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Diversity and spatio-temporal distribution of arthropods in the Atlas cedar (*Cedrus atlantica* Manetti) forest in Belezma National Park (Batna, Algeria)

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ABSTRACT. The study investigated the spatial and seasonal variations in arthropod diversity using different trapping methods within two types of cedar forests (dead and healthy) in Belezma National Park, located in Batna. The field survey was carried out from January 2017 to December 2018, employing three sampling techniques: Barber pots, coloured traps, and suspended traps. A total of 108 species belonging to four classes, 13 orders, and 66 families were recorded. Representing 95.4% of the total species richness, insects were the predominant class, with 46 species. Within this class, Hymenoptera had the highest incidence (46.01%), followed by Diptera (23.6%). The Shannon-Weaver index exceeded 3 across stations, seasons, and sampling methods, indicating high diversity. Additionally, Equitability values surpassed 70% across all observations. PERMANOVA analysis revealed significant differences in composition between the different stations, seasons, and sampling methods. This research highlighted several key factors influencing arthropod diversity, including the condition of the habitat (dead vs. healthy cedar forests), seasonal variations, and the effectiveness of various sampling techniques.

Keywords: entomofauna, inventory, cedar forests, North Africa, sampling methods, season

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INTRODUCTION

The Atlas cedar *Cedrus atlantica* (Endl.) Manetti (Carrière, 1855) is an economically, ecologically, and culturally important conifer species endemic to North Africa. The species inhabits the high-altitude mountainous regions of the Maghreb, including the Rif, the Middle Atlas, the High Atlas, and the Saharan Atlas in Algeria, with elevations typically ranging between 1500 to 1700 m (Quezel, 1998). In Algeria, the cedar forests cover about 27000 hectares in several fragmented regions, including Quarsenis, Teniet el Had, Atlas Mitidjien, Djurdjura, Babors, Hodna, Belezma, and Aures (Bentouati, 2008). Unfortunately, this coniferous tree has been experiencing an alarming decline and dieback since the early 1980s, particularly in the Aures region of Algeria (Bentouati, 2008; Fennane & Ibn Tattou, 2012). The Atlas cedar is threatened by several factors, such as droughts, fires, and climate change (Slimani et

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al., 2014a; Bouahmed et al., 2019). Additionally, bark beetles such as *Phaenops marmottani* (Fairmaire, 1868) and other pine beetles have been implicated in the decline and dieback of Atlas cedar populations, as these insects can infest and kill the trees, especially when they are already weakened by other stressors (Mouna, 2009; Beghami et al., 2020). In the Aures region, Belezma has been severely affected by multiple factors leading to dieback (Bentouati, 2008), thus resulting in a drastic decrease of more than 40% of its initial area between 1986 and 2021 (Ait Medjber et al., 2024).

Arthropods are key components of food webs and contribute to the decomposition of soil organic matter, and also to nutrient cycling (Soesanto, 2008). Therefore, their presence and activities are intrinsically linked to the health and functioning of these ecosystems. Historically, research in Algerian forests has predominantly concentrated on specific groups such as Coleoptera (Moumeni et al., 2021), Syrphidae (Djellab et al., 2019), and spiders (Chaib et al., 2023), rather than conducting comprehensive, large-scale surveys of arthropod population assemblages. Despite their ecological significance, studies on the arthropod fauna associated with cedar forests in the Belezma National Park remain scarce. In addition, while previous research has focused on aspects such as climate (Abdessemed 1981; Bentouati & Bariteau 2006; Bentouati, 2008; Slimani et al., 2014b; Kherchouche et al., 2019), phyto-ecology (Abdessemed, 1981), and certain insect groups like xylophagous species (Boukerker & Si Bachir, 2015), a comprehensive understanding of the overall arthropod diversity and their spatio-temporal patterns in cedar forests is lacking. This study aims to bridge this knowledge gap by conducting a comprehensive inventory of the arthropod fauna in the cedar forests of the Belezma National Park. The main objectives are to assess the diversity, composition, and trophic statuses of different arthropod groups, and to investigate their spatial and temporal distribution patterns.

MATERIAL AND METHODS

Study area. The study was conducted in Belezma (35°37'46"N, 06°10'45"E), a National Park situated in the northeastern Algerian province of Batna, encompassing 26,250 hectares of forest massif. It was created in 1984 to protect the endemic North African species *Cedrus atlantica* (Fig. 1). The zone is primarily made up of trees (*Juniperus oxycedrus* L., *Juniperus phoenicea* L., *Pinus halepensis* Mill., and *Quercus ilex* L.), herbaceous plants, and low maquis-type vegetation (mainly *Calycotome spinosa* (L.) Link, *Olea europaea* L., *Phillyrea angustifolia* L., *Pistacia lentiscus* L., and *Rosmarinus officinalis* L.) (Abdessemed, 1981).

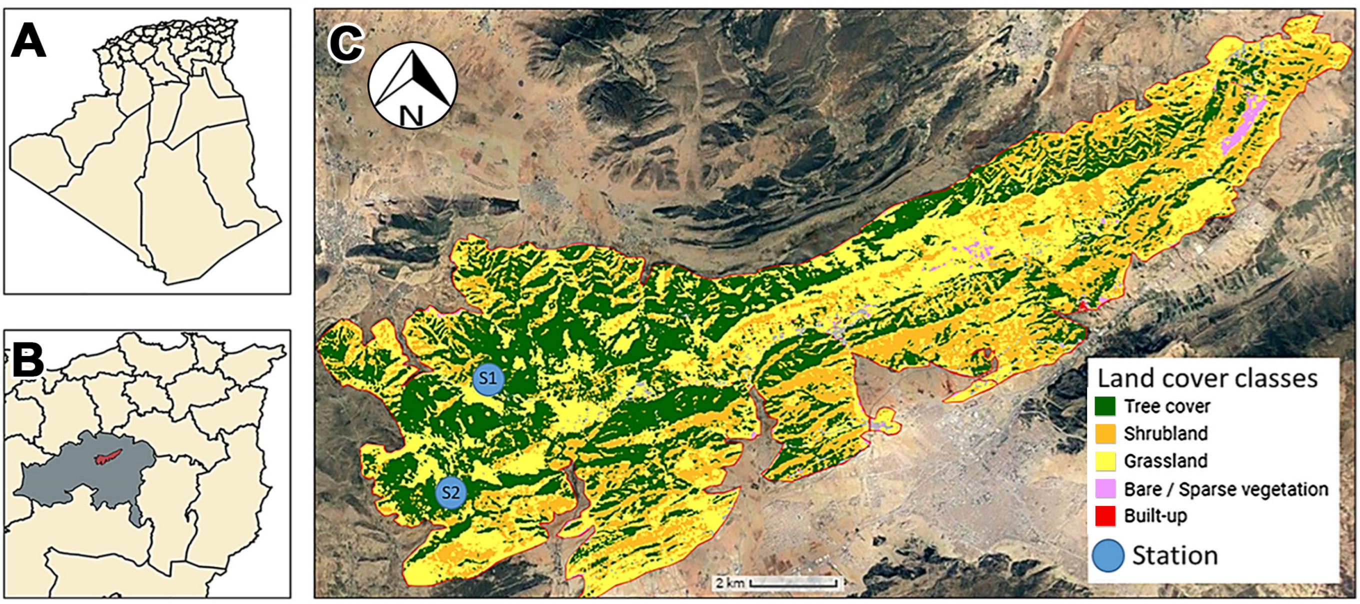

Figure 1. Geographical location of the Belezma National Park, and sampling stations. **A.** Algeria map; **B.** Location of Belezma National Park in Batna Province (grey); **C.** Land use and land cover of Belezma park and sampling stations.

We chose two stations in the Belezma area, the first one (Djebel Bordjem) being a weathered cedar grove, and the second (Djebel Tuggurt) being a healthy one. The first station was located at an altitude of 1650 m under the bioclimatic stage of Semi-arid with cold winters. The maximum temperature recorded here was 30.60 °C, while the minimum temperature was 2.12°C. The total precipitation recorded during the study period was 520.32 mm (Fig. 2). With Atlas cedar subjects exceeding 300 years, this station boasts luxuriant vegetation composed of the floristic procession of Atlas cedar with dry facies, such as *Acer monspessulanum* L., *Lonicera etrusca* Santi, *Ilex aquifolium* L., *Cotoneasters famiflora*, *Berberis hispanica* (Boiss.), *Crataegus oxyacantha* L., *Crataegus monogyna* Jacq., *Ophrys lutea* Cav., *Himantoglossum robertianum* (Loisel.) P. Delforge and *Epipactis helleborine* (L.) Crantz. Djebel Tuggurt was represented by a healthy, cedar stand at an altitude of 1620 m on a bioclimatic gradient. It is sub-humid with cool winters. The maximum temperature was recorded in August at 30.81 °C. The minimum temperature was recorded in January at -1.986 °C. The total precipitation recorded during the study period was 412.72 mm (Fig. 2). The floristic procession of the cedar in this station mainly consists of: *Acer monspessulanum* L., *Australis humilis, Calycotome spinosa* (L.) Link, *Cistus albidus* L., *Daphne gnidium* L., *Juniperus oxycedrus* L., *Juniperus phoenicea* L., *Pinus halepensis* Mill., *Malva sylvestris* L., *Ophrys apifera* Huds., and *Thapsia garganica* L.

