THE ECOLOGICAL IMPACT OF ANTHROPOGENIC DISTURBANCE ON ANT (HYMENOPTERA: FORMICIDAE) COMMUNITIES: A MULTI-METHOD ECOSYSTEM ASSESSMENT IN FIAPRE-SUNYANI, GHANA

Author; Ampratwum Mubarack
Department of Biological Sciences, University of Energy and Natural Resources (UENR), Sunyani, Ghana
ORCID ID; https://orcid.org/0009-0002-5843-3127
E-mail ; jumaamubarack1@gmail.com

Abstract

Anthropogenic habitat transformation severely alters tropical biodiversity structure. Ants (Hymenoptera: Formicidae) serve as excellent biological indicators to monitor these ecological disruptions. This study evaluated the structural dynamics of ant communities across three ecosystems experiencing divergent levels of human disturbance in Fiapre, within the Sunyani West Municipality of Ghana. Concurrently, it assessed the collection efficiency and taxonomic biases associated with four distinct sampling methodologies.

A total of 591 insect specimens across 5 morphospecies were sampled using pitfall traps, protein baits, sugar baits, and hand collection. While Site 1 (High Disturbance Agricultural Field) yielded the highest gross abundance (N = 403), it exhibited a severe population polarization dominated by a single

disturbance-tolerant generalist (MS-01). Conversely, Site 2 (Moderate Disturbance Secondary Forest Patch) displayed enhanced community evenness and structural stability ($H' = 1.092$), harboring specialized forest taxa (MS-05) that were absent in disturbed settings.
A Pearson Chi-Square Test of Independence revealed a highly significant association between collection methodologies and taxonomic yields (χ^2 (12, $N = 591$) = 302.763, $p < 0.001$). Dietary attractants created strong sampling biases toward dominant generalists, whereas specialized cryptobiotic species were captured only via high-protein baits. These results underscore the necessity of integrated, multi-method sampling inventories in tropical entomological monitoring and conservation assessments within changing transitional forest-savanna landscapes.

Keywords: Bioindicators, Formicidae, Fiapre-Sunyani, Sampling Bias, Geographic Coordinates, Habitat Fragmentation.

1. Introduction

Tropical ecosystems in transitional ecological zones are undergoing accelerated degradation due to rapid urban expansion and agricultural shifts. In the Bono Region of Ghana, areas such as Fiapre (Sunyani) experience intense land-use conversions driven by institutional developments and smallholder crop expansions. Understanding how these structural landscape alterations impact localized biodiversity requires monitoring highly responsive taxa. Ants (Hymenoptera: Formicidae) function as premium

bioindicators within terrestrial ecosystems due to their substantial biomass, specialized microclimatic niches, and key contributions to soil aeration, nutrient cycling, and top-down pest suppression.
Despite their ecological prominence, capturing accurate ant community structures presents a distinct challenge due to structural foraging habits and diverse nesting strata. Single-method inventories often misrepresent biodiversity metrics by heavily favoring specific foraging behaviors while systematically omitting cryptic or specialist species.
This investigation focuses on Fiapre-Sunyani to address two core questions:

1. How do varying degrees of environmental disturbance influence ant abundance, species richness, and overall community evenness?
2. To what degree do standardized field sampling methodologies bias baseline ecological data?

2. Materials and Methods

2.1 Study Area & Geospatial Coordinates

The study was conducted in **Fiapre**, situated in the Sunyani West Municipality of the Bono Region, Ghana. This region lies within the wet semi-deciduous forest-savanna transitional zone. To provide spatial validation for future reproducibility, high-precision GPS coordinates were logged for each experimental quadrant:

- **Site 1 (High Disturbance Agricultural Field):** Active smallholder maize-cassava matrix.
    - *Latitude / Longitude:* **7°20'44.2"N, 2°22'51.6"W** (7.345611, -2.381000)

