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Assessment of *Carabidae* Diversity (Coleoptera) in the Guelmim-Oued Noun Region (Southern Morocco)

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Abstract: This study involved the collection, sorting, and identification of *Carabidae* in eight stations, employing two sampling methods: beating and visual hunting. A total of 15 species belonging to ten tribes and six subfamilies were inventoried. The study reveals that the ecological diversity of the *Carabidae* beetle population can vary over time and space due to several factors such as seasonal variations, altitude, changes in habitat structure, environmental impacts, and climate change. Therefore, it is crucial to consider these factors when investigating Carabidae diversity to fully comprehend the mechanisms governing the spatial and temporal variation of these populations.

Keywords: *Carabidae*, ecology, ecosystem, Guelmim-Oued Noun

Introduction

The Guelmim-Oued Noun region is the largest hot zone in Morocco, covering 46,108 km². Despite its arid and inhospitable appearance, the region harbors a wide diversity of habitats, including dunes, wadis, palm groves, and mountains. These diverse and unique biotopes create exceptional and favorable ecological conditions for organisms, including carabids. However, despite their importance in the Sahara ecosystem, carabids have been largely under-studied, and limited data are available regarding their precise geographical distribution and abundance in these various habitats (K Chadi et al ,2022, C Ahlam et al, 2023, N Messai et al ,2022).

The study of carabids is of paramount importance due to their ecological role in Saharan ecosystems. As voracious predators, these insects act as regulators of insect populations, contributing to the maintenance of ecological balance. Their wide variety and abundance make them valuable bio-indicators, serving as indicators of the overall well-being of desert ecosystems (R Abbassen , 2023).

Despite the ecological studies on carabids colonizing biotopes in Saharan zones sparking the interest of numerous entomologists, the majority of research has been dedicated to studying populations limited initially to establishing a systematics for certain Carabidae species and documenting the geographic distribution of the cataloged species. Key contributors to this limited body of work include Antoine (1955 to 1963), Alluaude (1924), Bruneau de Mire (1958), Peyerimhoff (1943 to 1947), Pierre (1958 to 1954), Kocher (1956 to 1969), and Raymond (1948). This focus has resulted in a lack of comprehensive knowledge about the true diversity of Carabidae in the Guelmim-Oued Noun region. Therefore, it is imperative to conduct an exhaustive study to address this gap and gain a profound understanding of the various factors influencing their diversity and presence in Saharan ecosystems.

This study is part of integrated efforts aimed at deepening our understanding of carabids in Saharan biotopes by examining their diversity, distribution, behavior, and ecological role.

1. Materials and Methods

During the period of adult activity, the study was primarily conducted between March 25, 2019, to January 24, 2020.

2.1. Description of the Study Area

The Guelmim-Oued Noun region (Fig. 1) encompasses a unique combination of climate, vegetation, and soil quality that shapes its ecological characteristics. The climate is classified as semi-arid, characterized by hot summers and mild winters. In terms of vegetation, the study area hosts a variety of plant species adapted to the challenging conditions of the region (Pergularia tomentosa, Farsecia hamiltoni, Panicum turgedum, Anvilea radiata, Convolvulus *trabutianus, Acacia ehrerbengiana, Nitraria retusa, Ziziphus lotus, Limoniastrum infoniensi*). These plants include desert shrubs, succulent plants, and drought-tolerant grasses. Soil quality varies across different zones. In some areas, the soil is sandy and lacks organic matter, making it less fertile. In other regions, the soil is more clayey and can support agricultural activities

