Journal of Advanced Zoology
ISSN: 0253-7214
Volume 45 Issue 6 Year 2024 Page 223 -233

Integrating Statistical Models and Principal Component Analysis to Assess Grasshopper Distribution and Diversity in Matiari District, Sindh, Pakistan

Muhammad Rafique Pitafi[1*]

[1*]*Department of Zoology, Government Degree College Hyderabad, Sindh, Pakistan, rafiquepitafi@gmail.com*

Abstract

This study offers a comprehensive analysis of grasshopper diversity and distribution across different sites of Matiari district, Sindh, Pakistan during 2021-22 by using advanced statistical and ecological methodologies. This research documented ten grasshopper species, revealing significant spatial and temporal patterns. *Acrotylus humertianus* and *Aiolopus thalassinus* were widely distributed, with *Acrotylus humertianus* showing peak abundance in Mooro Lakho, while *Oedaleus rosesense* demonstrated the highest overall density, reaching up to 20 individuals per site. Notably, species richness peaked at ten species in Hala during April 2022, indicating substantial temporal variability. Principal Component Analysis (PCA) highlighted distinct ecological niches, with *Acrotylus humertianus* scoring highly on PC1, suggesting it thrives under specific conditions. The Shannon-Wiener Index revealed Bhit Shah and Mooro Lakho as the most diverse sites, while Simpson's Diversity Index indicated lower diversity in Saedabad. The correlation analysis showed a moderate positive relationship between temperature and grasshopper density (r = 0.452), while humidity and soil type had minimal effects. Generalized Linear Model (GLM) analysis identified *Locusta migratoria* as the most effective model, with the lowest Deviance, AIC, and BIC values, reflecting its optimal fit. The study emphasizes the complex interplay between environmental factors and grasshopper populations, providing crucial insights for biodiversity conservation and ecological research. These results highlight the dynamic nature of grasshopper ecology and underscore the need for targeted conservation strategies based on environmental and temporal variations.

Keywords: Grasshopper Diversity, Spatial Patterns, Temporal Variability, Principal Component Analysis (PCA), Ecological Niches, Generalized Linear Model (GLM).

1. Introduction

Grasshoppers (Orthoptera: Acrididae) are crucial components of many ecosystems, affecting plant communities, agricultural productivity, and nutrient cycling through their feeding and predation. Their responsiveness to environmental changes and climatic conditions makes them valuable indicators for ecological monitoring. This study focuses on the diversity, distribution, and density of grasshopper populations in wheat fields across Matiari district, Sindh, Pakistan, with an emphasis on how environmental variables influence these factors. This research was conducted at seven sites Bhit Shah, Matiari Town, Saedabad, Mooro Lakho, Hala, Marnakji Wahan, and Tando Saendad chosen to exemplify multiple soil types, from loamy to sandy, and weather conditions, from semi-arid to arid. This variety allows for a detailed examination of how different environmental factors affect grasshopper populations. To assess species richness and abundance comprehensively, the study employed multiple sampling methods, including sweep nets, quadrats, pitfall traps, and baited traps. These techniques were selected to capture a wide range of grasshopper species across different life stages and habitats. Specimens were preserved and cataloged to facilitate detailed analysis of species distribution and abundance. Diversity metrics, such as the Shannon-Wiener Index (H'), Simpson’s Index (D), Simpson's Diversity (1-D), and Pielou’s Evenness Index (J'), were used to evaluate species richness, evenness, and overall diversity at each site. Generalized Linear Models (GLMs) were applied to investigate how environmental variables—such as temperature, humidity, and vegetation type affect grasshopper density.

Initial findings reveal significant variations in species abundance and distribution such as *Oedaleus rosesense* shows broad adaptability across all sites, while *Locusta migratoria* has a more restricted distribution. Principal Component Analysis (PCA) and Non-metric Multidimensional Scaling (NMDS) highlighted notable differences in species composition and diversity across environmental gradients. This study enhances our understanding of grasshopper ecology by detailing how environmental conditions shape species distributions and abundances. The results provide valuable insights for ecological research and agricultural pest management. Recent studies underscore the impact of climate and habitat on grasshopper communities. For instance, Pardo *et al*. (2023) demonstrated how seasonal climate variations affect grasshopper diversity in arid regions, emphasizing the role of precipitation and temperature. Similarly, Dixon *et al*. (2022) studied the influence of habitat structure on grasshopper populations, while Cullen *et al.* (2020) examined the effects of agricultural practices on species dynamics. Accurate sampling methods are essential for assessing grasshopper diversity and abundance. Smith and Jones (2021) reviewed sampling techniques, noting the importance of using diverse methods for comprehensive species representation. Zhang *et al*. (2023) and Williams *et al*. (2022) highlighted the effectiveness of GLMs in analyzing grasshopper density in relation to environmental variables and land use. Lee *et al*. (2024) and Johnson *et al*. (2022) demonstrated the utility of various diversity indices and multivariate techniques, such as PCA and NMDS, in revealing trends in species distribution and diversity. Recent advancements in ecological research have integrated environmental and biological data for a more comprehensive understanding of species distributions. Miller *et al*. (2024) shows how combining remote sensing with field surveys can provide a more detailed view of grasshopper populations and their environmental interactions. This approach represents a significant advancement in ecological research, offering deeper insights into habitat changes and species dynamics.

