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RESEARCH NOTE

Chasing the Rains: Seasonal Dynamics of Herbivorous and Predatory Insects in Savannahs in Kruger National Park, South Africa

Fernando P. Gaona[1,2] | Sylvain Delabye[1,2] | Pavel Potocký[2] | Valeriy Govorov[3] | Jan Čuda[4] | Llewellyn C. Foxcroft[5,6] | Rafał Garlacz[7] | Martin Hejda[4] | Sandra MacFadyen[8,9] | Tomasz Pyrcz[10] | Klára Pyšková[1,4] | Ondřej Sedláček[1] | David Storch[1,11] | Petr Pyšek[1,4] | Robert Tropek[1,2]

[1]Department of Ecology, Faculty of Science, Charles University, Prague, Czechia | [2]Institute of Entomology, Biology Centre, Czech Academy of Sciences, České Budějovice, Czechia | [3]Department of Zoology, Faculty of Science, Charles University, Prague, Czechia | [4]Department of Invasion Ecology, Czech Academy of Sciences, Institute of Botany, Průhonice, Czechia | [5]Scientific Services, South African National Parks, Skukuza, South Africa | [6]Centre for Invasion Biology, Department of Botany and Zoology, Stellenbosch University, Matieland, South Africa | [7]Nature Education Centre, Jagiellonian University, Kraków, Poland | [8]Department of Mathematical Sciences, Mathematical Biosciences, Stellenbosch University, Stellenbosch, South Africa | [9]National Institute for Theoretical and Computational Sciences, Stellenbosch University, Matieland, South Africa | [10]Institute of Zoology and Biomedical Research, Jagiellonian University, Kraków, Poland | [11]Center for Theoretical Study, Charles University, Prague, Czech Republic

Correspondence: Fernando P. Gaona (fpgaona1@gmail.com)

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ABSTRACT

Tropical savannahs experience pronounced seasonality, especially in rainfall and temperature, shaping plant productivity and resource availability. Yet, temporal patterns in insect diversity remain poorly understood. We investigated seasonal variation in species richness and community composition of moths (herbivores) and mantises (predators) across four main landsystems in Kruger National Park, South Africa. Using light traps during early and late wet seasons, we captured 65 593 moths (817 morphospecies) and 3511 mantises (38 morphospecies). Species richness of both groups significantly increased from the early to the late wet season, particularly in the wetter southern landsystems, likely driven by rainfall-enhanced resource availability and habitat complexity. Community composition varied seasonally and among landsystems, with moths primarily influenced by seasonal changes, whereas mantises responded more strongly to landsystem differences. Our results indicate that rainfall-driven seasonal resource variability is a key determinant of insect phenological patterns in tropical savannahs. Predicted shifts in rainfall patterns due to climate change may alter insect emergence timing and trophic interactions, highlighting the importance of incorporating seasonal dynamics into biodiversity conservation and management strategies.

1 | Introduction

Tropical savannahs, recognised as global biodiversity hotspots, are characterised by pronounced seasonality, with precipitation concentrated within a distinct wet season lasting only a few months each year (Archibald et al. 2019). Seasonal rainfall drives plant phenology by regulating growth, flowering, and reproduction, which cascades through trophic levels and shapes insect communities (Fischer et al. 2022). Resource availability peaks during wet seasons, supporting increased insect diversity and abundance. In contrast, dry seasons, characterised by water deficiency and reduced vegetation productivity, constrain

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insect populations and species richness (Braga and Diniz 2018). These seasonal fluctuations substantially affect key ecological processes, including herbivory, seed predation, frugivory, and pollination (e.g., Stein et al. 2018; Fischer et al. 2022). While spatial patterns of insect diversity in savannahs have been extensively studied (e.g., D'Souza et al. 2021; Delabye et al. 2022; Gaona et al. 2025), temporal dynamics and processes driving insect phenological patterns remain poorly understood. This knowledge gap is particularly important given the pronounced seasonal and inter-annual climatic variability of savannah ecosystems (Archibald et al. 2019), which complicates accurate predictions of biodiversity responses to climate change.