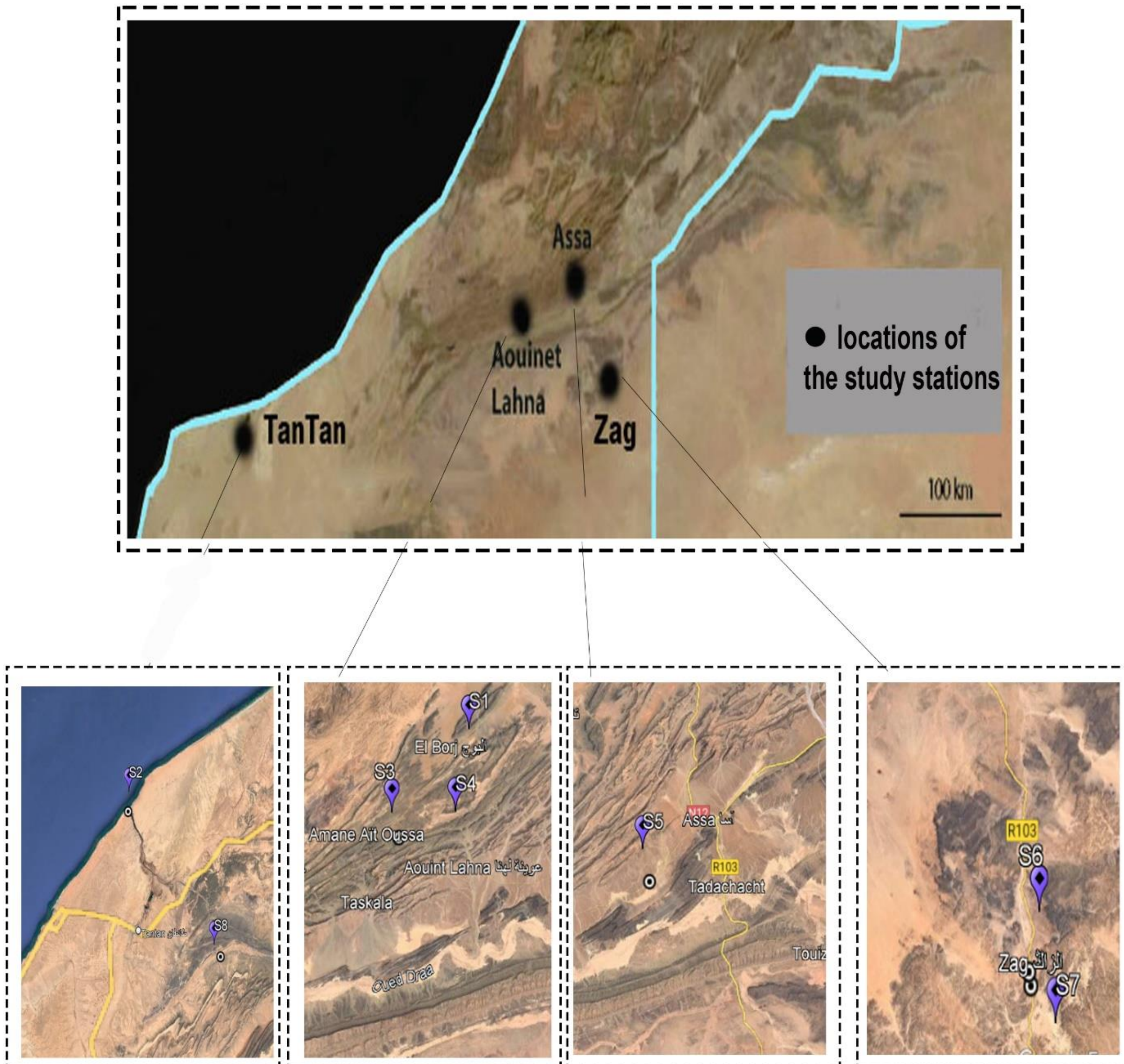

Figure 1: Aerial view depicting the locations of the study stations: Ouin Mesdour, Foum oued Drâa, Northwest of Aouinet Lahna, I.S. Station, Southwest of Assa, South of Zag, Zag (R103), and Ouin Madkour. (Google Earth4 pro)

2.2 Selection of Stations

The study sites are situated in various environments, namely, Dayas, Forest, Steppe (Fig. 1, Table 1).