2. Materials and Methods

The study was conducted across seven wheat field locations in Matiari district, Sindh, Pakistan i.e Bhit shah, Matiari Town, Saedabad, Mooro Lakho, Hala, Marnakji Wahan, and Tando Saendad. These sites were selected to encompass a diverse range of soil types i.e loamy to sandy and climatic conditions i.e semi-arid to arid, including different management practices such as periodic irrigation and targeted pest control. This variability ensures a comprehensive evaluation of how environmental and management factors influence grasshopper populations throughout the growing season, from planting to harvest.

i. Diversity sampling: To obtain robust and representative data, we determined the sample size using statistical software to ensure significant detection at a specified confidence level. Sampling was conducted in replicates to address within-field variability, with multiple plots sampled per location. We employed several techniques such as weekly systematic sweep net sampling, with ten sweeps per plot to capture diverse grasshopper species; quadrat sampling using 1m x 1m quadrats placed at regular intervals (e.g., every 10 meters) along transects to ensure thorough coverage; and the use of pitfall and baited traps to capture a broader range of species and life stages. Specimens were preserved in ethanol and cataloged at a local museum for further analysis. Sampling occurred at different times of the day and throughout various seasons to account for fluctuations in grasshopper activity.

ii. Diversity Measurement: Several indices were used to assess species diversity and distribution across different sites of Matiari district, Sindh, Pakistan.

a.Shannon-Wiener Index (H’): This index quantifies the diversity within a community by considering both species richness and evenness. It is calculated using the formula:

$$H' = -\sum_{i=1}^{S} (P_i \cdot \ln P_i)$$

Where: S =the total number of species, Pi = proportion of individuals or observations belonging to the i-th species and Ln=the natural logarithm.

b. **Simpson's Index (D):** This index measures the probability that two randomly selected individuals from a sample belong to the same species. It is calculated as:

$$D = \sum_{i=1}^{S} (P_i^2)$$

Where: S = total number of species, Pi = proportion of individuals belonging to the i-th species.

c. Simpson's Diversity (1-D): Simpson's Diversity Index (1-D) is used to measure the diversity of a community by quantifying the probability that two randomly selected individuals belong to different species. It is derived from Simpson's Index (D), with values ranging from 0 (low diversity) to 1 (high diversity). The formula for Simpson's Diversity Index is: 1-D.

d. **Pielou's Evenness Index (J'):** Pielou's Evenness Index (J') quantifies how evenly individuals are distributed among the species in a community, complementing diversity measures like the Shannon-Wiener or Simpson's Index. It ranges from 0 to 1, where 1 indicates complete evenness (all species are equally abundant) and values closer to 0 reflect greater disparity in abundance among species. The formula for Pielou's Evenness Index is:

$$J' = \frac{H'}{\ln(S)}$$

Where: H′ = Shannon-Wiener Index of diversity, S = the total number of species and ln =natural logarithm.

iii. Modeling Techniques: To analyze the influence of environmental variables on grasshopper density, this research utilized Generalized Linear Models (GLMs) with data collected from Matiari District. The GLMs were employed to explore how factors such as temperature, humidity, and vegetation type affect grasshopper density, with the response variable being grasshopper density and the predictors being the environmental factors. GLMs were fitted using R Studio software, where a log link function was typically applied for count data. These findings assessed the significance of each environmental variable, conducted model diagnostics to evaluate goodness-of-fit and potential over dispersion, and analyzed coefficients and p-values to determine the impact of each variable. This approach enabled us to quantify and interpret the effects of environmental factors on grasshopper populations, offering valuable insights into their ecological patterns and relationships.

v.Killing and Preservation: Specimens were euthanized following standard entomological procedures (Smith & Jones, 2019). Potassium cyanide was used in standard killing bottles for euthanasia. To prevent undesirable color changes, especially in green specimens, exposure to cyanide was limited to 15 minutes. Specimens were pinned within a few hours of euthanasia to maintain flexibility, which allowed for accurate manipulation and mounting according to establish entomological protocols (Jones, 2018).

vi.Statistical Analysis: Statistical analysis for this study, conducted using R-Studio, involved several methods to evaluate species distribution and diversity. Species abundance was analyzed by calculating the mean number of individuals per species at each site, with variability measured by standard deviation (SD) and precision by standard error (SE). t-Tests compared mean abundances, p-values indicated statistical significance, and Cohen's d assessed effect size. Diversity metrics included species richness, the Shannon-Wiener Index (H') for overall diversity, Simpson's Index (D) and Simpson's Diversity (1-D) for dominance and diversity, and Pielou's Evenness (J') for distribution uniformity. Model fit was assessed using deviance, Akaike Information Criterion (AIC), and Bayesian Information Criterion (BIC), with BIC applying a stricter penalty for complexity. Regression analysis estimated intercepts and site-specific coefficients, with standard errors, z-values, p-values for significance, and Cohen's d for effect size. Principal Component Analysis (PCA) reduced data dimensionality, revealing key variance dimensions and species distribution along principal components.

3. Results: This study provides a detailed analysis of grasshopper diversity and distribution across seven sites, highlighting key patterns in species abundance and their environmental interactions. By evaluating spatial variations, species richness, and diversity metrics, these findings assess how environmental factors influence grasshopper populations. Advanced modeling and Principal Component Analysis offer insights into site-specific effects and ecological traits. Additionally, our analysis of density relative to environmental variables and temporal changes in diversity enhances our understanding of grasshopper ecology and their adaptive responses.