Sampling methods and identification. Arthropods were sampled during an annual cycle between January 2017 and December 2018, with two samples per month. Each station was equipped with three types of traps (Barber pitfall traps, coloured traps, and suspended traps). Nine Barber pots (PT) were arranged on a homogeneous square plot with a surface area of 400 m² (Lamotte & Bourliere, 1969). These pots were sunk into the ground and 2/3 filled with water and a preservative liquid (detergent) preventing trapped invertebrates from escaping and being consumed by their predators (Fig. 3).

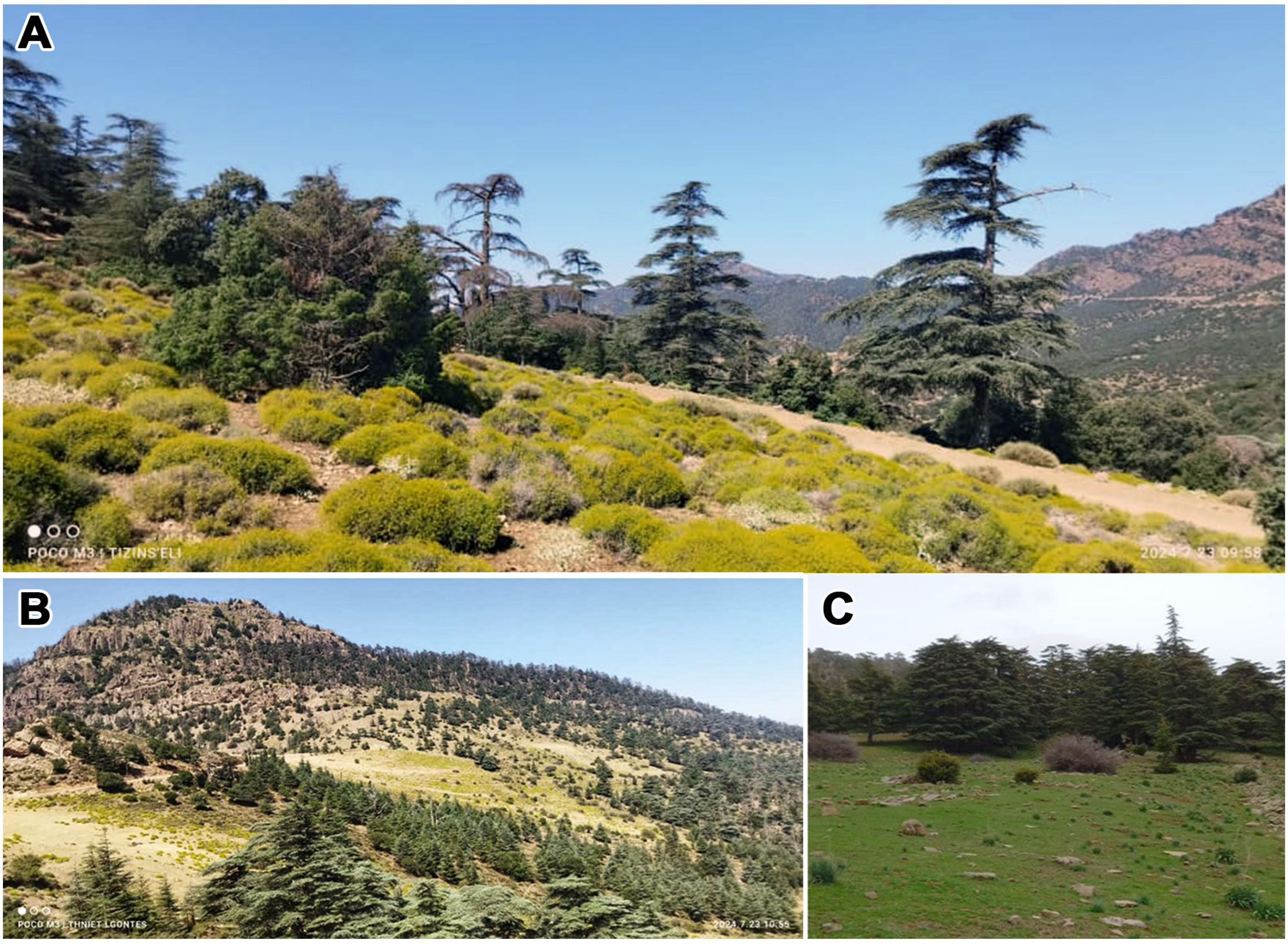

Figure 2. The Atlas cedar (*Cedrus atlantica*) forests, Algeria. **A.** The Belezma National Park; **B.** Djebel Bordjem; **C.** Djebel Tuggurt. (Photographic by Salima Zereg and Leila).

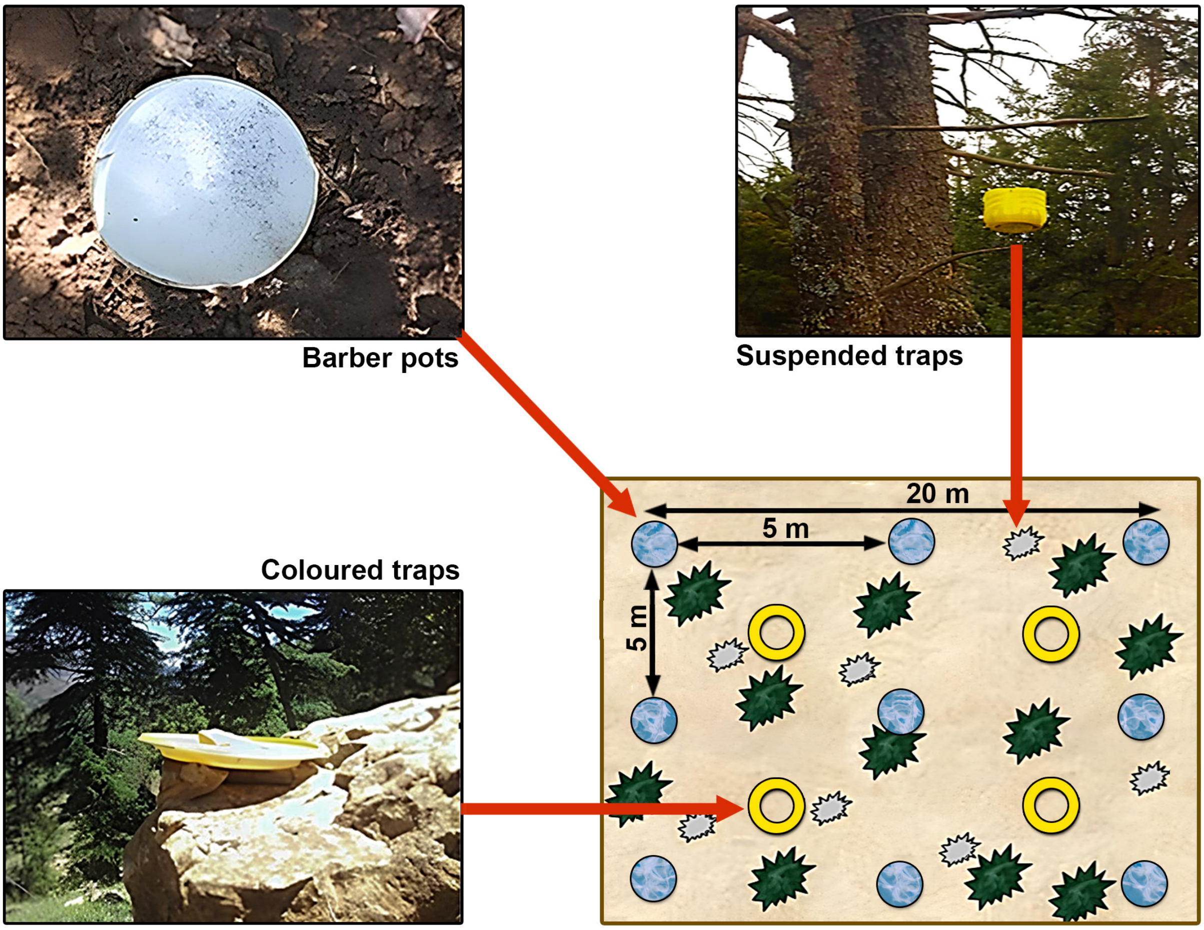

Figure 3. Arrangement of the Barber pitfall traps, coloured traps, and suspended traps.

