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Spatiotemporal diversity, structure and trophic guilds of insect assemblages in a semi-arid Sabkha ecosystem

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The current study highlights some knowledge on the diversity and structure of insect communities and trophic groups living in Sabkha Djendli (semi-arid area of Northeastern Algeria). The entomofauna was monthly sampled from March to November 2006 using pitfall traps at eight sites located at the vicinity of the Sabkha. Structural and diversity parameters (species richness, Shannon index, evenness) were measured for both insect orders and trophic guilds. The canonical correspondence analysis (CCA) was applied to determine how vegetation parameters (species richness and cover) influence spatial and seasonal fluctuations of insect assemblages. The catches totalled 434 insect individuals classified into 75 species, 62 genera, 31 families and 7 orders, where Coleoptera and Hymenoptera were the most abundant and constant over seasons and study stations. Spring and autumn presented the highest values of diversity parameters. Based on catch abundance, the structure of functional trophic groups was predator (37.3%), saprophagous (26.7%), phytophagous (20.5%), polyphagous (10.8%), coprophagous (4.6%); whereas in terms of numbers of species, they can be classified as phytophagous (40%), predators (25.3%), polyphagous (13.3%), saprophagous (12%), coprophagous (9.3%). The CCA demonstrated that phytophagous and saprophagous as well as Coleoptera and Orthoptera were positively correlated with the two parameters of vegetation, especially in spring and summer. While the abundance of coprophagous was positively correlated with species richness of plants, polyphagous density was positively associated with vegetation cover. The insect community showed high taxonomic and functional diversity that is closely related to diversity and vegetation cover in different site stations and seasons.

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Spatiotemporal diversity, structure and trophic guilds of insect assemblages in a semi-arid Sabkha ecosystem

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Running title: **Insect Assemblages of a Sabkha Ecosystem**

Abstract

The current study highlights some knowledge on the diversity and structure of insect communities and trophic groups living in Sabkha Djendli (semi-arid area of Northeastern Algeria). The entomofauna was monthly sampled from March to November 2006 using pitfall traps at eight sites located at the vicinity of the Sabkha. Structural and diversity parameters (species richness, Shannon index, evenness) were measured for both insect orders and trophic guilds. The canonical correspondence analysis (CCA) was applied to determine how vegetation parameters (species richness and cover) influence spatial and seasonal fluctuations of insect assemblages. The catches totalled 434 insect individuals classified into 75 species, 62 genera, 31 families and 7 orders, where Coleoptera and Hymenoptera were the most abundant and constant over seasons and study stations. Spring and autumn presented the highest values of diversity parameters. Based on catch abundance, the structure of functional trophic groups was predator (37.3%), saprophagous (26.7%), phytophagous (20.5%), polyphagous (10.8%), coprophagous (4.6%); whereas in terms of numbers of species, they can be classified as phytophagous (40%), predators (25.3%), polyphagous (13.3%), saprophagous (12%), coprophagous (9.3%). The CCA demonstrated that phytophagous and saprophagous as well as Coleoptera and Orthoptera were positively correlated with the two parameters of vegetation, especially in spring and summer. While the abundance of coprophagous was positively correlated with species richness of plants, polyphagous density was positively associated with vegetation cover. The

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insect community showed high taxonomic and functional diversity that is closely related to diversity and vegetation cover in different site stations and seasons.

Keywords: Sabkha Djendli; entomological biodiversity; insect community ecology; pitfall trapping; Algeria; ecological niche; functional groups; wetlands; conservation biology; semi-arid lands.

1. Introduction

Wetlands are recognized as important ecosystems in terms of biodiversity and functional role. These ecosystems include a remarkable range of habitats that are ecologically considered among the most productive ecosystems worldwide, with large socio-economic importance and high heritage values for humanity. They play crucial and major ecological functions, including trapping, absorbing and eliminating of potential toxic chemicals and pollutants, storage of natural carbon, recycling of nutrients, as well as they contribute to groundwater recharge in arid and semi-arid regions. Unfortunately, wetlands are experiencing rapid degradation due to severe transformations related to intensive human activities (Bobbink et al., 2006; Mitsch et al., 2009).

More than 2000 wetlands are listed in Algeria, including 50 sites classified on the Ramsar list of wetlands of international importance (Balla 2012). Most of large inland saline depressions and backwaters “Sabkhas, Chotts, and Oases” are located in arid and semi-arid regions, with a unique agglomeration of this type of sites in northeastern of the country (Chenchouni & Si Bachir, 2010). The most characteristic type of the Algerian wetlands is seasonal/intermittent endorheic type that consists of Sabkha ecosystems “saline lakes” with typical alternation of drought phase in summer and flooding in winter (Khaznadar et al., 2009; Balla, 2012).

Large-scale conservation programs focused on wetlands because these habitats support both terrestrial and aquatic biota where biodiversity therein is remarkably high (De Roeck et al., 2007). This biodiversity is the key factor maintaining the structure, stability, and functioning of these ecosystems (Ivask et al., 2008). What makes its conservation at different organizational levels "individual, population, community, ecosystem" has become an issue that deserves national and international attention (Bobbink et al., 2006; Montagna et al., 2012). Moreover, regional contributions have also proven their impact in improving the knowledge and conservation of these habitats (Piñero et al., 2011; Chaibi et al., 2012; Guezoul et al., 2013).

As a biological model, invertebrates embrace a large species richness ranging over several taxa with large magnitude of sizes. They colonise various microhabitats and perform an extraordinary divers functional roles, constituting thus key organisms at different trophic levels inside food webs of wetland ecosystems (Koricheva et al., 2000; Finke & Denno, 2002; Haddad et al., 2009; Piñero et al., 2011). Although their relevant importance in ecosystem functioning of wetlands, invertebrates were slightly used as criteria in conservation programs of wetlands compared to specific criteria based on waterbirds and fishes, since only recently, these organisms as well as other taxa were included in the ninth criterion used by Ramsar Convention for considering wetlands internationally important (Mitsch et al., 2009).

Furthermore, it is well known that biodiversity and structure of invertebrates, particularly insects, in saline inland temporary wetlands are governed by two main abiotic factors: hydroperiod “water regimes” and salinity (Bilton et al., 2001; Brock et al., 2005; Gascon et al., 2005; Waterkeyn et al., 2008). Whereas the involved biotic factors are dealing with vegetation traits and various biotic interactions of food webs (Koricheva et al., 2000; Carver et al., 2009; Haddad et al., 2009). However, although species diversity is a good parameter for valuing ecosystems and defining conservation strategies, scarcity of species should also be taken into account (Nijboer & Verdonschot, 2004).

Notwithstanding the multi-scale ecological surveys that investigated animal biodiversity of the Algerian wetlands, specifically at the northeast of the country; they focused on waterbirds (e.g. Samraoui and Samraoui, 2008), fishes (e.g. Chaibi et al., 2012), and some other taxa like dragonflies (e.g. Samraoui et al., 2011), whereas the ecology of terrestrial arthropods of Sabkha ecosystems remain very little studied in these saline environments (Hogarth & Tigar, 2002).