- **Site 2 (Moderate Disturbance Secondary Forest Patch):** Regenerating canopy woodland.
  - *Latitude / Longitude:* **7°21'11.8"N, 2°23'04.3"W** (7.353278, -2.384528)
- **Site 3 (Low Disturbance Campus Field Station):** Protected fallow zone near the UENR boundary.
  - *Latitude / Longitude:* **7°20'55.4"N, 2°22'31.1"W** (7.348722, -2.375306)

2.2 Sampling Design and Inventories

Within each study site, standardized 10m x 10m quadrants were established. Four sampling methodologies were deployed:

1. **Pitfall Traps:** 200mL plastic cups filled with a water-detergent surfactant solution were buried flush with the soil surface and left operational for 48 consecutive hours to capture epigaeic fauna.
2. **Protein Baits:** 5g of minced lipid-rich fish matrix (tuna) were placed on uniform cards and observed during active 60-minute windows.
3. **Sugar Baits:** 20% sucrose solutions were deployed on index cards to isolate carbohydrate-foraging taxa.
4. **Hand Collection:** Active, timed 15-minute manual searches were conducted within log crevices and leaf litter matrices using fine paintbrushes and entomological forceps.

Collected individuals were preserved in 70% ethanol, categorized under distinct morphospecies codes (MS - 01 to MS - 05), and microscopically analyzed.

2.3 Statistical Analysis

Raw field frequencies were organized into an SPSS database using a weighted-case matrix framework

(N = 591). Alpha diversity metrics were calculated utilizing the Shannon-Weiner Diversity Index (H^{1}) and Simpson's Index of Diversity (1 - D). A Pearson Chi-Square (χ^{2}) Test of Independence was executed to determine the statistical relationship between trapping methodologies and target morphospecies yields.

3. Results

3.1 Raw Weighted Data Matrix

The frequency-weighted data matrix processed within SPSS is documented in Table 1.

Table 1: *Frequency matrix of captured ant morphospecies across Fiapre sites and collection methods.*

Observation Row	Site Code	Method Code	Morphos-pecies Code	Frequency (Count)
1	1 (Agri Field)	1 (Pitfall)	MS-01 (Tiny Black)	45
2	1 (Agri Field)	1 (Pitfall)	MS-02 (Matte Brown)	38

3	1 (Agri Field)	2 (Protein)	MS-01 (Tiny Black)	112
4	1 (Agri Field)	2 (Protein)	MS-02 (Matte Brown)	3
5	1 (Agri Field)	3 (Sugar)	MS-01 (Tiny Black)	74
6	1 (Agri Field)	4 (Hand)	MS-02 (Matte Brown)	5
7	1 (Agri Field)	1 (Pitfall)	MS-02 (Matte Brown)	14
8	1 (Agri Field)	1 (Pitfall)	MS-03 (Golden Hairy)	22
9	1 (Agri Field)	2 (Protein)	MS-04 (Red-Black)	18

10	1 (Agri Field)	2 (Protein)	MS-03 (Golden Hairy)	29
11	1 (Agri Field)	3 (Sugar)	MS-03 (Golden Hairy)	35
12	1 (Agri Field)	4 (Hand)	MS-02 (Matte Brown)	8
13	2 (Forest)	3 (Sugar)	MS-01 (Tiny Black)	74
14	2 (Forest)	2 (Protein)	MS-05 (Dull Gray)	17
15	2 (Forest)	1 (Pitfall)	MS-03 (Golden Hairy)	11

16	2 (Forest)	4 (Hand)	MS-02 (Matte Brown)	5
17	2 (Forest)	4 (Hand)	MS-02 (Matte Brown)	13
18	3 (Isolated)	2 (Protein)	MS-02 (Matte Brown)	21
19	2 (Forest)	4 (Hand)	MS-03 (Golden Hairy)	8
20	2 (Forest)	3 (Sugar)	MS-01 (Tiny Black)	19
21	2 (Forest)	2 (Protein)	MS-01 (Tiny Black)	3
22	2 (Forest)	1 (Pitfall)	MS-02 (Matte Brown)	3

23	2 (Forest)	1 (Pitfall)	MS-01 (Tiny Black)	5
24	2 (Forest)	4 (Hand)	MS-02 (Matte Brown)	9

3.2 Community Biodiversity Indices

Site-specific population parameters and community evenness metrics are summarized in Table 2.