The dayas are oases, specifically Ouin Mesdour, the I.S. Station at Aouinet Torkoz, and Ouin Madkour, located at an altitude ranging between 260 and 290m. Forest environments include Foum oued Drâa, South of Zag, and Zag (R103), where Acacia is the predominant species. In the steppes, our selection focused on two stations: Northwest of Aouinet Lahna and Southwest of Assa, where the dominant plant species is Euphorbia echinus, accompanied by shrub vegetation.

Table 1. Geographic Coordinates and Altitudes of Monitoring Stations

Bioclimatic Zone	Stations	Localities	Abbreviations	Coordinates	Altitude (m)
Saharan Warm Winter	Aouinet Lahna				
	S 1	Ouin Mesdour	**OM**	28°26'27" **N** 09°45'55" **W**	260
	S 2	North-west of Aouinet Lahna	**NA**	28°31'51" **N** 09°59'27" **W**	500
	S 3	Station of the scientific institute	**SI**	28°28'21" **N** 09°51'20" **W**	290
Saharan Warm Winter	Assa				
	S 4	Southwest of Assa	**SA**	28°31'20" **N** 09°33'05" **W**	283
Saharan Warm Winter	Zag				
	S 5	South of Zag	**SZ**	28°00'12" **N** 09°17'36" **W**	409
	S 6	Zag (R103)	**ZA**	28°01'04" **N** 09°17'48" **W**	398
Saharan Warm Winter	TanTan				
	S 7	Foum oued Drâa	**FO**	28°40'35" **N** 11°07'23" **W**	30
	S 8	Ouin Madkour	**OMD**	28°23'20" **N** 10°50'21" **W**	163

2.3 Sampling Techniques

Sampling techniques have been described by various authors, particularly qualitative methods based on the studied biotopes, experimental protocols, and research objectives. These methods include visual hunting and beating to collect species living on the leaves of trees and shrubs [(Amiet J.L., 1967), (Chavanon G., 1992), (G., 1994), (N., 2003), (C., 1947)]. Our study spanned 2 years, from March 2019 to February 2020. For each period, beetles were sampled across different stations. Collection was carried out through direct visual hunting and under shelters (lifting stones and blocks, removing plant leaves, and wood debris).

The collected individuals were subsequently preserved, for each facies, in a vial with ethyl acetate pad, labeled, and then either identified in the laboratory using keys, placed on a layer, and transmitted to specialists for identification. The species identification was conducted by Arahou Mohamed (Scientific Institute of Rabat) and Labrique Harold from the Center for Conservation and Study of Collections (Museum of Lyon).

2. Results

3.1 Faunistic Study of Inventoried Taxa

3.1.1 List of Inventoried Taxa.

The analysis of the overall faunistic composition identified 15 species unevenly distributed across six subfamilies and ten tribes (Table 2).

Table 2. Distribution map of Carabidae in the Guelmim-Oued Noun Region

			Stations							
Subfamily	**Tribe**	**Species**	**OM**	**NA**	**SI**	**SA**	**SZ**	**ZA**	**FO**	**OMD**
Scaritini	Scaritinae	Scarites (Scallophorites) buparius							+	
Brachinini	Brachininae	*Pheropsophus africanus*	+					+		
Dyschiriini	Scaritinae	*Dyschirius (Dyschiriodes) punctatus*	+							
Melaeninae	Cymbionotini	*Cymbionotum semelederi*							+	
Trechinae	Bembidiini	*Bembidion (Notaphus) varium*							+	
		Bembidion (Ocydromus) atlanticum atlanticum	+	+	+				+	
		Tachyura (Tachyura) curvimana		+						
		Perileptus (Perileptus) areolatus areolatus							+	
Harpalinae	Abacetini	*Abacetus (Asigis) salzmanni*	+							
	Platynini	*Paranchus albipes*	+							+
	Chlaeniini	*Chlaenius (Chlaenites) spoliatus spoliatus*			+				+	

		Chlaenius (Nectochlaenius) canariensis seminitidus	+	+	+				+	
	Cyclosomini	*Masoreus orientalis*	+		+					
	Lebiini	*Cymindis (Cymindis) discophora*	+			+			+	
		Cymindis (Cymindis) suturalis pseudosuturalis		+		+	+			

3.1.2 Composition of the Carabid Entomofauna

During the study period, we inventoried 62 individuals belonging to 15 species, distributed across six subfamilies (*Scaritini*, *Brachinini*, *Dyschiriini*, *Melaeninae*, *Trechinae*, *Harpalinae*).