Located in high plains of Northeast Algeria, the Sabkha Djendli is a seasonal salt lake whose flora was thoroughly surveyed throughout the waterbody vicinity (Neffar et al., 2014). However, the faunal communities, including insects, inhabiting the Sabkha and its environs were very little investigated in connection with their biotope, except some ornithological surveys of wintering waterbirds (e.g. Samraoui and Samraoui, 2008; Bensizerara et al., 2013).

The study of relationships between spatiotemporal variation of invertebrate communities and ecological parameters provides valuable information for conservation assessment and restoration planning and may efficiently guide the implementation of future management program (Comin & Comin, 1992; Fischer & Lindenmayer, 2007; Montagna et al., 2012). Furthermore, the assessment of functional trophic groups is crucial to outline the structure of food webs and accordingly identify any perturbation in the ecosystem functioning (Chesson & Huntly, 1997; Gascon, 2005), particularly under changing environmental conditions. Indeed, some insect groups such as dragonflies, hoverflies and some ground beetles (particularly Carabidae) represent good indicators of biodiversity assessment and monitoring in wetlands and mesic environments (Rainio & Niemelä, 2003; Sánchez-Fernández et al., 2006; Hepp & Melo, 2013). In fact the core aim of the current study is placed within the perspective of insect biodiversity assessment for conservation purpose as outlined here above.

Thereby, the objectives of this pioneer study are dealing with the framework of understanding entomofauna composition of Sabkha Djendli. This treatise aims to (i) provide accurate information on the spatiotemporal variation of the composition, structure and diversity indices of the insect community inhabiting the vicinity of the Sabkha; (ii) evaluate ecological status and diversity of the functional trophic groups in relation to seasons and site orientations of the salt lake; (iii) understand the structural and functional similarities of entomofauna communities living around the Sabkha; (iv) assess the effect of seasons and site orientations on the spatiotemporal abundance variations of both insect orders and functional trophic groups; and (v) determine how vegetation parameters influence spatial and seasonal fluctuations of insect assemblages.

2. Materials and methods

2.1. Study area

Sabkha Djendli (35°42'56"N, 6°31'46"E) is one part of the wetland complex at the High Plains region including Batna in eastern Algeria (Figure 1). The site is a temporary lake with brackish–salt water that highly depends on rainfall amounts and water regime. Sabkha Djendli covers about 3,700 ha with an average altitude of 833 m in an area where inhabitants are mainly involved in agricultural activities like cereal and fruit cultivation and livestock of sheep and cattle.

Based on meteorological data provided by the meteorological station of Batna (WMO Id: 60468) of the period 1974–2013, the climate of the study area is typically semi-arid Mediterranean, characterised by cold-wet winters and hot-dry summers. The dry period extends over four months from June to September. Precipitations are erratic and experience large temporal variations. The coldest month is January with an average temperature of 5.3°C and the hottest month is July with an average temperature of 25°C. The relative humidity of the air fluctuates between 40% to

75% and the winds are generally low in dominance west to south-west, with the passage of Sirocco in summer during July–August.

The natural vegetation is represented by halophytes such as *Atriplex halimus*, *Suaeda fructicosa*, *Suaeda vermiculata*, and *Sarcocornia fructicosa*, but also other spontaneous vegetation like *Tamarix gallica*, *Artemisia herba-alba* and *Juncus maritimus* (Neffar et al., 2014). The current entomological survey was carried on the belt of halophytic vegetation surrounding the Sabkha (Figure 1).

2.2. Sampling design

At eight cardinal and inter-cardinal points of the site border of Sabkha Djendli, the insect fauna was monthly sampled during the period March to November 2006. Halophytic vegetation dominated in the entire sampled area. At each sampling points, insects were trapped using nine pitfall traps (Spence & Niemela, 1994), which were set up inside a square plot of 400 m² (20 m × 20 m). These uncovered traps are aligned 3–3 along three rows and spaced from each other with 5 m (Figure 1). Each trap was filled to 3/4 of water containing a wetting agent, and its catches were monthly recovered after one week trapping since first setting day. The caught specimens were identified to the genus and species. The nomenclature and taxonomy of species were based on up-to dated references (Bouchard et al., 2011; de Jong 2013; Löbl and Smetana, 2013; Anichtchenko et al., 2014; AntWeb, 2014; Eades et al., 2014).

2.3. Data mining and statistical analysis

Data of insect catches from the nine uncovered traps were pooled to form one sample per sampling station per month. Data were presented by taxonomic orders and trophic groups and were expressed for orientation points and seasons to facilitate spatiotemporal comparisons for all the following parameters. The relative abundance

(*RA*) was determined as the ratio of number of individuals rounded to the total number of individuals recorded (*Ni*). Occurrence frequency (Occ) was calculated for each species by the number of stations wherein the species was found / the total number of sampled stations (Magurran, 2004). Four species groups are distinguished by Bigot and Bodot (1973), according to their frequencies of occurrence: Very accidental species (Vac): an occurrence of less than 10%; Accidental species (Acc) occurrence varies between 10 and 24%; Common species (Cmt) are present in 25–49%; Constant species (Cst) are present in 50% or more of the samples.

Biodiversity of insects was assessed by species richness "*SR*", which corresponds to the total number of identified insect species at each station or season. In addition, Shannon's index ($H' = -\sum pi \times \log_2 pi$) and evenness ($\text{Evenness} = H'/\log_2 SR$) were applied for measuring insect diversity in each sampled station and season period based on the relative density *pi* of the i^{th} species (Magurran 2004).

Jaccard similarity index (C_J) was used to compare insect species richness between stations taken in pairs. Given two stations A and B, C_J was computed as: $C_J = c / (a + b - c)$. Where *a* and *b* = the total number of species present in station A and B, respectively; *c* = the number of species found in both stations (Magurran, 2004). Agglomerative hierarchical clustering (AHC) was applied to cluster sampled stations according to their species richness based on Jaccard similarity index (C_J). The method used in agglomeration was unweighting pair–group average.

Two-way ANOVAs were applied including the effect of 'Orientation' and 'Season' to test spatiotemporal variations of abundances of both taxonomic orders and trophic groups. Moreover, Pearson's Chi-squared test (χ^2) was applied to look for dependencies between the distributions of structural traits values (*Ni*, *SR*, *Ni/SR*, *H*', Evenness) of the functional trophic groups vis-à-vis both study stations and seasons.

The spatiotemporal gradients of insect assemblages were analyzed in relation with vegetation traits using a canonical correspondence analysis (CCA). The data used were the abundances of both taxonomic orders and trophic groups on the study seasons and orientations where they were counted. For the spontaneous vegetation, two parameters were assessed at each orientation and season: the vegetation cover (%) and total species richness (number of plant species). These data were generated from Neffar et al. (2014). Since the CCA has the ability to combine ordination and gradient analysis functions in a readily interpretable manner, it was applied to relate spatiotemporal insect abundances to vegetation variables in order to highlight relationships between spatiotemporal variations of insects and vegetation traits as explanatory variables (Jongman et al., 1995). At the end of overcoming the disadvantage effect of scale differences in data, insect densities as well as vegetation variables were normalized using normal distribution transformation based on the average and standard deviation of each input. Finally, Pearson's correlation was used to test the significance of relationships between densities of insect assemblages (of both taxonomic orders and trophic groups) and vegetation parameters (vegetation cover and species richness).

