

Article

Ecological Analysis of Beetle Communities in Naâma Agroecosystems

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Abstract: The objective of this study was to evaluate and contrast the abundance and biodiversity of beetle communities within two distinct agroecosystems of the Naâma region, namely a palm grove and a forage crop farm. This investigation was undertaken to ascertain the impact of local habitat characteristics and seasonal fluctuations on their ecological composition. The collection of beetles was undertaken using Barber traps in 2022, resulting in the identification of 22 species from 10 families. The PERMANOVA analysis indicated that the site had a significant effect on beetle communities ($R^2 = 0.157$; $p = 0.034$), suggesting that local environmental conditions are key determinants of community composition. Furthermore, NMDS analysis revealed that species composition varied across seasons, with certain species being typical of specific periods. For instance, *Adesmia biskrensis* and *Cicindela* sp. were predominantly encountered during the cold season, while *Laemostenus algerinus* and *Orthomus lacouri* exhibited a greater prevalence after the hot season. These findings underscore the importance of both seasonal dynamics and specific habitat characteristics in shaping beetle communities, thus providing valuable insights for the development of targeted conservation strategies and sustainable agroecosystem management in arid regions.

Keywords: Coleoptera; agricultural ecology; Naâma region; diversity

1. Introduction

It is imperative to comprehend the composition of arthropod communities, encompassing both pest and beneficial species, in order to formulate effective strategies for crop protection [1]. However, despite their crucial role, there is a persistent lack of taxonomic and biogeographic data, which hinders long-term monitoring of insect populations and the detection of significant trends within insect groups [2]. A paucity of studies has been observed in terms of the granularity necessary for in-depth temporal analysis. The order Coleoptera, which is one of the most diverse groups of insects, is particularly sensitive to seasonal variations and environmental factors (see [3]). The diversity and abundance of these species serve as valuable indicators of ecosystem processes, enabling the monitoring of environmental changes and guiding management and conservation strategies. Recent research has highlighted the importance of beetles in agroecosystems, particularly in Algeria and arid regions, where they contribute to pest control and the decomposition of organic matter [4, 5]. These studies underscore the intricacy of beetle communities in diverse agricultural environments, ranging from apple orchards to Saharan palm groves, and their response to agricultural intensification practices and altitudinal gradients.

Despite these advances, the diversity of beetles in agricultural ecosystems in the Naâma region remains largely unexplored. As demonstrated in the relevant literature on beetles in Algeria [6, 13], there is a paucity of specific information on this particular area. Consequently, the present study aims to address this knowledge gap by measuring the abundance and diversity of beetles in forage crops and palm groves in Naâma, taking seasonal variations into account. This approach will provide a more comprehensive understanding of the dynamics of these communities and yield essential data for the sustainable management of local agroecosystems.

2. Materials and Methods

2.1. Presentation of the Study Area

The study took place in the Naâma region, which lies between the Tell Atlas Mountains in the north and the Saharan Atlas in the south. This area is in southwestern Algeria, between latitude $33^{\circ}16' \text{ N}$ and longitude $00^{\circ}18' \text{ W}$, and covers $29,825 \text{ km}^2$ (Figure 1). Two sites were chosen for the research: a palm grove and a forage crop farm (alfalfa).

