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Diversity and composition of island insects of the Bejaia region (Algeria)

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Abstract

Diversity and composition of island insects of the Bejaia region (Algeria). The study was conducted on four islands located west of Bejaia (north–eastern Algeria) to collect baseline information about diversity and composition of insects. Data were collected during summer and spring of 2015 using traps, sweep nets and the Japanese umbrella sampling methods. A total of 1,691 individuals belonging to 112 species were collected. Totals of 72, 56, 41 and 34 species were recorded in Pisans Island, El Euch Island, Sahel Islet and Ail Islet, respectively. Of the 1,691 individuals recorded, 39.85 %, 30.51 %, 18.03 % and 11.59 % were recorded in Pisans Island, El Euch Island, Sahel islet and Ail islet, respectively. Shannon–Weaver index ranged from 2.96 to 3.34 and Equitability between 0.77 and 0.87. The composition of the insect community differed between sampled islands (NMDS, Stress = 0.013). Eleven (11) insect species composed over 50 % of dissimilarity between islands. Two species (*Cassida viridis* (L.) and *Pheidole pallidula* (Nyl.) accounted for more than 5 % of the diversity on all islands. Sorensen's similarity coefficient showed that Pisans and El Euch islands have the highest similarity (45.37 %), while the lowest similarity was recorded between Pisans Island and Sahel Islet (15.53 %).

Dataset published through GBIF (Doi: 10.15468/zs67ep)

Key words: Diversity, Insect composition, NMDS, SIMPER, Islands, Bejaia

Resumen

Diversidad y composición de la población de insectos de las islas de la región de Bugía (Argelia). El estudio se realizó en cuatro islas situadas al oeste de la región de Bugía (noreste de Argelia) para recopilar información de referencia sobre la diversidad y composición de la población de insectos. Los datos se obtuvieron durante la primavera y verano de 2015 utilizando métodos de muestreo mediante trampas, redes de barrido y paraguas japonés. Se capturaron un total de 1.691 ejemplares pertenecientes a 112 especies, con un total de 72 especies en la isla Pisans, 56 en la isla El Euch, 41 en el islote Sahel y 34 en el islote Ail. El 39,85 % de las capturas se efectuaron en la isla Pisans, el 30,51 % en la isla El Euch, el 18,03 % en el islote Sahel y el 11,59 % en el islote Ail. El índice de Shannon–Weaver oscila entre 2,96 y 3,34 y el de equitatividad entre 0,77 y 0,87. La composición de la comunidad de insectos es diferente en las islas muestreadas (NMDS, estrés = 0,013). Once especies de insectos son responsables de más del 50 % de la disimilitud entre islas y dos especies, *Cassida viridis* (L.) y *Pheidole pallidula* (Nyl.), explican cada una de ellas más del 5 % de la diversidad en todas las islas. El coeficiente de similitud de Sorensen muestra que las islas Pisans y El Euch presentan la mayor similitud (45,37 %), mientras que la menor similitud se registra entre la isla Pisans y el islote Sahel (15,53 %).

Datos publicados en GBIF (Doi: 10.15468/zs67ep)

Palabras clave: Diversidad, Composición de insectos, NMDS, SIMPER, Islas, Bugía

Resum

Diversitat i composició de la població d'insectes de les illes de la regió de Bugia (Algèria). L'estudi es va portar a terme en quatre illes situades a l'oest de la regió de Bugia (nord–est d'Algèria) per recopilar informació de referència sobre la diversitat i composició de la població d'insectes. Les dades es van obtenir durant la primavera i l'estiu de 2015 utilitzant mètodes de mostreig mitjançant paranys, xarxes d'escombratge i paraigua japonès. Es van capturar un total de 1.691 exemplars pertanyents a 112 espècies, amb un total de 72 espècies a l'illa Pisans, 56 a l'illa El Euch, 41 a l'illot Sahel i 34 a l'illot Ail. El 39,85 % de les captures es van fer a l'illa Pisans, el 30,51 % a l'illa El Euch, el 18,03 % a l'illot Sahel i l'11,59 % a l'illot Ail. L'índex de Shannon–Weaver oscil·la entre 2,96 i 3,34 i el d'equitativitat entre 0,77 i 0,87. La composició de la comunitat d'insectes és diferent a les illes mostrejades (NMDS, estrès = 0,013). Onze espècies d'insectes són responsables de més del 50% de la dissimilitud entre illes i dues espècies, *Cassida viridis* (L.) i *Pheidole pallidula* (Nyl.), expliquen cadascuna més del 5 % de la diversitat en totes les illes. El coeficient de similitud de Sorensen mostra que les illes Pisans i El Euch presenten la màxima similitud (45,37 %), mentre que la mínima similitud es registra entre l'illa Pisans i l'illot Sahel (15,53 %).