Notably, we observed that the Harpalinae subfamily is the most abundant, comprising 7 species, accounting for 46% of the total captured fauna. The *Trechinae* subfamily takes the second position with 27% (4 species). In the third position, we found the *Scaritini*, *Brachinini*, *Dyschiriini*, and *Melaeninae* subfamilies, each representing 7% (one species for each subfamily) (Fig. 2).

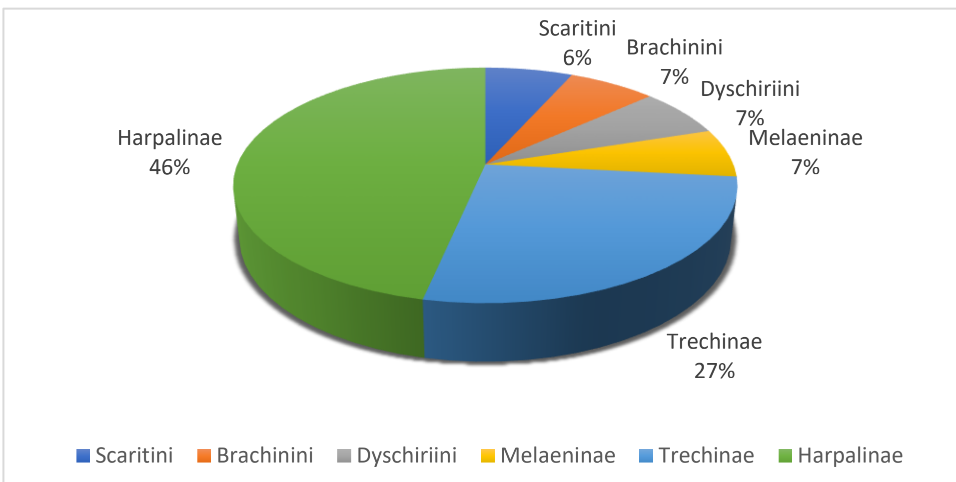

Figure 2: Proportions of Carabid Subfamilies Recorded in the Study Area

3.1.3 Biogeographical Distribution

We relied on the following works to determine the biogeographical distribution, following studies by (Bedel, 1895), Jeannel (1941-1942), Antoine (1955-1962), (Maachi, 1995), and (Taglianti, 2009).

The recorded species in this study (Fig. 3) appear to belong to three distinct groups: Mediterranean species (46.7%), Palaearctic species (33.3%), and North African species (20%).

Mediterranean species, distributed throughout the Mediterranean basin, dominate the population at 46.7%, including species such as Scarites buparius, Dyschirius punctatus, Tachyura curvimana, etc. Palaearctic species, distributed between Europe, North America, and Northern Asia, represent 33.3% of all species, including *Cymbionotum semelederi*, *Bembidion varium*, and *Bembidion atlanticum*, among others. North African species, distributed between Algeria, Morocco, and Tunisia, account for 20% of the total recorded species, *including Chlaenius canariensis*, *Cymindis discophora*, and *Cymindis suturalis.*