3. Results

3.1. Insect community and taxonomic composition

Pitfall sampling of entomofauna at Sabkha Djendli revealed an insect community composed of 75 species from 434 individuals caught. This entomofauna can be classified into 7 orders, 31 families and 62 genera (Table 1). Coleoptera was the best represented with 238 (54.8%) individuals caught belonging to 39 species and 15 families, followed by Hymenoptera with 149 (34.3%) individuals of 18 species and 8 families, then came Orthoptera with 22 individuals (10 species and 2 families). The orders Dermaptera, Heteroptera, Homoptera and Diptera were poorly represented by either species or catch abundance. Furthermore, the identified entomofauna included five functional trophic groups: the phytophagous with 30 species, predators with 19 species, polyphagous with 10 insects, saprophagous with 9 species and coprophagous with 7 species.

3.2. Relative abundance and occurrence

The main species with high relative abundance (*RA*) of catch were *Calathus circumseptus* (21.9%), *Cataglyphis biskrense* (15.4%), *Tetramorium biskrensis* (6%), *Zabrus* sp. (3.9%), *Anomala dubia* (3.9%), *Scarites laevigatus* (3.7%) and *Carabus* sp. (3%), respectively. Furthermore, families that dominated in terms of catches belonged to Coleoptera and Hymenoptera, including Formicidae with a total of 111 individuals (25.6%), Carabidae with 95 individuals (21.9%), Carabidae with 53 individuals (12.2%) and Scarabeidae with 40 individuals (9.2%), and Apidae with 29 individuals the equivalent of 6.0% of total caches (Table 1).

Regarding spatial occurrence of insect species at the eight sampled stations, almost all species (66 species) were accidental and very accidental, nevertheless three species were constant (Occ ≥ 50%) during the study period: *Chlaenius circumseptus* (Callistidae), *Cataglyphis bicolor* (Formicidae) and *Tetramorium biskrensis* (Formicidae). Common species (Occ = 25–50%) were characterized by six species: *Scolia* sp. (Scoliidae), *Apis mellifera* (Apidae) *Zabrus* sp. (Carabidae) *Carabus* sp. (Carabidae) *Scarites laevigatus* (Carabidae) *Forficula auricularia* (Forficulidae) (Table 1).

3.3. Spatiotemporal composition and diversity

The sampled station located southern Sabkha Djendli possessed the highest values of catch seize (93 individuals, *RA*=21.4%), species richness (27 species) and the ratio *Ni/SR* (3.4). Whereas the highest values of Shannon index and evenness were respectively recorded at station of West, Southeast, South, and East. Although this later station (East) had the lowest values of insect composition (Ni=43, RA=9.9%, SR=19).

As for seasons, values of diversity parameters of insect assemblages were higher during spring and autumn, with a slight leaning to spring values. However, the summer scored the lowest values. Overall, sampling insects using pitfall traps at Sabkha Djendli revealed a diversity equals to 4.7 bits according to Shannon index with an evenness of 76% (Table 2).

Despite the differences in insect abundances between seasons and study plot orientations, analysis of variance revealed no significant differences for the various taxonomic orders of identified insects based on two factors 'Orientation' and 'Season' (Table 3).

3.4. Spatial similarities of the entomofauna

The assessment of similarities of insect assemblage compositions between the sampled stations based on species richness revealed low similarities ranging between 12.8 and 35.3%. The highest values of Jaccard index (C_J=35.3%) were observed between North and West stations (Table 4).

According to values of Jaccard's index, the eight sampled stations were clustered into four different groups: (i) the first group gathered all stations located at South, East and West of the Sabkha including E, S, W, SE and NE, (ii) the SW station was distinguished alone and (iii and iv) the third and the fourth class represented by NW and N, respectively (Figure 2).

3.5. Structure and diversity of functional trophic groups

Predators and saprophagous held the highest catch rates with 37.3% and 26.7% of the total, respectively. Predators were more pronounced in south stations (42 ind.) especially in autumn (74 ind.) and spring (62 ind.), while saprophagous are concentrated in southwest (24 ind.) and south (22 ind.) stations during the summer (46 ind.).

In terms of numbers of species, phytophagous were the most abundant with 30 species distributed almost equally along seasons and sampled stations. As for *Ni*/*SR* ratio, it varied between 1 and 11 with an average of 3.2 in study stations and seasons, i.e. that each species of a given trophic group comprises an average of 3.2 individuals. This ratio is higher in saprophagous with 12.9, chiefly in stations of south (11), northwest (8.5), southwest (8), during the summer (9.2) and spring (9). Predators came in second place with 8.5 individuals per species.

The Shannon's index showed high diversity among phytophagous (H'=4.3) in both seasons and sampled stations. The values of this index were lower among predators, less important in polyphagous. Regarding saprophagous, the values recorded the lowest rates. Similarly to evenness, where coprophagous (91%), phytophagous (87%) and polyphagous (83%) showed higher values compared to values of predators (68%) and saprophagous (36%). It is noteworthy that apart from evenness, the coprophagous indicated the lowest values of ecological indices calculated for different trophic groups of insects.

The Chi-square test revealed a significant dependence for the distribution of the number of individuals of trophic groups along the orientations (χ^2=80.62, P<0.001) and seasons (χ^2=24.57, P=0.002) (Table 5). However, no significant dependence was observed for the rest of the features (Species richness, *Ni*/*SR* ratio, Shannon index, evenness) of trophic groups according to stations orientations and seasons.

Although the Chi-square test revealed a significant dependence for abundances of trophic groups on site directions and seasons (Table 5). However, the ANOVA showed that the abundance of each trophic group did not vary significantly according to seasons nor station orientations, except for the variation of polyphagous numbers between site orientations (P=0.015) (Table 6).

3.6. Relationship between insect communities and vegetation

The Eigenvalues of CCA applied for insect assemblages and vegetation parameters in canonical axis 1 and 2 were high and explaining 65.55% and 34.45% of constrained inertia, respectively. According to CCA, the density of polyphagous was positively associated with vegetation cover, but this parameter had a negative influence on the number of individuals of predators, Hymenoptera and Dermaptera, especially in autumn at northeast, southeast, north and east stations. In addition, coprophagous abundance was positively related with species richness of plants, however, Diptera and Homoptera were located on the negative side of the axis representing species richness of plants; and this in northwest, west, southwest and west stations. The phytophagous and saprophagous as well as Coleoptera and Orthoptera were also positively correlated with the both axes of the parameters of vegetation, particularly in spring and summer seasons. Conversely, the two parameters of vegetation negatively influenced on Heteroptera densities in north and east stations (Figure 3).

All the obtained significant-correlations were positive with vegetation parameters. These concerned the abundances of Dermaptera in connection with species richness of plants; and Orthoptera and Coleoptera with vegetation cover and richness of plants. As for the trophic groups of the entomofauna, the correlation test was significant for the numbers of polyphagous, phytophagous and saprophagous vs. vegetation cover on the one hand, and coprophagous, phytophagous and Saprophagous vs. plant species richness on the other (Table 7).

4. Discussion and conclusion

Salt lakes offer exceptional conditions for ecological studies of aquatic ecosystems, due to the frequency and intensity of changes in the biological communities compared to freshwater ecosystems (Comin & Comin, 1992). This feature is most notable in arid regions, so that these habitats are home to many original and well-adapted life forms (Chenchouni, 2012a).