Insects, with their high diversity and short generation times, represent an ideal group for studying temporal dynamics of savannah biodiversity (Braga and Diniz 2018). As primary and secondary consumers, they shape food webs and exhibit notable seasonal variation in activity and diversity. Herbivorous insects rely directly on plant resources, while carnivorous groups track prey availability, and both groups demonstrate seasonal activity patterns primarily driven by precipitation in tropical savannahs (e.g., Schmitt et al. 2021; Fischer et al. 2022). For example, wet-season increases in species richness have been documented for beetles (Davis et al. 2012; Mavasa et al. 2022), termites (Davies et al. 2015), and ground insects (Mhlanga et al. 2022) in Kruger National Park and other southern African savannahs, but also for butterflies in Kenya (Schmitt et al. 2021). However, some taxa exhibited different patterns: grasshoppers in grazed South African savannahs (Gebeyehu and Samways 2003) and bees in Burkina Faso (Stein et al. 2018) showed stable species richness across seasons, while species richness of arboreal hemipterans and dipterans peaked during the dry season in Namibia (Theron 2010). Communities of carnivorous arthropods typically follow prey abundance, with spiders, scorpions, and some hymenopterans peaking early in the South African wet season (Mhlanga et al. 2022; Mavasa et al. 2022; Druce et al. 2004). In contrast, ants showed minimal seasonal fluctuations due to colony persistence throughout the year (Mavasa et al. 2022). Seasonal shifts in community composition within African savannahs are primarily driven by species turnover (e.g., Schmitt et al. 2021; Mavasa et al. 2022; Mhlanga et al. 2022), closely associated with rainfall variability (e.g., Mavasa et al. 2022; D'Souza et al. 2021). Nevertheless, the seasonal dynamics of moth and mantis communities in African savannahs remain underexplored.

This study investigates seasonal variation in species richness and community composition of adult herbivorous moths and carnivorous mantises across the main landsystems in Kruger National Park. It represents South African savannahs characterised by pronounced seasonality and a clear north–south precipitation gradient. We expect lower species richness during the early wet season, when resources remain limited, compared to the late wet season, when prolonged rainfalls enhance vegetation growth and prey availability (Fischer et al. 2022). Additionally, we anticipate higher community similarity during the early wet season due to reduced resource heterogeneity, contrasting with the late wet season, when increased rainfall enhances plant and habitat diversity, supporting more diverse moth and mantis communities. The temporal dynamics of insect diversity are predicted to vary among landsystems, reflecting gradients in precipitation and other key environmental conditions, including geology and vegetation (Hejda et al. 2022; Gaona et al. 2025).

2 | Methods

Kruger National Park (KNP), one of South Africa's largest and oldest national parks, covers approximately 20000 km^2 and primarily comprises a heterogeneous mosaic of woodland savannahs (MacFadyen et al. 2016; Figure 1a). KNP experiences distinct seasonal patterns in precipitation and temperature (Figure 1b). Average monthly rainfall ranges from 10 mm in the south to 4 mm in the north during the dry season

