concentrated in a subset of taxa rather than being distributed evenly across a broad community. Soil-fauna responses to environmental stress can differ among taxa, so community-level effects may be expressed through changes in relative dominance as well as changes in total abundance (Rusek & Marshall, 2000; Menta & Remelli, 2020).

Collembola formed 50.8% of the individuals at A, while Cryptophagus sp. and Archogozetes magnus together accounted for 56.9% of the station total. The present data are consistent with a community in which a limited number of taxa were numerically favoured under the prevailing local conditions. However, because contaminant concentrations and taxon-specific tolerance were not independently measured, these taxa should not be described as proven indicators of flare tolerance.

4.3 Non-monotonic response to flare distance

Station C showed the clearest evidence of high community diversity, with the greatest taxonomic richness, Shannon diversity and Margalef richness. This pattern is compatible with a reduction in some flare-associated environmental pressures with distance, but it does not prove that distance from the flare alone caused the increase in diversity. The absence of a simple monotonic pattern is therefore an important finding rather than a weakness to be corrected.

4.4 Influence of land-use and vegetation context

Land use provides an important contextual explanation for the heterogeneous pattern. Stations A and C were farmland with vegetation, whereas Stations B and D were residential areas with no or little vegetation. Land-use conversion can substantially alter soil-fauna abundance and richness through changes in habitat, vegetation inputs and soil conditions (Chiappero et al., 2024). Therefore, the differences among the Agbada stations cannot reasonably be attributed to flare distance in isolation.

4.5 Interpretation of the external reference station

Station D should be interpreted as an external reference rather than a pristine control. Its residential setting and limited vegetation make it environmentally different from the vegetated farmland at Stations

A and C. The fact that Station C exceeded D in richness and Shannon diversity therefore demonstrates that the reference condition was not a theoretical maximum of biodiversity. Similarly, the nonsignificant C–D comparison should not be interpreted as proof that flare influence had disappeared by 5 km.

4.6 Ecological meaning of the high abundance at 500 m

High numerical abundance at the closest station does not necessarily represent better ecological condition. The relatively low richness and evenness at station A indicate that many individuals were concentrated in relatively few taxa. This distinction is important because an increase in individual abundance may coexist with reduced community breadth. Consequently, abundance should be interpreted jointly with richness, diversity, evenness and taxonomic composition.

4.7 Implications for environmental monitoring

The results support the use of multiple biodiversity measures rather than abundance alone. The contrasting patterns highest abundance at A but highest richness and Shannon diversity at C show that a single metric could produce an incomplete assessment. Soil-fauna assessment can therefore complement conventional environmental monitoring in gas-flaring landscapes, particularly where biological responses are spatially heterogeneous (Menta & Remelli, 2020).

4.8 Overall interpretation

Taken together, the findings indicate that the Agbada soil-fauna community exhibited heterogeneous spatial responses across the flare-distance framework. The strongest numerical response occurred at the nearest station, whereas the greatest community breadth occurred at 5 km. This divergence demonstrates why distance alone should not be treated as a sufficient proxy for ecological condition in a landscape where land use and vegetation also vary.

5. CONCLUSION

At Agbada Flow Station, soil-fauna abundance differed significantly among the four distance-referenced sampling stations, but the response was heterogeneous rather than a simple linear decline or increase with distance. Station A at 500 m recorded the highest abundance, whereas Station C at 5 km recorded the highest taxonomic richness and Shannon–Wiener diversity. The significant ANOVA result, $F(3,8) = 4.816$, $p = 0.0335$, was associated principally with the A–B difference identified by Tukey HSD. The findings demonstrate that abundance and biodiversity describe different dimensions of community response. Soil-fauna monitoring can therefore provide valuable complementary evidence in environmental assessment of gas-flaring landscapes, but attribution of specific community changes to flaring requires integration with measured soil, habitat and contaminant conditions.

REFERENCES

Adeoye, A. E. (2022). A review of the environmental impact of gas flaring on the physiochemical properties of water, soil and air quality in the Niger Delta region of Nigeria. Earthline Journal of Chemical Sciences, 7(1), 35–52. https://doi.org/10.34198/ejcs.7122.3552

Chiappero, M. F., Rossetti, M. R., Moreno, M. L., & Pérez-Harguindeguy, N. (2024). A global meta-analysis reveals a consistent reduction of soil fauna abundance and richness as a consequence of land use conversion. Science of the Total Environment, 946, 173822. https://doi.org/10.1016/j.scitotenv.2024.173822

Magurran, A. E. (2004). Measuring biological diversity. Blackwell Publishing.

Menta, C., & Remelli, S. (2020). Soil health and arthropods: From complex system to worthwhile investigation. Insects, 11(1), 54. https://doi.org/10.3390/insects11010054

Ologunorisa, T. E. (2001). A review of the effects of gas flaring on the Niger Delta environment. International Journal of Sustainable Development & World Ecology, 8(3), 249–255. https://doi.org/10.1080/13504500109470082

Pielou, E. C. (1966). The measurement of diversity in different types of biological collections. Journal of Theoretical Biology, 13, 131–144. https://doi.org/10.1016/0022-5193(66)90013-0

Rusek, J., & Marshall, V. G. (2000). Impacts of airborne pollutants on soil fauna. Annual Review of Ecology and Systematics, 31, 395–423. https://doi.org/10.1146/annurev.ecolsys.31.1.395

Seiyaboh, E. I., & Izah, S. C. (2017). A review of impacts of gas flaring on vegetation and water resources in the Niger Delta region of Nigeria. International Journal of Economy, Energy and Environment, 2(4), 48–55. https://doi.org/10.11648/j.ijeee.20170204.11

Shannon, C. E. (1948). A mathematical theory of communication. Bell System Technical Journal, 27(3), 379–423. https://doi.org/10.1002/j.1538-7305.1948.tb01338.x

Simpson, E. H. (1949). Measurement of diversity. Nature, 163, 688. https://doi.org/10.1038/163688a0