For coloured traps (PC), we placed them on stones at the level of the herbaceous layer and simply filled them with water containing a wetting product (detergent) (Fig. 3) (Zahradnik, 1988). Suspended yellow-coloured box traps (PCS) were positioned at eye level, from 1.50 m to 1.70 m in height. The trapped species were collected in Petri dishes and then labelled with the pot trap number and the date of trapping. Moreover, the samples were sorted, counted, and ultimately identified based on their stages of development using specialized identification keys: Pierrier (1964); Helgard (1984); Zahradnik (1988); Auber (1999); Berland (1999a, 1999b); Dierl & Ring (2009); Bouragba (2010); Aguib (2014). The depository for the voucher specimens is in the laboratory of functional ecology, Batna University, and they are available for examination upon request.

Data analysis. The results were expressed in total richness (*S*), which represents the number of families or species captured at each station during a sampling session. Mean species richness (*Sm*) refers to the average number of species present in a sample (Ramade, 1984). Relative abundance (*RA*) was calculated by dividing the number of individuals of each species by the total (*N*) recorded in each station, then multiplying by 100 to express the value as a percentage. The frequency of occurrence of species I (*Occ*), also referred to the frequency of appearance or consistency index, was calculated using the formula: *Occ = (ri x 100) / R*, where ri represents the number of samples containing at least one individual of each species *i*, and *R* is the total number of samples taken (Dajoz, 1985). In their classification system, Bigot & Bodot (1973) categorized species into distinct groups based on their frequency of occurrence: Constant species (*CN*): Species present in 50% or more of the samples taken, Common species (*CM*): Species found in 25% to 49% of the samples, Accidental species (*AC*): Species with a frequency of occurrence less than 25% but greater than or equal to 10%, Very accidental species (*VA*): Often referred to as sporadic, these species have a frequency of occurrence of less than 10%.

The community diversity was assessed with the Shannon index reflecting the overall diversity and the evenness index providing insights into the distribution of individuals among the different species. The Shannon index was calculated as follows: $H' = -\Sigma(Pi \times logPi)$, where Pi represents the proportion (FA) of species, relative to the total number of recorded individuals (N). Additionally, the evenness index (E) was calculated using the equation $E = H' / log2S$, where 'S' represents the total number of species, and H' represents the Shannon index (Magurran, 2004). The evenness index ranges from 0 to 1, with a value close to 1 indicating that the species have similar abundances (species are evenly abundant), and a value close to 0 ($E < 0.5$) suggesting that the community is dominated by one or few species (Barbault, 1981). Subsequently, differences in terms of diversity indices between sites, sampling traps and seasons were assessed using a generalized linear model (GLM) with negative binomial distributions for richness and abundance (due to considerable overdispersion) (Stoklosa et al., 2022), and Gaussian distribution for Shannon, Simpson, evenness, and Hmax indices. Similarities in richness were explored using three Venn diagrams (Yan & Yan, 2023), illustrating the number of unique and shared taxa among sites, seasons, and trapping methods respectively. A Pearson correlation test was conducted to display any potential relationships between different aspects of diversity indices. Then, a correlation matrix chart was generated using the package Performance (Lüdecke et al., 2021). Non-metric multidimensional scaling (NMDS) based on Bray–Curtis similarities was performed using the vegan package (Oksanen et al., 2013) to explore the assemblages of insect taxa. Permutational analysis of variance (PERMANOVA) was performed on the Bray-Curtis dissimilarity matrix using the function "*adonis2*" to investigate insect composition differences across different sites, seasons, and trapping methods. Subsequently, multilevel pairwise comparisons for permutational analysis were carried out using the function "*pairwise.adonis2*" function from the R package pairwiseAdonis (Martinez Arbizu, 2020), to discern differences in the levels of significant factors identified the PERMANOVA analysis.

RESULTS

Composition of captured arthropods. A total of 108 species were captured, and distributed across 66 families, 13 orders, and 4 classes (Arachnida, Diplopoda, Malacostraca, and Insecta). Insects were the most abundant class, accounting for 95.39% of the total captures, followed by Arachnida (3.66%), Diplopoda (0.76%), and Malacostraca (0.20%). Within insects, Hymenoptera, Coleoptera, and Diptera were the most prevalent orders (Table 1). Notably, *Cataglyphis bicolor* (Fabricius, 1793) was the most abundant species. The captured species were classified into six trophic guilds, with phytophagous species dominating (53 species) and predators following (26 species). Four species namely: *Cataglyphis bicolor*, *Vespula germanica* (Fabricius, 1793), *Polistes gallicus* (Linnaeus, 1761), and *Aporia crataegi* (Linnaeus, 1758), were protected under Algerian regulations (Table 2).

Table 1. Individual numbers and species richness of arthropod orders captured in the Cedar forests (Belezma National Park, Algeria).

Class	RA (%)	Orders	N		RA (%)	SR
Arachnida	3.66	Aranea	108		3.56	1
		Scorpiones	3		0.1	1
Malacostraca	0.2	Isopoda	6		0.2	1
Diplopoda	0.76	Julida	23		0.76	3
Insecta	95.39	Blattoptera	10		0.33	2
		Ensifera	2		0.07	2
		Caelifera	2		0.07	1
		Heteroptera	9		0.3	4
		Hemiptera	12		0.4	3
		Coleoptera	714		23.52	41
		Hymenoptera	1397		46.01	27
		Lepidoptera	34		1.12	4
		Diptera	716		23.58	18

Abbreviations: RA – Relative abundance (%); N – Number of individuals; SR – Species richness.

Spatial, seasonal and sampling patterns of diversity indices. In our study, the three trophic categories including predator, phytophagous and polyphagous were the most dominant categories in the two stations, seasons and the type of trapping, either in terms of the number of individuals or species richness (Fig. 4). In stations study, species were classified into four classes of occurrence: the most numerous were the constant species with 648 (station 1) and 828 (station 2) but in terms of species, the class of very accidental species dominated with 50 species in station 1 and 51 in station 2. Analysis of the occurrence according to the seasons showed that most of the individuals were constant species in all seasons on the other hand in terms of species were very accidental species. According to different trapping methods, four classes of occurrence were also noted in Barber pot, common species dominated in terms of numbers with 1229 individuals in this method. While, according to the species, the class of very rare (less frequent) species dominated with 63 species. Three classes of occurrence were noted in other trapping methods (Fig. 4). The highest overall species richness was observed at station 1, which contained 88 species on average (mean species richness = 21.9 ± 9.9 species/sample). Station 2 also exhibited high species richness, with 87 species (Fig. 5).

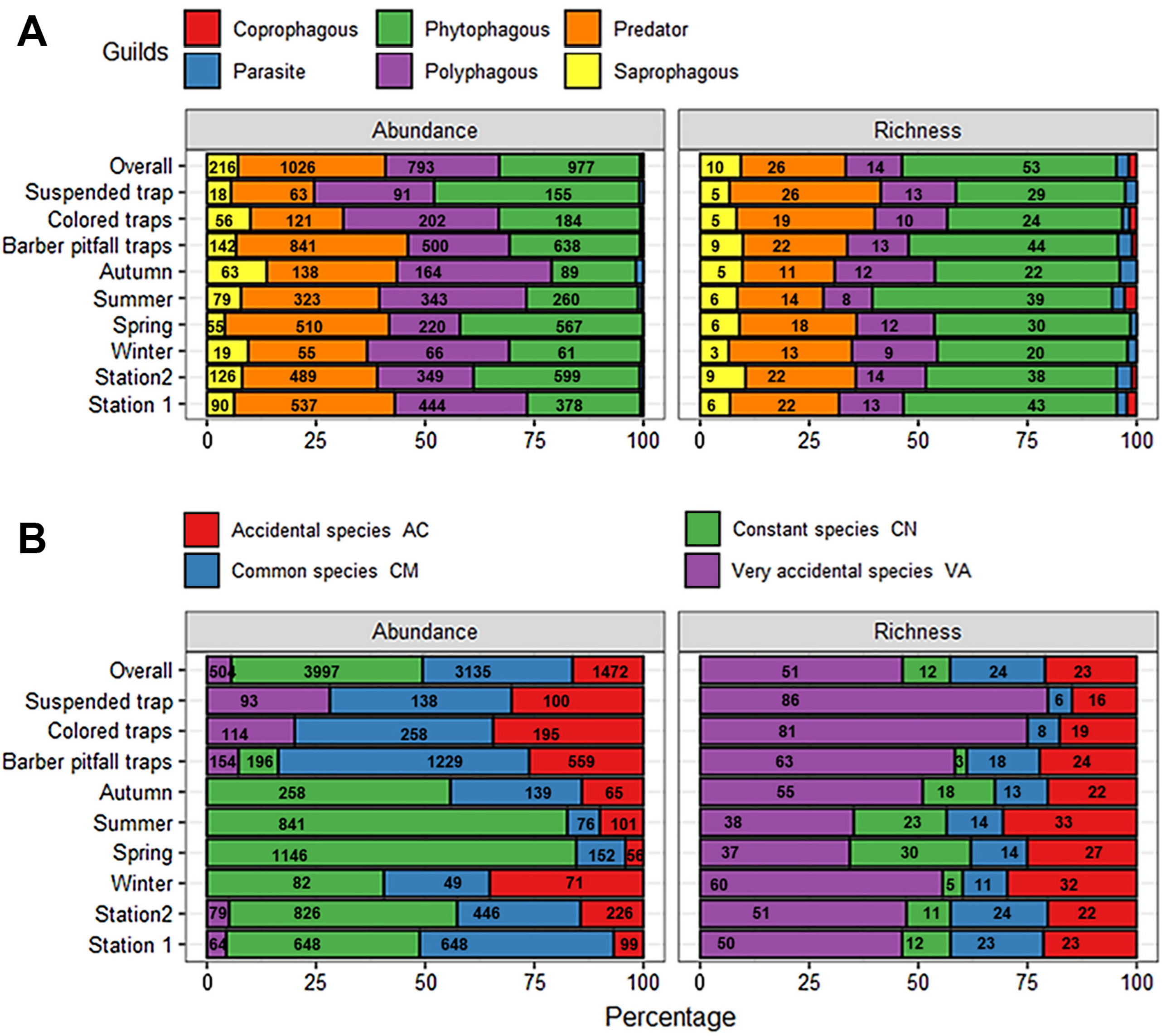

Figure 4. Trophic guilds, and categories of occurrences of arthropods fauna according to the two types of Cedar forests, season and, three sampling methods in the Belezma National Park (Algeria). The values in the histograms represent the absolute abundances (N) and species richness. **A.** Trophic category; **B.** Frequency of occurrence.