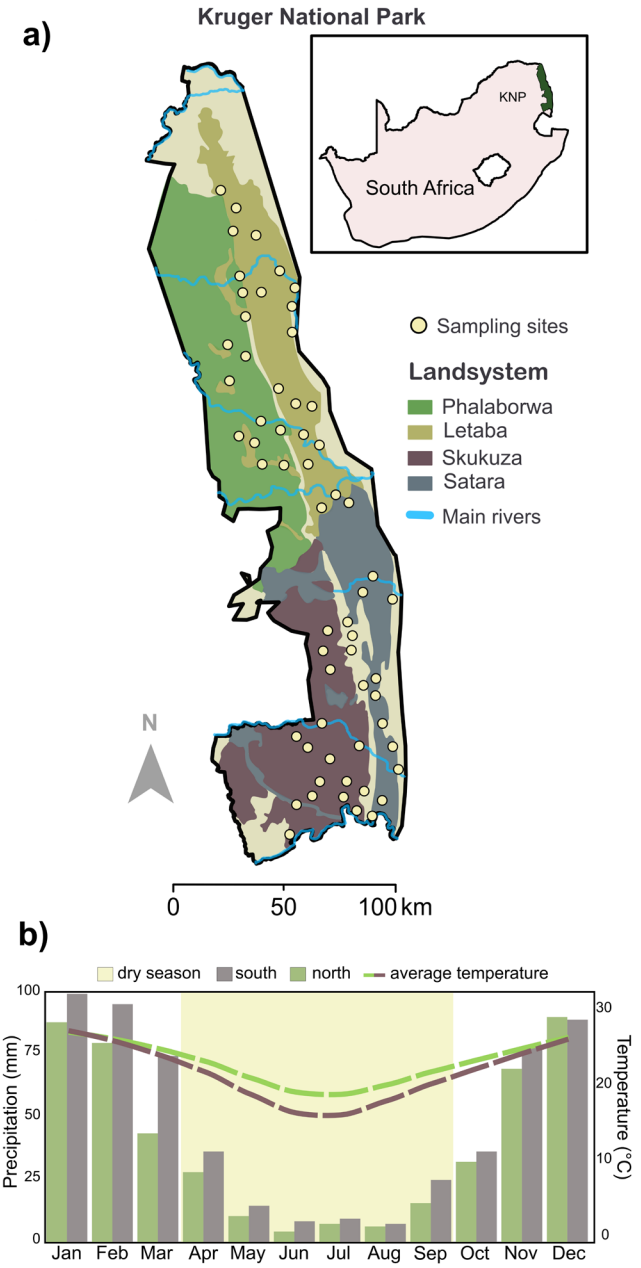

FIGURE 1 | Study area and regional climate. (a) Insect sampling sites in Kruger National Park, South Africa. (b) Seasonal variation in monthly precipitation and temperature for the southern and northern regions (modified from Zambatis 2003).

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(April–September), and from 100 to 80 mm during the wet season (October–March) (Zambatis 2003; Figure 1b). Annual precipitation exhibits a pronounced south-to-north gradient, with the southern regions receiving approximately twice as much rainfall (740 mm) as the northern areas (440 mm) (Zambatis 2003; MacFadyen et al. 2016). Temperature shows the opposite pattern, with monthly averages ranging from 16°C in the south to 20°C in the north during the dry season, and from 24°C to 26°C during the wet season (Zambatis 2003).

Insect samples were collected at 60 plots (50 × 50 m) established across KNP and organised into triplets along a gradient of water availability, with plots within each triplet selected to match landsystem, bedrock type, and vegetation structure, as part of the MOSAIK project (Monitoring Savanna Biodiversity in the Kruger National Park; Hejda et al. 2022; Gaona et al. 2025). Sampling focused on four main landsystems defined by geology, altitude, climate, and vegetation (Hejda et al. 2022): Letaba, Phalaborwa, Satara, and Skukuza (Figure 1a). Precipitation data (long-term annual mean and standard deviation) was derived from a 20-year dataset (2000–2019) with a 4 km^2 resolution (Funk et al. 2015).

At each plot, insects were collected using portable light traps (see Gaona et al. 2025 for further details), placed at the plot centre and operated for a complete night per season, during the early (November) and late (February–March) wet seasons from 2018 to 2020. Moths belonging to 12 families (Table S1) and all mantises were identified to (morpho)species based on external morphology and genitalia dissection (Gaona et al. 2025).