Out of all the conducted samples, the Sabkha of Djendli houses 75 insect species related to 31 families and 7 orders. In terms of individual numbers caught, the orders of Coleoptera and Hymenoptera dominate other insect orders, while Dermaptera, Heteroptera, Homoptera and Diptera are slightly present with very similar densities in different study stations. This distribution of the composition could be attributed to the low dispersal ability of these insects, as well as the scarcity of these categories (Cobos, 1987), but mostly to the ineffectiveness of pitfall traps to capture flying insects since this type of trap is specifically designed for ground arthropods (Spence & Niemelä, 1994).

Since saline environments in hot arid regions are characterized by large spatial and temporal fluctuation of water level and salinity, community of inland insects can be modelled either by the synergistic effect of several factors (abiotic and biotic) that are related to these two parameters; or by the predominance of one factor over others (e.g. vegetation parameters) (Vidal-Abarca et al., 2004; Velasco et al., 2006). Moreover, the state of the composition of insect assemblage in inland saline environments can be explained by the morphological and physiological adaptations necessary to cope with the extreme and unpredictable conditions of these habitats on one hand, and their life cycle, phenological adaptations and behaviour on the other hand (Cloudsley-Thompson, 1975; Louw and Seely, 1982).

The study of variations in the frequency of abundance and occurrence of different insect orders shows that the beetles represent the most abundant order that appears regularly in different sampling stations during the study period. This frequency is reflected by the presence of three constant species (Coleoptera and Hymenoptera), six common species (Coleoptera, Hymenoptera and Dermaptera) and 66 accidental species. This finding is in contrast to the observation made by

Boix et al. (2008) where it has been found that beetles are the most affected group within insects of saline environments, while our results are similar to those of Vidal-Abarca et al. (2004) who argue that in the salt wetlands of arid and semi-arid areas, Coleoptera and Diptera were the most abundant groups because of their large adaptation to critical and extreme conditions. It is well known that the beetles are the most abundant and occurring insect group in nature (Bouchard et al., 2011). In addition to their dominance in the animal kingdom, they are an important food resource for consumers at different levels in the food web; thereby their number of species represents a good biological indicator of habitat quality (Rainio & Niemelä, 2003; Sánchez-Fernández et al., 2006). Moreover, because of their sensitivity to environmental modifications, they constitute a model of choice for assessing the diversity of habitats (Haddad et al., 2009).

Regarding insect species richness, the highest value is recorded in the west and south stations with 27 species. According to Neffar et al. (2014), these stations are characterized by certain homogeneity in their floristic composition. These areas are grazed and fertilized by dung they receive and therefore stimulate the development of certain flowering herbaceous and thus attract more pollinators. While cattle dung favor the abundance of coprophagous, mostly Scarabaeidae in our case. These observations were confirmed by the CCA where we found that coprophagous density was positively correlated with plant diversity, which was negatively associated with west and south stations. The vegetation significantly affects the different trophic groups (herbivores, parasitoids and predators) of the insect fauna living at the herbaceous layer, through its floristic composition and functional diversity (Koricheva et al. 2000), but also through the density of vegetation cover that creates a microclimate for soil-dwelling species (Siemann, 1998). According to Haddad et al. (2009), species richness of predators and herbivores is positively related to species richness and plant biomass, without being affected by its composition. However, in lentic ecosystems, high electrical conductivity causes a significant decline in the abundance and taxonomic richness of macroinvertebrate fauna (Waterkeyn et al., 2008; Carver et al., 2009).

Based on the values of the Shannon index and evenness, insect diversification is well marked in the different stations and seasons, indicating a balance between the number of sampled invertebrate populations, although it may be that the constituent species of assemblages are generalists, adapting to most environmental conditions, as suggested by Rainio & Niemelä (2003) and Montagna et al. (2012).

Furthermore, the dominance of accidental species (66/75) may be connected to the sparce structure of vegetation of the Sabkha. Because the presence of dense vegetation reduces predation against herbivores that therein also find abundant food, but also reduces the antagonistic effect between predators (Finke & Denno, 2002); this is not the case with the open vegetation of Sabkha Djendli which is characterized by a medium to low coverage (Neffar et al. 2014). Otherwise the same type of structure and composition of vegetation cover are almost noted in arid and semi-arid wetlands of Algeria and North Africa (Khaznadar et al., 2009; Chenchouni, 2012b). This particular pattern of species occurrences may also be explained by the unpredictable environmental changes inciting species to the coexistence, and consequently the increase of diversity (Chesson & Huntly, 1997; Piñero et al., 2011). But generally, seasonality remains the primary determinant factor of invertebrate diversity in any ecosystem (Wolda, 1988). Because the metabolism of poikilotherms requires low investment in energy, making of these invertebrates highly effective organisms for the survival in extreme environments (Heatwole, 1996). This explains the significant variation in predator numbers between the studied seasons.

The study of trophic status of insect species reveals their affiliation to different ranks of consumers and thus these species virtually occupy different levels in the food web. Species richness decreases in the following order herbivores> predators>

polyphagous> saprophages> coprophagous with 40%, 25.3%, 13.3%, 12.0% and 9.3%, respectively. According Piñero et al. (2011), seasonal variations have profound effects not only on the number of species, abundance and biomass of invertebrates during different times of the year, but also on the trophic and functional structures of communities. For his part, Siemann (1998) suggested that the diversity, quality and/or composition of plant species can in their turn influence the diversity of higher trophic levels, not only by changing the diversity of herbivores, parasites and predators but also by affecting the quality of the food of herbivores and the ease with which they can be captured. Therefore, the spatiotemporal variation in traits of vegetation (composition and cover) between the eight stations and seasons (Neffar et al., 2014) is the cause of the significantly uneven spatiotemporal distribution (according to Chi-square test) of insect group densities. Indeed, the CCA has allowed the characterization of insect assemblage responses to vegetation parameters.

The comparison of specific composition between different stations using the Jaccard index shows low similarity values, commonly not exceeding 35%. This similarity would find its explanation in the heterogeneity of ecological conditions for this fauna, in particular the composition and structure of the sparse vegetation which is based of halophytes including *Suaeda* spp. *Atriplex* spp. and *Salicornia* spp. (Neffar et al., 2014), reflecting thus the degraded conditions prevailing on the physicochemical properties of soil in which they grow (Khaznadar et al., 2009). According to Baguette (1992), the inter and intra-specific competitions, predation and parasitism regulate the spatial and temporal distribution of species and structure communities. Also, the distribution of a given species is a dynamic phenomenon that involves a set of extinction and recolonisation stages of local populations following changes in environmental conditions. Even more so, several studies have shown that changes in communities across habitats are influenced by environmental variables, in particular the type of substrate (Ligeiro et al., 2010) and even the coarse organic matter (Hepp & Melo, 2013).

The spatial variability of the insect fauna of Sabkha Djendli is related to the combination of several factors, among others, the climate is critical to the distribution of arid arthropods (Langlands et al., 2006), the reproductive potential and dispersal capabilities (Thompson and Townsend, 2006), and environmental heterogeneity may be a contributing factor to their low dispersion.

