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THE ABUNDANCE AND DIVERSITY OF GRASSHOPPER (ORTHOPTERA: CAELIFERA) ALONG AN ALTITUDINAL GRADIENT IN JIJEL DISTRICT, ALGERIA

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Abstract

Grasshoppers (Orthoptera: Caelifera) diversity were studied in three sites at different altitude in Jijel district (North East Algeria). The insects were captured with sweep net weekly from April to August 2016. It appears that 30 Grasshopper species belonging to 4 families and 11 subfamilies were identified amongst 712 individuals. Acrididae species (25) were the most frequent. The species richness was higher at medium altitude (23 species) and high altitude (22 species) than at low altitude (18 species). Species abundance distribution fitted the Broken stick model at low and high altitude while it fitted the Geometric or Motumura model at medium altitude. Grasshopper abundance increased with the altitude while diversity was not correlated with increasing altitude since diversity indices values were high in medium altitude.

KEY WORDS: abundance, species richness, diversity, altitude, Caelifera, Jijel district

Introduction

Grasshoppers are of great importance as they can cause serious damage to crops. They are recognized as important source of food for reptiles, amphibians, mammals and other arthropods (Doumandji & Doumandji-Mitiche, 1994) and birds (SiBachir *et al*., 2001) and are also important bio-indicators because of their specific habitat preferences and sensibility to any changes in their habitats (Thomas, 2005, Guido & Gianelle, 2001; Cigliano *et al*., 2011).

In Algeria, this insect group was studied initially by Chopard (1943). In the 1980s, the Department of Agricultural and Forest Zoology of the Higher National School of Agronomy in Algiers became interested in them and several studies have been conducted (Chara, 1987; Doumandji-Mitiche *et al*., 1991; Doumandji *et al*., 1992; 1993; Benzara, 2004; Ould-El-Hadj, 2004; Bounechada *et al.*, 2006; Allal-Benfekih, 2006;

Mesli, 2007; Benkennana, 2012; Moussi 2012; Rouibah 2017). Despite this, they are insufficiently known and remain subject to much other research on a systematic, biological and ecological level. Kabylie of Babors has not yet been to real fauna surveys, and even less of Orthopteran surveys despite its geographic, climatic, botanical features which makes it an ecological virgin island. Currently, our knowledge of the diversity of this region is poor excluding some plants (Gharzouli & Djellouli 2005) and animal groups such as birds (Bellatreche, 1999; Bougaham & Moulai, 2014, Bougaham *et al*., 2019).

The main objective of this study is to carry out an ecological study in order to describe the composition and structure of grasshoppers according to the altitude in this region after an inventory of the existing species and determinate if species diversity is correlated with increasing altitude.

Jijel district has not yet been to real fauna surveys, and even less of Orthopteran surveys despite of its geographic, climatic, botanical features which makes it an ecological virgin island. Currently, our knowledge of the grasshopper diversity of this region is poor. Only few records about the grasshoppers of Jijel district are available which are scatted throughout the literature with Tekkouk (2008) and Rouibah (2017).

Material and methods

Study area

Three sites of different altitude were selected in Jijel district in the Northern East of Algeria: Kaous, Djimla, and Ferdjioua (Fig. 1).

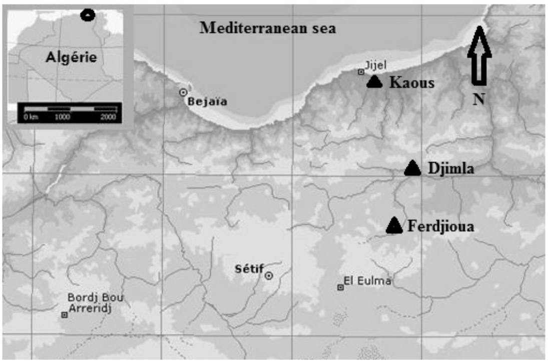

Figure 1. Location of sampling sites

Site 1 (low altitude) is located in Kaous (36°46’13’’ N 5°48’49’’ E). It is a valley on a plane soil with sandy clay texture, near the sea on an altitude of 60 m, the recovery rate is 60%; the most dominant plant species are *Dittrichia viscosa* Greuter, 1973*, Nerium oleander* L, 1753*, Juncus effuses* L., 1753 and *Anacyclus clavatus* (Desf.) Pers. 1807 (Fig. 2a).

Djimla site (medium altitude) (36°34’53’’ N 5°53’6’’ E) is a strub with silty clay soil, the altitude is about 600 m, exposed to the North-West, and the slope is 25%. The recovery rate is 60%. *Dittrichia viscosa* Greuter, 1973 *Taraxacum officinale* F.H. Wigg. 1780.*, Galactites tomentosus* Moench 1794 and *Hordeum murinum* L.1753 dominate the flora on this site (Fig. 2b).