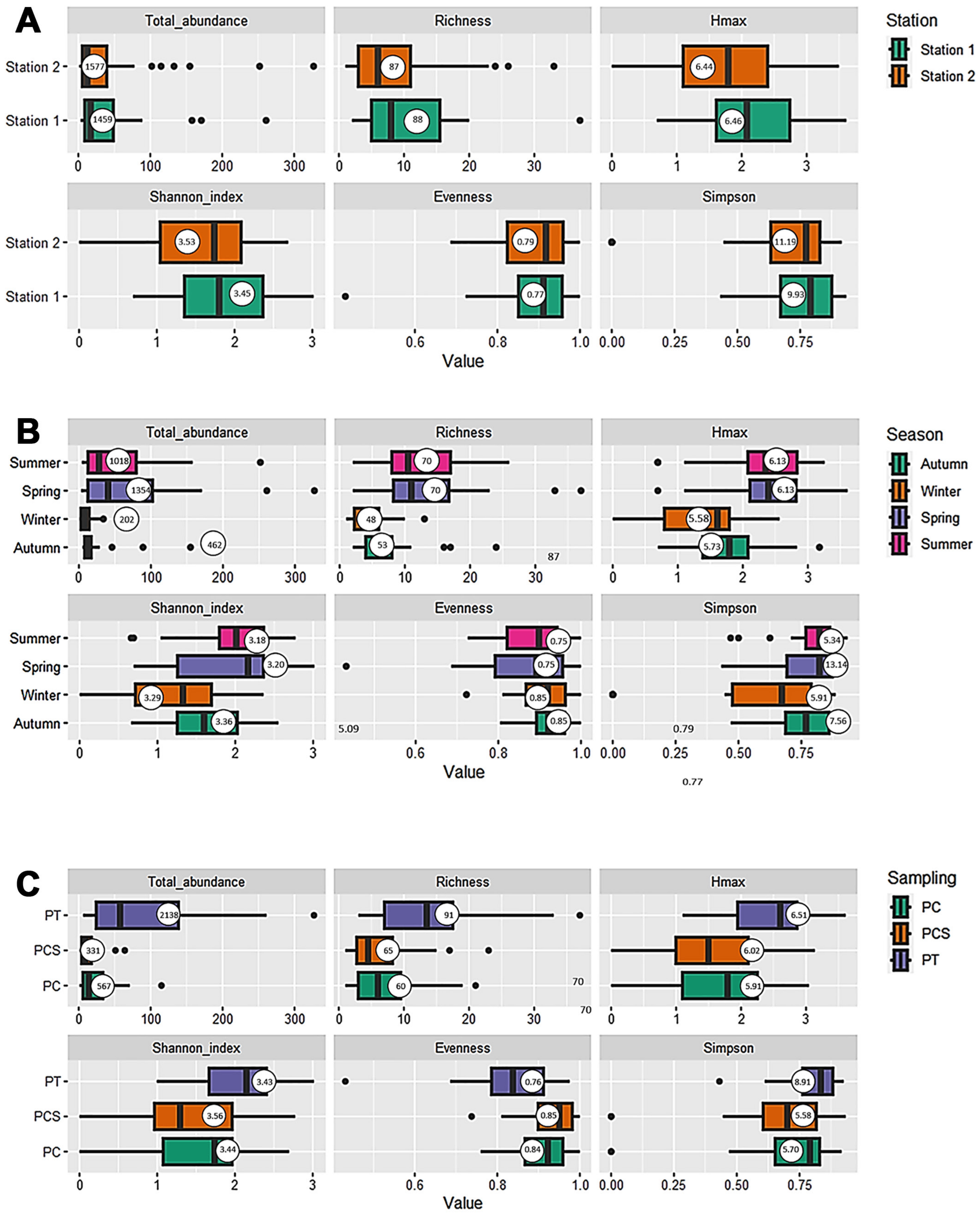

Figure 5. Diversity parameters of arthropod following Station, seasons and type of sampling in Cedar forests. White dots reflect the mean of the observed data depicted in the boxplot (sample-based data), while white circles represent the averaged estimates of each index for the pooled sample data per season or biotope. Solid black circles represent outliers. **A.** Stations; **B.** Seasons; **C.** Sampling methods.

Table 2. Systematic list, relative abundances "RA," frequencies of occurrence "Occ" (%), Trophic category and national protection of Arthropoda species of the Belezma National Park.

Class	Order/ Family	Species	RA (%)	Occ (%)	Oc	TC	NPS
Arachnida	**Aranea:** Araneidae	Araneidae sp. ind.	3.53	75	CN	Pre	No
	Scorpiones: Buthidae	*Buthus* sp.	2.78	8.33	VA	Pre	No
Malacostraca	**Isopoda:** Armadillidiidae	*Armadillidium* sp.	0.2	25	AC	Pol	No
Insecta	**Blattodea**						
	Blatidae	*Blattella germanica* (Linnaeus, 1767)	3.7	12.5	AC	Pol	No
		Blatta orientalis Linnaeus, 1758	0.2	12.5	AC	Pre	No
	Orthoptera						
	Acrididae	*Oedipoda* sp.	0.07	4.17	VA	Phy	No
	Gryllidae	*Gryllus* sp.	0.93	4.17	VA	Phy	No
	Gryllotalpidae	*Gryllotalpa gryllotalpa* (Linnaeus, 1758)	0.03	4.17	VA	Phy	No
	Coleoptera						
	Carabidae	*Carabus* sp.	0.59	33.33	CM	Pre	No
		Zabrus sp.	0.1	8.33	VA	Pre	No
		Callistus sp.	0.89	20.83	AC	Pre	No
		Brachinus sp.	0.43	16.67	AC	Phy	No
		Chlaenius sp.	0.03	4.17	VA	Pre	No
	Staphylinidae	*Staphylinus* sp.	0.66	33.33	CM	Pre	No
		Ocypus sp.	0.13	12.5	AC	Pre	No
	Histeridae	*Hister* sp.	0.03	4.17	VA	Pre	No
	Cleridae	*Trichodes* sp.	0.76	29.17	CM	Phy	No
	Buprestidae	*Capnodis tenebrionis* Linnaeus, 1761	1.68	25	AC	Phy	No
		Capnodis sp.	4.22	45.83	CM	Phy	No
		Buprestis (*Ancylocheira*) sp.	0.03	4.17	VA	Phy	No
		Chrysobothris sp.	0.13	12.5	AC	Phy	No
		Buprestidae sp. ind.	0.3	12.5	AC	Phy	No
	Dermestidae	*Anthrenus* sp.	0.1	4.17	VA	Sap	No
		Dermestes sp.	0.3	16.67	AC	Sap	No
	Mycetophagidae	*Mycetophagus* sp.	7.87	50	CN	Pol	No
	Anobiidae	Anobiidae sp. ind.	0.76	8.33	VA	Phy	No
	Oedemeridae	Oedemeridae sp. ind.	0.03	4.17	VA	Phy	No
	Pyrochroidae	Pyrochroidae sp. ind.	0.2	8.33	VA	Phy	No
	Meloidae	*Mylabris* sp.	0.07	8.33	VA	Cop	No
	Tenebionidae	*Timarcha* sp.	0.36	16.67	AC	Pol	No
	Scarabaeidae	*Cetonia* sp.	0.2	12.5	AC	Phy	No
		Aphodius sp.	0.3	25	AC	Sap	No
		Geotrupes sp.	0.07	8.33	VA	Sap	No
		Gymnopleurus sp.	0.3	8.33	VA	Sap	No
		Onthophagus sp.	0.36	8.33	VA	Sap	No
		Scarabaeus sacer	0.03	4.17	VA	Sap	No
	Cantharidae	*Cantharis* sp.	0.56	4.17	VA	Sap	No
	Cerambycidae	Cerambycidae sp. ind.	0.16	20.83	AC	Phy	No
	Chrysomelidae	*Chrysomela* sp.	0.23	29.17	CM	Phy	No
		Chrysomelidae sp. ind.	0.26	20.83	AC	Phy	No
	Curculionidae	*Polydrusus* sp.	0.03	4.17	VA	Phy	No
		Hylobius sp.	0.1	8.33	VA	Phy	No
		Pityogenes sp.	0.1	4.17	VA	Phy	No
		Curculionidae sp. ind.	0.2	12.5	AC	Phy	No
		Bruchus sp.	0.69	20.83	AC	Phy	No
		Ips sp.	0.03	4.17	VA	Phy	No
	Bostrichidae	Bostrichidae sp.	0.07	4.17	VA	Phy	No
	Apionidae	*Apion* sp.	0.03	4.17	VA	Phy	No
	Elateridae	Elateridae sp. ind.	0.13	8.33	VA	Phy	No
	Diptera						
	Tabanidae	*Tabanus* sp.	1.09	29.17	CM	Pol	No
	Asilidae	*Asilus* sp.	0.4	16.67	AC	Pre	No
		Asilidae sp. ind.	0.2	8.33	VA	Pre	No
	Syrphidae	*Eristalis* sp.	0.13	4.17	VA	pol	No
		Syrphus sp.	1.38	33.33	CM	Pre	No
	Drosophilidae	*Drosophila* sp.	2.73	66.67	CN	Pol	No
	Muscidae	*Musca* sp.	0.86	33.33	CM	Sap	No
		Muscidae sp. ind.	2.83	54.17	CN	Pol	No