The halophytic belt of Sabkha Djendli have a high richness of insects especially in spring and autumn, coinciding in part with their breeding period. As the recorded species are mostly phytophagous, their number naturally increases in the spring with the increase of plant diversity and vegetation cover, whereas the predators generally depend on the availability of prey (Koricheva et al., 2000; Haddad et al., 2009). This statement is supported by findings of the CCA where the abundant insect groups (Coleoptera, phytophagous) were found linked to vegetation parameters mainly in spring and summer.

Following this study, the use of pitfall traps in Sabkha Djendli revealed some knowledge about the entomofauna. The insect community shows high taxonomic richness and diversity in different stations and seasons. The composition of functional trophic groups are closely related to diversity and vegetation cover. The conservation of this biological heritage so rich but little known, non-invested and generally underestimated by managers, can only be possible by improving and deepening our knowledge about biodiversity including the functional communities in relation with threatening factors and disturbances that affect the proper conduct of their vital activities.

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1

Figure 1

Location of the sampled station and sites at Sabkha Djendli (Batna, Northeast Algeria) and sampling design of pitfall traps.

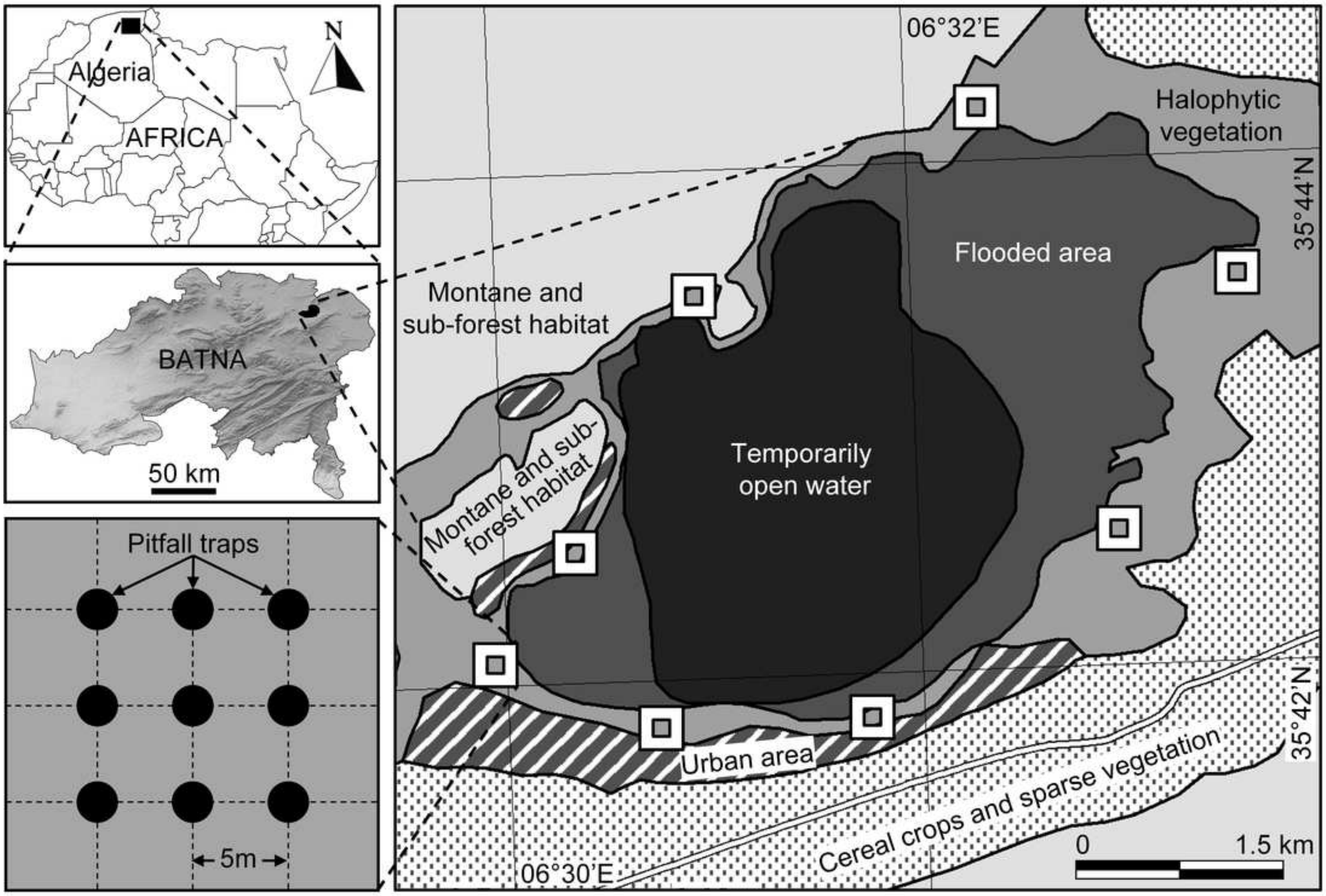

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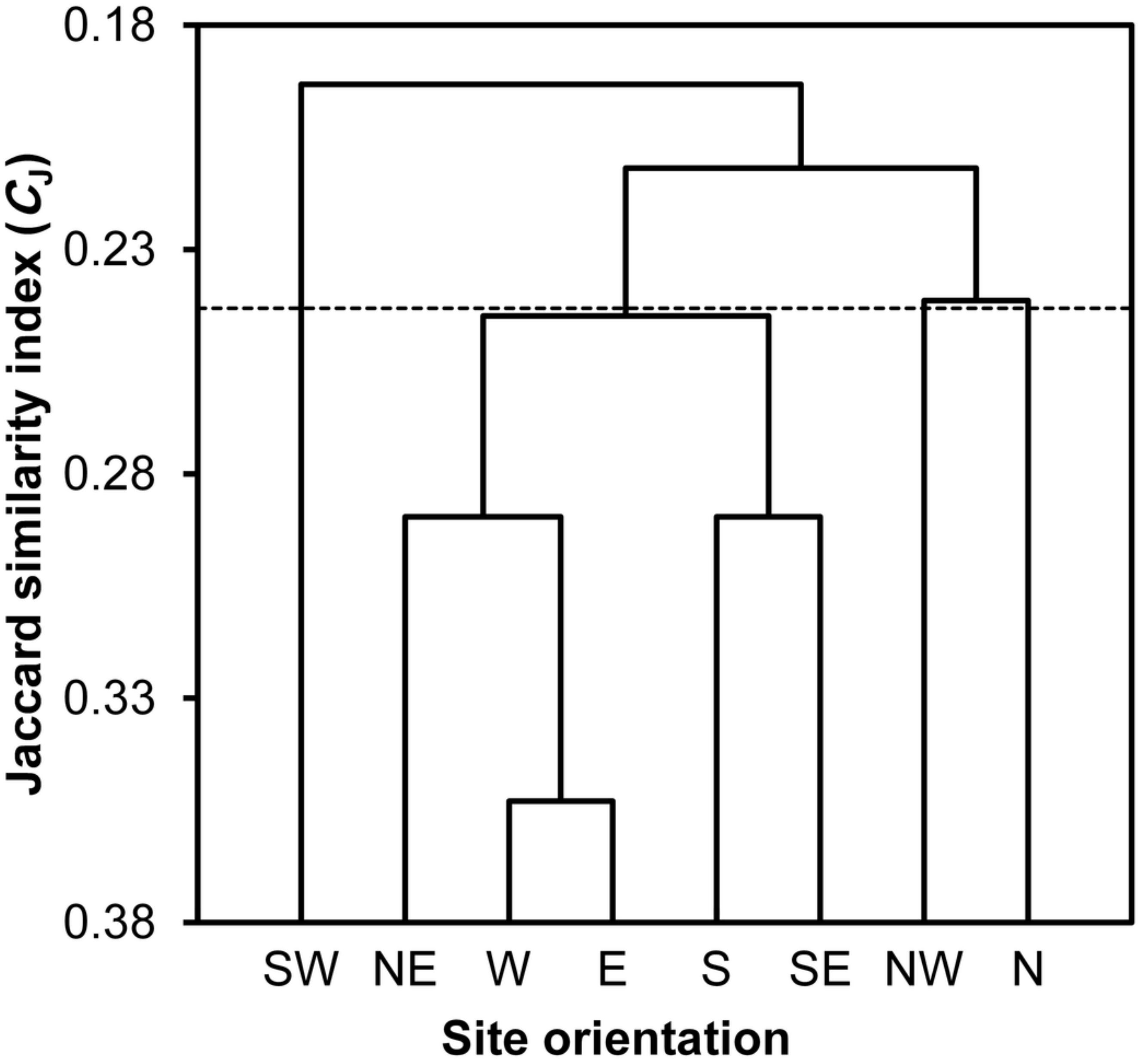
Figure 2