Ferdjioua site (high altitude) (36°24’32’’N 5°56’45’’E) is a cultivated area which culminates at 1100 m, soil is silty without stones and the recovery rate is 80%. *Triticum durum* Desf.1798*, Cynodon dactylon* (L.) Pers. 1805*, Bromus hordeaceus* L. 1753 and *Hordeum murinum* L. 1753 are the dominant plants (Fig. 2c).

Figure 2. A - Kaous, low altitude; B - Djimla, midium altitude; C - Ferdjioua, high altitude.

Study design

Jijel is dominated by the Mediterranean climate (Meddour, 2010), which is characterized by hot and dry summers and mild and rainy winter. Temperatures indicate a great homogeneity caused by the influence of the sea. Annual average temperature range from 11.3°C to 26°C at site 1, from 6.9°C to 23.2°C at site 2, and from 7.1°C to 24°C at site 3.The average rainfall is about 814 mm at site 1, 941 mm at site 2, and 673 mm at site 3 (O.N.M., 2016).

Sampling

A sampling of grasshoppers was carried out from April to August 2016, every week. We used a quadrats method which consists on a predefined sampling surfaces of nine square meter, bounded by a string within grasshoppers are captured by a sweep net with a diameter of 30 cm at the mouth and a beg length of 60 cm. For each of three stations we performed five quadrats every week. Samples are made in the morning from 9 a.m. to 11 a.m. under sunny skies and light winds. The sampling period takes from 2 hours to 2 hours and a half at each station.

Grasshopper identification

Acridian identification was performed using a binocular stereomicroscope and specialized keys of Chopard (1943), Mestre (1988), http://acrinwafrica.mnhn.fr and http:/orthoptera.species.org. Specimens examined during the study are deposited in a Higher National School of Agronomy, Department of Agricultural and Forest Zoology, Zoology laboratory, El-Harrach, Algiers.

Data analysis

PAST 3.04 Software (Hammer *et al*., 2001) was used to calculate:

Relative abundance (*RA*% = 100p_i) of each species ($p_i = n_i$ / N: n_i = number of individual of species i, N = total number of individuals collected) (Zaime & Gautier, 1989).

Occurrence frequency (*FO*): $FO_i(\%)= \frac{C_i x100}{k}$, (Fo ≥ 50%: constant species; 25% ≤ Fo < 50%: accessory species; Fo < 25%: accidental species); Ci = the number of sampling units containing the species i, K: total number of sampling unit (Dajoz, 1971).

Shannon-Weaver index (H): H = $-\frac{1}{ln2}\sum_{i=1}^{S} p_i ln$ (Ramade, 1984).

p_i: relative abundance for each species.
S: number of species.

Pielou index (J): $J=\frac{H}{H'_{max}}$ (Blondel, 1979).

H: Shannon-Weaver index.
H'max = *log2 S*

To establish the species abundance distribution model of the community studied (geometrics, log series, broken stick or log-normal), four models are traditionally used to describe patterns of species abundance (geometric series, log series, log-normal, and broken stick).

Whether the data were parametric or non-parametric was determined by applying Kolmogorov-Smirnov (normality) test, the correlation between grasshopper diversity/abundance and plant diversity was determined by performing a Spearman's rank correlation test, those tests were performed using statistical package for the social sciences (SPSS) version 10.0.

Other statistical tests such as Chi-square (χ^2) and Correspondence Factor Analysis (CFA) (Thibaut, 2002) were also done with the help of XLStat software (Copyright © 2016 Addinsoft).