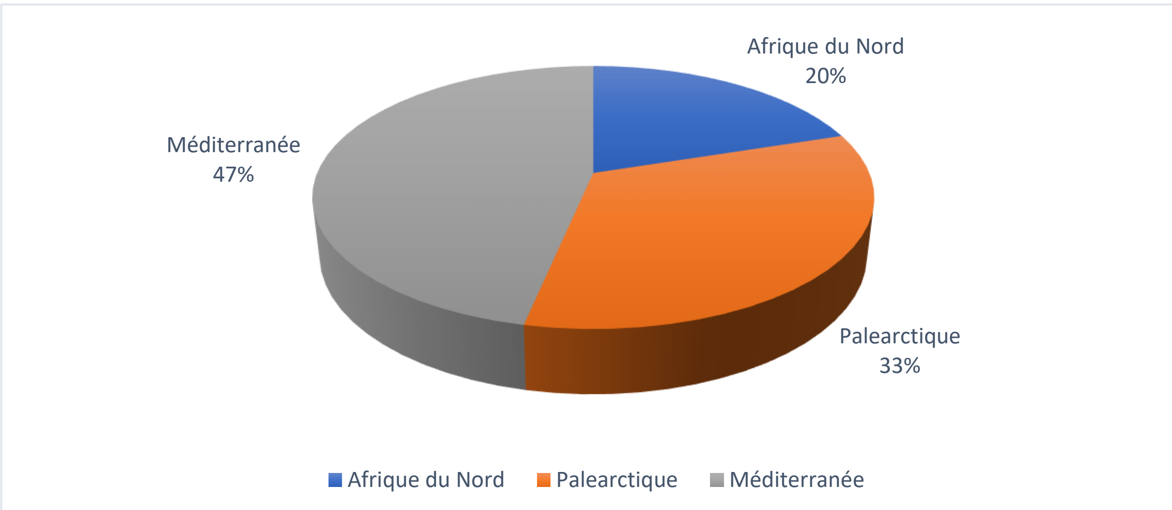

Figure 3: Spectrum of the Biogeographical Distribution of all Carabid Species in the Study Area

3.2 Structure and Dynamics of the Carabid Entomofauna

3.2.1 Specific Richness of the Carabid Entomofauna

The results of this study, as depicted in Figure 4, reveal that the species richness of carabid entomofauna across the eight stations is notably high in stations (S1 and S2) with 8 species each and stations (S3 and S4) with 5 species each, in comparison to the other five stations.

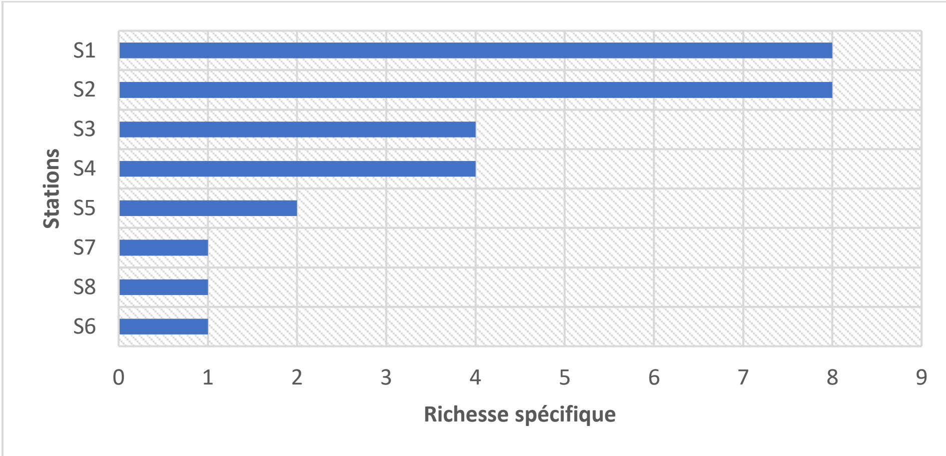

Figure 4: Representation of the Abundance and Specific Richness of Carabid Species per Station

The dominance of two species, Bembidion atlanticum and Chlaenius canariensis, was accessory. Meanwhile, the sub-dominant species (*Chlaenius spoliatus* and *Cymindis suturalis*), with the first species being Accidental and the second accessory. Among the accessory species encountered, including *Bembidion varium* and *Cymindis discophora*, (73%) of the recorded species were Accidental, such *as Scarites buparius*, *Pheropsophus africanus, Dyschirius punctatus*, etc. (Table 4).