Dades publicades a GBIF (Doi: 10.15468/zs67ep)

Paraules clau: Diversitat, Composició d'insectes, NMDS, SIMPER, Illes, Bugia

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Introduction

The inventory of island fauna is a crucial step for ecological and biogeography studies (Solomon and Mikheyev, 2005). Islands have an important additional role in insect conservation as they are refuge and translocation sites for species and populations severely threatened on the nearby mainland (Ponel and Passetti, 2012). Magnanou (2005) recalls some general laws that characterize island biodiversity. The species richness of islands depends on their surface area; for the same surface area, island biodiversity is lower than continental biodiversity. Species richness results from a balance between the rate of colonization and the rate of extinction (Mc Arthur and Wilson theory, 1967). One of the main factors in this model is the distance between the island and the mainland as this defines its degree of isolation. However, island biodiversity depends on many other factors besides size and isolation (Mc Arthur and Wilson, 1967). Some authors refute the hypothesis of equilibrium of biodiversity considering that it also depends on the particularity of each species, the diversity of ecosystems and their equilibrium, and the specific characteristics of each island (Lomolino and Weiser, 2001; Lomolino and Smith, 2003; Magnanou, 2005; Aissat, 2019).

The insects of Algerian islands have been little studied to date. Only the ants of the Habibas Islands (Bernard, 1958) and the insects of the Jijel islands (Aissat and Moulai, 2016) have been recorded until now. The present study on insect diversity of the islands located on the west coast of the Bejaia region constitutes an original approach to establish the first elements of a faunistic inventory on these environments. This study was conducted to analyse the diversity and the composition of the insects of Bejaia islands (Algeria).

Material and methods

Study area

The study area is located on the west coast of Bejaia (36º 15' N and 4º 20' E). It extends over approximately 60 km of coastline along the Mediterranean Sea, from Cape Carbon to Cape Sigli. This area includes the main islets of the region which are, from east to west, the islet of Sahel, the island of Pisans, the islet of Ail and the island of El Euch (fig. 1). All sites have a largely rocky structure. The islet of Sahel is dominated by carbonate tuff, the island of El Euch and the island of Pisans are dominated by fine sandstone with siliceous cement (Quartzite), and the islet of Ail is dominated by Quaternary sandstone (fossil beach) strongly eroded by sea spray (Duplan, 1952).

Pisans Island (36º 49' 31.01'' N 4º 59' 50.88'' E) is located at 1,250 m from the shore with a surface of 1.2 ha and a maximum height of 30 m. The vegetation cover is dominated by *Phillyrea angustifolia* L.

El Euch Island (36º 53' 34.08'' N 4º 47' 20.30'' E) is about 120 m from the shore; it covers an area of 0.8 ha with a maximum height of 20 m. The plant cover is dominated by *Phillyrea angustifolia* L. and *Atriplex halimus* L.

Sahel Islet (36º 47' 38.69'' N 5º 01' 23.33'' E) is separated from the shore by a distance of 7 m; its area is 0.2 ha with a maximum height of 15 m. The structure of the vegetation shows a dominance of *Olea europaea* L. and *Pistacia lentiscus* L.

Ail Islet (36º 48' 55.61'' N 4º 580' 41.85'' E) is located only 100 m from the shore. It measures about 0.4 ha in area, only half of which is covered by vegetation. It is locally nicknamed 'the Islet of Garlict' because of its apparent vegetation from the mainland, dominated by large stems of *Allium* sp with summer flowering (Vela, 2016).