Results

The abundance, species richness and diversity of grasshopper across elevation

A total of 30 Caelifera species belonging to 4 families and 11 subfamilies were recorded amongst the 712 individuals collected in the Acrididea community of Jijel district in North East Algeria (Table I). The species richness was higher at medium altitude (23 species) and high altitude (22 species) than at low altitude (18 species). This suggested that in Jijel, the species richness is not positive correlated to the increase of the altitude. The family Acrididae was represented by 25 species (83.33%); while Pamphagidae was represented by 3 species (10% of all species) and Pyrgomorphidae as well as Tetrigidae were monospecific (3.33%). Amongst the 712 individuals captured, Acrididae were the most sampled and present at three sites with high relative abundance: 98.91% in Kaous, 99.60% in Ferdjioua and 95.60% in Djimla (Table I). Abundances of Pamphagidae, Pyrgomorphidae and Tetrigidae were low and did not exceed 2.56% (Table I). The number of individuals increases with the altitude (184 at site 1 ≤ IN ≤ 273 at site 3), Oedipodiane was also richest in species. *Oedipoda caerelescens sulfurescens* (Saussure, 1884) was the most abundant species (10.62% ≤ RA ≤10.86%), followed by *Calliptamus barbarus* (Costa, 1836) (6.52% ≤ RA ≤ 12.45%), *Aiolopus strepens* (Latreille, 1804) (7.84% ≤ RA ≤ 9.89%), *Pezotettix giornae* (Rossi, 1794) (1.08% ≤ RA ≤ 13.55%) and *O. fuscocincta* Lucas, 1845 (6.52 ≤ RA ≤9.01%). The comparison between the individual numbers of different grasshopper species according to the altitude of the site shows the existence of a high significant difference (χ^2_{Obs} = 276.2; ddl = 58; p<0.0001). In general, Acridian abundance increased with the altitude. By considering each species, this general trend was maintain for *Aiolopus strepens*, *Calliptamus barbarus*, *C. wattenwylianus* Pantel, 1896, *Pezotettix giornae*, *Omocestus raymondi* (Yersin, 1863), *Ochrilidia filicornis* (Krauss, 1902), *Dociostaurus jagoi jagoi* Soltani, 1978, *Thalpomena algeriana* (Lucas, 1849), *Pamphagus* *elephas* (Linnaeus, 1758), *Ocneridia volxemii* (Bolivar, 1878), *O. nigropunctata* (Lucas, 1849), *Pyrgomorpha conica* (Olivier, 1791). This trend was decreased for *Acrida turrita* (Linnaeus, 1758), *Eyprepocnemis plorans* (Charpentier, 1825), *Heteracris annulosa* (Walker, 1870), *H. littoralis* (Rambur, 1838), *Anacridium aegyptium* (Linnaeus, 1758), *Acrotylus insubricus* (Scopoli, 1786), *Thalpomena algeriana* (Lucas, 1849), *Truxalis nasuta* (Linnaeus, 1758), *T. annulata* Thunberg, 1815, *Paratettix meridionalis* (Rambur, 1838), *Aiolopus puissanti* Defaut, 2005, *Omocestus lucasii* (Brisout, 1850), *A. patruelis* (Herrich-Schaffer, 1838), *A. longipes* (Charpentier, 1845), *Oedipoda caerelescens sulfurescens, O. fuscocincta*, *Sphingonotus rubescens* (Walker, 1870), *S. azurescens* (Rambur, 1838), and *Locusta migratoria cinerascens* (Reiche & Fairmaire, 1849).

Table I. Abundance of acridian species in three different altitude sites in Jijel district.

	Low altitude (140m)	**Medium altitude (600m)**	**High altitude (1090 m)**
Acrididae (1)			
Acrida turrita (Linnaeus, 1758)	10.86 (20)	2.35 (6)	0.36 (1)
Aiolopus strepens (Latreille, 1804)	9.23 (17)	7.84 (20)	9.89 (27)
Aiolopus puissanti Defaut, 2005	0 (0)	1.96 (5)	0.36 (1)
Eyprepocnemis plorans (Charpentier, 1825)	20.65 (38)	1.17 (3)	1.09 (3)
Heteracris annulosa (Walker, 1870)	7.06 (13)	1.17 (3)	0(0)
Heteracris littoralis(Rambur, 1838)	1.08 (2)	0(0)	0(0)
Calliptamus barbarus (Costa, 1836)	6.52 (12)	9.41 (24)	12.45 (34)
Calliptamus wattenwylianus Pantel, 1896	0 (0)	0(0)	1.83 (5)
Pezotettix giornae (Rossi, 1794)	1.08 (2)	10.58 (27)	13.55 (37)
Anacridium aegyptium (Linnaeus, 1764)	2.71 (5)	1.17 (3)	0.73 (2)
Omocestus lucasii (Brisout, 1850)	0.54 (1)	2.35 (6)	0.73 (2)
Omocestus raymondi(Yersin,1863)	0(0)	1.17 (3)	1.09 (3)
Ochrilidia filicornis (Krauss, 1902)	1.08 (2)	7.84 (20)	8.42 (23
Dociostaurus jagoi jagoi Soltani, 1978	0(0)	8.23 (21)	9.15 (25)
Acrotylus patruelis (Herrich-Schaffer, 1838)	4.34 (8)	7.84 (20)	6.59 (18)
Acrotylus longipes (Charpentier, 1845)	0(0)	1.17 (3)	0(0)
Acrotylus insubricus (Scopoli, 1786)	9.23 (17)	5.09 (13)	4.76 (13)
Oedipoda caerelescens sulfurescens (Saussure, 1884)	10.86 (20)	11.76 (30)	10.62 (29)
Oedipoda fuscocincta Lucas, 1849	6.52 (12)	9.01 (23)	7.69 (21)
Thalpomena algeriana (Lucas, 1849)	3.26 (6)	5.09 (13)	5.86 (16)
Sphingonotus rubescens (Walker, 1870)	0(0)	1.17 (3)	0(0)
Sphingonotus azurescens (Rambur, 1838)	0(0)	1.17 (3)	0(0)
Locusta migratoria cinerascens Reiche & Fairmaire, 1849	0(0)	1.17 (3)	0.36 (1)
Truxalis nasuta (Linnaeus, 1758)	1.08 (2)	0(0)	0(0)
Truxalis annulata Thunberg, 1815	2.71 (5)	0.78 (2)	0(0)
Total 1	**98.91 (182)**	**99.60 (254)**	**95.60 (261)**
Pamphagidae (2)			
Pamphagus elephas (Linnaeus, 1758)	0(0)	0(0)	0.73 (2)
Ocneridia volxemii (Bolivar, 1878)	0(0)	0(0)	1.09 (3)
Ocneridia nigropunctata (Lucas, 1849)	0(0)	0(0)	0.73 (2)
Total 2	**0**	**0**	**2.56 (7)**
Pyrgomorphidae (3)			
Pyrgomorpha conica (Olivier, 1791)	0(0)	0(0)	1.83 (5)
Total 3	**0**	**0**	**1.83 (5)**