Table 1. Ecological Status of the Annual Activity of Recorded Carabid Species at the Study Stations

Species	Ecological Status
Scarites buparius	Accidental.
Pheropsophus africanus	Accidental.
Dyschiriuspunctatus	Accidental.
Cymbionotumsemelederi	Accidental.
Bembidionvarium	Accidental
Bembidionatlanticum	Accessory.
Tachyuracurvimana	Accidental.
Perileptusareolatus	Accidental
Abacetussalzmanni	Accidental

Paranchusalbipes	Accidental
Chlaeniusspoliatus	Accidental
Chlaeniuscanariensis	Accessory
Masoreus orientalis	Accidental
Cymindisdiscophora	Accessory
Cymindissuturalis	Accessory

3.2.2 Monthly Variations of the Carabid Entomofauna

The spatio-temporal diversity of the carabid entomofauna can provide valuable insights into the structure and dynamics of the carabid entomofauna in the study area. We calculated the Annual abundance and specific richness. Thus, the Annual variations in abundance and specific richness indicate that the highest captures were made during the study period at stations (S1, S4) compared to other sites (Fig. 5).

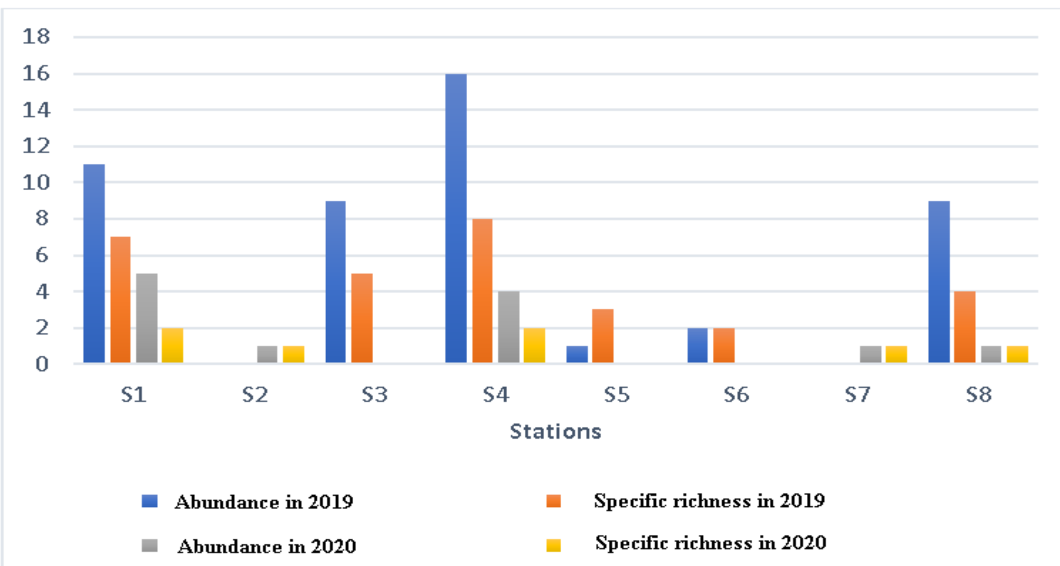

Figure 5: Monthly variations in abundance and specific richness

According to the results obtained, we observed that *Pheropsophus africanus, Bembidion atlanticum, Chlaenius spoliatus*, and *Chlaenius canariensis* significantly contributed to the peaks in abundance.

The variations in the carabid entomofauna can be observed both temporally and spatially. These variations may be attributed to several factors, including seasonal variations, changes in habitat structure, and environmental disturbances. Additionally, certain *Carabidae* species may be more abundant in specific geographic regions or habitat types, while others may be more widespread and diversified.

