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# Plant Species Richness and Diversity as Bioindicator of Environmental Disturbance Assessment of Selected Communities in Rivers State, Nigeria

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## ABSTRACT

Plant species richness and diversity are widely used bioindicators of environmental condition, yet studies that trace a specific richness or diversity deficit to a specific, field-identified mechanism remain uncommon in the Niger Delta. This study assessed plant species diversity by quadrat sampling across six communities in three contrasting Local Government Areas (LGAs) of Rivers State namely; Ahoada West, Tai and Okirika. Sampling was carried out in both the wet and dry season, computing species richness, Shannon, Simpson and Margalef indices. Korokoro Tai in Tai LGA recorded the highest species richness in both seasons (14.00 ± 3.92 wet; 13.50 ± 3.70 dry), while Okirika Main Town recorded the lowest diversity of any site in both seasons (Shannon: 0.86 ± 1.03 wet; 0.45 ± 0.53 dry) despite recording the highest individual plant count of any site in the dry season (385 individuals, 25.9% of the 1,488 individuals counted across all nine sites that season), a combination indicating dominance by a small number of tolerant taxa rather than a genuinely unproductive site. Species-level analysis identified the specific mechanism: Nypa fruticans was recorded in every quadrat sampled at both Okirika-LGA communities in both seasons, and was the sole species present at two of four quadrats specifically, consistent with its documented profile as an aggressive, tidally distributed coloniser of disturbed mangrove and estuarine habitat. These findings demonstrate that a consolidated diversity deficit can, with appropriately fine-grained field data, be resolved into a specific, targetable ecological mechanism rather than treated as generalised habitat degradation with direct implications for how restoration resources should be allocated at Okirika Main Town, and for how diversity assessments are designed more broadly in disturbed tropical landscapes.

**Keywords:** Niger Delta, *Nypa fruticans,* plant species richness, bioindicator, invasive species, Shannon diversity index.

## Introduction

Plant species diversity is among the most widely used biological indicators of environmental condition, because vegetation integrates the cumulative effect of soil quality, hydrology, disturbance history and land use over time in a way that many other environmental measurements do not (Fricke et al., 2022). However, location's diversity indices species richness, and evenness measures such as the Shannon and Simpson indices which should therefore carry diagnostic information about the kind and severity of environmental pressure acting on that location. In practice, most field-diversity studies stop at reporting the indices themselves, leaving the specific mechanism behind a low-diversity result unresolved: a low Shannon index is consistent with several very different underlying conditions, including genuine species poverty, patchy disturbance concentrated in a subset of sampling locations, or dominance by a single aggressive coloniser. These all require different, and sometimes opposite, management responses (Fricke et al., 2022). Biodiversity is multidimensional, and richness and diversity are related but distinct constructs within it. Species richness measures the number of species present at a site, independent of how individuals species are distributed among them; diversity indices such as Shannon's and Simpson's incorporate both richness and relative abundance, and are therefore sensitive to evenness expression how equally individuals are distributed among the species present in a way that richness alone is not (Shannon, 1948; Simpson, 1949).

A site can be species-rich yet low-diversity if a small number of species dominate numerically, or comparatively species-poor yet high-diversity if the few species present are evenly represented. A robust bioindicator assessment therefore reports richness and diversity together rather than treating either alone as a complete measure of ecological condition (IPBES,



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2019), and it is precisely this joint reporting that distinguishes a genuine diagnosis of disturbance from a single summary statistic.

The Niger Delta is a productive setting in which to resolve this ambiguity, because it combines high underlying floristic potential such as freshwater swamp forest in the region. It has been shown to support well over 100 plant species across relatively small sampling areas under low-disturbance conditions (Igu, 2016), with severe, spatially uneven anthropogenic pressure from petroleum exploration, industrial development, dredging and urban expansion (Numbere, 2021; Mgbeze and Numbere, 2023; Uchegbu and Ibe, 2023; Eze and Okafor, 2024). This combination means that where diversity is low in this region, the cause is rarely ambiguous for want of a plausible explanation. The analytical challenge is to identify which explanation actually applies at a given site, using field evidence rather than inference from land-use category alone.

This study addresses that challenge directly for six communities across three LGAs as to establish whether plant diversity differs significantly and consistently, across both a wet and a dry sampling season; among communities occupying an inland-to-coastal disturbance gradient; and, where a significant diversity deficit is found, to use species-level field data to identify the specific mechanism responsible rather than reporting the deficit as an undifferentiated indicator of "disturbance".