Dendrogram of agglomerative hierarchical clustering (AHC) illustrating species richness similarity (Jaccard coefficient) among insects captured from eight stations around Sabkha Djendli (linkage rule: unweighted pair-group average).



3

Figure 3

Diagram of the canonical correspondence analysis (CCA) relating spatial and seasonal densities of insect assemblages of both taxonomic orders and trophic groups with vegetation cover and species richness. (Cop: coprophagous, Phy: phytophagous, Pol: polyphagous, Pre: predator, Sap: saprophagous).

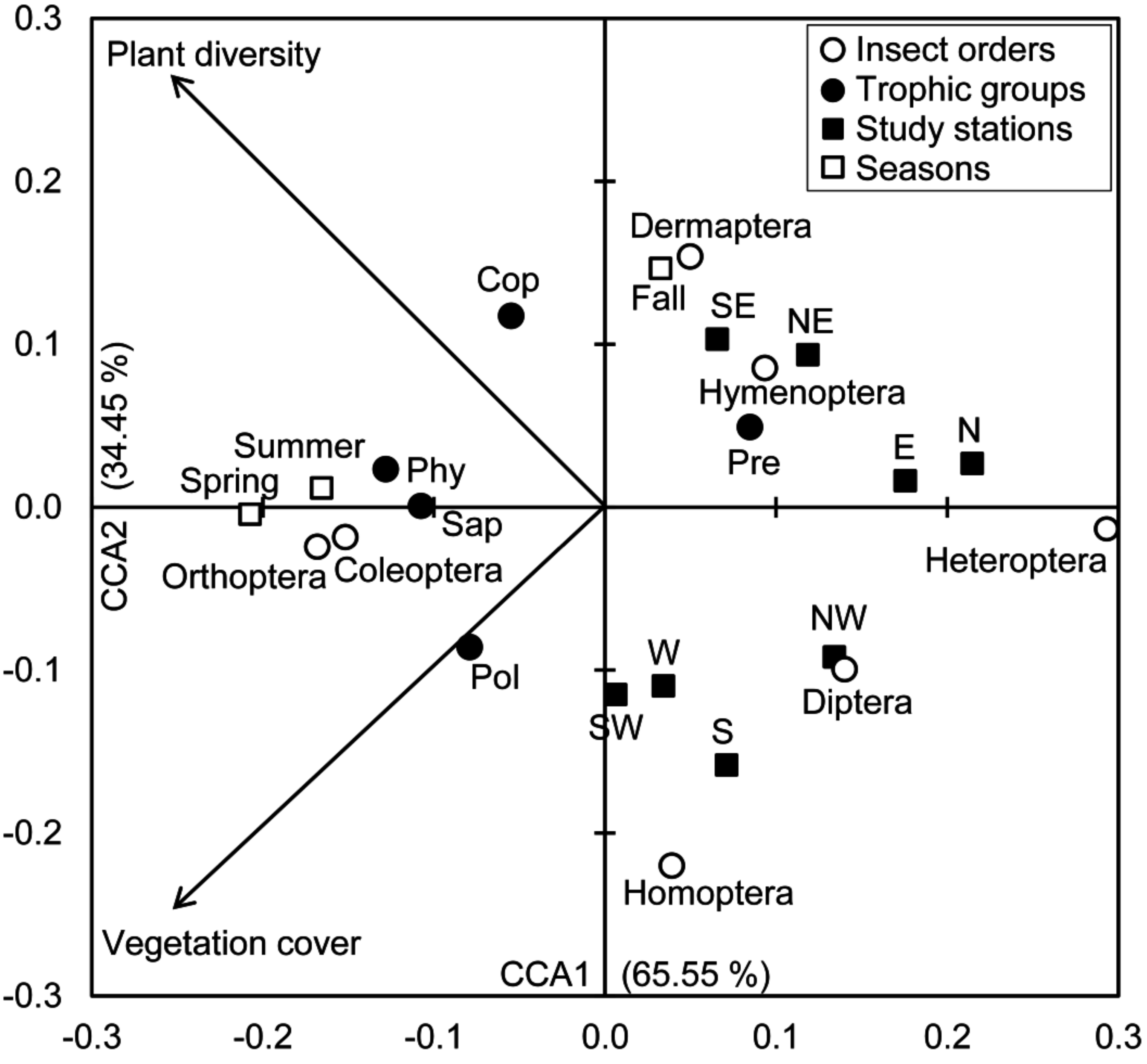


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Table 1(on next page)

Table 1

Systematic list, trophic status, abundances and occurrences of insect species captured using pitfall traps at edges of Sabkha Djendli, Northeast Algeria. (RA: relative abundance (%), FTG: functional trophic groups, Ni: total number of caught individuals, Occ: occurrence frequency, Cop: coprophagous, Phy: phytophagous, Pol: polyphagous, Pre: predator, Sap: Saprophagous, Vac: very accidental species, Acc: accidental species, Cmt: common species, Cst: constant species)