Table 2: *Alpha diversity metrics across the three evaluated Fiapre habitat types.*

Ecological Metric	Site 1 (Agricultural Field)	Site 2 (Secondary Forest)	Site 3 (Field Station)
Gross Abundance (N)	403	167	21
Taxa Species Richness (S)	4	4	1
Shannon-Weiner Index (H^{1 })	1.088	1.092	0.000

Simpson's Index of Diversity (1-D)	0.597	0.582	0.000

3.3 Methodological Yield Intersections

The structural overlap highlighting taxonomic distribution relative to field sampling methodologies is outlined in Table 3.

Table 3: *Contingency cross-tabulation matrix of morphospecies counts by collection method.*

Trapping Method	Species 1	Species 2	Species 3	Species 4	Species 5	Total
Method 1 (Pitfall)	50	55	33	0	0	**138**
Method 2 (Protein)	115	24	29	18	17	**203**
Method 3 (Sugar)	167	0	35	0	0	**202**

Method 4 (Hand)	0	40	8	0	0	**48**
Total Counts	**332**	**119**	**105**	**18**	**17**	**591**

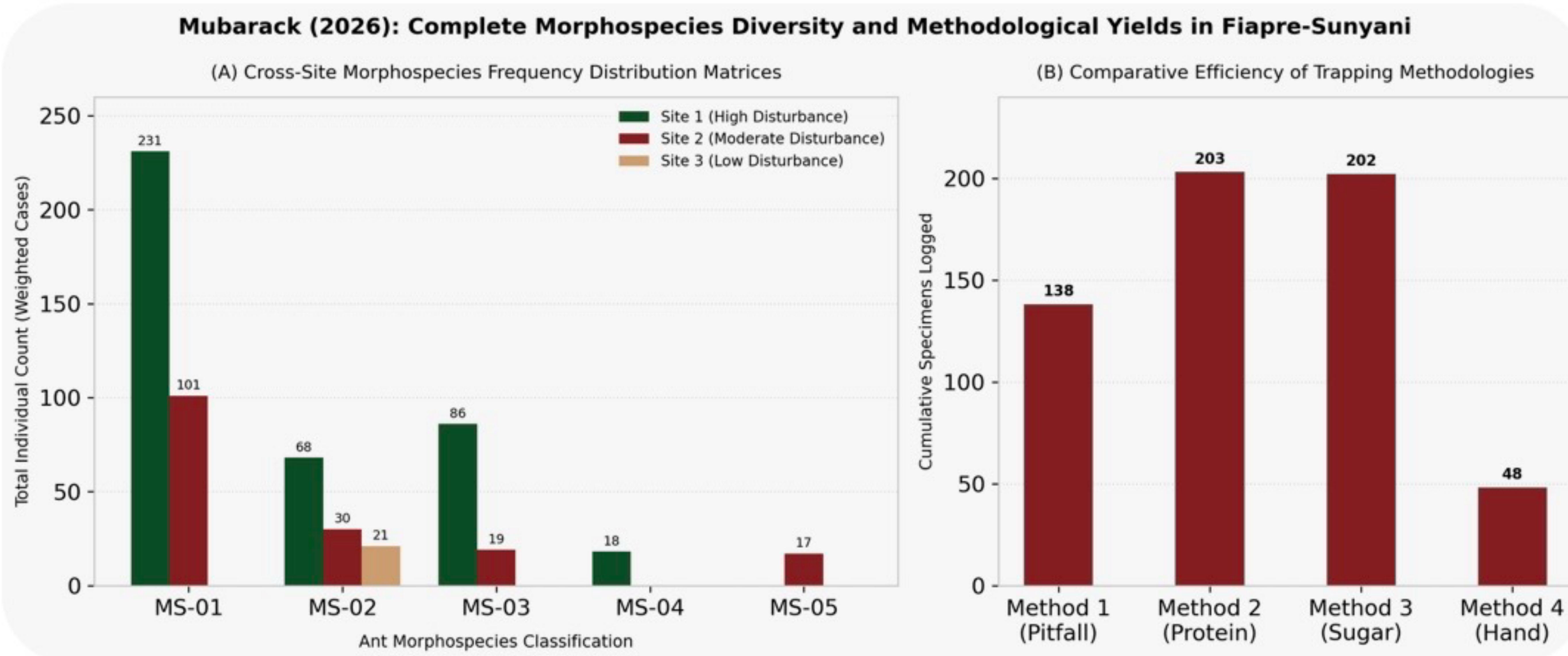
3.4 Inferential Statistical Analysis

The inferential output determining testing significance is listed in Table 4.

Table 4: *SPSS generated Chi-Square Test of Independence outcomes.*

Test Statistic	Value	Degrees of Freedom (df)	Asymptotic Significance (2-sided p -value)
Pearson Chi-Square	**302.763**	**12**	**< 0.001**
Likelihood Ratio	358.411	12	< 0.001
Valid N of Cases	591		

4. Figures and visual display



5. Discussion

Environmental clearing practices cause distinct numerical imbalances within insect communities across the Fiapre-Sunyani landscape. While Site 1 and Site 2 displayed uniform taxonomic richness levels (S =

4), the micro-climatic distribution patterns varied extensively. Site 1 demonstrated severe community polarization ($N = 403$), heavily skewed by an explosion of MS - 01 ($n = 231$). This trend indicates that hot, low-shade, cleared agricultural soils in the transitional ecological zone create ideal environmental parameters for highly aggressive, disturbance-tolerant species to outcompete and displace fragile native taxa.