Statistical analyses were performed separately for moths and mantises. To assess the effects of season (early wet vs. late wet), precipitation (mean and SD), and landsystem (four landsystems) on species richness (i.e., combined number of species and morphospecies per plot and season), we fitted Generalised Linear Mixed Models (GLMMs) with a Poisson distribution for moths and a quasi-Poisson distribution for mantises. Spatial autocorrelation was accounted for by including triplets as random effects. Post hoc pairwise comparisons of estimated marginal means were subsequently performed.

To explore differences in community composition associated with season, precipitation, and landsystem, we performed Permutational Multivariate Analysis of Variance (PERMANOVA) based on Bray–Curtis dissimilarity, with species abundances per plot and season as response variables. Additionally, we tested for homogeneity of dispersion between groups using the *betadisper* function. Community composition patterns were visualised using non-metric multidimensional scaling (NMDS). All analyses were performed in R v.4.3.3 (R Core Team 2024) employing the *lme4*, *emmeans* and *vegan* packages.

3 | Results

Altogether, we collected 65 593 moth specimens representing 817 species (461 identified, 356 morphospecies) and 3511 mantis specimens representing 38 species (31 identified, 7 morphospecies; Table S1).

GLMMs indicated significant effects of season, landsystem, and their interaction on species richness for both insect groups (Table S2), with species richness significantly higher during the late wet season (Figure 2). However, the seasonal differences varied among landsystems, being more pronounced for both insect groups in the southern landsystems (Satara and Skukuza), while less distinct and significant only for moths in the northern landsystems (Letaba and Phalaborwa; Figure 2). During the early wet season, species richness of both groups was higher in the northern landsystems (Figure 2a). This pattern reversed for moths in the late wet season, whereas no clear geographic pattern emerged for mantises. Additionally, mean annual precipitation was negatively associated with species richness for both moths (estimate: −0.26, $p < 0.001$) and mantises (estimate: −0.28, $p < 0.001$), while precipitation variability (SD) had no significant effect on either group (Table S2).

PERMANOVA revealed significant effects of both season and landsystem on community composition for both insect groups (homogeneity of dispersion confirmed by *betadisper*, $p > 0.05$; Table S3). For moths, community composition was primarily

