INFLUENCE OF OVERHEAD ELECTRICAL INFRASTRUCTURE ON ECOLOGICAL COMMUNITIES IN KENYA: INTEGRATING VEGETATION, AVIAN, AND EXPERT PERSPECTIVES

A Research Project Supported by the African Bird Club Conservation Fund [ABC 2023_CA17]

African Bird Club
Working for birds and conservation in Africa

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NOVEMBER 2025

EXECUTIVE SUMMARY

This project examined the ecological effects of overhead power infrastructure on avian and vegetation communities in a Kenyan savanna landscape. The work was initially proposed as a mortality-focused assessment of raptor and vulture electrocution/collision risk; however, early project phases revealed extremely low carcass detection rates due to rapid scavenger removal and minimal incident occurrence. In response, the project was redesigned to align with both ABC conservation priorities and MSc research requirements, shifting towards a vegetation–bird community approach while retaining a strong focus on infrastructure impacts.

Across 30 permanent plots surveyed in Dry and Wet seasons (60 plot-season observations), the study documented significant reductions in vegetation structure (canopy cover and tree density) within the powerline corridor. Although overall bird abundance and Shannon diversity were comparable between treatments, multivariate analyses revealed a substantial shift in avian species composition (PERMANOVA, $R^2 = 0.253$, $P = 0.001$), indicating functional filtering caused by habitat simplification. Expert insights from Power Systems, Conservation, and Government stakeholders further highlighted policy gaps, inconsistent clearing practices, and limited ecological monitoring as key drivers of observed patterns.

The results underscore the need for coordinated policy frameworks, season-sensitive vegetation management, and long-term avian monitoring to mitigate ecological impacts. ABC's support enabled the generation of actionable evidence to guide infrastructure-biodiversity coexistence and contributes directly to conservation planning within utility corridors.

BACKGROUND INFORMATION

1.1 Original ABC-Funded Project Scope

The initial project proposal submitted to the African Bird Club sought to determine the electrocution and collision risk posed by overhead powerlines to vultures and raptors in Kenya. The original objectives included:

- Mapping hazardous infrastructure,
- Conducting systematic carcass searches,
- Quantifying mortality risk,
- Identifying particularly vulnerable species,
- And recommending mitigation measures.

This design was grounded in the urgent conservation needs of African vultures, many of which are globally endangered or critically endangered. As such, the project aligned strongly with ABC's interest in avian conservation within landscapes impacted by energy transmission infrastructure.

1.2 Emergence of Early Challenges

During the first phase of fieldwork, two critical constraints became immediately clear:

1. Extremely low detection of bird carcasses, despite repeated and carefully planned searches.
2. Rapid scavenger removal, which meant that carcasses rarely persisted long enough to be detected.

These limitations rendered carcass-based mortality estimation statistically unviable. Continuing this approach would have produced inconclusive data and therefore failed to contribute meaningfully to ABC's conservation mission.

1.3 Strategic Redesign of the Project

After discussions with indepth academic supervisors, the project was redesigned into a more comprehensive ecological assessment focusing on:

- Vegetation structure and species composition,
- Bird abundance, diversity, and community composition,
- And expert insights into powerline management and environmental policy.

The revised design allowed the project to retain its relevance to infrastructure-related conservation while producing robust, actionable ecological insights.

1.4 Project Objectives

The refined objectives guiding the remainder of the study were:

1. To assess the effects of overhead power infrastructure on vegetation structure and species composition.
2. To evaluate how the power corridor influences avian abundance, diversity, and species composition.
3. To integrate expert insights to understand the policy, management, and operational drivers underlying the observed ecological patterns.

These objectives maintained a strong link to ABC's conservation priorities, while ensuring ecological rigor.

PROJECT METHODS

2.1 Study Area and Research Design

The project was conducted within the Hells Gate National Park ecosystem, which is intersected by a major overhead power transmission corridor. The research design combined ecological field sampling with expert Key Informant Interviews (KIIs) to provide both quantitative and qualitative insights into infrastructure–biodiversity interactions.