Methods

The entomological fauna inventory was conducted during spring and summer, between April and July 2015. For insects evolving at ground level, 20 traps were established on each island along a 100 m linear transect, consisting of 102 ml plastic cups (12 cm height x 10 cm diameter) driven into the soil, with the top of the cups flush with the ground surface, and with a separated distance of 10 m between traps. The cups were filled to 3/4 with an unattractive mixture of propylene glycol (which acts as a preservative by avoiding the decomposition of the harvested insects) and drops of dishwashing liquid were added, breaking the surface tension. Traps were left in place on the islands for seven days. Insects frequenting the herbaceous stratum were collected by sweep net. On a plot of 100 m^2, we took 4 plots of 9 m^2; 40 shots of nets were made on the latter, which made 160 shots on the surface already mentioned (100 m^2). This approach was repeated for each field campaign. Insects present in the shrub layer were collected

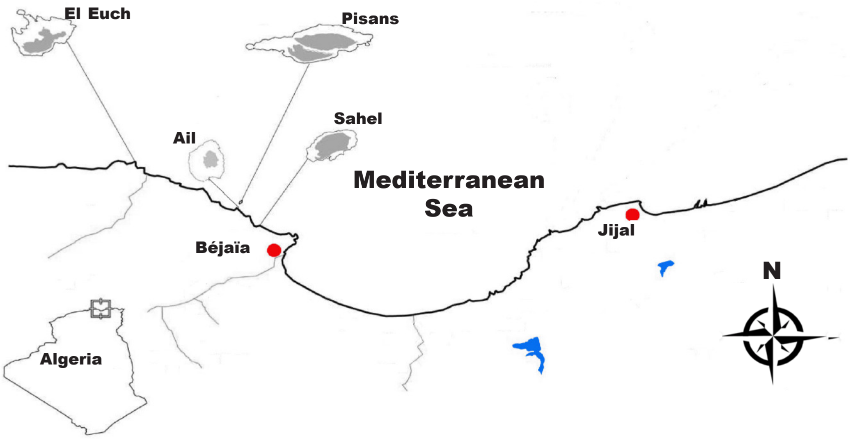

Fig. 1. Geographical location of the west coast and the main island environments of Bejaia (map modified: Hussein et al., 2021).

Fig. 1. Localización geográfica de la costa occidental y de los principales entornos insulares de la región de Bugía (mapa modificado: Hussein et al., 2021).

by using a Japanese umbrella. A light–colored square cloth of 120 x 120 cm was stretched over a folding wooden frame. This was held in one hand while the other hand was used to shake the branches of the trees so that the insects fell onto the mat and could be easily collected.

The collected insects were preserved in 75 % ethyl alcohol. These specimens were identified under a stereomicroscope using the following specialized bibliography: Portevin (1924), Perrier (1935, 1961, 1963, 1964), Chopard (1943), Bernard (1958), Plateaux–Quéner (1972), Delvare and Aberlenc (1989), Auber (1999). Collections containing insects collected in the nearby continental environment were also consulted, notably those present at the Applied Zoology and Ecophysiology Laboratory of the University of Bejaia.

Indexes specific richness (S), Shannon–Weaver diversity index (H') and equitability index (E) were calculated in order to describe the community.

In the absence of normal distribution, Kruskal–Wallis's test was used to compare abundance and richness of insect species between islands.

Differences in insect composition of the four islands were explored by non–metric multidimensional scaling (NMDS) analysis using the Bray–Curtis similarity index as a distance measure. A SIMPER analysis using the Bray–Curtis similarity index as a distance measure was applied to highlight the contribution of each insect species to the dissimilarity between the various islands. All statistical analyses were performed using PAST software (Hammer et al., 2001).

A different method was used to highlight the contribution of the main species to the diversity of all the islands. This method was inspired by that of Lam Hoai et al. (1987), an approach developed on zooplankton when confronted with the need to discard rare species. The method consists of calculating the contribution of a species K to local (intra–island) or global (inter–island) diversity using the following formula:

$$C = H'_1 – H'_2 / H'_1$$

where H'_1 is the diversity (Shannon–Wiener index of the station (local contribution), and H'_2 is the recalculated diversity without the species K considered, i.e., $H'_2 = H'_1 – H'_K$

In order to quantify the changes in species composition, the Sorensen similarity index (presence/absence of species) was established between all modalities (Legendre and Legendre, 1984).