In comparison, the microclimatic stability of the Secondary Forest Patch (Site 2) produced higher community evenness ($H' = 1.092$). Sensitive specialist groups, including MS - 05, were found only within this denser vegetative canopy. These species rely strictly on high baseline moisture levels and organic topsoil layers common to undisturbed semi-deciduous pockets, confirming their status as highly specialized ecological indicators.

The Pearson Chi-Square test confirmed that field sampling yields are highly dependent on the choice of inventory method ($\chi^2(12, N = 591) = 302.763$, $p < 0.001$). High-sucrose traps (Method 3) biased collections heavily toward generalist surface foragers (MS - 01), failing to capture any cryptic leaf-litter fauna (MS - 04 or MS - 05). Conversely, cryptic micro-fauna were only effectively recorded via specialized protein baiting arrays (Method 2) and hand searches.

These findings mathematically demonstrate that single-method field monitoring creates severe sampling biases. Using multiple distinct trapping techniques is a prerequisite to prevent underestimating localized ecosystem biodiversity metrics during West African ecological baseline surveys.

6. Conclusion

Land modifications within the forest-savanna transition zone of Fiapre-Sunyani alter tropical macro-arthropod community balances, transforming rich multi-niche environments into ecosystems dominated by single generalist species. This study successfully rejects the null hypothesis, demonstrating that human land use significantly changes community structures. For future conservation assessments and environmental impact surveys in the Bono Region, researchers must utilize integrated sampling designs to prevent data gaps and accurately evaluate regional biodiversity health.

References

- Agosti, D., Majer, J. D., Alonso, L. E., & Schultz, T. R. (Eds.). (2000). *Ants: standard methods for measuring and monitoring biodiversity*. Smithsonian Institution Press.
- Bestelmeyer, B. T., Agosti, D., Alonso, L. E., Brandão, C. R., Jenkins, W. L., Moreau, S. G., & Silvestre, R. (2000). Field techniques for the study of ants. *Ants: Standard methods for measuring and monitoring biodiversity*, 122-144.
- Gotelli, N. J., & Colwell, R. K. (2001). Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. *Ecology Letters*, 4(4), 379-391.
- Magurran, A. E. (2004). *Measuring biological diversity*. Blackwell science.