2.1.1 Ecological Sampling Design

A total of 30 permanent sampling plots were established, comprising:

- Impact plots located directly under or immediately adjacent to the powerline corridor
- Control plots located in undisturbed adjacent habitat

Each plot was surveyed twice—during the Dry and Wet seasons—resulting in 60 plot-season ecological observations. Within each plot, standardized vegetation and avian survey protocols were implemented to measure structural attributes, species richness, abundance, and community composition.

2.1.2 Qualitative Sampling Design (Key Informant Interviews)

To complement the ecological findings, a structured qualitative component was incorporated. The sampling strategy followed a purposive expert selection approach, ensuring representation across the primary stakeholder groups involved in energy infrastructure development and biodiversity conservation.

A total of 15 Key Informant Interviews (KIIs) were conducted, consisting of:

- 5 Power Systems Experts (utility engineers, maintenance supervisors)
- 5 Conservation Experts (ornithologists, NGO practitioners, wildlife ecologists)
- 5 Government and Planning Officials (energy regulation, environmental planning, land management authorities)

Participants were selected based on:

- Their role in powerline planning, regulation, or maintenance;
- Documented experience with avian conservation or habitat management;
- Institutional relevance to energy–biodiversity interactions.

Interviews followed a semi-structured format, allowing participants to elaborate on policy frameworks, operational constraints, species vulnerability, mitigation practices, and environmental challenges. All interviews were audio-recorded, transcribed verbatim, and coded thematically in NVivo.

This mixed-methods design—integrating ecological field sampling with expert perspectives—enabled a robust understanding of both biological impacts and the policy/management processes shaping them.

3.2 Quantitative Data Collection

Vegetation Surveys

Vegetation measurements included:

- Canopy cover (%),
- Tree density (counts per plot),
- Species richness,
- Shannon diversity for vegetation communities.

Bird Surveys

Standardized point-count methodology quantified:

- Total abundance of all bird species detected,
- Species richness,
- Shannon diversity,
- Species identity and abundance for community analyses.

3.3 Ecological Data Analysis

Analyses were conducted in R (v4.3.2) using:

- Linear Mixed-Effects Models (LMM) for normally distributed variables,
- Generalized Linear Mixed-Effects Models (GLMM) for count data,
- Non-metric Multidimensional Scaling (NMDS),
- PERMANOVA using Bray–Curtis dissimilarity,
- Random intercepts for Plot_ID to handle repeated measures.

3.4 Qualitative Data Collection and Analysis

Semi-structured interviews were conducted with three expert groups:

- Power Systems Engineers,
- Conservation Experts,
- Government/Planning Officials.

Transcripts were coded in NVivo using a mixed inductive-deductive approach. This resulted in five thematic categories representing policy, operational, and ecological issues.

PROJECT RESULTS

4.1 Sampling Summary

The study generated:

- 60 complete vegetation and avian datasets,
- 3 expert categories with diverse insights,
- Multivariate ecological datasets for community analysis.

4.2 Objective 1: Vegetation Structure and Composition

4.2.1 Structural Impacts

The infrastructure corridor produced clear structural degradation:

- Canopy Cover: significantly lower in impacted plots (*P = 0.021*).

Variable	Estimate	SE	t	P-value
(Intercept)	12.939	1.969	6.572	0.000
TreatmentImpacted	-6.804	2.784	-2.444	0.021
SeasonWet	3.233	0.482	6.713	0.000
TreatmentImpacted:SeasonWet	-1.530	0.681	-2.247	0.033

Table 1: LMM Results for Canopy Cover

- Tree Density: significantly reduced (*P = 0.028*).

Variable	Estimate	SE	z	P-value
(Intercept)	2.590	0.230	11.276	0.000
TreatmentImpacted	-0.728	0.332	-2.194	0.028
SeasonWet	0.108	0.083	1.300	0.194
TreatmentImpacted:SeasonWet	-0.074	0.143	-0.515	0.606

Table 2: GLMM Results for Tree Density (Poisson)

- Treatment × Season Interaction: significant for canopy cover (*P = 0.033*), indicating suppressed seasonal recovery beneath the powerline.