## Materials and Methods

### Study Area

Six communities were sampled across three Local Government Areas of Rivers State: Jonkarama JK4 and Ubeta (Ahoada West LGA, freshwater swamp forest and secondary rainforest under agricultural pressure), Korokoro Tai and Nonwa (Tai LGA, similarly characterised), and Okirika Main Town and Ogoloma (Okirika LGA, coastal and estuarine, under sustained pressure from petroleum industry activity, dredging and urban expansion). A paired control location was sampled in each LGA.

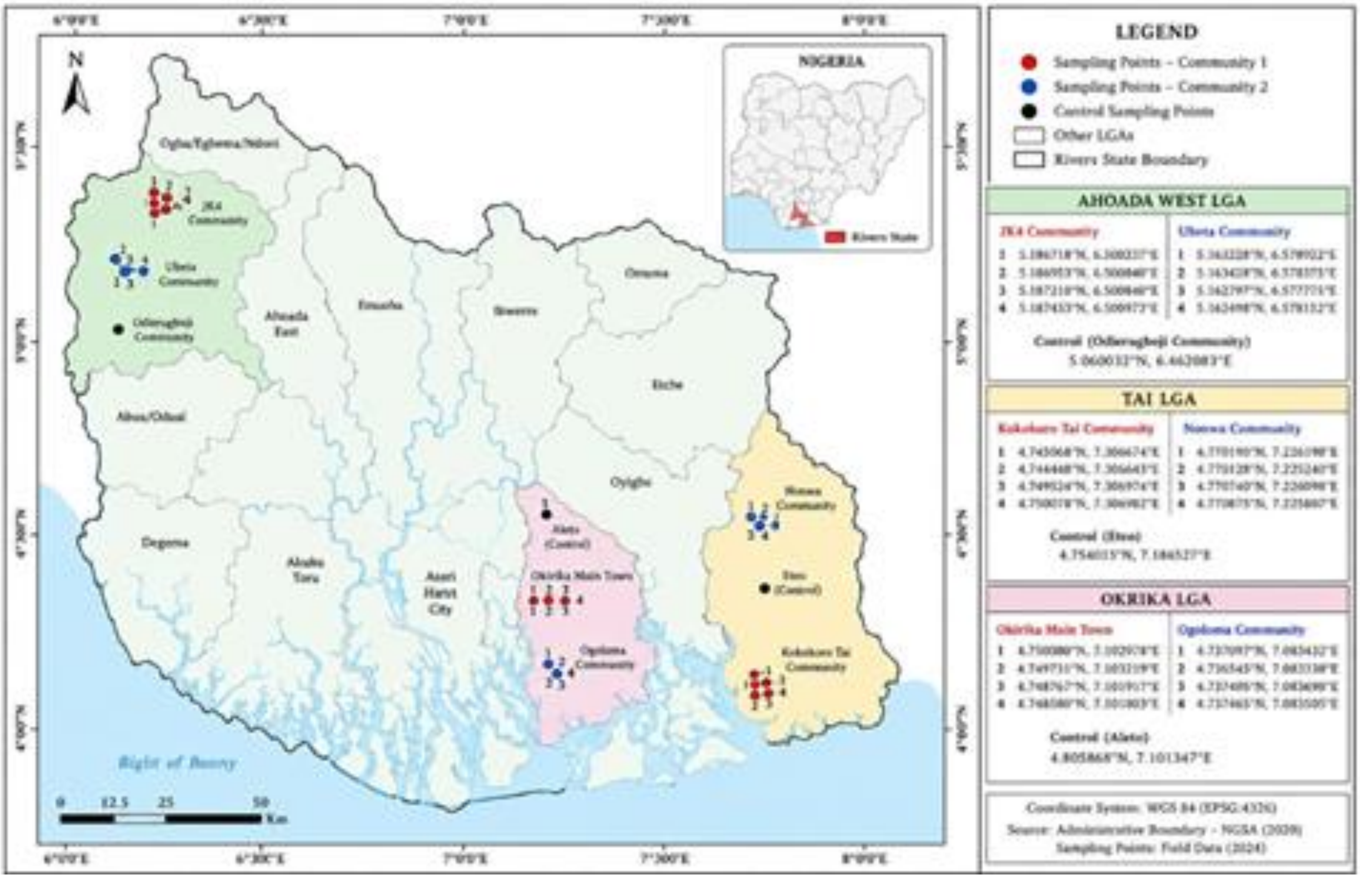


**Figure 3.1: Map of Rivers State showing sampling points in Ahoada West, Okrika and Tai LGAs**

**Source:** Administrative/geospatial information adapted from the Nigeria Geological Survey Agency (NGSA, 2020); sampling locations based on field GPS observations (Field Data, 2024).