3.2.3 Comparison of Diversities among Study Stations

Results of the calculated structural indicators for the carabid entomofauna are listed in Figure 7. Stations (S1, S2, S3, S4) appear significantly richer in taxa and individuals compared to the other stations. The Shannon diversity index values recorded were 1.858 for S2, 1.754 for S1, 1.271 for S4, and 1.221 for S3. These values express a high diversity of the sampled entomofauna in favor of stations (S1, S2, S3, S4). However, the evenness index values, calculated above 0.8 for all four stations, tend to approach 1, indicating that the apprehended species exhibit a state of ecological balance among them.

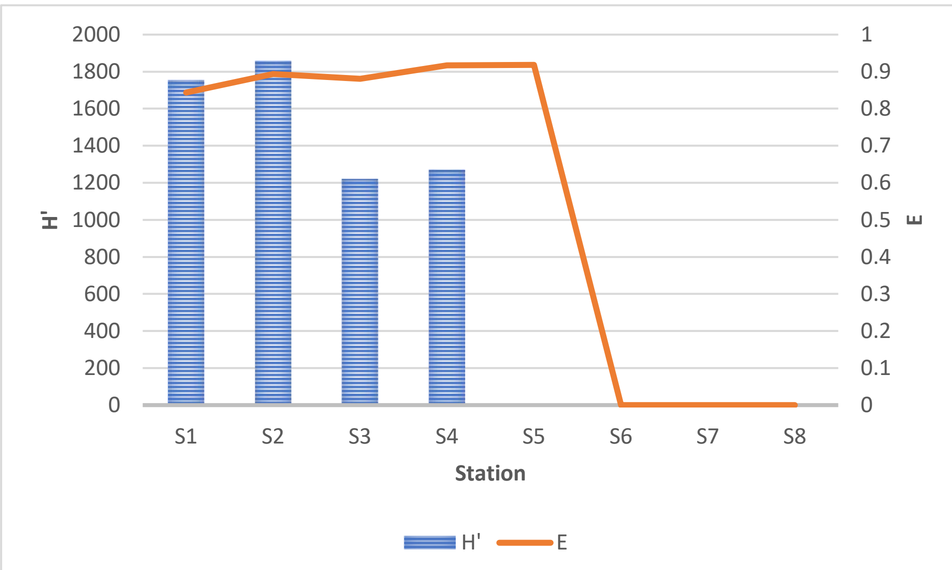

Figure 7: Summary of Ecological Index Measures

The values of abundance and specific richness seem to align with the diversity index (1.85) and evenness (0.91) values. It is noteworthy that these values reflect the diversity and stability of the study area, primarily in Station (S2) and Station (S1), which strongly contribute to these two indices.

Regarding evenness, this value reflects the distribution of individuals among species. Consequently, we observed that certain species are characterized by a very large number of individuals, as is the case with *Bembidion atlanticum* (14 individuals) and *Chlaenius canariensis* (13 individuals), while for others, we counted species with one to nine individuals.

3. Discussion

A comparative study of carabids across eight stations has revealed certain differences among them. These differences may be linked to anthropogenic conditions leading to habitat deterioration, transforming it into a more or less disturbed biotope. Additionally, carabid entomofauna is sensitive to temperature variations, and climate changes can impact their habitat and the availability of food resources.

The collected data will undergo statistical analysis to determine significant differences between biotopes and explore the relationships between carabid diversity and environmental factors.

The calculated diversity index, providing an estimate of carabid diversity in the study area, has also indicated a biotope favorable to the establishment of various species, where the microclimate appears tolerable, and food resources are available. Indeed, its value reflects the diversity of the study area. This analysis helps understand how these factors influence the diversity and distribution of carabid entomofauna.

On the other hand, altitude can play a significant role in Carabidae diversity. Carabidae may exhibit specific habitat preferences based on altitude (Ghannem et al., 2017). Therefore, it is crucial to consider these factors when studying Carabidae diversity to fully understand the mechanisms governing the spatial and temporal variation of these populations (AMRI et al., 2019).

The results of this study will contribute to enhancing our understanding of biodiversity in deserts and aid in the conservation of carabids and their habitats.

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