Table I – continued

Tetrigidae (4)			
Paratettix meridionalis (Rambur, 1838)	1.08 (2)	0.39 (1)	0(0)
Total 4	**1.08 (2)**	**0.39 (1)**	**0**
Total 1+2+3+4	**100 (184)**	**100 (255)**	**100 (273)**

Oedipodinae (34.23 ≤ RA% ≥ 43.52), Acridinae (10.62≤ RA% ≥ 20.10), Eyprepocnemidinae (1.09 ≤ RA% ≥ 28.80), and Gomphocerinae (1.63% ≤ RA ≥ 19.60%), and Calliptaminae (6.52% ≤ RA ≥ 14.28%), were the most abundant subfamilies, whereas Truxallinae (0.78% ≤ RA ≥ 3.8%), Cyrtacanthacridinae (0.73% ≤ RA ≥ 2.71%), Pezotettiginae (1.08 ≤ RA% ≥ 13.55), and Tetriginae (0.39% ≤ RA% ≥ 1.08), Pamphaginae (RA = 2.56%) and Pyrgomorphinae (RA = 1.83%) showed low relative abundances (Table II).

Table II. Absolute and relative abundance of grasshopper subfamilies in three different altitude sites in Jijel district.

Subfamilies	Low altitude		Medium altitude		High altitude	
	ni	RA (%)	*ni*	RA (%)	*ni*	RA (%)
Acridinae	37	20.10	31	12.15	29	10.62
Eyprepocnemedinae	53	28.80	6	2.35	3	1.09
Calliptaminae	12	6.52	24	9.41	39	14.28
Pezotettiginae	2	1.08	27	10.58	37	13.55
Cyrtacanthacridinae	5	2.71	3	1.17	2	0.73
Gomphocerinae	3	1.63	50	19.60	53	19.41
Oedipodinae	63	34.23	111	43.52	98	35.89
Truxallinae	7	3.80	2	0.78	0	0
Pamphaginae	0	0	0	0	7	2.56
Pyrgomorphinae	0	0	0	0	5	1.83
Tetriginae	2	1.08	1	0.39	0	0
Total	**184**	**100**	**255**	**100**	**273**	**100**

Frequencies of occurrence of the grasshopper species

All species that have high occurrence frequency and are constant in the three study sites belong to Acrididae, and they are *Oedipoda caerelescens sulfurescens* (Fo= 60%, 80% and 75% in site 1, site 2 and site 3b respectively), *Aiolopus strepens* (50%, 50% and 75%) and *O. fuscocincta* (50%, 55% and 55%). Species that are constant in two of the three sites also belong to Acrididae, they are *Calliptamus barbarus* (60% and 65%), *Pezotettix giornae* (55% and 70%), *Ochrilidia filicornis* (55% and 50%) and *Dociostaurus jagoi jagoi* (50%). (Table III).

Table III. Occurrence frequency (%) of acridian species in three different altitude sites in Jijel district.