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Classification (RA in %)	Species	FTG	Ni	RA	Occ	Scale
O: DERMAPTERA (3.2)						
F: Forficulidae (3.2)	*Anisolabis mauritanicus*	Pol	4	0.92	16.7	Acc
	Forficula auricularia	Pol	10	2.30	25.0	Cmt
O: ORTHOPTERA (5.1)						
F: Gryllidae (2.1)	*Acheta domesticus*	Phy	3	0.69	12.5	Acc
	Gryllus bimaculatus	Phy	2	0.46	8.3	Vac
	Gryllus campestris	Phy	2	0.46	8.3	Vac
	Gryllus sp.	Phy	2	0.46	8.3	Vac
F: Acrididae (3.0)	*Acrotylus patruelis*	Phy	3	0.69	12.5	Acc
	Calliptamus barbarus	Phy	4	0.92	12.5	Acc
	Ephippiger sp.	Phy	1	0.23	4.2	Vac
	Oedipoda fuscocincta	Phy	3	0.69	12.5	Acc
	Sphingonotus rubescens	Phy	1	0.23	4.2	Vac
	Sphingonotus sp.	Phy	1	0.23	4.2	Vac
O: HETEROPTERA (0.2)						
F: Lygaeidae (0.2)	*Lygaeus sexatilis*	Phy	1	0.23	4.2	Vac
O: HOMOPTERA (0.2)						
F: Cicadellidae (0.2)	*Cicadela variabilis*	Phy	1	0.23	4.2	Vac
O: COLEOPTERA (54.8)						
F: Cicindelidae (0.7)	*Calomera littoralis*	Pre	1	0.23	4.2	Vac
	Cassolaia maura	Pre	2	0.46	8.3	Vac
F: Callistidae (21.9)	*Calathus circumseptus*	Sap	95	21.89	87.5	Cst
F: Carabidae (12.2)	*Calathus* sp.	Pre	1	0.23	4.2	Vac
	Macrothorax morbillosus	Pre	1	0.23	4.2	Vac
	Carabus sp.	Pre	13	3.00	37.5	Cmt
	Scarites laevigatus	Pre	16	3.69	41.7	Cmt
	Scarites sp.	Pre	5	1.15	16.7	Acc
	Zabrus sp.	Phy	17	3.92	33.3	Cmt
F: Geotrupidae (0.9)	*Geotrupes* sp.	Sap	4	0.92	16.7	Acc
F: Scarabaeidae (9.2)	*Geotrogus* sp.	Sap	7	1.61	16.7	Acc
	Anomala dubia	Pol	17	3.92	20.8	Acc
	Bubas bison	Cop	4	0.92	16.7	Acc
	Gymnopleurus flagellatus	Cop	4	0.92	16.7	Acc
	Onthophagus taurus	Cop	5	1.15	20.8	Acc
	Oxythyrea funesta	Phy	1	0.23	4.2	Vac
	Scarabaeus sacer	Cop	1	0.23	4.2	Vac
	Scarabaeus sp.	Cop	1	0.23	4,2	Vac
F: Silphidae (0.2)	*Silpha opaca*	Pre	1	0.23	4.2	Vac
F: Staphylinidae (0.7)	*Staphylinus olens*	Pol	3	0.69	12.5	Acc
F: Cetonidae (0.5)	*Cetonia ablonga*	Phy	1	0.23	4.2	Vac
	Cetonia funeraria	Phy	1	0.23	4.2	Vac
F: Cantharidae (0.2)	*Cantharis* sp.	Phy	1	0.23	4.2	Vac
F: Meloidae (1.4)	*Mylabris crocata*	Phy	1	0.23	4.2	Vac
	Mylabris quadripunctata	Phy	2	0.46	8.3	Vac
	Mylabris variabilis	Phy	3	0.69	12.5	Acc
F: Tenebrionidae (2.3)	*Adesmia microcephala*	Sap	1	0.23	4.2	Vac
	Blaps mortisaga	Sap	1	0.23	4.2	Vac
	Blaps nitens	Sap	1	0.23	4.2	Vac
	Opatrum sp.	Sap	2	0.46	8.3	Vac
	Tentyria bipunctata	Sap	1	0.23	4.2	Vac
	Tentyria sp.	Sap	4	0.92	12.5	Acc
F: Dermestidae (1.2)	*Dermestes* sp.	Cop	1	0.23	4.2	Vac
	Trogoderma sp.	Cop	4	0.92	16.7	Acc

F: Cucujidae (0.7)	*Canthartus* sp.	Pol	3	0.69	8.3	Vac
F: Curculionidae (0.5)	*Coniocleonus excoriatus*	Phy	1	0.23	4.2	Vac
	Lixus punctiventris	Phy	1	0.23	4.2	Vac
F: Chrysomelidae (2.3)	*Chrysomela* sp.	Phy	9	2.07	16.7	Acc
	Entomoscelis sp.	Phy	1	0.23	4.2	Vac
O: HYMENOPTERA (34.3)						
F: Formicidae (25.6)	*Camponotus* sp.	Pre	1	0.23	4.2	Vac
	Cataglyphis bicolor	Pre	67	15.44	58.3	Cst
	Messor barbarous	Pre	7	1.61	12.5	Acc
	Pheidole pallidula	Pol	1	0.23	4.2	Vac
	Tapinoma nigerrimum	Pre	9	2.07	20.8	Acc
	Tetramorium biskrense	Pre	26	5.99	50.0	Cst
F: Vespidae (0.2)	*Polistes gallicus*	Pre	1	0.23	4.2	Vac
F: Apidae (4.9)	*Apis mellifera*	Phy	10	2.30	29.2	Cmt
	Apis sp.	Phy	5	1.15	16.7	Acc
	Bombus pascuorum	Phy	2	0.46	4.2	Vac
Megachilidae (1.2)	*Megachile* sp.	Phy	5	1.15	16.7	Acc
Halictidae (0.9)	*Sphecodes* sp.	Phy	1	0.23	4.2	Vac
	Halictus sp.	Phy	3	0.69	12.5	Acc
F: Scoliidae (1.6)	*Scolia* sp.	Pre	7	1.61	25.0	Cmt
F: Sphecidae (0.7)	*Ammophila hirsute*	Pre	1	0.23	4.2	Vac
	Ammophila sabulosa	Pre	1	0.23	4.2	Vac
	Sphex funerarius	Pre	1	0.23	4.2	Vac
F: Mutillidae (0.2)	*Mutilla* sp.	Pre	1	0.23	4.2	Vac
O: DIPTERA (2.1)						
F: Tabanidae (0.5)	*Tabanus* sp.	Pol	2	0.46	8.3	Vac
F: Muscidae (0.7)	*Musca domestica*	Pol	1	0.23	4.2	Vac
	Musca sp.	Pol	2	0.46	8.3	Vac
F: Sarcophagidae (0.9)	*Sarcophaga* sp.	Pol	4	0.92	16.7	Acc

Table 2(on next page)

Table 2

Spatial and seasonal variation of the diversity parameters of insect assemblages in Sabkha Djendli, Northeast Algeria

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Parameter	Orientation								Season			Total
	S	SW	W	NW	N	NE	E	SE	Spring	Summer	Fall	
Abundances (*Ni*)	93	48	60	44	52	50	43	45	163	116	155	434
RA (%)	21.4	11.0	13.8	10.1	11.8	11.5	9.9	10.3	37.5	26.7	35.6	100
Species richness (*SR*)	27	24	27	19	17	22	19	22	46	38	51	75
Ratio *Ni/SR*	3.4	2.0	2.2	2.3	3.1	2.3	2.3	2.0	3.5	3.1	3.0	5.8
Shannon index (*H*')	3.9	3.6	4.1	3.5	3.1	3.8	3.7	3.9	4.5	4.0	4.6	4.7
Evenness (%)	81	79	86	83	77	84	86	87	82	76	82	76

Table 3(on next page)

Table 3

ANOVAs testing the variances in the abundance of insect orders according to site orientations and study seasons in Sabkha Djendli, Northeast Algeria