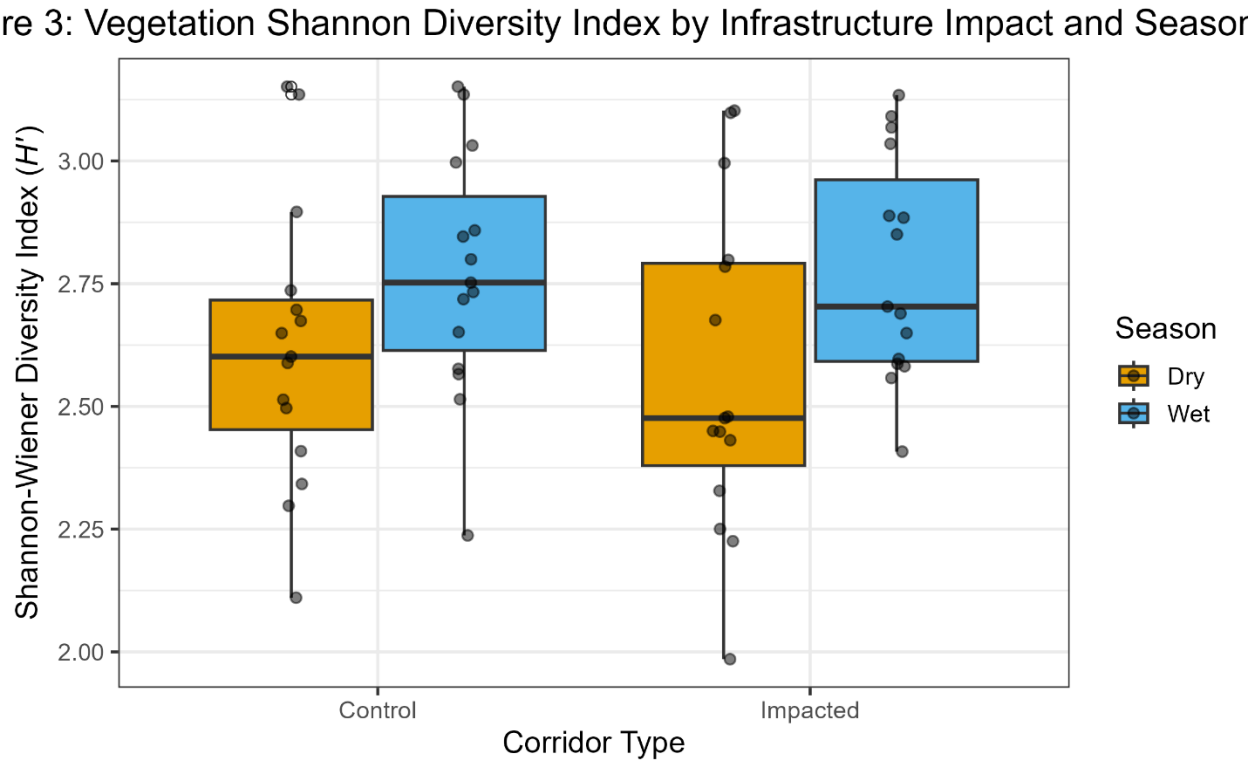

Figure 1: Vegetation Diversity Boxplot

These results point to frequent or intensive clearing activities.

4.2.2 Vegetation Community Composition

Despite structural disturbances, vegetation species composition showed no significant differences between impacted and control plots (*PERMANOVA P = 0.309*). This suggests size-selective rather than species-selective impacts.

Source	Df	Sum of Squares	R-squared	F-statistic	P-value
Model	3	0.623	0.057	1.123	0.309
Residual	56	10.360	0.943		
Total	59	10.983	1.000		

Table 3: PERMANOVA Results for Vegetation Species Composition (Bray-Curtis)

4.3 Objective 2: Avian Abundance, Diversity, and Composition

4.3.1 Abundance and Diversity

- Bird abundance increased during the Wet season (*P < 0.001*).