Species	Low altitude	Result	Medium altitude	Result	High altitude	Result
Acrida turrita	60	Constant	10	Accidental	5	Accidental
Aiolopus strepens	50	Constant	50	Constant	75	Constant
Aiolopus puissanti	0		10	Accidental	5	Accidental
Eyprepocnemis plorans	70	Constant	5	Accidental	5	Accidental
Heteracris annulosa	30	Accessory	10	Accidental	0	
Heteracris littoralis	5	Accidental	0		0	
Calliptamus barbarus	25	Accessory	60	Constant	65	Constant
Calliptamus wattenwylianus	0		0		10	Accidental
Pezotettix giornae	5	Accidental	55	Constant	70	Constant
Anacridium aegyptium	10	Accidental	10	Accidental	5	Accidental
Omocestus lucasii	5	Accidental	10	Accidental	5	Accidental
Omocestus raymondi	0		5	Accidental	10	Accidental
Ochrilidia filicornis	5	Accidental	55	Constant	50	Constant
Dociostaurus jagoi jagoi	0		50	Constant	50	Constant
Acrotylus patruelis	15	Accidental	35	Accessory	50	Constant
Acrotylus longipes	0		5	Accidental	0	
Acrotylus insubricus	25	Accessory	20	Accidental	25	Accessory
Oedipoda caerelescens sulfurescens	60	Constant	80	Constant	75	Constant
Oedipoda fuscocincta	50	Constant	55	Constant	55	Constant
Thalpomena algeriana	15	Accidental	20	Accidental	35	Accessory
Sphingonotus rubescens	0		5	Accidental	0	
Sphingonotus azurescens	0		5	Accidental	0	
Locusta migratoria cinerascens	0		10	Accidental	5	Accidental
Truxalis nasuta	10	Accidental	0		0	
Truxalis annulata	10	Accidental	5	Accidental	0	
Pamphagus elephas	0		0		5	Accidental
Ocneridia volxemii	0		0		10	Accidental
Ocneridia nigropunctata	0		0		5	Accidental
Pyrgomorpha conica	0		0		10	Accidental
Paratettix meridionalis	5	Accidental	5	Accidental	0	

Grasshopper diversity

Diversity indices values indicate high diversity at site 2, comparatively to site 1 and 3. Indeed, the values of Shannon-Weaver index shows that diversity is important in medium altitude (2.86) than in low (2.51) and high altitude (2.61). For the evenness (Pielou index), there is a tendency towards balance between species of the medium altitude than in low and high altitude since we have noted high values in low altitude (0.68) comparatively to medium (0.64) and high altitude (0.62) (Fig. 2).

Abundance distribution model of grasshopper communities

Our result revealed that grasshopper community structure of Ferdjioua (Fig. 3c) and Kaous (Fig. 3a) fitted a Boken stick model (chi'2= 10.68; P= 0.64 and chi'2= 3.32; P= 0.99, respectively). This model rarely characterizes animal community and it corresponds to a species abundance distribution where a few group of species share each other an important resource. Besides, the community of Djimla (Fig. 3b) is in accordance with Geometric model (k= 0.15; chi'2= 5.13 and P= 0.92).

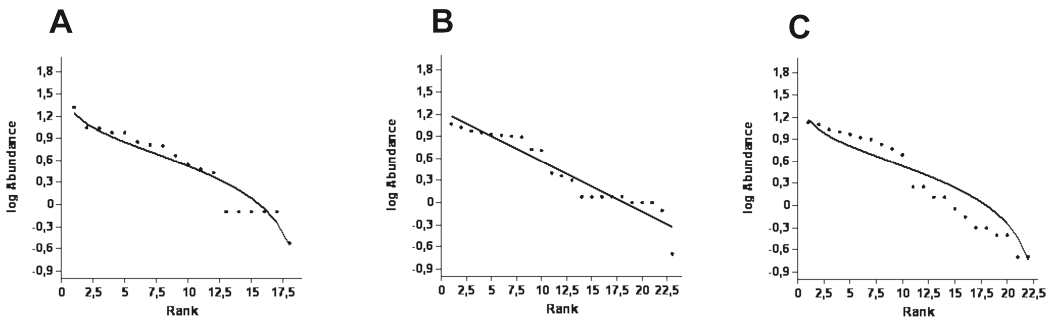

Figure 4. Species abundance distribution model in three different altitude sites in Jijel district. A - Kaous site (broken stick model); B - Djimla site (Geometric model); C - Ferdjioua site (Broken stick model).

Grasshopper assemblage patterns

The clouds of points of the Correspondence Factor Analysis of (CFA) show a staggering of grasshopper species according to the two main axes: species which range according to a gradient of humidity that progresses from the left to the right of the first axis, and species which range according to an elevation gradient that progresses from the bottom to the top of the second axis. The axis 1 and 2 have a respective inertia of 63.60% and 36.40%, they give, by altitudinal gradient three groups (Fig. 4): the first group includes nine species that were frequent in low altitude : *Heteracris annulosa*, *H. littoralis*, *Paratettix meridionalis, Truxalis annulata*, *T. nasuta*, *Anacridium aegyptium, Acrida turrita*, *Eyprepocnemis plorans* and *Acrotylus longipes.*

The second group is represented by 18 species: *Oedipoda caerelescens sulfurescens*, *O. fuscocincta, Calliptamus barbarus, C. wattenwylianus, Aiolopus strepens, A. puissanti*, *Thalpomena algeriana, Pezotettix giornae, Locusta migratoria, Ochrilidia filicornis, Sphingonotus rubescens, S. azurescens, Omocestus lucasii O. raymondi, Dociostaurus jagoi jagoi*, *Acrotylus insubricus*, *A. patruelis* and *Pyrgomorpha conica*.