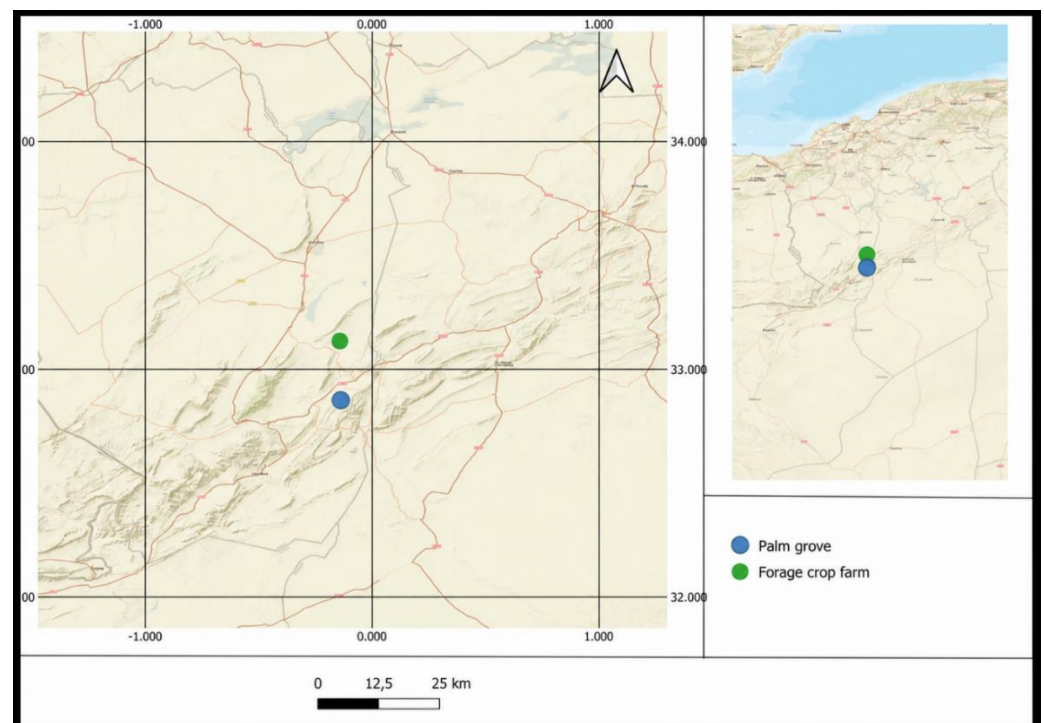


Figure 1. Location of the study area: palm grove and forage crop farm.

2.2. Sampling and Identification

The collection of beetles was conducted in the field from February to November 2022 using Barber traps, also known as pitfall traps [14]. These traps have been demonstrated to be effective in the capture of ground-dwelling arthropods and select flying insects that come into contact with them. Each trap comprised a container measuring 15 cm in width and 18 cm in height. The sampling design involved a monthly frequency, with 10 traps set up in a line and spaced 5 meters apart [14] during each session. The total sampling effort was thus 100 traps, with 10 traps being deployed per month for a period of 10 months. The traps were left in the field for 24 hours per session in order to avoid over-sampling and to reduce trap loss. Subsequent to collection, the beetles were placed in Petri dishes, which were labelled with the trap number and date. A few days later, the samples were checked, identified, and counted using a binocular microscope and taxonomic identification keys, particularly those developed by Perrier [15-17]. The validation of species

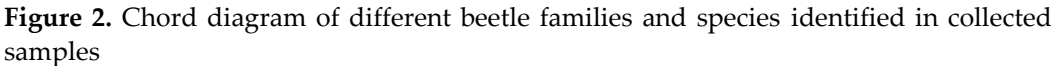
identifications was conducted through comparative morphological analysis, using the provided keys. In order to ensure the replicability of the experiment and for the purpose of future reference, voucher specimens were preserved and deposited in collection boxes.

2.3. Data Analysis

Results were given as total richness (S), meaning the number of families or species found at each site during each sampling session. Relative abundance (RA) was found by dividing the number of individuals of each species by the total number (N) at each site, then multiplying by 100 to get a percentage. We measured community diversity using the Shannon index, which measures overall diversity, and the evenness index, which measures how evenly individuals are distributed among species. The Shannon index was calculated as $H' = -\sum (P_i \times \log P_i)$, where P_i is the proportion of each species out of the total number of individuals (N). The evenness index was calculated as $E = H' / \log 2S$, where S is the total number of species and H' is the Shannon index [18]. The evenness index ranges from 0 to 1. A value near 1 indicates that species are equally common, while a value below 0.5 indicates that a few species dominate [19]. We used PERMANOVA on the Bray-Curtis dissimilarity matrix with the 'adonis2' function in R 4.2.2 to compare beetle communities at different sites. This non-parametric statistical test is particularly suitable for ecological data, which often do not meet the assumptions of traditional parametric tests. The analysis was conducted using a Bray-Curtis dissimilarity matrix, a widely accepted measure for ecological community data that accounts for both species presence/absence and abundance [20]. We also used NMDS (Non-Metric Multidimensional Scaling) with the MetaMDS function in the R vegan package [21] to explore relationships among beetle groups. Venn diagrams were made to show which taxa were unique or shared among sites and seasons. The Bray-Curtis distance matrix based on species numbers was used to compare the two sites and four seasons.

3. Results

A total of 138 beetles were recorded, comprising 22 species, 21 genera, and 10 families. It is important to note that this relatively low number of individuals may limit the statistical power and robustness of subsequent diversity and multivariate analyses. The chord diagram illustrates the distribution of beetle families and species within the samples (Figure 2). Of these, 72 beetles were found at the forage crop site (site 2) and 66 at the palm grove. The samples comprised ten main families. Of the beetles observed, the most prevalent were those belonging to the family Anthicidae, constituting 31.2% of the total. The Staphylinidae family represented the second most prevalent classification, accounting for 18.8% of the total, and included species such as *Aleochara* sp., *Bledius* sp., and *Ocypus olens*.