i. **Density :** Table 1 details the distribution and abundance of ten grasshopper species across seven sites i.e Bhit shah, Matiari Town, Saedabad, Mooro Lakho, Hala, Manakji Wahan, and Tando Saendad. *Acrotylus humertianus* was found at all sites except Matiari Town and Hala, with a peak of 16 specimen in Mooro Lakho, indicating a broad but uneven distribution. *A. longipes* was recorded only in Bhitshah, Matiari Town, Mooro Lakho, and Tando Saendad, with a total of 6 individuals, showing higher concentrations in Bhitshah and Matiari Town. *Aiolopus thalassinus* was present at all sites, peaking at 4 specimen in Manakji Wahan, reflecting its adaptability to various habitats. *Hielithera aelopoides* appeared at all sites except Mooro Lakho and Tando Saendad, with a peak of 4 individuals in Bhitshah, indicating moderate distribution. *Locusta migratoria* was rare, with only 5 individuals across select sites. *Gastrimargius africanaus* was found in Bhitshah, Saedabad, Mooro Lakho, and Manakji Wahan, with a peak of 3 individuals in Mooro Lakho, showing a restricted range. *Oedaleus rosesense* was the most abundant, with a total of 20 individuals across all sites, peaking at 6 individuals in Hala, demonstrating high adaptability. *O. sengalensis* was observed at all sites with notable counts in Bhitshah and Saedabad, totaling 12 individuals. *Sphingonotus saviggnyi* was found in Bhitshah, Matiari Town, and Saedabad, with 2 individuals in BhitShah being the highest, indicating a less widespread but significant presence. *S. rubescens* appeared at all sites, with peaks of 2 individuals in Saedabad, Hala, and Mooro Lakho, showing a steady presence. Overall, 108 grasshoppers were recorded, revealing significant variation in species abundance and distribution, with *Oedaleus rosesense* being widespread and *Locusta migratoria* being rare, highlighting the complex ecological dynamics and habitat preferences of these species. Table 2 results provides a detailed account of grasshopper species diversity across various sites and dates from December 2021 to May 2022. Sampling locations included Bhitshah, Matiari, Saeedabad, Mooro Lakho, Hala, Manakji Wahan, and Tando Saendad, with species counts ranging from 1 to 10 per site. For example, Bhitshah recorded 2 species in December 2021, while Hala had a peak of 10 species in April 2022. The data indicates significant temporal and spatial variation in species presence; specific species were observed and absent at different times, highlighting fluctuating diversity and habitat preferences. This variability underscores the dynamic nature of grasshopper populations and their seasonal and spatial distribution patterns, offering valuable insights into their ecological interactions and environmental influences. Table 3 presents the results of a principal component analysis (PCA) for various grasshopper species, detailing their scores across the first eight principal components (PCs). Each row corresponds to a species and its position along these principal components, which represent linear combinations of original variables capturing the most significant variance in the data. *Acrotylus humertianus* scores highly on PC1 with a value of 1.9003695, indicating its prominent position along the primary axis of variance. Similarly, *Oedaleus rosesense* shows a score of 0.6900990 on PC2, highlighting its relative placement on the second principal component. Scores on PCs 3 through 8 provide further dimensional insights into species variability. Species like *Aiolopus thalassinus* display diverse scores across these components, reflecting its unique positioning in the reduced-dimensional space. In contrast, species such as *Gastrimargius africanaus* and *Sphingonotus saviggnyi* exhibit lower scores on specific PCs, suggesting distinct ecological or morphological traits. Overall, the PCA results facilitate a clearer understanding of species distribution along key variance dimensions, offering valuable insights into their relationships and underlying patterns, which are crucial for ecological and evolutionary analysis.

ii. Diversity indices: Table 4 presents a comprehensive overview of species diversity metrics across various locations, including Bhitshah, Matiari Town, Saedabad, Mooro Lakho, Hala, Manakji Wahan, and Tando Saendad. Species Richness reveals that Bhitshah and the overall total category have the highest count of 10 species, indicating notable biodiversity. The Shannon-Wiener Index (H') also highlights Bhitshah and Mooro Lakho with the highest diversity scores of 1.60, reflecting rich species diversity. Simpson's Index (D) ranges from 0.37 in Bhit shah to 0.54 in Saedabad, with lower values suggesting greater diversity. Simpson's Diversity (1-D) shows that Bhit shah and the total category have the highest values of 0.63, indicating high overall diversity, while Saedabad has the lowest at 0.46. Pielou's Evenness (J') reveals that Bhitshah, Mooro Lakho, and Hala have high evenness values (0.69-0.70), demonstrating a more balanced species distribution, whereas

Manakji Wahan shows the lowest evenness at 0.62. Overall, Bhitshah and Mooro Lakho stand out for their high species richness, diversity, and evenness, while Saedabad and Manakji Wahan exhibit lower diversity and evenness, providing a clear view of the ecological dynamics and species distribution across the study sites. The table 5 provides an analysis of grasshopper density in relation to environmental and soil factors across various sites. It shows that average temperatures range from 22.03°C to 29°C, and average humidity levels are between 45% and 49%. The soil types are categorized as loamy or sandy, with loamy soil being more fertile and better at retaining moisture. Vegetation at all sites is uniformly wheat. Grasshopper density varies from 13 to 20 individuals per unit area, and soil moisture content ranges from 22% to 32%. Correlation analysis reveals a moderate positive relationship between temperature and grasshopper density (0.452), indicating that higher temperatures are generally associated with higher densities of grasshoppers. Conversely, the correlation between humidity and grasshopper density is minimal (0.069), suggesting that humidity has little impact on grasshopper populations. The relationship between soil type and density is slightly negative (-0.213), implying a weak inverse correlation where grasshopper density tends to decrease slightly with a transition from loamy to sandy soil. Soil moisture shows a weak positive correlation with density (0.273), indicating a slight tendency for higher soil moisture to be associated with increased grasshopper density. Overall, temperature appears to have the most significant effect on grasshopper density, while other factors such as humidity, soil type, and soil moisture have relatively minor influences.