The Sorensen index (S_i) is based on the presence/absence of species and is calculated according to the equation:

$$S_i = 2J / S_{A} + S_B$$

where S_A is the number of species of the first island; S_B is the number of species of the second island; and J is the number of species common to both islands.

Results

Insect diversity and composition of Bejaia islands

A total of 112 species of insects were recorded on the islands (table 1 and dataset published through GBIF, Doi: 10.15468/zs67ep). There were 72 species on the island of Pisans with 674 individuals, distributed over eight orders and 41 families. On the Island of El Euch, 56 species with 516 individuals were found, divided into seven orders and 37 families. On Sahel Islet, 41 species with 305 individuals were sampled, distributed in five orders and 23 families. On Ail Islet, 34 species were inventoried, with 196 individuals, distributed in seven orders and 25 families (table 2). These results are consistent with the Shannon–Weaver index, where the highest value (3.34 bits) was on Pisans Island, followed by El Euch and Sahel Islands with values of 3.12 and 2.96, respectively. The lowest value (2.96 bits) was recorded on the Sahel Islet (table 2). In addition, Ail Islet seemed to be the most balanced, with a value of equitability equal to 0.87. Next came the three islands, Sahel, Pisans and El Euch, with values of 0.79, 0, 78, and 0.77 respectively (table 2).

Richness and abundance of insect species

Mean richness

Pisans Island had the highest mean richness, 18 ± 3.55, followed by El Euch Island, with a mean richness of 14.25 ± 3.49. The lowest values were recorded on Sahel Islet (10.50 ± 2.08) and Ail Islet (8.5 ± 2.69) (fig. 2). The difference in mean insect abundance between the four islands was significant (χ^2 = 24.32, P < 0.0001).

Mean abundance

Pisans Island had the highest mean abundance (168.5 ± 23.17), followed by El Euch Island with a mean abundance of (129 ± 19.33). The lowest values were recorded on Sahel Islet (76.25 ± 16.29) and Ail Islet (49 ± 8.4) (fig. 3). The difference in mean insect abundance between the four islands was significant (χ^2 = 24.85, P < 0.0001).

Non–metric multidimensional scaling (NMDS) analysis

The non–metric multidimensional scale (NMDS) analysis showed that all the islands had a different insect composition (fig. 4). The average dissimilarity rate (given by SIMPER) between the four islands was 75.45 % (table 2).

Species contribution to dissimilarity between species assemblages of all islands

The table shows the contribution of each insect species to dissimilarity between the four islands. In total, 11 insect species were responsible for more than 50 % of the differences found between all islands (table 3).

Table 1. The list of insect species of the four islands of Bejaia and their abundance. (See also the dataset published through GBIF, Doi: 10.15468/zs67ep).

Tabla 1. Lista de especies de insectos de las cuatro islas de la región de Bugía y abundancia de individuos. (Ver también la tabla de datos publicada en GBIF, Doi: 10.15468/zs67ep).