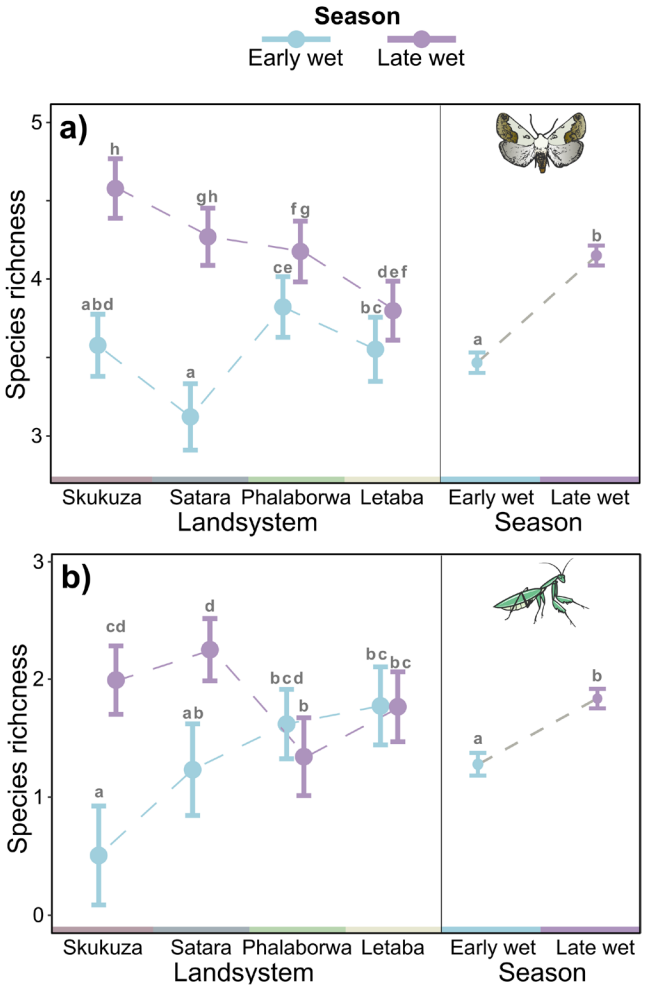

FIGURE 2 | Species richness of (a) moths and (b) mantises during the early wet (light blue) and late wet (purple) seasons across the four main landsystems in Kruger National Park. Points represent GLMM-derived means ± 1 SE. Letters indicate results of post hoc pairwise comparisons ($p < 0.05$); groups sharing at least one letter do not differ significantly.

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related to season (14% explained variability), with seasonal difference attributable to NMDS axis 1 and landsystem (13%), mainly differentiating southern from northern landsystems along NMDS axis 2 (Figure 3a; Table S3). For mantises, community composition was mainly explained by landsystem (12%) and season (9%), with a minor contribution from mean precipitation (1%), showing similar differentiating patterns as observed for moths (Figure 3b; Table S3). Additionally, community composition of both groups was more homogeneous during the early wet season and showed greater differentiation in the late wet season, particularly for herbivorous moths (Figure 3).

4 | Discussion

This study documented seasonal patterns in species richness and community composition of adult moths and mantises in savannahs of KNP. We found clear seasonal peaks in species richness for both insect groups during the late wet season, accompanied by high seasonal community dissimilarity and significant variation among landsystems. As our sampling included only adult specimens collected during the wet season, the observed seasonal patterns likely reflect the synchronisation of adult emergence with rainfall-driven resource availability for both adults and the first larval/nymphal stages, as moth caterpillars typically hatch just after or during the adult flight period, and mantis nymphs just after initial rains (Wolda 1988). Although we did not sample insects during the dry season, previous studies indicated that only a small proportion of highly specialised insect species are active as adults during this colder, resource-limited season (e.g., Braga and Diniz 2018), and such sampling of communities would therefore be inefficient.

The observed increase of moth and mantis species richness during the late wet season likely reflects delayed adult emergence following periods of dormancy during the cold dry season with limited resources. In moths, such emergence is typically triggered by rainfall and subsequent vegetation growth (Braga and Diniz 2018), as seen in species like *Gonimbrasia belina* (Saturniidae; Stack et al. 2003). This pronounced synchronisation contrasts with the less variable wet-season patterns observed in other savannah herbivores, such as butterflies (Schmitt et al. 2021) and beetles (Mavasa et al. 2022), but resembles patterns documented in decomposer insects like dung beetles and termites studied in KNP (Davis et al. 2012; Davies et al. 2015). For mantises, late wet-season peaks in richness primarily reflect adult male flight activity following maturation, although early stages typically hatch from dry-season oothecae triggered by initial rains. As these non-flying nymphs rarely appear in light traps, true peaks in mantis richness likely occur earlier in the wet season. Such temporal dynamics allow mantises to exploit seasonal prey abundance (Fischer et al. 2022), with variation in community composition among landsystems further suggesting their dependence on diverse, seasonally varying microhabitats. Similar patterns of species richness peaking earlier during the wet season were observed in other carnivorous arthropods such as spiders, scorpions, and some hymenopterans (Druce et al. 2004; Mavasa et al. 2022; Mhlanga et al. 2022).