Regarding abundance, richness, and diversity indices for the studied stations (Figure 3), our results show considerable differences. The Shannon index for the palm grove was 3.12, while for the forage crop farm it was 2.15. Total abundance was 72 individuals at the forage crop farm and 66 at the palm grove. In terms of richness, the palm grove recorded 14 species, compared with 11 species at the forage crop farm. Pielou's evenness index was 0.82 for site 1 and 0.62 for site 2. Hmax, or theoretical maximum diversity, was 3.81 for site 1 and 3.46 for site 2. Simpson's index was 0.85 for the palm grove and 0.61 for the forage crop farm.

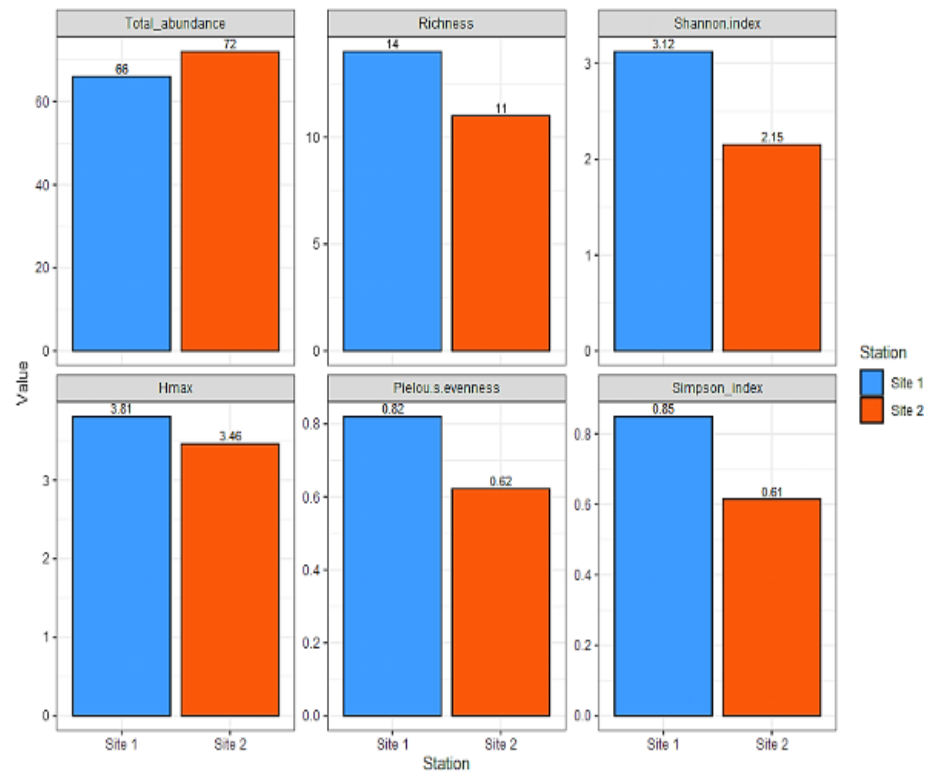


Figure 3. Diversity indices and beetle abundance across both stations

The difference between sites was statistically significant for beetle community composition ($p = 0.034$, $R^2 = 0.158$), which suggests that local factors at each site affect which beetles are present (Table 1).

Table 1. Significance of dissimilarity according to sites

Source	Df	SumOfSqs	R ²	F	Pr(>F)
Site	1	0.7908	0.15767	2.059	0.034*
Residual	11	4.2246	0.84233		
Total	12	5.0153	1.00000		

Df: degrees of freedom, SumOfSqs: sum of squares, R²: proportion of variance explained, F: permuted F-test statistic, and Pr(>F): p-value based on permutations

Non-metric multidimensional scaling (NMDS) (Figure 4) shows that species composition differed over time and between sites in two dimensions (NMDS1 and NMDS2) (Figure 4a). The distance between points shows how different the communities are. The palm grove had high species diversity, with *Tribolium castaneum*, *Anthaxia* sp. and *Adesmia bis-krensis* found there during the cold season. In contrast, *Pentodon* sp., *Anthicus* sp. and *Gonocephalum sericeum* were more common at site 2 during the hot season.