Treatment	Season	N	Abundance_Mean	Abundance_SD	Richness_Mean	Richness_SD	Shannon_Mean	Shannon_SD
Control	Dry	15	61.67	17.82	13.47	2.42	2.33	0.23
Control	Wet	15	86.27	27.71	12.40	3.44	2.25	0.32
Impacted	Dry	15	56.33	16.66	14.07	3.01	2.33	0.23
Impacted	Wet	15	74.07	28.81	12.60	3.60	2.23	0.30

Table 4: Summary of Avian Abundance and Diversity by Infrastructure Impact and Season.

- Treatment had no significant effect on abundance (*P = 0.382*).

Variable	Estimate	SE	z	P-value
(Intercept)	4.086	0.080	51.046	0.000
TreatmentImpacted	-0.099	0.114	-0.874	0.382
SeasonWet	0.336	0.043	7.808	0.000
TreatmentImpacted:SeasonWet	-0.062	0.063	-0.990	0.322

Table 5: GLMM Results for Bird Abundance (Poisson)

- Shannon diversity remained stable across treatments (*P = 0.972*).

Variable	Estimate	SE	t	P-value
(Intercept)	2.333	0.070	33.122	0.000
TreatmentImpacted	-0.004	0.100	-0.035	0.972
SeasonWet	-0.085	0.050	-1.704	0.099
TreatmentImpacted:SeasonWet	-0.011	0.070	-0.157	0.876

Table 6: LMM Results for Bird Shannon Diversity

Thus, univariate bird metrics showed limited sensitivity to corridor impacts.

4.3.2 Avian Species Composition

The multivariate result was definitive:

- Bird species composition differed significantly between impacted and control plots, with 25.3% of variation explained ($R^2 = 0.253$, $P = 0.001$).

Source	Df	Sum of Squares	R-squared	F-statistic	P-value
Model	3	3.708	0.253	6.306	0.001
Residual	56	10.975	0.747		
Total	59	14.683	1.000		

Table 5b: PERMANOVA Results for Avian Species Composition (Bray-Curtis)