The magnitude of seasonal changes in species richness varied among landsystems, with more pronounced seasonal effects in the southern landsystems (Satara, Skukuza) compared to the northern areas (Letaba, Phalaborwa). This regional variation likely reflects differences in rainfall, as the southern landsystems receive higher annual precipitation, enhancing vegetation productivity and habitat heterogeneity (MacFadyen et al. 2016; Hejda et al. 2022; Gaona et al. 2025). Although geological differences (granite bedrock in the west versus basalt in the east; Hejda et al. 2022) significantly shape plant diversity and habitat structure (Hejda et al. 2022), the

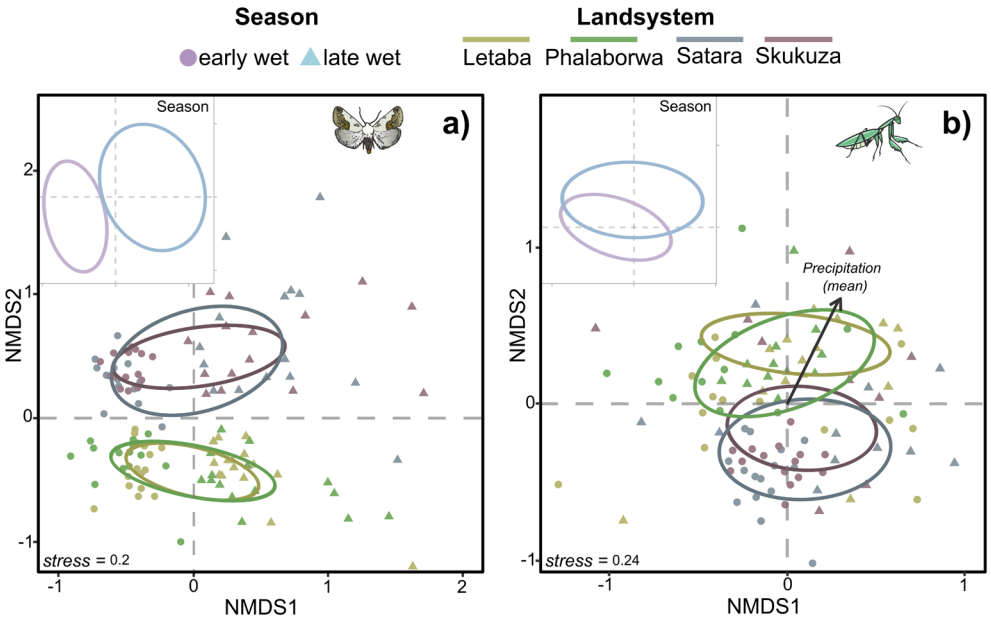

FIGURE 3 | NMDS ordination diagrams of (a) moth and (b) mantis community composition sampled during the early and late wet seasons across four main landsystems in Kruger National Park, South Africa. Main panels show 95% confidence ellipses for landsystems; insets show ellipses for seasons. Vectors indicate environment variables significantly correlated with NMDS axes.

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rainfall-driven seasonality clearly emerged as the primary factor determining temporal patterns in insect community composition in our study.

Our findings emphasise that moth and mantis communities in KNP exhibit clear seasonal dynamics, with pronounced shifts in species composition between the early and late wet seasons. These changes likely reflect temporal specialisation of species in response to rainfall-driven fluctuations in resource availability and habitat heterogeneity affecting life stage persistence during dry periods, hatching of early instars, adult emergence timing, food resources availability, and community assembly processes. These seasonal shifts have important implications for trophic interactions and ecosystem functions, potentially affecting herbivory rates, pollination dynamics, and predator–prey interactions within savannah ecosystems.

Considering predicted climate changes, including delayed and reduced rainfall across southern Africa (Thavhana et al. 2024), the seasonal dynamics observed in KNP may shift, altering insect emergence patterns and reducing synchrony with resource availability and interacting species (Fischer et al. 2022). Such changes could delay moth emergence and reduce prey availability for mantises, potentially leading to reduced adult insect species richness in the late wet season and altered community structure and interspecific interactions. To effectively anticipate these biodiversity responses, future research should investigate complete insect life cycles, including dry-season stages and voltinism patterns, to provide the comprehensive insights essential for biodiversity conservation and management in Afrotropical savannahs.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data used in this study were previously published and are publicly available on Zenodo at the following link: https://zenodo.org/records/12204570.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Table S1:** aec70115-sup-0001-Tables.docx.

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