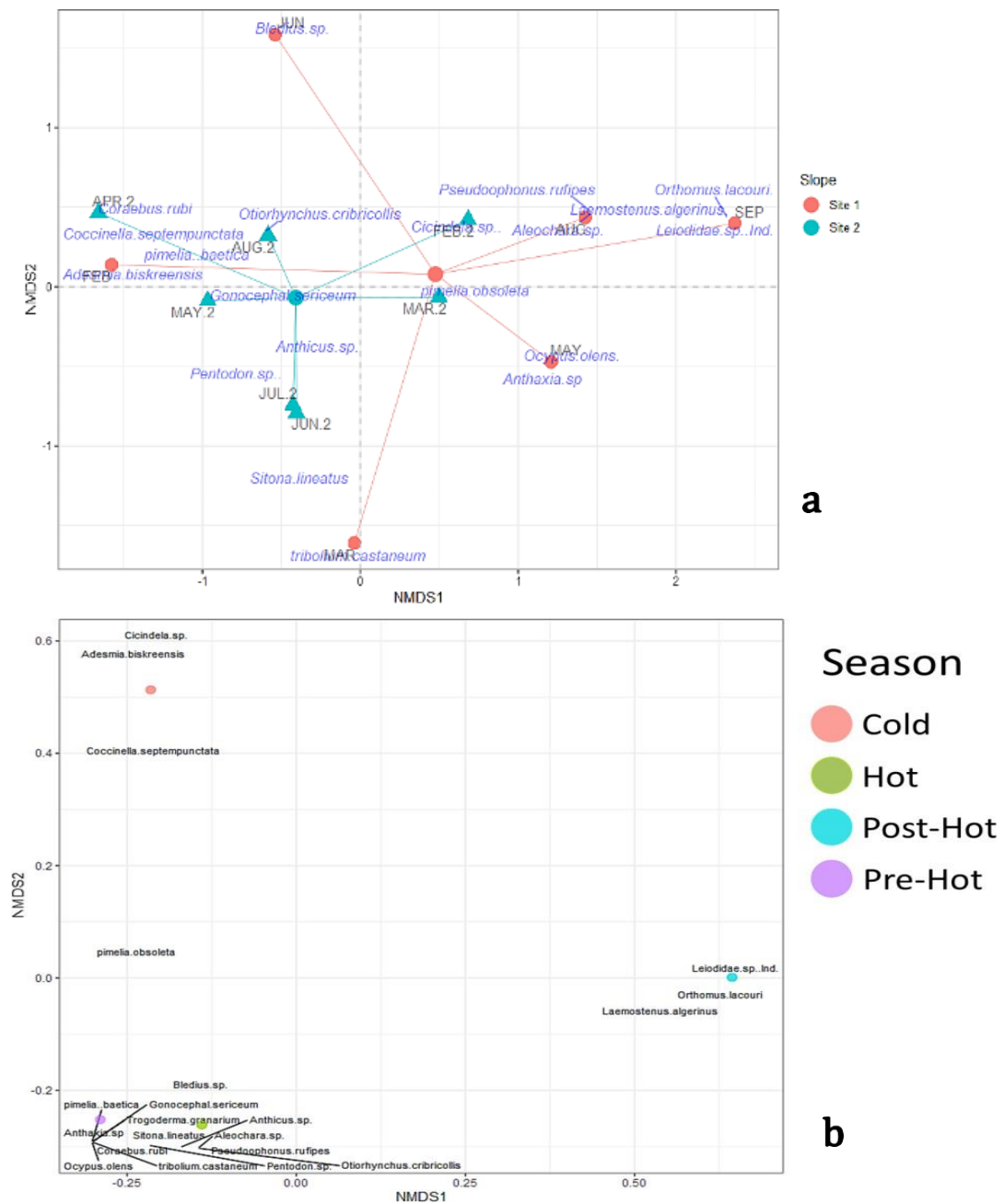


Figure 4. Non-metric multidimensional scaling (NMDS) ordination for the distribution of beetle species among stations (a) and across four seasons (b) in the Naâma region

The Venn diagram depicts the distribution of species across the study area (Figure 5). Of the 22 taxa identified, five were common to both stations, 10 were exclusive to station 1, and seven were unique to station 2 (Figure 5A). Seasonally, only one species was present in all four seasons (Figure 5B). Spring exhibited the highest number of exclusive taxa (seven), followed by summer with three unique taxa. There was considerable overlap in taxa among spring, summer, and winter.