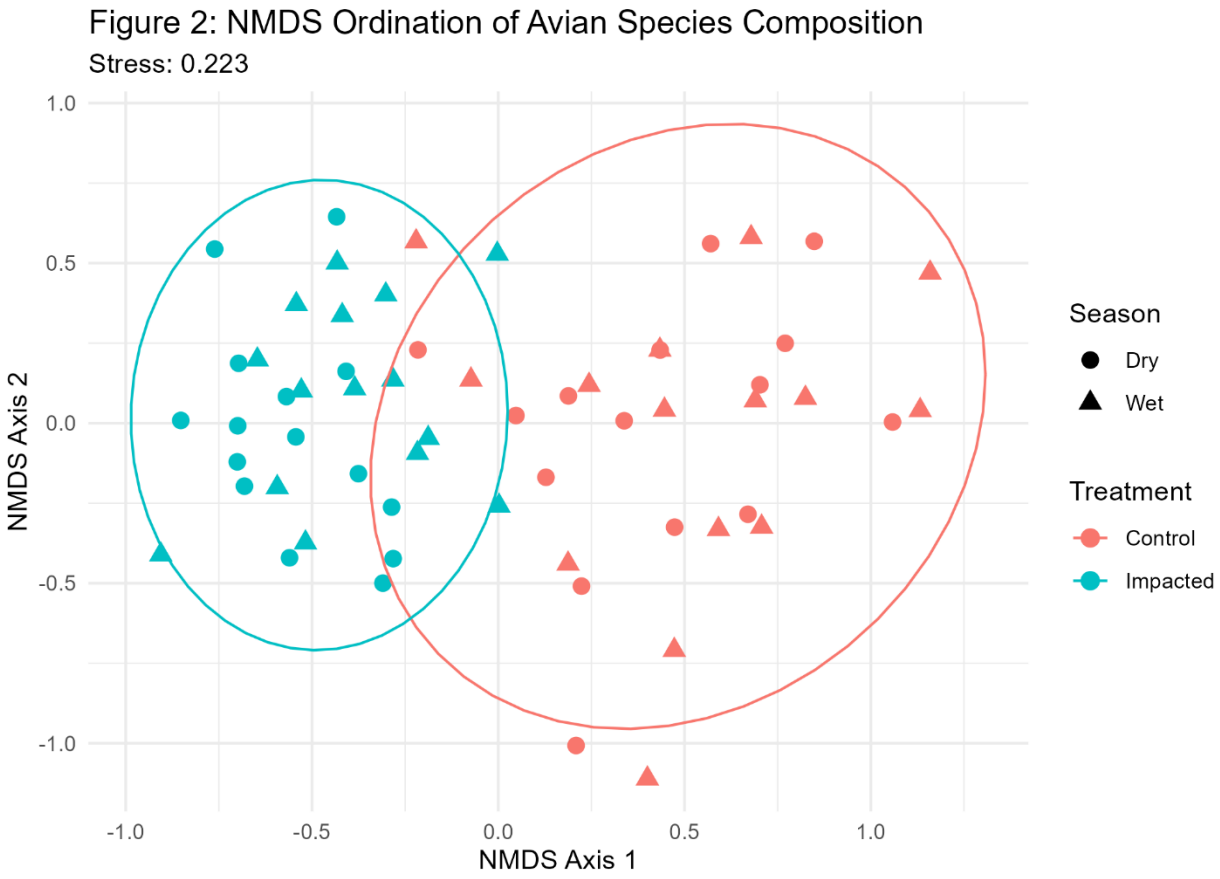

Figure 2: Avian NMDS chart

This reflects strong habitat filtering consistent with loss of vegetation structure.

4.4 Objective 3: Expert Insights

Five major themes emerged:

1. Policy, Regulation, and Collaboration

2. Challenges in Implementation & Management
3. Effectiveness of Mitigation Measures
4. Trade-offs in Infrastructure Planning
5. Species Vulnerability Insights

Theme	Power Systems Experts	Conservation Experts	Government & Planning Officials	Total Theme References
The Role of Policy, Regulation, and Collaboration	40	60	120	220
Challenges in Implementation & Management	60	30	66	156
Effectiveness and Limitations of Mitigation Strategies	30	40	30	100
Trade-offs in Infrastructure Planning & Routing	40	16	36	92
Observed Impacts and Species Vulnerability	16	40	30	86
Total Professional Effort	186	186	282	654

Table 7: Theme Prioritization Code Matrix

Experts consistently highlighted policy fragmentation, operational pressures, and ecological blind-spots in current placement and maintenance practices.