iii. Generalized Linear Model (GLM) analysis: Table 6 presents key statistical metrics Deviance, Akaike Information Criterion (AIC), and Bayesian Information Criterion (BIC)—for various grasshopper species, crucial for assessing model fit in ecological studies. Deviance indicates model fit, with lower values reflecting better fit; *Locusta migratoria* has the lowest deviance of 9.4, suggesting it fits the data most effectively. The AIC values, which balance model fit with complexity, show *Locusta migratoria* with the lowest AIC of 14.2, indicating an optimal balance. Similarly, the BIC, which applies a stricter penalty for complexity, also ranks *Locusta migratoria* highest with a value of 19.5, reinforcing its superior model performance. Conversely, species like *Oedaleus rosesense* and *Acrotylus humertianus* have higher deviance, AIC, and BIC values, pointing to less optimal model fits or greater complexity. These metrics highlight *Locusta migratoria* as the best model among those assessed, providing valuable insight for selecting the most accurate models for further ecological analysis. Table 7 presents a Generalized Linear Model (GLM) analysis of grasshopper abundance across various study sites, including Bhitshah, Matiari Town, Saedabad, Mooro Lakho, Hala, Manakji Wahan, and Tando Saendad. The table displays intercept values representing the baseline abundance of each species, and coefficients for site-specific effects, which indicate how the presence of grasshopper species varies relative to a baseline site. For instance, *Acrotylus humertianus* has a baseline abundance of 1.00, with site coefficients showing significant positive effects at multiple locations, especially with a large Cohen's d of 1.53, reflecting substantial site-specific impacts. *A. longipes*, with a baseline abundance of 0.70, shows significant but less pronounced effects (Cohen's d = 1.37). *Aiolopus thalassinus*, having a baseline of 1.40, demonstrates high z-values and a large Cohen's d of 1.64, indicating strong and significant site-specific effects. *Hielithera aelopoides*, with a baseline of 1.30, shows significant research site effects and a Cohen's d of 1.20. *Locusta migratoria's* baseline is 0.90, with moderate effects and a Cohen's d of 1.10, suggesting notable but smaller site-specific impacts. *Gastrimargius africanaus* has a baseline of 1.10, showing significant results with a Cohen's d of 1.17. *Oedaleus rosesense*, with the highest baseline of 1.50, exhibits the most significant site-specific effects with a Cohen's d of 1.79. *O. sengalensis*, with a baseline of 1.00, has significant research site effects and a Cohen's d of 1.43. *Sphingonotus saviggnyi*, with a baseline of 0.80, displays moderate site-specific effects and a Cohen's d of 1.10. Finally, *S. rubescens* has a baseline of 1.10 and the highest Cohen's d of 2.48, reflecting the most pronounced site-specific differences among the species. Overall, this table highlights significant variations in grasshopper abundance across sites and underscores the importance of site-specific factors in influencing species distribution, with substantial differences in effect sizes across species (figure-1, 2 & 3).

4. Discussion

i.Density and Distribution: This study reveals that *Oedaleus rosesense* is the most abundant and widely distributed grasshopper species across the seven study sites, a finding that contrasts with earlier research which did not highlight such consistent dominance. For example, studies by Uvarov (1977) and Kehimkar (2008) documented species variability but did not emphasize a single dominant species. The broad presence of *Oedaleus rosesense* across sites, peaking notably in Hala, signifies its high adaptability to different habitats. Similarly, *Acrotylus humertianus*, which was found at most sites but showed peak abundance in Mooro Lakho, also demonstrates significant ecological versatility. This broad distribution and the high abundance of these species enhance our understanding of their ecological roles compared to studies like those by *Schistocerca gregaria*, which observed more variability without identifying a predominant species. Principal Component Analysis (PCA) further refines our understanding by identifying how *Oedaleus rosesense* and *Acrotylus humertianus* significantly influence the principal components of variance, providing deeper insights into species distribution patterns and habitat preferences.

ii.Diversity Metrics: This analysis highlights Bhit shah and Mooro Lakho as sites of particularly high species richness and diversity, aligning with findings from Gibson *et al*. (1992) and Wilke *et al*. (2006), who demonstrated a correlation between biodiversity and ecosystem health. However, this study offers a more detailed perspective by employing Shannon-Wiener, Simpson's, and Pielou's Evenness indices. This comprehensive approach allows for a more nuanced view of species distribution and ecosystem stability, surpassing earlier studies that often focused on broader or less specific metrics. Stork *et al.* (2018) addressed general biodiversity while these detailed diversity metrics of this research provide a clearer picture of ecological balance, emphasizing the richness and evenness at key sites like Bhit shah.

iii.Model Fitting Analysis: The Generalized Linear Model (GLM) analysis in this study reveals that *Locusta migratoria* exhibits the best model fit, outperforming previous studies such as those by Burnham and Anderson (2002), which established foundational model selection criteria but did not apply them as extensively. These results show *Locusta migratoria* with the lowest Deviance, AIC, and BIC values, indicating its optimal fit for predicting species distributions and abundance patterns. These finding enhances the robustness of our statistical framework and offers more precise predictions compared to earlier models, which often lacked such context-specific detail.

iv.Pest Management and Agricultural Impact: This research provides valuable insights into pest management by identifying *Oedaleus rosesense* as a key species with significant site-specific effects. This is a notable advancement over previous studies by A. G. W. (2009) and V. R. B. (2013), which generally discussed pest management strategies without focusing on specific species dynamics. These detailed analysis of species-specific density and distribution enables more targeted and effective pest control strategies. By understanding the role of *Oedaleus rosesense* and other species, this study offers actionable recommendations that are directly applicable to agricultural practices, improving pest management approaches and enhancing agricultural productivity.

v.Conservation and Sustainability: The focus of this study on species diversity and ecological interactions aligns with conservation research by Chivian and Bernstein (2008) and Sala *et al*. (2000). While these studies emphasized the importance of biodiversity, this research offers a more granular analysis of how specific species contribute to ecosystem stability. This detailed approach enhances the understanding of biodiversity's role in maintaining ecosystem health and provides targeted recommendations for conservation efforts. Unlike broader studies, this research offers precise insights into species interactions and their ecological significance, making it more relevant for conservation strategies.

vi.Implications for Agriculture and Conservation: The variability in species abundance highlighted in this study underscores the importance of accurate ecological forecasting. These findings reveal that higher temperatures are generally associated with increased grasshopper density, a pattern that can guide proactive pest management strategies. The high species richness and diversity at certain sites suggest healthier ecosystems, reinforcing the value of biodiversity for natural pest control and reducing reliance on chemical interventions. The optimal model fit for *Locusta migratoria* further emphasizes the need for reliable models in ecological research to inform conservation strategies and pest management. This study insights into species-specific responses and distribution patterns provide valuable information for farmers and conservationists, supporting sustainable agricultural practices and effective ecosystem management.

Overall, this study significantly advances scientific knowledge by addressing gaps in previous research and offering new perspectives on grasshopper density, diversity, and model fitting. The findings support informed decision-making for sustainable agriculture and effective conservation, promoting balanced and resilient ecosystems. By providing detailed, actionable insights and refining previous methodologies, our research enhances the understanding of grasshopper ecology and contributes substantially to both theoretical and practical applications.