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## Field Sampling

Plant species diversity was assessed using quadrat sampling, with four replicate quadrats sampled at each community and control location in the wet season and four in the dry season. Within each quadrat, all plant species present were identified in the field and their frequency (number of individuals) recorded.

Species names recorded with minor spelling variants across quadrats were reconciled to a single canonical name before analysis; where a species was recorded as present without a numeric frequency, a nominal frequency of one was assigned so that the species contributed to richness without inflating apparent abundance.

Both conventions were applied uniformly across every quadrat, community and season, following standard vegetation-sampling practice (Mueller-Dombois & Ellenberg, 1974).

## Diversity Indices and Statistical Analysis

For each quadrat, species richness (S), total individual count (N), the Shannon diversity index ($H' = -\Sigma\ p_i \ln p_i$), the Simpson diversity index ($D = 1 - [\Sigma\ n(n-1)] / [N(N-1)]$) and the Margalef richness index ($R = (S-1) / \ln N$) were calculated.

Community- and LGA-level values are reported as the mean ± standard deviation across the four constituent quadrats, rather than as a single index computed on pooled quadrat data, since this reveals within-site variability that a pooled calculation cannot show. Community- and LGA-level differences in each index were tested by one-way analysis of variance (ANOVA), with mean separation by Duncan's Multiple Range Test (DMRT) at the 5% significance level wherever the ANOVA was significant; means not sharing a superscript letter differ significantly at $p < .05$. Sorensen's similarity index was used to compare species composition between site pairs and between seasons (Sørensen, 1948).

## Results

Plant species diversity by community and season differed significantly and consistently among the nine sampled locations (six communities and three paired controls) across all five diversity metrics and both seasons (Table 1). Species richness followed a clear gradient: Korokoro Tai recorded the highest richness of any location in both seasons (wet: 14.00 ± 3.92; dry: 13.50 ± 3.70), statistically indistinguishable from its paired Eteo control (wet: 12.25 ± 3.85[a] and from Jonkarama JK4, Ubeta, Odierugboji control and Nonwa, Okirika Main Town recorded the lowest richness of any location in both seasons (wet: 5.50 ± 5.45; dry: 3.75 ± 3.20), significantly lower than every other community and its own paired Aleto control (wet: 6.50 ± 3.82; dry: 5.38 ± 3.34) in both seasons, indicating that the deficit is specific to Okirika Main Town rather than a shared characteristic of the wider Okirika LGA landscape.

Individual plant abundance revealed a pattern that diversity indices alone would not capture. In the wet season, individual counts were broadly comparable across most locations (24.88–38.00 individuals per quadrat), with Okirika Main Town (29.50 ± 4.12) unremarkable relative to the other communities. In the dry season, however, Okirika Main Town's individual count rose sharply to 96.25 ± 51.89 and the highest of any location in either season, and significantly higher than its own wet-season value and every other dry-season community except Ogoloma and control Aleto (65.38 ± 49.23). This combination the highest abundance recorded in the entire dataset occurring at the same location, and in the same season, as the lowest species richness and Shannon diversity (0.449 ± 0.528)

Across all five metrics, the paired controls provide an internal check on this interpretation. Odierugboji, Eteo and Aleto controls each grouped with the higher-diversity tier of communities on most indices, in both seasons Aleto being the partial exception.



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**Table 1: Plant Species Diversity by Community and Wet and Dry Season (Mean ± SD)**