The third group is represented by species preferring environments with high altitude. These are: *Ocneridia volxemii*, *O. nigropunctata* and *Pamphagus elephas.*

Diversity and abundance of grasshopper in relation to vegetation diversity

The data normality analyzed by one-Sample Kolmogorov-Smirnov test showed that distribution was not normal, and that data Asymptote of significant is 0.001 (less than 0.05) means data was not normally distributed. Based on data skewness (moderate positive skewness), transformation data was fit with square transformation.

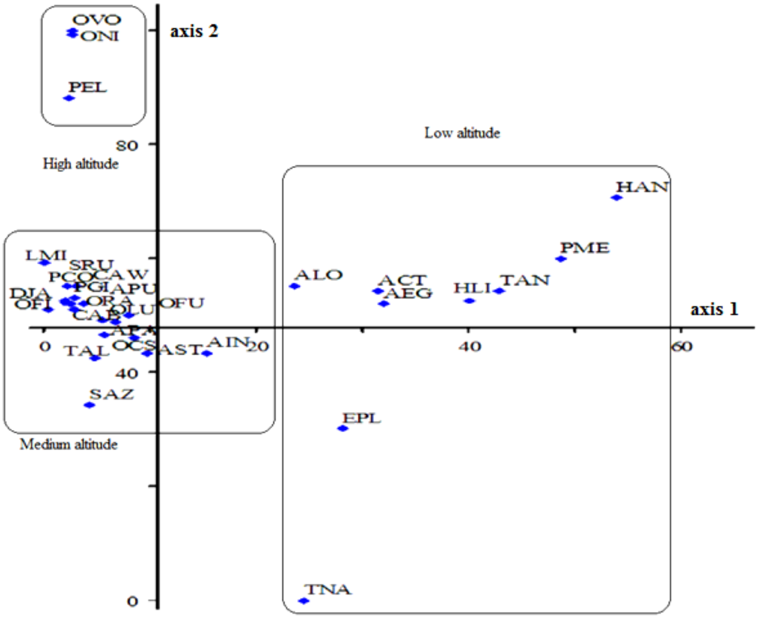

Figure 4. Graphical of the correspondence factor analysis of altitudinal distribution of grasshoppers at three different altitude in Jijel district.

Analysis of correlation between grasshopper diversity and plant diversity and between grasshopper abundance and plant diversity showed that correlation was significant $P < 0.001$; based on Correlation Coefficient value which was 0.466 for grasshopper diversity and plant diversity and 0.487 for grasshopper abundance and plant diversity, this correlation was considered fair.

Discussion

This species richness represents 22% of the Caelifera fauna knowing in Algeria (Louveaux & Benhalima, 1987). This richness was explained in large part by the ecological conditions of Jijel district which is among the richest regions in fauna and flora in Algeria (Bounar, 2014).

The high species richness of the family Acrididae might be an African phenomenon because it has also been noted several part of the continent (Seino *et al*., 2013; Kekeunou *et al*., 2017), and might be explained by the high number of subfamilies and species belonging to this family. These results are in agreement with those of Sofrane (2016), Hamadi & Doumandji (2014), Antonotas *et al*. (2014) and Kekeunou *et al*. (2017) who also noted a great abundance of Acrididae. Moussi (2012) also noted a high number of genera and species in Oedipodinae in southern Algeria. Insects are extremely mobile and occupy a habitat that transiently, while others, may be sedentary and have a reduced habitat but they play an important role in the ecology of this area (Southwood *et al*., 1979).

The literature contains many examples showing that the relation between insect diversity and altitude is diverse and dispersed and three patterns emerge: a decline of diversity with increasing altitude (Stevens, 1992), important diversity at medium altitude (Gagne 1979, McCoy, 1990; Rahbek, 1995), and increased diversity with decreasing altitude (Randall, 1982; Price *et al*., 1998).