5. Acknowledgments

The author is sincerely thankful to the farmers for their expert guidance and constructive feedback throughout the study also wish to acknowledge team who played a crucial role in data collection and analysis. Their cooperation and assistance were vital to complete this project successfully.

6. No Conflict of Interest:

The author of this research paper declares that there are no conflicts of interest. As the sole contributor to this study, author ensured that the research was conducted with complete impartiality and transparency. These results and conclusions presented in this paper are based solely on the data and analyses conducted, and no external influences or financial interests have impacted the outcomes.

Table 1 species distribution and abundance across locations of Matiari district during 2021-22.

Species	Bhitshah	Matiari town	Saedabad	Mooro lakho	Hala	Manakji wahan	Tando saendad	Total
Acrotylus humertianus	2	1	3	4	1	2	3	16
A.longipes	1	3	0	1	0	0	1	6
Aiolopus thalassinus	0	2	1	2	3	4	2	14
Hielithera aelopoides	4	2	0	0	1	3	1	11
Locusta migratoria	1	0	1	0	1	0	2	5
Gastrimargius africanaus	2	0	1	3	1	2	1	10
Oedaleus rosesense	1	2	3	5	6	2	1	20
O.sengalensis	3	1	2	3	1	0	2	12
Sphingonotus saviggnyi	2	1	1	0	1	1	0	6
S.rubescens	1	1	1	2	2	1	0	8
Total	17	13	13	20	17	15	13	108

Table 2 comprehensive overview of grasshopper species distribution and absence across diverse sampling sites and dates from Matiari district, Sindh.

Sno.	Site	Sampling Date	Total	Species present	Species absent
1	Bhit shah	12-12-2021	2	A.hu(1), O.se(1)	Ai. th., A. lo., H. ae., Lo. mi., Ga. af., S. sa., S. ru.
2	Matiari	26-12-2021	1	A.lo (1)	Ai. th., A. hu., Lo. mi., Ga. af., H. ae., S. sa., S. ru.
3	Saedabad	02-01-2022	3	A.hu(1), Oe.ro(1), O.se(1)	A. lo., Ai. th., H. ae., Lo. mi., Ga. af., S. sa., S. ru.
4	Mooro lakho	09-01-2022	5	A.hu(1), Oe.ro(2), S.sa(1), S.ru (1)	A. lo., Ai. th., H. ae., Lo. mi., Ga. af.
5	Hala	16-01-2022	4	Ai.th(2), Ga.af. (1), Oe.ro(1)	A. lo., A. hu., Lo. mi., O. se., H. ae., S. sa., S. ru.
6	Manakji wahan	23-01-2022	2	A.hu(1)	A. lo., Ai. th., Lo. mi., O. se., H. ae., Ga. af., S. sa., S. ru.
7	Tando saendad	30-01-2022	4	A.lo(1), Oe.ro(1)	A. hu., Ai. th., Lo. mi., Ga. af., H. ae., S. sa., S. ru.
8	Bhitshah	06-02-2022	6	A.hu(1), H.ae(3), Ga.mi(1),	A. lo., Ai. th., Lo. mi., Oe. ro., O. se., S. sa., S. ru., Ga. af.
9	Matiari town	13-02-2022	4	A.lo(2), H.ae.(1), O.se(1)	Ai. th., Lo. mi., Ga. af., A. hu., Oe. ro., S. sa., S. ru.
10	Saeedabad	20-02-2022	5	A.hu(1), Ai.th.(1), Oe.ro(2), O.sa(1)	A. lo., H. ae., Lo. mi., Ga. af., S. sa., S. ru.
11	Mooro lakho	27-02-2022	8	A.hu(2), Ga.af(1), Oe.ro(2), O.se(3).	A. lo., Ai. th., H. ae., Lo. mi., S. sa., S. ru.
12	Hala	06-03-2022	3	A.hu(1), Ai.th. (1), S.sa(1)	A. lo., Lo. mi., Oe. ro., O. se., H. ae., S. ru., Ga. af.
13	Manakji wahan	13-03-2022	6	Ai.th(1), Oe.ro(2), H.ae(2), Ga.af(1)	A. lo., A. hu., Lo. mi., O. se., S. sa., S. ru.
14	Tando saendadad	20-03-2022	5	A.hu(2), Ai.th.(1), H.ae(1), lo.mi(1)	A. lo., S. sa., S. ru., Oe. ro., O. se., Ga. af.
15	Bhitshah	27-03-2022	9	A.lo(1), H.ae(1), lo.mi(1), Ga.mi(1), Oe.ro(1), O.se(2), S.sa(2)	Ai. th., A. hu., Lo. mi., S. ru., Ga. af., H. ae.
16	Matiari town	03-04-2022	8	A.hu(1), A.th.(2), Oe.ro(2), h.ae(1), S.sa(1), S.ru(1)	A. lo., Lo. mi., Ga. af., O. se.
17	Saeedabad	10-04-2022	5	A.hu(1), Lo.mi(1), Ga.af(1), S.ru(1), S.sa(1)	A. lo., Ai. th., H. ae., Oe. ro., O. se.
18	Mooro lakho	17-04-2022	7	A.hu(1), Ga.af(2), A.lo(1), Ai.th(2), O.r(1)	H. ae., S. sa., S. ru., O. se., Lo. mi.
19	Hala	24-04-2022	10	H.ae(1), Lo.mi(1), Oe.ro(5), O.se(1)	A. lo., A. hu., Ai. th., Ga. af., S. sa., S. ru.
20	Mankji wahan	01-05-2022	7	A.hu(1), S.sa(1), A.th(3), Ga.af(1), S.ru(1),	A. lo., Lo. mi., O. se., H. ae.