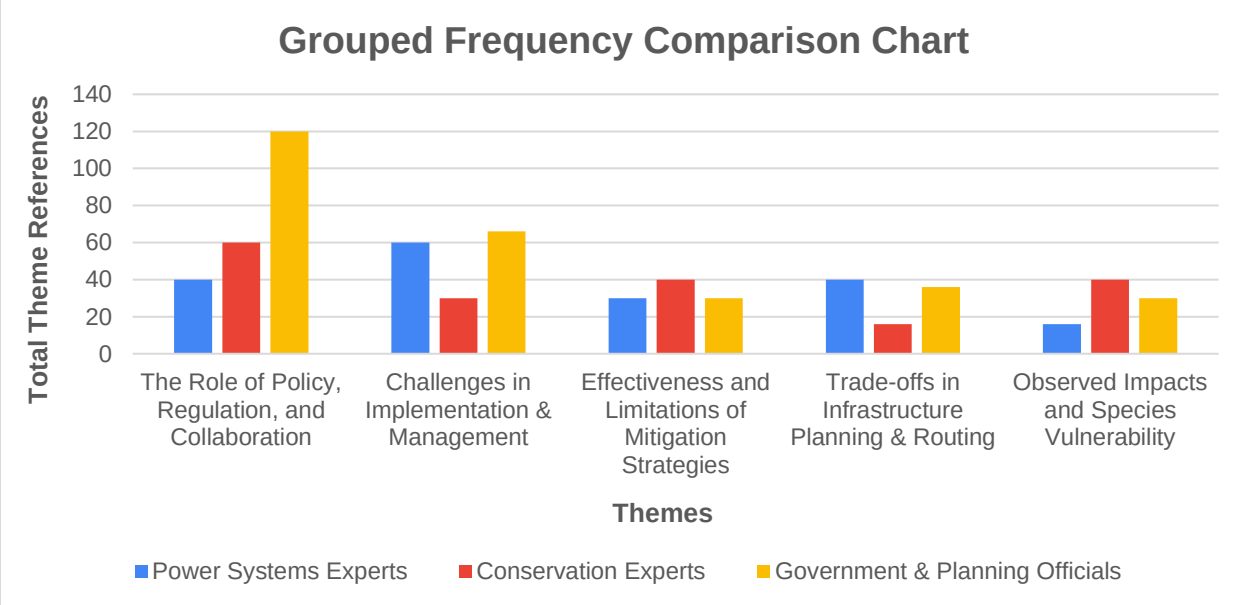

Figure 3: Grouped Frequency Comparison Chart

DISCUSSION

5.1 Vegetation Impacts and Management Mechanisms

Vegetation structure was heavily reduced in the corridor, yet plant species composition remained largely unchanged. This pattern aligns with selective removal of tall vegetation for electrical safety clearance, confirming engineers' descriptions in the qualitative themes.

5.2 Avian Community Filtering

While abundance and Shannon diversity were stable, the species identity—the core of ecological function—shifted significantly. Specialist species reliant on canopy cover or tall shrubs were replaced by generalists adapted to open habitats. This phenomenon is typical where vertical complexity is lost.

5.3 Policy Ambiguity and Operational Constraints

The combination of ecological and interview data demonstrates that the drivers of ecological impact are primarily managerial, including:

- Poorly coordinated clearing schedules,
- Inconsistent enforcement of environmental guidelines,
- and lack of ecological monitoring.

These management inconsistencies amplify ecological impacts more than the infrastructure itself.

5.4 Seasonality as an Ecological Lever

The wet season produces natural vegetation recovery and peak bird activity. When clearing coincides with breeding seasons, impacts are exacerbated — a risk highlighted strongly by conservation experts.

CONCLUSIONS & RECOMMENDATIONS

6.1 Conclusions

The project led to several key conclusions:

1. Vegetation structure is significantly compromised under overhead powerlines, suppressing seasonal recovery.
2. Bird abundance and diversity remain stable, but species composition shifts strongly.
3. Current maintenance practices—not infrastructure—are the primary ecological stressor.

The redesigned project provides ABC with high-value conservation insights despite initial methodological challenges.

6.2 Recommendations

6.2.1 Policy and Governance

- Develop a unified, inter-agency corridor management policy.
- Mandate ecological trade-off analyses for future routing decisions.

6.2.2 Corridor Management and Mitigation

- Restrict non-emergency clearing to the dry/non-breeding season.
- Shift from blanket to selective vegetation removal.
- Implement long-term ecological monitoring of mitigation measures.

6.2.3 Future Research

- Experimental trials of seasonal and selective maintenance.
- Long-term monitoring of raptors and other vulnerable species.

ETHICAL COMPLIANCE

All work complied with national laws and protected area regulations. ABC is acknowledged as a funder in all outputs, which include all reports shared with the Egerton University, Kenya Wildlife Service, Wildlife Research and Training Institute, Hells Gate National Park, and all publication manuscripts which are under review. God bless you and Asante sana ABC!

APPENDIX


HELLS GATE N.PARK
HEADQUARTERS
ELSA GATE
GORGE CLOSED!
TRESSPASSERS WILL BE PROSECUTED
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