| Diversity Index / Season | JK4 | Ubeta | Odierugboji (Control) | Okirika Main Town | Ogoloma | Aleto (Control) | Korokoro Tai | Nonwa | Eteo (Control) |
|---|---|---|---|---|---|---|---|---|---|
| **Species (Wet)** | $11.50 \pm 2.38^{abc}$ | $11.75 \pm 3.30^{ab}$ | $11.62 \pm 2.67^{ab}$ | $5.50 \pm 5.45^{def}$ | $7.50 \pm 1.29^{bcde}$ | $6.50 \pm 3.82^{c}$ | $14.00 \pm 3.92^{a}$ | $10.50 \pm 3.32^{abcd}$ | $12.25 \pm 3.85^{a}$ |
| **Individuals (Wet)** | $38.00 \pm 17.47^{a}$ | $22.00 \pm 12.25^{abcde}$ | $30.00 \pm 16.38^{a}$ | $29.50 \pm 4.12^{ab}$ | $27.25 \pm 13.60^{abcd}$ | $28.38 \pm 9.38^{ab}$ | $28.00 \pm 9.31^{abc}$ | $21.75 \pm 3.77^{abcdef}$ | $24.88 \pm 7.38^{abc}$ |
| **Shannon (Wet)** | $2.028 \pm 0.429^{abc}$ | $2.103 \pm 0.147^{ab}$ | $2.066 \pm 0.299^{ab}$ | $0.864 \pm 1.027^{ef}$ | $1.508 \pm 0.202^{abcde}$ | $1.186 \pm 0.767^{c}$ | $2.237 \pm 0.352^{a}$ | $1.957 \pm 0.513^{abcd}$ | $2.097 \pm 0.434^{a}$ |
| **Simpson (Wet)** | $0.843 \pm 0.100^{abc}$ | $0.877 \pm 0.099^{a}$ | $0.860 \pm 0.094^{a}$ | $0.375 \pm 0.440^{f}$ | $0.726 \pm 0.068^{abcde}$ | $0.550 \pm 0.346^{c}$ | $0.869 \pm 0.062^{ab}$ | $0.829 \pm 0.125^{abcd}$ | $0.849 \pm 0.094^{ab}$ |
| **Margalef (Wet)** | $3.005 \pm 0.915^{abcd}$ | $3.598 \pm 0.585^{ab}$ | $3.302 \pm 0.778^{ab}$ | $1.331 \pm 1.592^{ef}$ | $2.073 \pm 0.500^{bcde}$ | $1.702 \pm 1.163^{c}$ | $3.899 \pm 0.914^{a}$ | $3.102 \pm 1.143^{abc}$ | $3.501 \pm 1.048^{a}$ |
| **Species (Dry)** | $12.00 \pm 4.24^{ab}$ | $11.00 \pm 4.76^{abcd}$ | $11.50 \pm 4.21^{ab}$ | $3.75 \pm 3.20^{ef}$ | $7.00 \pm 2.94^{bcde}$ | $5.38 \pm 3.34^{c}$ | $13.50 \pm 3.70^{a}$ | $11.50 \pm 2.08^{abc}$ | $12.50 \pm 2.98^{a}$ |
| **Individuals (Dry)** | $40.75 \pm 21.85^{b}$ | $21.00 \pm 12.30^{bcdef}$ | $30.88 \pm 19.52^{b}$ | $96.25 \pm 51.89^{a}$ | $34.50 \pm 20.53^{bc}$ | $65.38 \pm 49.23^{a}$ | $29.00 \pm 10.55^{bcd}$ | $26.50 \pm 7.05^{bcde}$ | $27.75 \pm 8.41^{bc}$ |
| **Shannon (Dry)** | $2.114 \pm 0.427^{abc}$ | $1.966 \pm 0.299^{abcd}$ | $2.040 \pm 0.350^{ab}$ | $0.449 \pm 0.528^{f}$ | $1.304 \pm 0.154^{e}$ | $0.877 \pm 0.582^{c}$ | $2.265 \pm 0.278^{a}$ | $2.143 \pm 0.222^{ab}$ | $2.204 \pm 0.242^{a}$ |
| **Simpson (Dry)** | $0.867 \pm 0.076^{abc}$ | $0.855 \pm 0.098^{abcd}$ | $0.861 \pm 0.081^{ab}$ | $0.209 \pm 0.246^{f}$ | $0.655 \pm 0.054^{e}$ | $0.432 \pm 0.290^{c}$ | $0.888 \pm 0.038^{a}$ | $0.885 \pm 0.051^{ab}$ | $0.887 \pm 0.041^{a}$ |
| **Margalef (Dry)** | $3.129 \pm 1.332^{abcd}$ | $3.359 \pm 1.026^{ab}$ | $3.244 \pm 1.107^{ab}$ | $0.703 \pm 0.828^{ef}$ | $1.710 \pm 0.633^{e}$ | $1.206 \pm 0.869^{c}$ | $3.712 \pm 0.766^{a}$ | $3.269 \pm 0.757^{abc}$ | $3.491 \pm 0.744^{a}$ |

**Note:** *Mean ± SD within a row not sharing a superscript letter differ significantly (Duncan's Multiple Range Test, $p < .05$). Okirika Main Town is significantly less diverse than every other community on every index, in both seasons; Odierugboji, Eteo and Aleto controls each group predominantly with the higher-diversity communities.*



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## Discussion

*Nypa fruticans* is a coastal and estuarine palm, and its concentration specifically in the two Okirika-LGA communities, the only communities in this study with direct tidal and estuarine exposure while its complete absence from the inland freshwater-swamp communities of Ahoada West and Tai is consistent with the species' known habitat requirements. Nypa palm is recognised as an opportunistic coloniser that establishes rapidly and becomes naturalised specifically where mangrove and estuarine vegetation has already been disturbed, meeting comparatively little resistance from native species once it gains a foothold (Numbere and Moudingo, 2023), aided by its rhizomatous growth habit and prolific, water-dispersed seed production (Barenblitt et al., 2023).