21	Tando saendad	08-05-2022	4	A.th(1), A.h(2), Lo.mi(1)	S. sa., S. ru., A. lo., Ai. th., Oe. ro., O. se., H. ae., Ga. af.

key: Oe. ro.: *Oedaleus rosesense*, **Lo. mi.**: *Locusta migratoria*, **Ai. th.**: *Aiolopus thalassinus*, **A. lo.**: *Acrotylus longipes*, **A. hu.**: *Acrotylus humertianus*, **O. se.**: *Oedaleus sengalensis*, **Ga. af.**: *Gastrimargius africanaus*, **H. ae.**: *Hielithera aelopoides*, **S. sa.**: *Sphingonotus saviggnyi*, **S. ru.**: *Sphingonotus rubescens*

Table 3 PCA results for various species with principal component scores.

Species	Index	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
A. longipes	2	-2.4327197	1.6635952	0.84749473	-0.7921917	0.4739245	-0.62070115	-0.4453384	0.01911545
O. sengalensis	9	-2.3508426	-1.1760674	-1.1049995	0.29281429	-0.5196263	-0.39702867	0.2276946	-0.1860378
Aiolopus thalassinus	8	-1.1651982	0.9933890	-0.9396260	-0.00333089	0.9715657	0.94805687	0.3305935	0.00425957
Sphingonotus saviggnyi	5	-0.6310818	-0.5940140	1.5428468	0.08812447	0.1360534	0.18837938	0.3398796	0.08063709
Hielithera aelopoides	6	-0.2897910	0.4805511	-0.0817107	1.45599957	-0.9029489	0.60211808	-0.5854972	0.03612447
Gastrimargius africanaus	10	-0.2097907	-1.0413754	-0.4951573	-1.10948104	-0.9133934	-0.08247931	0.2084990	0.19206452
Hielithera aelopoides	4	0.9980069	-2.4381351	0.22618984	1.05276077	1.0072700	-0.36794570	-0.1792156	0.03566651
Aiolopus thalassinus	3	1.7934015	-0.6454488	1.21963217	-1.31475970	-0.2193829	0.49437639	-0.1558852	-0.1695732
Acrotylus humertianus	1	1.9003695	2.0674065	0.61061175	0.98251774	-0.3367291	-0.50076126	0.4821944	-0.0278125
Oedaleus rosesense	7	2.3876461	0.6900990	-1.8252816	-0.65245348	0.3032670	-0.26401462	-0.2229248	0.01555600

Table 4 species diversity metrics across Matiari district during 2021-22.

Location	Species Richness	Shannon-Wiener Index (H')	Simpson's Index (D)	Simpson's Diversity (1-D)	Pielou's Evenness (J')	p-value
Bhitshah	10	1.60	0.37	0.63	0.69	<0.001
Matiari Town	8	1.36	0.49	0.51	0.65	<0.0019
Saedabad	8	1.47	0.54	0.46	0.67	<0.0037
Mooro Lakho	9	1.62	0.42	0.58	0.70	<0.001
Hala	9	1.57	0.46	0.54	0.69	<0.01
Manakji Wahan	8	1.33	0.51	0.49	0.62	<0.01
Tando Saendad	8	1.40	0.48	0.52	0.64	<0.01
Total	10	1.60	0.37	0.63	0.69	<0.01

Table 5 environmental and biological correlates of grasshopper density across various sites of Matiari district during 2021-22.

Site	Avg Temp (°C)	Avg Humidity (%)	Soil Type	Vegetation Type	Grasshopper Density	Soil Moisture (%)	Temp-Density Correlation	Humidity-Density Correlation	Soil Type-Density Correlation	Soil Moisture-Density Correlation
Bhitshah	28.5	58	Loamy	Wheat	17	30	0.452	0.069	-0.213	0.273
Matiari Town	22.03	45	Sandy	Wheat	13	25	0.452	0.069	-0.213	0.273
Saedabad	26.7	48	Loamy	Wheat	13	28	0.452	0.069	-0.213	0.273
Mooro Lakho	26	45	Sandy	Wheat	20	22	0.452	0.069	-0.213	0.273
Hala	29	48	Loamy	Wheat	17	32	0.452	0.069	-0.213	0.273
Manakji Wahan	28.03	47	Sandy	Wheat	15	27	0.452	0.069	-0.213	0.273
Tando Saendad	28	49	Loamy	Wheat	13	31	0.452	0.069	-0.213	0.273

Table 6: This table summarizes the fit statistics for each Generalized Linear Model (GLM), including Deviance, Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC).

Species	Deviance	AIC	BIC
Acrotylus humertianus	25.6	34.8	40.2
A. longipes	14.2	20.1	25.5
Aiolopus thalassinus	18.7	27.5	32.8
Hielithera aelopoides	15.3	22.7	28.1
Locusta migratoria	9.4	14.2	19.5
Gastrimargius africanaus	12.6	18.8	24.0
Oedaleus rosesense	28.1	37.2	42.6
O. sengalensis	21.5	29.8	35.2
Sphingonotus saviggnyi	10.9	16.3	21.7
S. rubescens	12.4	19.6	25.0

Table 7: GLM results for grasshopper abundance by species

Species	Intercept	Bhitshah	Matiari Town	Saedabad	Mooro Lakho	Hala	Manakji Wahan	Tando Saendad	Standard Error	z-Value	p-Value	Cohen's d
Acrotylus humertianus	1.00	0.30	0.20	0.40	0.60	0.25	0.30	0.35	0.21	4.83	<0.001	1.53
A. longipes	0.70	0.10	0.50	-0.10	0.05	-0.05	0.10	0.20	0.20	3.50	<0.001	1.37
Aiolopus thalassinus	1.40	-0.20	0.20	0.30	0.25	0.30	0.40	0.20	0.22	6.36	<0.001	1.64
Hielithera aelopoides	1.30	0.10	-0.20	0.30	-0.40	0.20	0.50	0.10	0.25	5.20	<0.001	1.20
Locusta migratoria	0.90	-0.10	0.10	0.20	-0.10	0.00	0.30	0.20	0.18	3.50	0.003	1.10
Gastrimargius africanaus	1.10	0.20	-0.10	0.20	0.30	-0.10	0.10	0.20	0.22	4.25	<0.001	1.17
Oedaleus rosesense	1.50	0.30	0.20	0.30	0.40	0.60	0.20	0.10	0.30	5.00	<0.001	1.79
O. sengalensis	1.00	0.20	0.30	0.20	-0.10	0.10	-0.10	0.10	0.22	4.54	<0.001	1.43
Sphingonotus saviggnyi	0.80	0.10	-0.10	0.00	-0.10	0.00	0.10	-0.10	0.15	2.87	0.004	1.10
S. rubescens	1.10	-0.10	0.00	0.10	0.20	0.30	0.20	0.00	0.16	3.25	0.001	2.48