Class	Order/ Family	Species	RA (%)	Occ (%)	Oc	TC	NPS
	Calliphoridae	*Calliphora vicina* Robineau-Desvoidy, 1830	0.2	12.5	VA	Pol	No
		Lucilia Caesar (Linnaeus, 1758)	1.35	58.33	CN	Pol	No
	Sarcophagidae	*Sarcophaga* sp.	4.25	66.67	CN	Sap	No
		Scathophaga sp.	0.07	4.17	VA	Cop	No
	Tachinidae	*Tachinus* sp.	6.85	87.5	CN	Pol	No
	Culicidae	*Culex* sp.	0.59	20.83	AC	Pol	No
	Bombyliidae	*Bombylius* sp.	0.2	4.17	VA	Pre	No
	Biobionidae	*Bibio* sp.	0.23	4.17	VA	Phy	No
	Tephritidae	Tephritidae sp. ind.	0.07	8.33	VA	Phy	No
	Diptera	Diptera sp. ind.	0.16	12.5	AC	Pol	No
	Hemiptera						
	Cercopidae	Cercopidae sp. ind.	0.16	4.17	VA	Phy	No
	Cicadidae	*Cicadella* sp.	0.1	4.17	VA	Phy	No
	Issidae	*Issus* sp.	0.13	12.5	AC	Phy	No
	Heteroptera						
	Pentatomidae	Pentatomidae sp. ind.	0.03	4.17	VA	Phy	No
	Coreidae	Coreidae sp. ind.	0.07	4.17	VA	Phy	No
	Pyrrhocoridae	*Pyrrhocoris apterus* (Linnaeus, 1758)	0.07	8.33	VA	Phy	No
	Miridae	*Lygus* sp.	0.13	12.5	AC	Phy	No
	Hymenoptera						
	Cynipidae	Cynipidae sp. ind.	0.33	16.67	AC	Phy	No
	Chrysididae	*Chrysis viridula* Linnaeus, 1761	0.13	8.33	VA	Par	No
		Chrysis sp.	0.3	20.83	AC	Par	No
	Formicidae	*Pheidole pallidula* (Nylander, 1849)	1.29	54.17	CN	Pre	No
		Aphaenogaster sp.	2.67	29.17	CM	Phy	No
		Messor barbarus (Linnaeus, 1767)	0.2	12.5	AC	Phy	No
		Monomorium salamonis (Linnaeus, 1758)	1.52	25	AC	Phy	No
		Camponotus barbaricus Emery, 1905	1.68	50	CM	Pre	No
		Camponotus sp.	7.71	37.5	CM	Pre	No
		Cataglyphis bicolor Fabricius, 1793	9.92	45.83	CM	Pre	Yes
	Pompilidae	*Anoplius* sp.	3.1	20.83	AC	Pre	No
		Pompilidae sp. ind.	0.07	4.17	VA	Pre	No
	Vespidae	*Vespula germanica* (Fabricius, 1793)	0.03	4.17	VA	Pre	Yes
		Polistes gallicus Linnaeus, 1761	0.16	12.5	AC	Pre	Yes
	Sphecidae	*Sphex maxillosus* Gussakovskij, 1934	0.16	16.67	AC	Pre	No
		Ammophila sabulosa (Linnaeus, 1758)	0.63	29.17	CM	Pre	No
		Sphex sp.	0.53	29.17	CM	Pre	No
		Sphecidae sp. ind.	0.07	4.17	VA	Pre	No
	Apodae	*Halictus* sp.	1.88	33.33	CM	Phy	No
		Xylocopa sp.	0.03	4.17	VA	Phy	No
		Bombus sp.	0.13	12.5	AC	Phy	No
		Apis mellifera Linnaeus, 1758	2.6	54.17	CN	Phy	No
		Apis sp.	7.58	66.67	CN	Phy	No
		Apidae sp1. ind.	1.02	20.83	AC	Phy	No
		Apidae sp2. ind.	0.46	20.83	AC	Phy	No
	Cynipidae	*Cynips* sp.	0.23	12.5	AC	Par	No
		Hymenoptera sp. ind.	1.61	54.17	CN	Pol	No
	Lepidoptera						
	Pieridae	*Aporia crataegi* (Linnaeus, 1758)	0.03	4.17	VA	Phy	Yes
		Pieris sp.	0.13	4.17	VA	Phy	No
	Noctuidae	Noctuidae sp. ind.	0.79	41.67	CM	Phy	No
	Sphingidae	Sphingidae sp. ind.	0.16	29.17	CM	Phy	No
	Julida						
Diplopoda	Julidae	Julidae sp1. ind.	5.56	16.67	AC	Phy	No
		Julidae sp2. ind.	0.53	16.67	AC	Phy	No
		Julidae sp3. ind.	0.03	4.17	VA	Phy	No
Class= 4 Orders= 13 / Families= 66 Genera= 102 Species = 108							

RA, relative abundance; Occ, frequency of occurrence; OC, Occurrence categories; species absence, CN, constant species (Occ ≥ 50%); CM, common species (25% ≤ Occ < 50%); AC, accidental species (10% ≤ Occ < 25%); VA: very accidental species (Occ < 10%); Cop, Coprophagous; Par, Parasite; Pol, Polyphagous; Phy, Phytophagous; Pre, Predator; Sap, Saprophagous.

In contrast, the Shannon diversity index highlighted that station 2 harbours the most diverse community assemblages, with a value of 3.53 nats, whereas station 1 had a slightly lower Shannon diversity of 3.45 nats. The total richness captured by the three trapping methods was 92, 65, and 60 taxa for the Barber pitfall traps, pitfall traps, and coloured traps respectively. Cedar forests, season and, three sampling methods in the Belezma National Park (Algeria). The values in the histograms represent the absolute abundances (N) and species richness. In terms of abundance, the Barber pitfall trap recorded the highest value, with 2,138 individuals per species, followed by the coloured trap, which captured 567 individuals, and lastly, the suspended pitfall traps, which collected 331 individuals. In terms of seasonal variation, the lowest species abundances were recorded in the cold seasons, winter and autumn, with 202 and 462 individuals respectively. The highest abundance was recorded during the warm season (spring and summer). The Shannon index revealed a relatively high diversity during the winter season with H = 3.36 nats, which was quite similar to the diversity recorded during the warm season (H = 3.18 and 3.20). In a comparison of different insect trapping methods, Barber pots captured a total of 91 species, and Colored traps gathered 63 species, prominently featuring *Tachinus* sp. (14.11%) and *Apis* sp. (10.93%). Suspended pots accounted for 80 species, with *Apis mellifera* (Linnaeus, 1758) showing a relative abundance of 12.99%, followed by *Apis* sp. (8.76%). The Shannon diversity indices calculated for each type of insect trap were found to be H' = 3.43 nats and $H\ max$ = 4.52 for Barber pots; H' = 3.56 nats and $H\ max$ = 4.17 for hanging traps; and H' = 3.62 nats and $H\ max$ = 4.68 for coloured traps. The evenness of species across various trapping methods was quantified as follows: E = 0.85 for suspended traps, E = 0.84 for coloured traps, and E = 0.76 for Barber pots. These values, approaching 1, suggested a relatively balanced distribution of species across the different types of traps.