The differences in grasshopper diversity could be explained by the difference of ecological conditions caused by climatic variations with altitude which influence the specific richness of the insects as well as their distribution (Whittaker *et al*., 2001). Their composition, abundance and habitat selection change along altitudinal gradients such as temperature, humidity, precipitation and light intensity (Whitman, 1987). As altitude increases, temperature and partial pressure of atmospheric gases will decrease. The abundance and diversity of different arthropod groups might, as a result of these environmental changes, be expected to change with increasing altitude, although responses are likely to vary among different taxa. Some groups of species may be widely distributed along an altitudinal gradient, while others might specialize in particular extremes of the climate continuum associated with changes in altitude (Boulter *et al*., 2011). The decline of grasshopper diversity and in species richness with increasing altitude is consistent with previous findings, indicating that the diversity of many taxa decreases with colder temperatures (Currie, 1991; Kennedy, 1994). Several authors observed that specific richness decreases with altitude: (Wolda, 1987) in Panama, (Wettstein & Schmid, 1999) in the Swiss Mountains, (Grytnes & Vetaas, 2002) in Nepal, (Benjelloun *et al*., 2014) in Morocco. Sun *et al*. (2015) also noted that species richness is important at low altitudes which offer wide range of habitats where many species can coexist at the same time, compared to high altitude. Although the variation is extremely low, our results are consistent with those of Boitier (2005) in France where specific richness is maximum in medium altitude. Leksono *et al*., 2017 noted that altitude has a significant effect on the Odonata abundance ($p < 0.05$) but that has no significant effect for species richness and diversity. Moreover, the diversity is conditioned by the stability of the environment and climatic factors. Dajoz (1971) reported that when the conditions of life of the community are favorable, there are many species represented by a low number of individuals; the diversity index is then high. In contrast, when the conditions of life of the community are unfavorable, there is a little number of species which are represented by a many individuals; the diversity index is then low. When values of diversity index are low (less than 1.5 bits) the community dominated by one or a few species (Faurie *et al*., 2008), high values of this index indicate balanced species distribution (Frontier, 1982).

The broken stick model observed in low and high altitude is one of models of one-dimensional resources partitioning, each species that entered the assemblage took a random fraction of the resources of the previous invaders (Tokeshi, 1990), it corresponds to ecosystems where different species colonize and partition a single resource simultaneously and randomly (Frontier *et al*, 2008).

The Geometric model observed in site 2 characterize ecosystems exposed to anthropic perturbations (Hughes, 1986), this model assumes that species arrived at regular time intervals and sequestered a constant fraction of the remaining resources.

This model also explain that medium altitude community is controlled by a constrain environmental factor. Our results are not in accordance with that of Kekeunou *et al*. (2017) who reported that the grasshopper community fitted a lognormal model. The observed differences could be justified by differences in grasshopper community composition of Algeria and that of Cameroon.

The species of first group are hygrophilous and phytophilous. Their presence in the site with humid climate can be explained because of its proximity to the sea. Indeed, *Paratettix meridionalis* was associated to the wetlands in France including the edges of the plans of water (Duhaze & Bonifait, 2014). In addition, *Eyprepocnemis plorans* is hygro-mesophylious whereas *Heteracris annulosa* is meso-xerophilous, phytophilous and lives near valleys (Lecoq, 1989).

The species of the second group seem to possess a wide ecological valence and can colonize several biotopes. The site of medium altitude is distinguished by an appreciable wealth which can be explained by its intermediate situation between the sites of high and low altitude, which makes it a transition zone where are gathered the ecological factors favorable to more grasshoppers species. For example, *Locusta migratoria* is meso-hygrophylious, graminicolous and lays in the soils of moistened shortfalls areas and perch on the stems of *Zea mays* L. (Popov *et al*., 1990).

Acrotylus patruelis is typically a Mediterranean pioneer species (Sardet *et al*., 2005); it prefers sandy habitat (Bellmann & Luquet, 1995) and she also lives in xerothermic biotopes such as sand dunes, lawns grazed, rockeries, beaches and coastal dunes and can fit up to an altitude of 1040 m (Braud *et al*., 2002). Voisin (1986) suggests that locusts have various ecological preferences; some species preferred an extended ecological habitat where they can adapt to changes of ecological factors; whereas others present a narrow ecological habitat and a low capacity for adaptation to changes in environmental factors, these species are restricted to a specific habitat.

In the third group *Ocneridia volxemii* lives on the high plateaus (Chopard, 1943); its association with *O. nigropunctata* is due to the presence of wheat fields where it swarms most of time and causes important damage to cereals.

It is known that the temperature decreases from the level of the sea to an elevation of 3000 m of 18°C, which corresponds to a decrease of 0.6°C to each 100 m of altitude (McCain & Grytnes, 2010).This causes a loss due to the decrease in the temperature of as much more that one knows that many of locusts in Algeria are mesophilous and xerophilous.

Insect diversity increase with high temperatures (Daniel & Meyers, 1995; Mekkioui & Mesli, 2010) and plant richness (Bonnet *et al*., 1997; Mariottini *et al.* 2013). Prendini *et al.* (1996) noted that grasshopper abundance was lower in the mowed area than in either the lightly grazed or the heavily grazed areas, but similar in the lightly grazed and heavily grazed areas. The heavily grazed area was a favorable habitat by comparison, owing to high greenness of grass and high frequency of forbs, but the lightly grazed area, with tall vegetation and high aerial cover, was also favorable, though for a different assemblage of species.