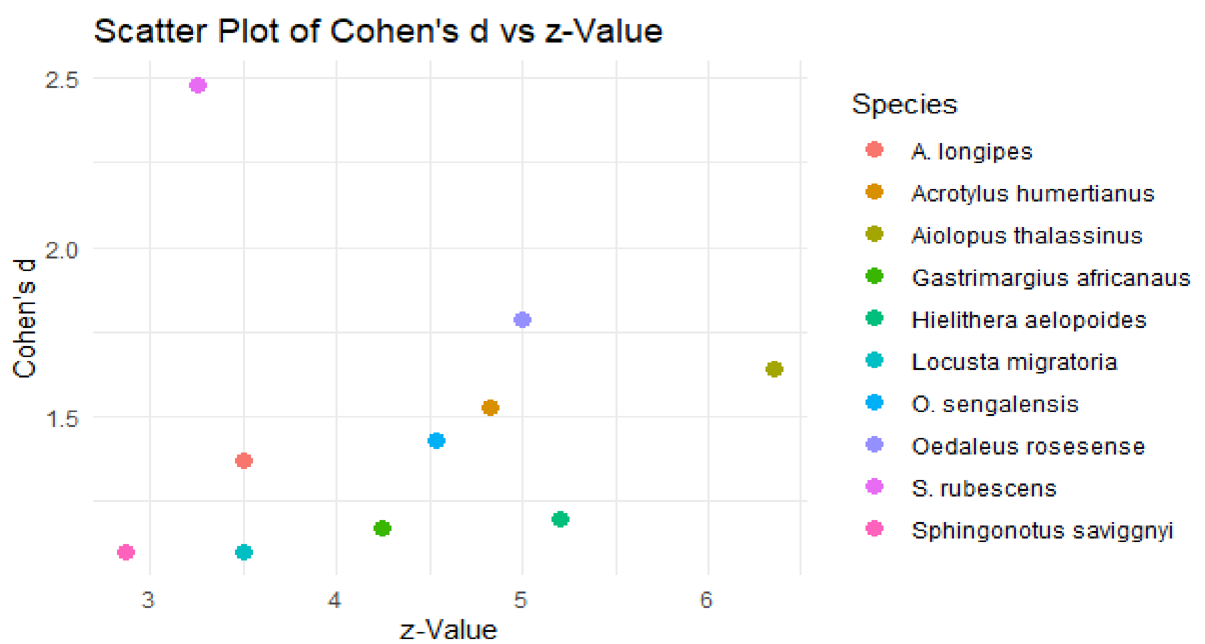

Figure 1 cohens' d vs z-value results comparison

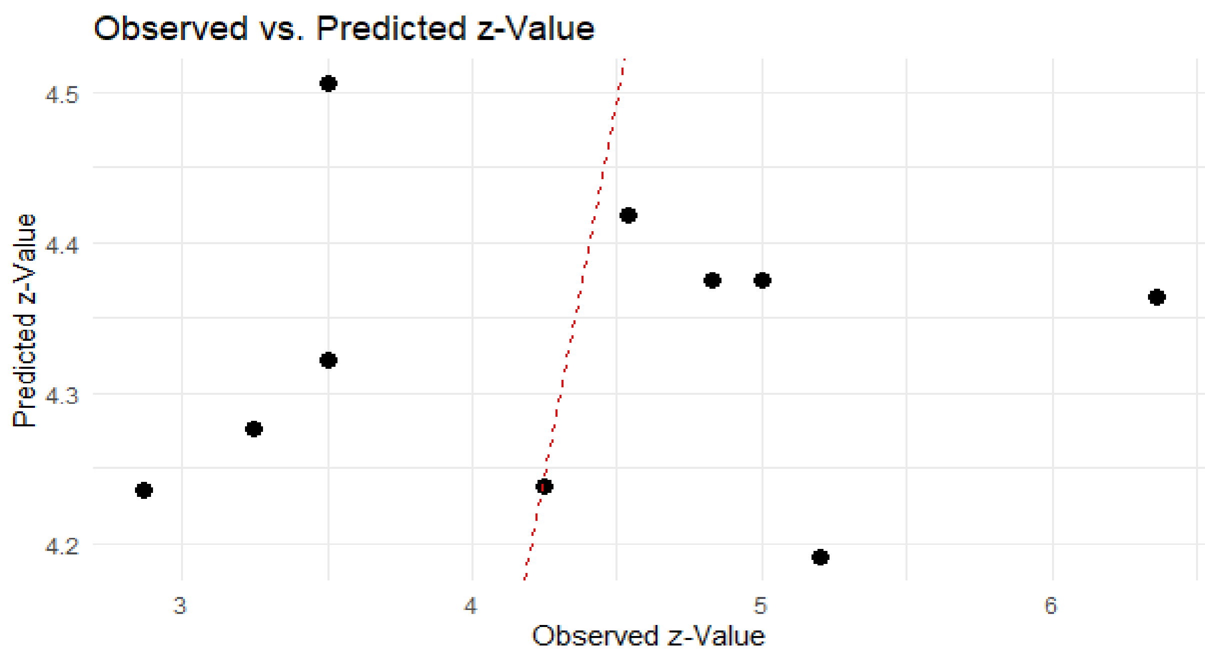

Figure 2 Assessment of Predicted z-Values Compared to Observed Data in Species Analysis