Orders	Families	Genera/species	Pisans Island	El Euch Island	Sahel Islet	Ail Islet
Orthoptera	Tettigoniidae	*Calliptamus barbarus* (Costa, 1836)	0	0	0	10
Dermaptera	Carcinophoridae	*Anisolabis mauritanicus* (Linnaeus, 1758)	0	5	0	0
Dictyoptera	Mantidae	*Mantis religiosa* (Linnaeus, 1758)	0	2	0	4
Blattaria	Blatellidae	*Loboptera decipiens* (Germar,1817)	0	1	1	0
Hemiptera	Lygaeidae	*Heterogaster* sp.	1	1	0	0
		Oxycarenus lavaterae (Linnaeus, 1761)	11	4	0	0
	Anthocoridae	*Orius niger* (Wolff, 1811)	6	0	0	0
	Miridae	*Adelphocoris* sp.	8	27	0	0
		Psallus ambiguus (Fallén, 1807)	1	0	0	0
		Lygus sp. 1	18	11	0	9
		Lygus sp. 2	11	11	0	5
		Lygus sp. 3	3	1	0	4
		Lygus sp. 4	2	0	0	0
		Tuponia sp.	1	0	0	0
	Pentatomidae	*Nezara viridula* (Linnaeus, 1758)	20	15	3	2
	Cicadellidae	*Allygus* sp. 1	8	8	1	0
		Allygus sp. 2	0	5	0	0
		Cicadella sp. 1	13	35	2	3
		Cicadella sp. 2	5	2	0	0
		Cicadella sp. 3	0	4	0	0
		Cicadella sp. 4	0	3	0	0
		Agalliota sp.	0	0	1	0
		Deltocephalinae sp. ind.	0	0	0	1
	Saldidae	*Salda littoralis* (Linnaeus, 1758)	0	0	1	0
	Pyrrhocoridae	*Pyrrhocoris apterus* (Linnaeus, 1758)	1	1	0	0
	Coreidae	*Syromastus rhombeus* (Linnaeus, 1767)	0	0	0	0
Coleoptera	Staphylinidae	*Ocypus olens* (Muller, 1764)	0	1	0	0
		Staphylin sp.	1	0	0	0
		Oxytelus sp.	12	2	0	0
	Cetoniinae	*Oxythyrea funesta* (Poda, 1761)	0	0	0	2
	Apionidae	*Apion* sp. 1	1	1	1	0
		Apion sp. 2	1	0	1	0
	Chrysomelidae	*Lachnaia paradoxa* (Olivier, 1808)	1	0	1	0
		Longitarsus jacobaeae (Waterhouse, 1858)	0	0	9	0
		Leptomona erythrocephala (Olivier, 1790)	9	0	17	0
		Psylliodes sp.	1	38	0	0
		Smaragdina sp.	8	0	19	0
		Cassida viridis (Linnaeus, 1767)	59	101	0	3
		Cassida sanguinosa (Suffrian, 1844)	0	78	0	1
	Buprestidae	*Trachys fabricii* (Obenberger, 1918)	0	0	1	0
	Coccinellidae	*Scymnus interruptus* (Goeze, 1717)	2	0	0	0
		Scymnus apetzoides (Capra and Fursch, 1967)	2	0	0	0
		Coccinella septempunctata (Kovar, 1977)	0	2	1	0
		Clitostethus arcuatus (Rossi,1794)	1	0	0	0
		Adalia bipunctata (Linnaeus, 1758)	0	20	0	0
		Adalia decempunctata (Linnaeus, 1758)	1	0	1	0
	Mordellidae	*Variimorda villosa* (Schrank, 1781)	2	0	0	0
		Mordella aculeata (Linnaeus, 1758)	1	0	0	0
	Scraptiidae	*Anaspis flava* (Linnaeus, 1758)	1	0	0	0
	Tenebrionidae	*Stenosis frioli* (Linnaeus, 1758)	10	4	0	4
		Heliotaurus ruficollis (Fabricius, 1781)	0	0	1	7
	Oedemeridae	*Oedemera podagrariae* (Linnaeus, 1767)	0	0	0	7
		Oedemera tristis (W. Schmidt, 1846)	11	0	0	0
	Curculionidae	*Curculio* sp.	2	0	0	0