Pairwise comparisons (Table 3) from the generalized linear model (GLM) indicated significant differences in both richness and abundance across seasons and sampling methods. However, no significant differences were detected between Station 1 and Station 2 for either richness or abundance. Moreover, there were no significant differences observed in terms of Hmax, Shannon, Simpson, and evenness indices across stations, seasons, or sampling methods. Specifically, spring and summer exhibited higher richness and abundance compared to other seasons, while the PT sampling method generally yields higher richness and abundance compared to PC and PCS methods.

Table 3. Pairwise comparison of richness and abundance using negative binomial GLM

	Contrast	Estimate	standard error	statistic	adj.p.value
RICHNESS					
Station	Station 1 - Station 2	-0.21	0.14	-1.51	0.13
Season	Spring – Autumn	0.62	0.19	3.3	**0.01**
	Summer – Autumn	0.46	0.19	2.4	**0.08**
	Winter – Autumn	-0.47	0.21	-2.26	0.11
	Summer – Spring	-0.17	0.18	-0.92	0.8
	Winter – Spring	-1.1	0.2	-5.46	**<0.001**
	Winter – Summer	-0.93	0.2	-4.6	**<0.001**
Sampling	PCS – PC	-0.19	0.18	-1.1	0.52
	PT – PC	0.65	0.16	3.98	**<0.001**
	PT – PCS	0.84	0.17	5.04	**<0.001**
ABUNDANCE					
Station	Station 1 - Station 2	-0.19	0.19	-0.98	0.33
Season	Spring – Autumn	1.02	0.27	3.74	**<0.001**
	Summer – Autumn	0.69	0.27	2.51	0.06
	Winter – Autumn	-0.72	0.28	-2.56	0.05
	Summer – Spring	-0.33	0.27	-1.23	0.61
	Winter – Spring	-1.74	0.28	-6.24	**<0.001**
	Winter – Summer	-1.41	0.28	-5.04	**<0.001**
Sampling	PCS – PC	-0.55	0.24	-2.25	0.06
	PT – PC	1.23	0.24	5.23	**<0.001**
	PT – PCS	1.78	0.24	7.43	**<0.001**

However, there were no significant differences between PC and PCS methods in terms of richness or abundance. All diversity metrics were significantly and positively correlated with each other, except for evenness, which was not correlated with the Simpson and Shannon indices (*P-value* > *0.05*) and showed a significant negative correlation with total abundance and Hmax (Fig. 6).

Spatio-temporal and sampling methods for similarity analysis. Out of 108 taxa, 67 were common between the two sampled stations, 21 taxa were exclusively present in Station 1, and 20 taxa were exclusively present in Station 2 (Fig. 7A). Seasonally, only nine species were shared across all four seasons (Fig. 7B), while, spring had the highest exclusive taxa (13), followed by summer with 8 unique taxa. Spring, summer, and autumn exhibited overlap in their constituent taxa, sharing many taxa in pairs or trios. Concerning sampling methods (Fig. 7C), the three methods have 39 common taxa, and 28, 6, and 6 exclusive taxa for pitfall trapping (PT), coloured traps (PC), and suspended trap (PCS) methods, respectively. Pitfall trapping (PT) shared 14 taxa with PCS and 11 with PC, however, only 4 taxa (*Bombylus* sp., *Bibio* sp., Dipterae sp. ind., *Anthrenus* sp.) were common between the two latter methods.

Arthropod assemblages. The non-metric multidimensional scaling (NMDS) ordination (Fig. 8) revealed distinct insect community compositions across different stations, seasons, and trapping methods. Notably, specific taxa were associated with certain stations and seasons. The three different trapping techniques (PC, PCS, and PT) captured divergent taxa assemblages (Fig. 8B), where PC and PCS methods appeared to have sampled a larger distribution of taxa compared to PT. In addition, the two stations seem to partially host significant dissimilar insect community structures (Fig. 8C), where some taxa were more associated with Station 1, such as *Chrysobothris* sp., *Mylabris* sp., *Pentatomidae* sp. ind., and *Pityogenes* sp., while others like *Camponotus* sp., *Asilus* sp., *Monomorium salamonis* (Linnaeus, 1758), *Sphex maxillosus* (Gussakovskij, 1934) and Julidae sp1. ind. were more related to Station 2.

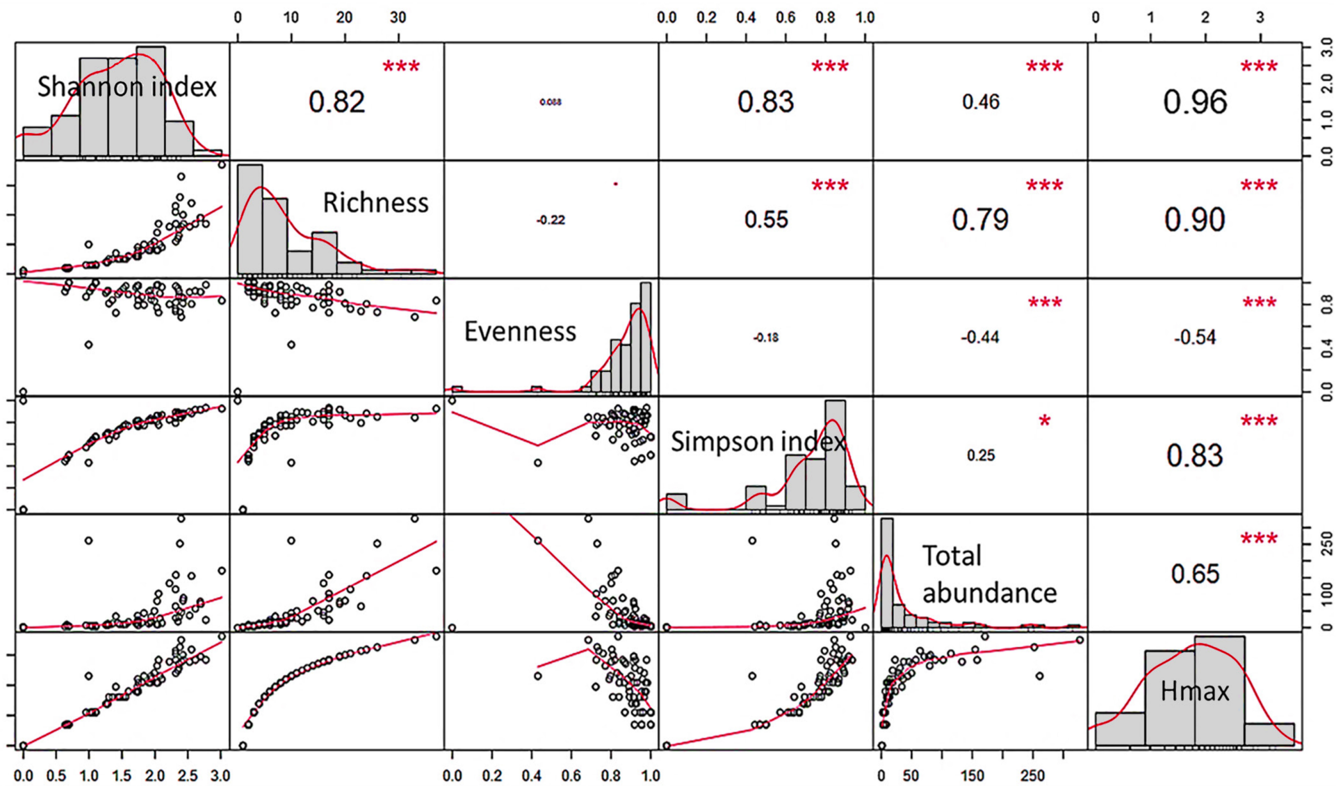

Figure 6. Pearson's correlation tests between ecological diversity indices. Pearson's correlation results are expressed as asterisks (*P-values*) and correlation coefficient values.