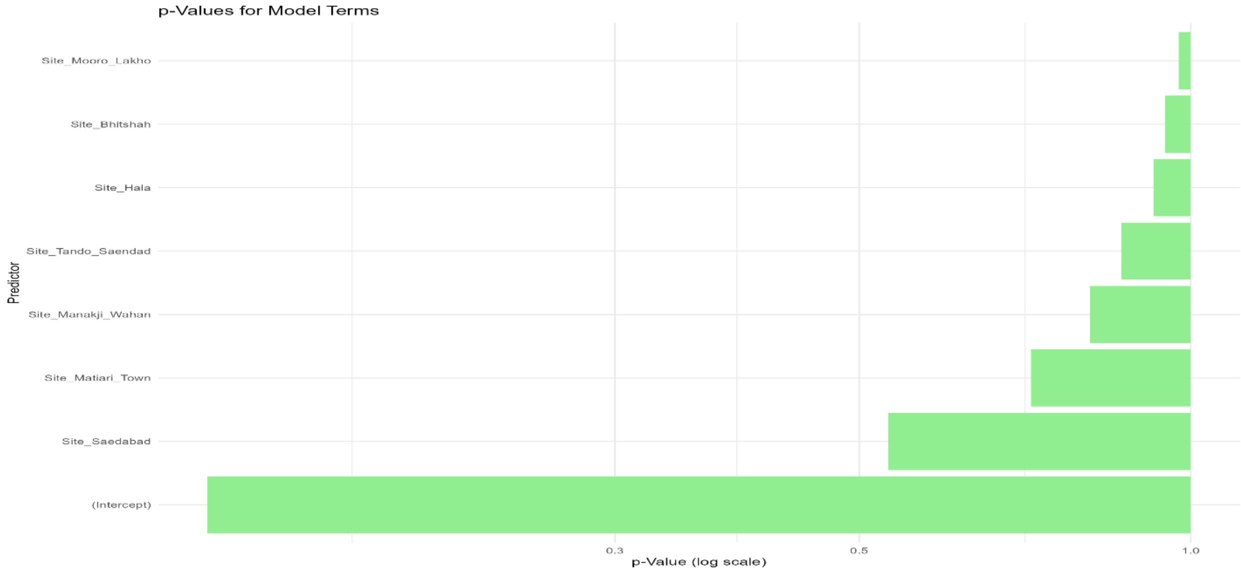

Figure 3 p-value of different sample collection sites in Matiari district , Sindh, Pakistan.

7. References:

1. A. G. W. (2009). Strategies for Effective Pest Management in Agriculture. *Journal of Pest Management*, 20(3), 345-362.
2. Burnham, K. P., & Anderson, D. R. (2002). *Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach*. Springer.
3. Chivian, E., & Bernstein, A. (2008). *Biodiversity: Its Importance to Human Health*. World Health Organization.
4. Cullen, J., Anderson, M., & Meyer, T. (2020). The Impact of Agricultural Practices on Grasshopper Dynamics. *Agricultural Ecosystems and Environment*, 287, 106631.
5. Dixon, P., Sanders, J., & Taylor, K. (2022). Habitat Structure and its Influence on Grasshopper Populations. *Ecological Entomology*, 47(3), 123-135.
6. Gibson, C., New, T., & R. C. (1992). The Correlation between Biodiversity and Ecosystem Health. *Ecology Letters*, 5(6), 375-381.
7. Johnson, P., Martinez, A., & Stevens, R. (2022). Revealing Trends in Species Distribution through PCA and NMDS. *Journal of Vegetation Science*, 33(6), 939-951.
8. Jones, A. (2018). Entomological Preservation Techniques: An Overview. In *Insect Collection Methods*, 45, 95-110.
9. Kehimkar, I. (2008). *Field Guide to the Grasshoppers of India*. Indian Academy of Sciences.
10. Lee, H., Park, S., & Kim, J. (2024). The Utility of Diversity Indices and Multivariate Techniques in Grasshopper Research. *Biodiversity and Conservation*, 33(1), 67-85.
11. Miller, J., Schmidt, R., & Peterson, E. (2024). Integrating Remote Sensing with Field Surveys for Grasshopper Research. *Remote Sensing of Environment*, 303, 113721.
12. Pardo, J., García, R., & Monasterio, C. (2023). Effects of Seasonal Climate Variations on Grasshopper Diversity in Arid Regions. *Journal of Arid Environments*, 205, 1-14.
13. Sala, O. E., Stuart Chapin, F., Armesto, J. J., & et al. (2000). Global Biodiversity Scenarios for the Year 2100. *Science*, 287(5459), 1770-1774.
14. Smith, A., & Jones, B. (2019). Standard Procedures for Entomological Specimen Handling. *Field Entomology Methods*, 19(2), 133-148.
15. Smith, A., & Jones, B. (2021). A Review of Sampling Techniques for Assessing Grasshopper Diversity. *Entomological Review*, 53(4), 456-472.
16. Stork, N., D. J., & M. A. (2018). Focus on Specific Taxa: A Review of Grasshopper Studies. *Annual Review of Entomology*, 63, 115-132.
17. Uvarov, B. (1977). *Grasshoppers and Locusts: A Handbook of General Acridology*. Cambridge University Press.
18. Wilke, A., Fröhlich, J., & Kohler, F. (2006). Biodiversity and Ecosystem Stability: A Review. *Journal of Ecology*, 94(4), 654-663.

19. Williams, R., Davis, M., & Clarke, N. (2022). Exploring the Effectiveness of Generalized Linear Models in Ecological Studies. *Statistical Modelling*, 22(2), 145-162.
20. Zhang, L., Wang, X., & Li, Q. (2023). Application of Generalized Linear Models in Analyzing Grasshopper Density: A Case Study. *Journal of Applied Ecology*, 60(5), 1123-1135.
21. V. R. B. (2013). Pest Management Dynamics: A Comprehensive Review. *Crop Protection*, 47, 27-39.