		Lixus (Ortholixus) angustus (Herbst, 1795)	20	4	0	0
	Cantharidae	*Cantharis* sp.	1	1	0	0
	Melyridae	*Psilothrix* sp.	1	0	0	0
		Dasytes sp.	0	0	30	15
		Enicopus sp.	2	0	2	0
	Dermestidae	*Megatoma undata* (Linnaeus, 1758)	71	11	2	0
	Byturidae	*Byturus* sp.	0	11	0	0
Neuroptera	Chrysopidae	*Chrysopa viridana* (Schneider, 1845)	1	0	0	0
Hymenoptera	Eulophidae	Eulophidae sp. ind.	1	1	1	0
	Ormyridae	*Ormyrus* sp.	1	0	3	4
	Chalcididae	*Brachymeria* sp.	0	0	0	3
	Ichneumonidae	*Ichneumonidae* sp. ind.	4	10	0	2
	Braconidae	Braconidae sp. 2 ind.	4	5	0	2
	Pteromalidae	*Pteromalus* sp.	4	1	1	3
		Systasis sp.	0	0	0	7
	Formicidae	*Camponotus atlantis* (Forel, 1890)	0	0	1	0
		Camponotus ruber (Emery,1925)	0	8	23	0
		Cataglyphis bicolor (Fabricius, 1793)	3	10	15	10
		Lasius flavus (Fabricius, 1823)	0	0	15	0
		Lasius sp.	0	0	4	0
		Crematogaster scutellaris (Olivier, 1792)	35	0	20	0
		Crematogaster auberti (Emery, 1869)	3	0	0	0
		Tapinoma simrothi (Krausse, 1911)	0	0	30	18
		Tapinoma magnum (Mayr, 1861)	0	0	10	0
		Pheidole pallidula (Nylander, 1849)	86	0	50	31
		Tetramorium biskrense (Forel, 1904)	0	8	0	0
		Plagiolepsis shmitzii (Forel, 1895)	0	0	0	20
	Halictidae	*Halictus quadricinctus* (Fabricius, 1777)	0	0	15	0
		Halictus intumescens (Pérez, 1895)	10	3	0	0
	Vespidae	*Vespula germanica* (Fabricius, 1793)	3	0	5	1
	Apidae	*Apis mellifera* (Linnaeus, 1758)	20	5	3	3
Lepidoptera	Pieridae	*Pieris rapae* (Linnaeus, 1758)	1	1	1	1
	Lycaenidae	*Lampides boeticus* (Linnaeus, 1767)	1	1	0	1
		Polyommatus icarus (Rottemburg, 1775)	0	2	0	1
		Lycaena phlaeas (Linnaeus,1761)	0	1	0	0
	Nymphalidae	*Vanessa atalanta* (Linnaeus, 1758)	1	0	0	0
	Erebidae	*Utetheisa pulchella* (Linnaeus, 1758)	2	0	0	0
	Noctuidae	Noctuidae sp. 1	0	1	0	0
		Noctuidae sp. 2	0	1	0	0
Diptera	Calliphoridae	*Calliphora vicina* (Robineau–Desvoidy, 1830)	5	3	3	0
		Calliphora sp. 1	3	0	0	0
		Lucilia caesar (Linnaeus, 1758)	7	1	3	2
	Lonchaeidae	Lonchaeidae sp. 1 ind.	1	0	0	0
		Lonchaeidae sp. 2 ind.	1	0	0	0
	Anthomyiidae	*Pegomyia* sp.	5	3	0	0
		Delia sp.	90	8	0	5
		Anthomya sp.	7	7	0	0
	Muscidae	*Musca domestica* (Linnaeus, 1758)	7	1	4	3
	Tephritidae	*Tephritis* sp. 1	4	1	0	2
		Tephritis sp. 2	2	5	0	0
	Chloropidae	*Meromyza* sp.	5	4	0	0
	Sarcophagidae	*Sarcophaga* sp.	2	0	1	0
		Miltogramma sp.	0	0	0	0
	Tachinidae	*Nowickia* sp.	0	0	0	0
		Exorista sp.	0	5	1	0
	Fanniidae	*Fannia* sp.	15	10	1	0
	Stratiomyidae	*Chloromyia formosa* (Scopoli, 1763)	5	0	0	0
	Syrphidae	*Episyrphus balteatus* (De Geer, 1776)	5	0	0	0