Orders	Variations	*Df*	*MS*	*F*	*P*
Dermaptera	Season	2	0.17	0.17	0.845
	Orientation	7	1.12	1.15	0.390
	Residuals	14	0.98		
Orthoptera	Season	2	1.04	0.92	0.423
	Orientation	7	0.55	0.48	0.832
	Residuals	14	1.14		
Heteroptera	Season	2	0.04	1.00	0.393
	Orientation	7	0.04	1.00	0.471
	Residuals	14	0.04		
Homoptera	Season	2	0.04	1.00	0.393
	Orientation	7	0.04	1.00	0.471
	Residuals	14	0.04		
Coleoptera	Season	2	15.04	0.60	0.561
	Orientation	7	29.21	1.17	0.378
	Residuals	14	24.95		
Hymenoptera	Season	2	54.29	1.56	0.246
	Orientation	7	47.23	1.35	0.298
	Residuals	14	34.91		
Diptera	Season	2	0.50	1.11	0.358
	Orientation	7	0.33	0.72	0.655
	Residuals	14	0.45		

Table 4 (on next page)

Table 4

Similarity matrix of insect assemblages in the studied sites at Sabkha Djendli, Northeast Algeria. The values are referred to Jaccard similarity index "C_J" (under the diagonal) and the number of shared species (above the diagonal). Station locations "orientations" of the first row are associated in the first column with species richness (*SR*) values

Orientations	S	SW	W	NW	N	NE	E	SE
SE (22)	11	7	9	6	8	8	6	
E (19)	9	7	12	7	6	10		17.1
NE (22)	11	8	10	8	6		22.2	32.3
N (17)	7	5	5	7		25.8	20.0	18.2
NW (19)	10	8	9		17.1	22.6	24.2	24.1
W (27)	13	8		22.5	35.3	25.6	12.8	24.3
SW (24)	9		17.9	19.4	21.1	13.9	22.9	18.6
S (27)		28.9	24.3	28.9	18.9	27.8	31.7	21.4

Table 5(on next page)

Table 5

Spatial and seasonal variations of insect trophic guilds living in Sabkha Djendli, Northeast Algeria

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	Orientations								Seasons			Total
Parameter	S	SW	W	NW	N	NE	E	SE	Spring	Summer	Fall	
Individual numbers	(χ^2_{28}=80.62, *P*<0.001)								(χ^2_{8} =24.57, *P*=0.002)			
Coprophagous	4	1	4	1	0	3	3	4	8	5	7	20 (4.6%)
Phytophagous	20	10	13	7	8	6	11	14	35	26	28	89 (20.5%)
Polyphagous	4	3	19	7	5	4	2	3	22	13	12	47 (10.8%)
Predator	42	10	21	12	28	21	15	13	62	26	74	162 (37.3%)
Saprophagous	22	24	3	17	11	16	12	11	36	46	34	116 (26.7%)
Species richness	(χ^2_{28}=15.65, *P*=0.971)								(χ^2_{8} =4.81, *P*=0.777)			
Coprophagous	4	1	3	1	0	2	3	3	4	4	5	7 (9.3%)
Phytophagous	8	9	8	7	6	6	6	9	19	14	15	30 (40%)
Polyphagous	4	3	5	4	3	2	2	2	9	5	8	10 (13.3%)
Predator	8	8	8	5	5	8	4	6	10	9	15	19 (25.3%)
Saprophagous	2	3	3	2	3	4	4	2	4	5	8	9 (12%)
Ratio *Ni/SR*	(χ^2_{28}=22.09, *P*=0.779)								(χ^2_{8} =3.35, *P*=0.911)			
Coprophagous	1.0	1.0	1.3	1.0	0.0	1.5	1.0	1.3	2.0	1.3	1.4	2.9
Phytophagous	2.5	1.1	1.6	1.0	1.3	1.0	1.8	1.6	1.8	1.9	1.9	3.0
Polyphagous	1.0	1.0	3.8	1.8	1.7	2.0	1.0	1.5	2.4	2.6	1.5	4.7
Predator	5.3	1.3	2.6	2.4	5.6	2.6	3.8	2.2	6.2	2.9	4.9	8.5
Saprophagous	11.0	8.0	1.0	8.5	3.7	4.0	3.0	5.5	9.0	9.2	4.3	12.9
Shannon's index	(χ^2_{28}=13.18, *P*=0.992)								(χ^2_{8} =0.58, *P*=0.999)			
Coprophagous	2.0	0.0	1.5	0.0	0.0	0.9	1.6	1.5	1.9	1.9	2.2	2.5
Phytophagous	2.5	3.1	2.7	2.8	2.4	2.6	2.2	2.8	3.8	3.5	3.7	4.3
Polyphagous	2.0	1.6	1.2	1.8	1.4	0.8	1.0	0.9	2.6	2.0	2.9	2.7
Predator	2.5	2.9	2.8	2.1	1.3	2.4	1.7	2.0	2.5	2.4	2.9	2.9
Saprophagous	0.3	0.9	1.6	0.5	1.1	1.2	1.2	0.4	0.9	0.7	1.6	1.2
Evenness (%)	(χ^2_{28}=17.71, *P*=0.999)								(χ^2_{8} =3.85,			

									P=0.999)			
Coprophagous	100	0	95	0	0	92	100	95	95	96	96	91
Phytophagous	85	98	88	100	93	100	86	89	90	92	93	87
Polyphagous	100	100	50	92	86	81	100	92	80	88	95	83
Predator	83	97	92	92	56	80	84	79	76	75	75	68
Saprophagous	27	56	100	52	69	59	60	44	47	30	52	36

Table 6(on next page)

Table 6

Two-way ANOVAs testing the variation of abundance of insect trophic guilds between seasons and station orientations in Sabkha Djendli, Northeast Algeria.

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Trophic groups	Variations	*Df*	*MS*	*F*	*P*
Coprophagous	Season	2	0.29	0.32	0.731
	Orientation	7	0.86	0.94	0.507
	Residuals	14	0.91		
Phytophagous	Season	2	2.79	0.64	0.542
	Orientation	7	6.90	1.58	0.220
	Residuals	14	4.36		
Polyphagous	Season	2	3.79	1.46	0.266
	Orientation	7	10.14	3.90	0.015
	Residuals	14	2.60		
Predator	Season	2	78.00	3.07	0.079
	Orientation	7	37.50	1.47	0.254
	Residuals	14	25.43		
Saprophagous	Season	2	5.17	0.51	0.614
	Orientation	7	15.14	1.48	0.251
	Residuals	14	10.21		

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Table 7(on next page)

Table 7

Pearson correlation tests between abundance of orders and trophic guilds of insects and spontaneous vegetation characteristics (cover and species richness) of Sabkha Djendli, Northeast Algeria

Variables	Vegetation cover		Plant species richness	
	r	*P*	*r*	*P*
Taxonomic orders				
Dermaptera	0.214	0.527	0.613	0.045
Orthoptera	0.717	0.013	0.796	0.003
Heteroptera	-0.030	0.930	0.109	0.750
Homoptera	0.591	0.055	0.295	0.378
Coleoptera	0.656	0.028	0.742	0.009
Hymenoptera	0.215	0.526	0.505	0.113
Diptera	0.308	0.357	0.257	0.445
Trophic groups				
Coprophagous	0.429	0.188	0.786	0.004
Phytophagous	0.586	0.048	0.748	0.008
Polyphagous	0.604	0.049	0.571	0.066
Predator	0.262	0.437	0.488	0.128
Saprophagous	0.591	0.046	0.717	0.013

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