This pattern of *Nypa fruticans* displacing native vegetation is independently documented at a regional scale across the wider Niger Delta (Nwobi et al., 2020; Barenblitt et al., 2023; Numbere and Moudingo, 2023), and the present study's quadrat-level field evidence provides a direct, site-specific instance of that regional pattern, resolved down to the level of two identifiable sampling locations rather than reported only as a general regional trend.

This Rivers State-specific pattern is further corroborated by two locally focused studies: an early field study of Nypa palm's biological characteristics in Rivers State (Ukoima et al., 2008) documented the species' colonising capacity well before its expansion became a regionally recognised concern, while a more recent assessment of mangrove floristic diversity in polluted soil at Ikuru Town, Andoni, Rivers State (Gogo et al., 2022) found a comparably reduced native mangrove diversity under disturbance, consistent with the mechanism identified at Okirika Main Town in the present study.

The consistency of the two-quadrat monoculture pattern across two independent seasons is itself scientifically significant. A single-season observation of complete dominance could plausibly reflect a transient bloom or a sampling artefact; recording the identical pattern, at the identical two quadrats, several months apart under different climatic conditions, is much stronger evidence of an established, persistent ecological state.

Ogoloma's intermediate pattern nypa palm present everywhere but dominant nowhere is consistent with an earlier stage of the same colonisation process, suggesting the two Okirika communities may represent different points along a single disturbance-and-invasion trajectory rather than two unrelated outcomes.

Tai and Ahoada West's significantly higher, and mutually indistinguishable, diversity is consistent with these two LGAs retaining more intact freshwater swamp forest and secondary rainforest vegetation, in line with the general ecological expectation that greater environmental heterogeneity in soil properties, drainage, canopy cover and other microhabitat conditions supports more plant species than a more uniform or disturbed habitat (Aigbokhan, 2014; Onyekwelu et al., 2022; Adekunle et al., 2021). The magnitude of diversity recorded at these two LGAs remains well below what has been documented for undisturbed to transitional freshwater swamp forest elsewhere in the Niger Delta, where a comparative survey recorded 138 species across 100 genera and 41 families in 24 one-hectare plots (Igu, 2016) a reminder that "significantly more diverse than Okirika" is a relative, not an absolute, benchmark, and that even the higher-diversity LGAs in this study may themselves be operating below the region's underlying floristic potential.

## Conclusion

This study demonstrates that plant species diversity differs significantly and consistently, across two independent seasons, among six Rivers State communities spanning an inland-to-coastal disturbance gradient, and that quadrat-level, species-resolved field data can convert a general diversity deficit into a specific, mechanistically explained finding. Okirika Main Town's distinct low diversity is not general habitat degradation but the identifiable consequence of Nypa fruticans monoculture at two consistently affected quadrats, consistent with the species' documented regional expansion across the Niger Delta. This demonstrates that diversity indices, reported alone, risk under-describing ecological condition, and that pairing them with species-level field data is a low-cost, high-value addition to biodiversity assessment in disturbed tropical landscapes.



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## Recommendations

1. Biodiversity restoration at Okirika Main Town should target the two field-identified affected quadrats specifically through Nypa fruticans control and native mangrove-species replanting rather than being allocated as generalised, community-wide habitat restoration, since the diversity deficit documented here is localised rather than uniform.
2. Future biodiversity assessments in disturbed tropical landscapes should pair standard diversity indices (Shannon, Simpson, Margalef) with quadrat-level species identification, since aggregate indices alone can mask the specific mechanism driving a diversity deficit, as demonstrated by Okirika Main Town's combination of high individual abundance and low diversity.
3. Given the documented pattern of Nypa fruticans expansion across the Niger Delta, periodic re-monitoring of the currently unaffected quadrats at Okirika Main Town and at Ogoloma is recommended, to detect early signs of further spread before it becomes established.
4. Environmental management agencies and mangrove conservation authorities operating in the Niger Delta should incorporate species-level, quadrat-resolved field data into site assessments, rather than relying solely on aggregate diversity scores, to ensure restoration investment is targeted efficiently.
5. Further research should investigate the specific ecological and anthropogenic disturbance factors that render the two affected quadrats at Okirika Main Town more susceptible to Nypa fruticans colonisation than the two unaffected quadrats within the same community, to inform preventive management elsewhere in the region.

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