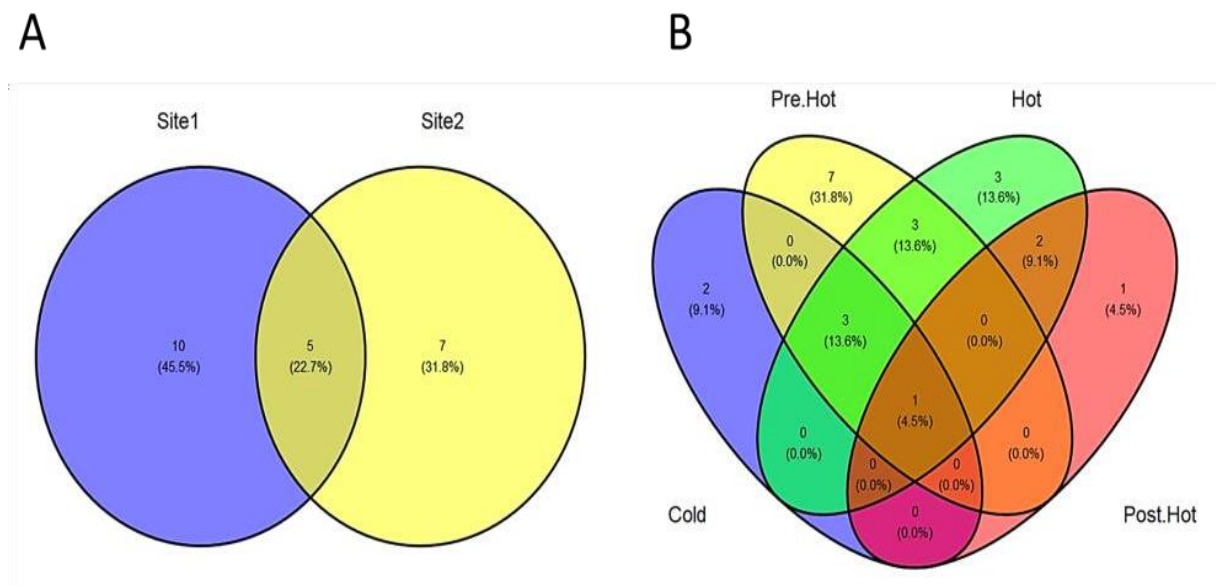


Figure 5. Venn diagram illustrating beetle distribution among stations and across four seasons in the Naâma region.

4. Discussion

The present study documented 138 individuals, classified into 22 species, 21 genera, and 10 families. It is imperative to consider the relatively low number of individuals when interpreting the results, as this may limit the statistical power and robustness of diversity and multivariate analyses. In comparison to previous studies in other Algerian ecosystems, which reported higher levels of beetle diversity (e.g., 68 taxa in Ouled Bechih forest [22], 42 in Belezma National Park [23], 76 in El Kala National Park [13], and 34 in M'Sila's cork oak forest [25]), the observed species richness in the Naâma region appears lower. While several factors, such as the arid climate, intensive agriculture, and overgrazing, are generally recognised as impacting biodiversity in similar regions, further site-specific investigations and supporting data would be necessary to definitively link these broader ecological pressures to the specific patterns observed in this study.

The analysis of abundance, richness, and diversity indices revealed considerable differences between the studied sites. The palm grove demonstrated higher levels of biodiversity, as evidenced by a Shannon index of 3.12 and a Simpson index of 0.85, in comparison to the forage crop farm (Shannon: 2.15, Simpson: 0.61). A predominance of certain species was observed. These patterns imply that local habitat features play a significant role in shaping beetle community structure and diversity.

It is evident that climatic factors exert a significant influence on species distribution and development. Indeed, certain beetle species have been observed to demonstrate considerable adaptability to diverse climates [25]. The most prevalent families identified were Anthicidae, Staphylinidae, and Tenebrionidae. The community structure suggests a mix of families with complementary ecological roles, including decomposers, phytophages, and predators. The distribution of beetles in the studied environments may be influenced by the specific conditions provided by each biotope [3], and ecosystems can offer favourable microclimatic conditions for particular species, contributing to a more stable environment [26]. However, it is important to note that arriving at definitive conclusions regarding environmental stability or the direct causal relationships between these factors and the observed community structure necessitates additional evidence that extends beyond the scope of this study.

5. Conclusions

This study, conducted in farmlands, observed a relatively low beetle species richness. Notwithstanding this fact, the distribution of species indicated a functional community structure, with a balanced representation of decomposer, phytophagous, and predatory beetles. The findings suggest that local habitat characteristics and seasonal variations play a role in shaping beetle communities, as evidenced by differences in species composition between sites and across seasons. The presence of diverse functional groups, including less common families, is indicative of a certain level of habitat heterogeneity that contributes to maintaining insect diversity within these agroecosystems.

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