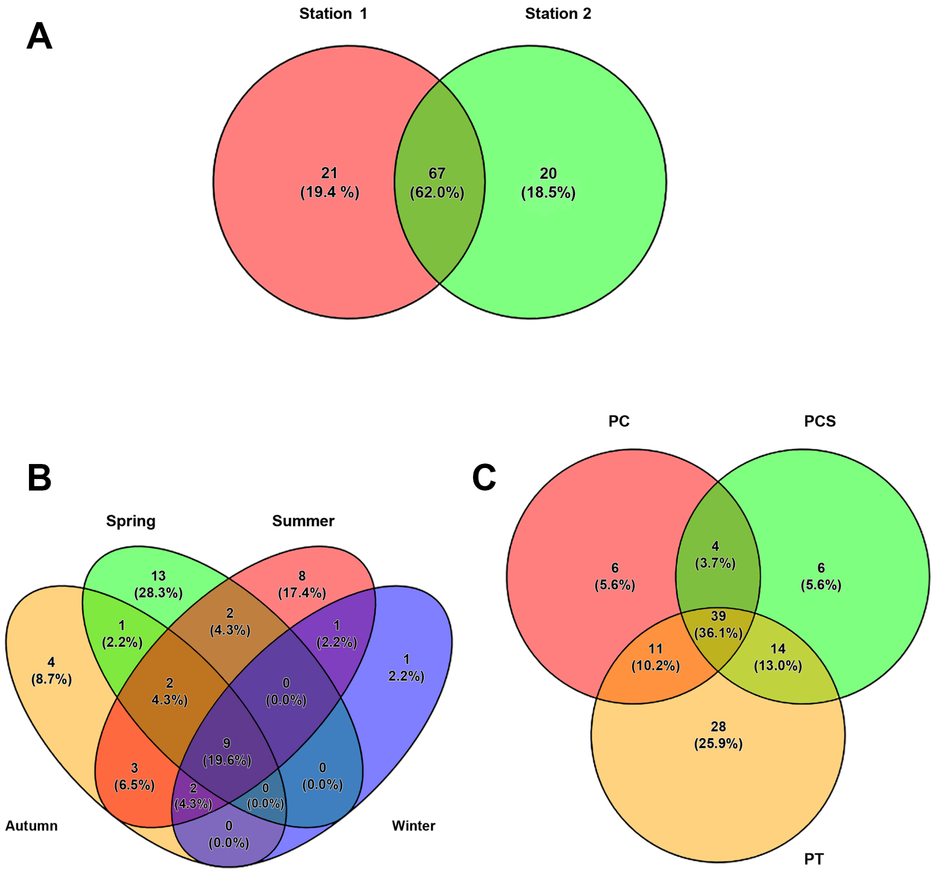

Figure 7. Venn diagram displaying arthropods taxa richness according to station (A) season (B) and sampling methods (C).

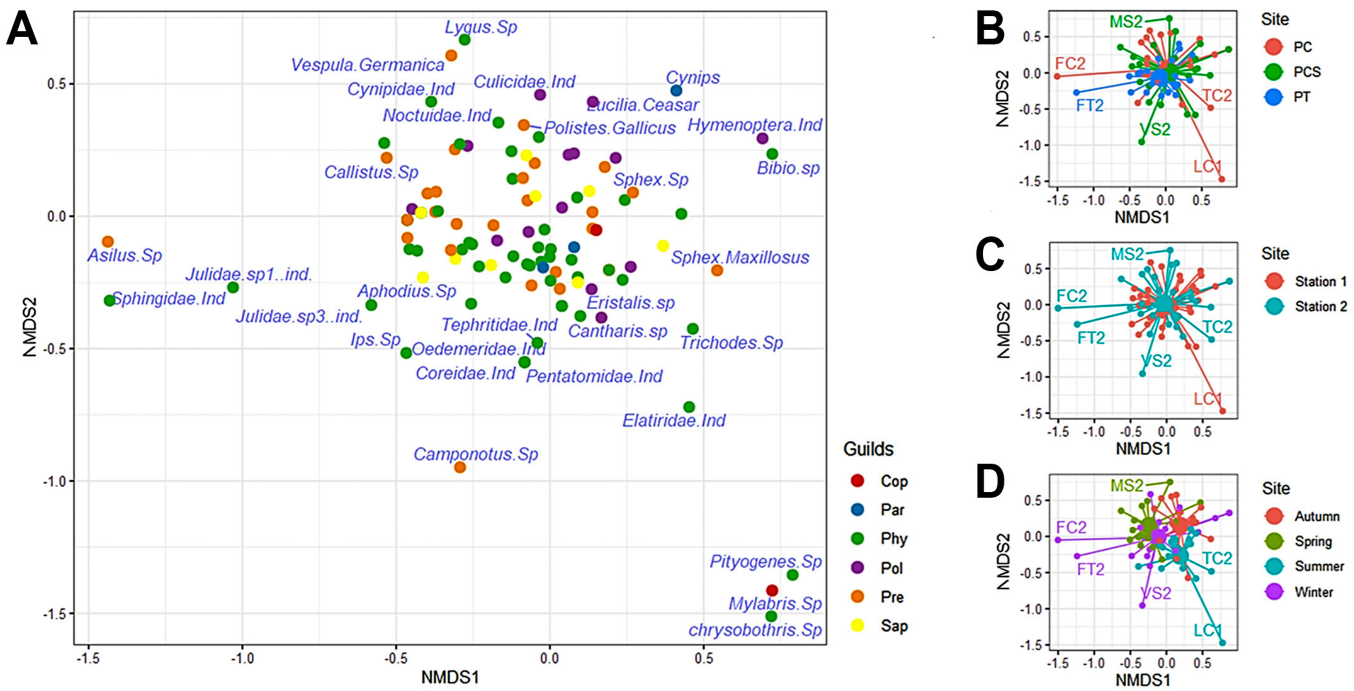

Figure 8. Non-metrical multidimensional scaling (NMDS) based on Bray-Curtis similarities index. **A.** Taxa distribution, entomofauna community structures based on; **B.** Sampling methods (PC, PCS, PT), **C.** Stations (1 and 2), and **D.** Seasons (autumn, spring, summer, winter).

In terms of season (Fig. 8D), *Camponotus* sp., Julidae sp1. ind., Sphingidae sp. ind., *Asilus* sp., *Bibio* sp., and Julidae sp3. ind. were associated with winter, in contrast to Pentatomidae sp. ind., *Oedemeridae* sp. ind., *Chrysobothris* sp., *Mylabris* sp., Pentatomidae sp. ind which were associated to summer. In addition, autumn was characterised by *Onthophagus* sp., *Monomorium salamonis*, *Messor barbarus* (Linnaeus, 1767), *Vespula germanica*, *Cynips* sp., and *Lucilia caesar* (Linnaeus, 1758). Permanova analysis confirmed significant differences in arthropod composition based on the sampling method ($F = 2.0604$, $p\text{-value} = 0.001$), station ($F = 1.53$, $p\text{-value} = 0.032$), and season ($F = 2.2519$, $p\text{-value} = 0.001$). Pairwise Permanova (Table 4) confirmed significant differences in arthropod composition between the PT method and both the PC and PCS methods. Additionally, every seasonal pair exhibited statistically significant differences in composition.

Table 4. Pairwise PERMANOVA comparisons examining the differences in entomofauna composition across different seasons and sampling methods

	Comparison	Df	Sums of squares	R2	F statistic	P-value
Season	Winter vs Spring	1	0.81	0.054	1.95	**0.004 ****
	Winter vs Summer	1	1.14	0.075	2.77	**0.001 *****
	Winter vs Autumn	1	0.69	0.046	1.60	**0.03 ***
	Spring vs Summer	1	1.04	0.073	2.69	**0.001 *****
	Spring vs Autumn	1	0.92	0.065	2.28	**0.002 ****
	Summer vs Autumn	1	0.68	0.049	1.71	**0.02 ***
Sampling	PC vs PCS	1	0.47	0.023	1.09	0.34
	PC vs PT	1	0.78	0.041	1.93	**0.003 ****
	PCS vs PT	1	1.15	0.057	2.79	**0.001 *****

DISCUSSION

Our arthropod inventory in the Cedar grove identified 108 species across 66 families, 13 orders, and 4 classes. The dominance of class Insecta was consistent with a previous study by Hadjoudj et al. (2018) that examined the arthropod community in dunes and a palm grove (*Phoenix dactylifera*) in the Touggourt region of the Septentrional Sahara. Both studies found that Insecta was the most prevalent, with a relative abundance of 95.9%. In comparison, other studies reported different species compositions: Guettala-Frah (2009) documented 348 species from 97 families and 13 orders in an apple orchard in the Aures region; Boukerker et al. (2016) recorded 327 species across 148 families, 23 orders, and 4 classes in the Belezma cedar; Chafaa et al. (2019) recorded 125 species in an apricot orchard, distributed among 9 orders and 54 families; and Guermah et al. (2019) recorded 125 species across 64 families, 10 orders, and 3 classes on apple crops. Another study conducted by Guermah et al. (2019) investigated arthropod diversity in apple crops in the Sidi Naâmane area (Tizi-Ouzou) and sampled three classes of Arthropoda. Insecta was the dominant class, accounting for 88.5%, followed by Arachnida at 7.07%. Aouimeur et al. (2017) studied the abundance and diversity of Arthropoda in the palm groves of Oued Souf and identified 244 species across four classes (Arachnida, Malacostraca, Insecta, and Diplopoda). Insecta was found to be the most abundant, representing 92.7% of the total. The current results showed that Hymenoptera and Coleoptera were the predominant orders observed at both study sites. Chafaa (2013) reported comparable findings in an olive grove in Batna, where Coleoptera and Hymenoptera constituted the most represented taxa, comprising 47.1% and 18.9% of the total, respectively. The remaining orders mentioned had percentages of less than 10%. This seems to be largely attributed to the importance of beetles as a food source for secondary consumers and their role as biological indicators of environmental health (Sánchez-Fernández et al., 2006). Indeed, Beetles have been known as notably sensitive to alterations in their habitats, rendering them valuable for assessing environmental richness (Haddad et al., 2009).