Our results are in concordance with those of Gardiner (2010) who signaled that orthopteroid abundance and species richness was significantly correlated with the number of woody plants in the hedgerows that provide shelter for those insects. It is known that vegetation serves not only as a food but also as a shelter and plays a major role in the dynamics of those insects. In contrast, Sirin *et al.* (2010) suggested that there is no correlation between grasshopper diversity and plant diversity and noted that the site with the highest number of grasshopper species was the poorest site in plant diversity while the site with the maximal grasshopper abundance was ranked as the third poorest in plant diversity.

Locusts find shelter, perch and food in vegetation. Three factors of differentiation intervene in the perception of the vegetal carpet: its floristic composition, its structure (lawn, meadow, savannah, steppe, and forest) and its phenological state (germination, leafing, and flowering). The vegetation offers living conditions that are different from the surrounding environment; the ascidians usually finds a different temperature and relative humidity, alternate shadows of sun and shade, shelter from the wind or rain. The roosting role is more or less important for the species depending on whether they prefer to be on the soil (geophilic) or in vegetation (phytophilous), on low plants or in trees. In all cases, locusts perch for all molts, except the first that takes place on the soil. The quantity and quality of the food influences the characteristics of locust populations as the birth rate, mortality and dispersion (Duranton *et al*., 1982). Grasshoppers are exclusively phytophagous (Boue & Chanton, 1971), consume especially Graminae (Barataud, 2003) and the ecological adaptations of those insects depend mainly of the plant environment (Le Gall & Gillon, 1989). Grasshoppers show much species-specific variation in food plant use which ranges from specialists to generalists. Despite of the large ranges of plants, those insects are selective (Uvarov, 1977) and exhibit varying degrees of plant selectivity (Joern, 1979). In our study, some species feed on only one or few plant species while other species feed on a wide variety of plant species. *Hordeum murinum* L. and *Inula viscosa* L. are abundant in medium attitude site, which can partly explain the presence of several grasshopper species in this site. *Aiolopus strepens* and *Calliptamus brbarus* are polyphageous but prefers *Hordeum murinum* for the first species (Benkenana, 2012; Medane, 2013) and *Inula viscosa* for the second species (Hassani, 2010). *L. migratoria* is observed on *Zea mais* L., which is also present at medium altitude. Allal-Benfekih (2006) signaled that this grasshopper consumes exclusively Gramineae. *Ochrilidia filicornis* finds refuge between the strands of *Ampelodesmos mauretanicus*, and *Heteracris annulosus* on *Dittrichia viscosa*. Other species prefers more than one plant species as *Eyprepocnemis plorans* which finds refuge in the stems of *Nerium oleander* and *Juncus effuses*.

Conclusion

The general intent of this study was to determinate if grasshopper diversity change with altitude. In our small scale (Jijel district, Norhern East of Algeria) we confirmed negative correlation diversity and increasing altitude, but further research is needed to provide concrete evidence that grasshopper diversity is important in mid-elevations and the mechanism causing variation of grasshopper in this region. Our results can be considered as a database for comparisons of grasshopper diversity at local than national level and could be used as a first step in analyzing the potential use of those insects as bioindicators. In order to better understand, future studies of various grasshopper communities in Algeria should focus on the patterns of certain species and their relationship to environmental variations, as well as the interaction between ecosystem components and grasshopper species. Environmental influences on biodiversity are of great importance for the implementation of effective conservation management, especially under the effects of rapid climate change.

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АБУНДАНТНОСТ И ДИВЕРЗИТЕТ СКАКАВАЦА (ORTHOPTERA: CAELIFERA) ПРЕМА ВИСИНСКОМ ГРАДИЈЕНТУ У ЈИЈЕЛ ДИСТРИКТУ, АЛЖИР

Амар Азил и Абделмаджид Бензехра

Извод

Диверзитет скакаваца (Orthoptera: Caelifera) проучавана је на три локалитета на различитој надморској висини у округу Јијел (североисточни Алжир). Инсекти су узорковани мрежом недељно од априла до августа 2016. Од 712 јединки је идентификовано 30 врста скакаваца сврстане у 4 фамилије и 11 подфамилија. Врсте фамилије Acrididae (25) биле су најчешће. Богатство врста било је веће на средњој надморској висини (23 врсте) и великој надморској висини (22 врсте) него на малој надморској висини (18 врста). Расподела врста се уклапа у модел „сломљеног штапа“ на малој и великој надморској висини, док је геометријски или Мотумура модел уклапа на средњу надморску висину. Абундантност скакаваца се повећавала са надморском висином, док диверзитет није био у корелацији са повећањем надморске висине јер су вредности индекса диверзитета биле високе на средњој надморској висини.

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