The diversity parameters calculated for the different types of diet revealed the dominance of phytophages, predators, and polyphages and a very low number of saprophages, parasites, and coprophage species. In the Juniperus woodland, phytophagous species prevail, comprising 2237 individuals across 113 species composition (Zereg, 2011), followed by Polyphages, Predators, Saprophages, Parasites/Parasitoids, and Coprophages. Chafaa et al. (2019) found that in apricot gardens of *Prunus armeniaca*, foliage-feeders were the most dominant with 71 species, followed by predators with 31 species, and polyphages with 13 species. They also observed a small presence of saprophages (5), parasites (4), and coprophages (1) species. Xylophages, Frugivorous insects, and saproxylics can attack various plants (Villiers, 1979; Ricklefs & Miller, 2005). Conversely, phytophagous insects were very selective regarding the plant species they prefer. Coprophages contribute to soil formation through their digging activities and the incorporation of organic matter into the upper horizons (Bachelier, 1978); they aid in the proper soil structuring by promoting the recycling of dung into humus and providing nitrogen to the soil (Dajoz, 1985). Furthermore, saprophages utilize all dead substances, particularly decomposing plant litter, through the action of microorganisms, fungi, and then insects, which will form humus (Villiers, 1979).

The arthropod fauna was influenced by the condition of the forest especially the abundance, and the diversity values *H′* and *H max*. Population densities were notably higher in Djebel Tuggurt (a healthy cedar grove) compared to Djebel Bordjem (a withered cedar grove). Naeem et al. (2010) reported higher numbers of arthropods in tree rows compared to forest plots and woodlots in an agroforestry landscape. Several factors influence the abundance of arthropods, such as the impact of habitat type, crop diversity, landscape complexity, orientation, vegetation structure concerning exposure, and tree rows. Additionally, external stressors like urbanization, climate change, forest fires, and deforestation further result in decreased species richness (Murphy et al., 2020). These factors, separated by the arable alleys, might have facilitated insect movement (Paudel & Tiwari, 2022). Philpott et al. (2013) extend the investigation into the impacts of both local and landscape drivers, revealing that habitat type as well as specific local shape the abundance and richness of urban arthropods and landscape variables. Healthy habitats support a rich diversity of arthropods due to robust soil health and diverse plant communities, while weathered habitats experience diminished arthropod diversity and functionality due to poorer soil conditions and reduced plant diversity (Menta & Remelli, 2020). Weathered plots are more sensitive to environmental variations; thus, vegetation recovery following thinning and fire treatments significantly influences arthropod recovery by supplying dead organic matter and moderating the microclimate of the forest floor (Marra & Edmonds, 2005). In addition, vegetation heterogeneity and leaf litter dynamics are crucial for supporting arthropod abundance and diversity by providing essential habitat and nourishment (Silva et al., 2011). In an olive grove located in Batna, variations in arthropod richness correlate with seasonal changes (Chafaa, 2013). Aouimeur et al. (2017) observed a similar seasonal pattern in the Souf region, with arthropod presence influenced by their phenology, climatic conditions, and plant cover. Coleoptera are more common in spring, summer, and autumn, while Hymenoptera dominate in winter. Conversely, in the Souf region, Hymenoptera are prevalent year-round except for winter, when Homoptera are dominant. The presence and disappearance of insects may be explained by their phenology, which is linked to environmental variables such as climate and plant cover. Seasonal variations reveal that summer and spring exhibit the highest species diversity and abundance, likely due to harsh winter conditions that limit insect activity (Chafaa, 2013). Physical variables such as temperature, precipitation, and moisture content directly influence seasonal changes in soil fauna (Wiwatwitaya & Takeda, 2005). Many species may experience significant population declines due to low temperatures in winter and the drying out of litter in summer. In addition, warmer temperatures and increased resource availability during spring and summer favour higher insect diversity and population growth. The Shannon diversity index (*H*') was higher in all four seasons, attributed to the environmental diversification during sampling periods. Favourable conditions such as mild climate and the presence of flowers in both the arboreal and herbaceous strata contribute to this phenomenon. The greatest Shannon values throughout all four seasons are mostly assigned to environmental diversification during these periods, where beneficial factors such as a moderate climate and the abundance of flowers in both arboreal and herbaceous strata, contribute to this phenomenon.

Regarding sampling methods, the barber traps proved more effective in capturing a greater diversity of arthropod species, while the suspended traps yielded fewer species. These results align with a previous study in an olive orchard, where higher species richness was reported using barber pots compared to colour traps (Frah et al., 2015). In a more recent study by Guermah et al. (2019), it was noted that the diversity metrics for species captured using both trapping techniques and barber pots were similar to those observed in the current results. This suggests that while barber traps may generally yield higher diversity, the effectiveness of both methods can vary depending on specific ecological contexts and the target arthropod communities. Barber traps, primarily used to study medium to large epigeic arthropods, mainly capture walking arthropods and also flying insects, such as adult dipterans (Obrist & Duelli, 1996). However, Pitfall traps are subject to biases, such as overestimating the abundance of large arthropods, and their effectiveness is more related to the locomotive abilities of the terrestrial captured species (McCravy, 2018). In contrast, suspended yellow traps, which are known to attract many pollinating insects, effectively drew numerous flying insects, including Diptera and Hymenoptera (Le Berre, 1969; Aouimeur et al., 2017).

This study was conducted to identify and describe the invertebrate populations linked to cedar dieback in the Belezma National Park area, specifically at Djebel Bourdjem and Djebel Tuggurt. This study underscored the rich diversity of arthropods in cedar groves, with 108 species identified across four classes. Insecta was the most dominant class, particularly Hymenoptera, Diptera, and Coleoptera. Seasonal variations showed higher diversity in summer and spring, influenced by favourable climatic conditions. Barber traps were the most effective sampling method, capturing the highest species diversity. Forest health significantly impacted arthropod populations, with healthier groves supporting greater densities and diversity. The disappearance of species that depend on cedar groves might indicate the deterioration of these forests, primarily caused by illegal logging, deforestation for electricity poles, and pollution from solid waste discharge. In conclusion, this study contributes to our understanding of arthropod diversity in cedar groves and highlights the intricate relationships between environmental factors, forest health, and arthropod community dynamics. Continued monitoring and conservation efforts would be essential to preserve these diverse and ecologically important communities.

AUTHOR'S CONTRIBUTION

The authors confirm their contribution to the paper as follows: A. Mouane and S. Zereg: participated in the conceptualization and design of the study; S. Zereg: carried out field sampling and identification; A. Aouadi and A. Mouane analyzed data; S. Zereg, A. Aouadi, and A. Mouane drafted the manuscript. The authors read and approved the final version of the manuscript.

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AVAILABILITY OF DATA AND MATERIAL

The specimens listed in this study are deposited in the laboratory of functional ecology, Batna University 2 and are available from the curator, upon request.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study only included plants and arthropod material, and all required ethical guidelines for the treatment and use of animals were strictly adhered to in accordance with international, national, and institutional regulations. No human participants were involved in any studies conducted by the authors for this article.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this paper.

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تنوع و توزیع فضایی-زمانی بندپایان در جنگل سرو اطلس (*Cedrus atlantica* Manetti) در پارک ملی بلزمه (بتنا، الجزایر)

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چکیــده: این تحقیق با استفاده از روش‌های مختلف تله‌گذاری به بررسی نوسانات توزیع فضایی و فصلی در تنوع بندپایان در دو نوع جنگل سرو (جنگل‌های مرده و سالم) در پارک ملی بلزمه واقع در بتنا می‌پردازد. بررسی‌های میدانی از ژانویه ۲۰۱۷ تا دسامبر ۲۰۱۸ انجام شد و سه تکنیک نمونه‌برداری شامل تله‌های باربر، تله‌های رنگی و تله‌های معلق به کار گرفته شد. در مجموع ۱۰۸ گونه متعلق به چهار رده، ۱۳ راسته و ۶۶ خانواده از بندپایان ثبت شد. حشرات با ۴۶ گونه، ۹۵٫۴٪ از تنوع کل گونه‌ها را تشکیل می‌دهند و این رده غالب‌ترین رده بود. در این رده، بال‌غشاییان بالاترین فراوانی را داشت (۴۶٫۰۱٪)، و پس از آن دوبالان با (۲۳٫۶٪) قرار داشتند. شاخص شانون-ویور در تمام ایستگاه‌ها، فصول و روش‌های نمونه‌برداری بیش از ۳ بود که نشان‌دهنده تنوع بالا است. همچنین مقادیر شاخص برابری در تمام مشاهدات بیش از ۷۰٪ بود. تحلیل PERMANOVA تفاوت‌های معنی‌داری در ترکیب بین ایستگاه‌های مختلف، فصول و روش‌های نمونه‌برداری نشان داد. این تحقیق چندین عامل کلیدی مؤثر بر تنوع بندپایان از جمله وضعیت زیستگاه (جنگل‌های مرده در مقابل جنگل‌های سالم سرو)، تغییرات فصلی و اثربخشی تکنیک‌های مختلف نمونه‌برداری را مورد تأکید قرار داد.

واژگـان کلیدی: فون حشرات، فهرست‌برداری، جنگل سدر، شمال آفریقا، روش‌های نمونه‌برداری، فصل