Table 2. Different ecological indexes applied to the insects of Bejaia islands: S, total richness; N, number of individual; H', Shannon–Weaver index; E, equitability.

Table 2. Índices ecológicos aplicados a los insectos de las islas de la región de Bugía: S, riqueza total; N, número de individuos; H', índice de Shannon–Weaver; E, equitabilidad.

Parameters	Pisans Island	El Euch Island	Sahel Islet	Ail Islet
S	72	56	41	34
N	674	516	305	196
H’ (bits)	3.34	3.12	2.96	3.07
E	0.78	0.77	0.79	0.87

Method of contribution to diversity, based on Lam Hoai et al. (1987)

Analyzing this table shows that two species, *Pheidole pallidula* (Nylander, 1849) and *Cassida viridis* (L., 1758), made up more than 5 % of the diversity; contributions of the rest of the species varied between 1 and 4 % (table 4)

Sorensen's similarity index applied to Bejaia islands

To compare the insect composition between Bejaia Islands, we used the Sorensen similarity index. The similarity between El Euch Island and Pisans Island was highest, with a value of 45.37 %. It was followed by Sahel and Ail Islet with values of 32.35 %, and El Euch Island and Ail Islet with values of 30.23 %. The similarity coefficient between Pisans Island and Sahel Islet was the lowest, with 15.53 % (table 5).

Discussion

The abundance of insect species found on the Bejaia islands is particularly interesting not only in terms of biodiversity and biological resources, but also from a purely ecological point of view as this abundance of species reflects a diversity of both micro–habitats and resources, and may indicate a relative 'good health' of these islands. On the scale of Bejaia islands, 1,691 individuals belonging to 112 species of insects were counted. By way of comparison, on Jijel islands in northern Algeria, Aissat and Moulai (2016) counted 1,011 individuals belonging to 144 species. Despite their very small size, not exceeding 2 hectares, and the prevailing harsh ecological conditions, expressed both by the action of the wind and the effect of sea spray which do not attest in favor of a great richness, the islands of Bejaia seem, against all odds, to offer a wide range of species.

The contribution of insect species is not uniform, however, either in terms of richness or abundance. Nevertheless, on the islands of Bejaia, among the Coleoptera, some species predominate, such as *Cassida viridis* (L.) (Chrysomelidae: 101 individuals), *Megatoma undata* (L., 1758) (Dermestidae: 79 individuals), *Dasytes* sp. (Dasytidae: 45 individuals). However,

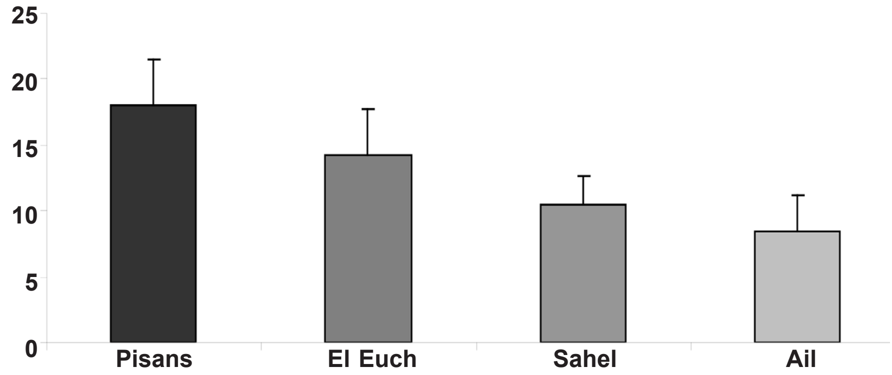

Fig. 2. Mean richness of the insects of Bejaia islands.

Fig. 2. Riqueza media de insectos de las islas de la región de Bugía.

on the islands of Jijel, Coleoptera still predominate but with a different species assemblage: *Heliotaurus ruficollis* (Fab. 1781) (Tenebrionidae: 85 individuals), *Mordella aculeata* (Linnaeus, 1758) (Mordellidae: 65 individuals), *Dasytes* sp. (Dasytidae: 40 individuals), and *Oxythyrea funesta* (Poda, 1761) (Cetoniidae: 19 individuals) (Aissat and Moulai, 2016). The majority of these species captured coincided with the flowering of a number of herbaceous plants (*Sonchus tenerimus* L., *Dittrichia viscosa* L., *Hyoserus radiate* L., *Lotus creticus* L. etc.).

Hymenoptera are also quite present on all islands. It is clear that Formicidae and Apidae families are those which contribute strongly to the diversity and abundance of this order. Plant community (structure, composition and species richness) is important for Apiformes community diversity (Kuhlmann, 2009; Gotlieb et al., 2011). In our study, the herbaceous stratum was the most favorable site for Apoidae both in terms of abundance and species richness. It is interesting to note that the majority of bee species were collected on several plants, namely, *Sonchus tenerrimus* L., *Inula crithmoides* (L.), *Asteriscus maritimus* (Gre-

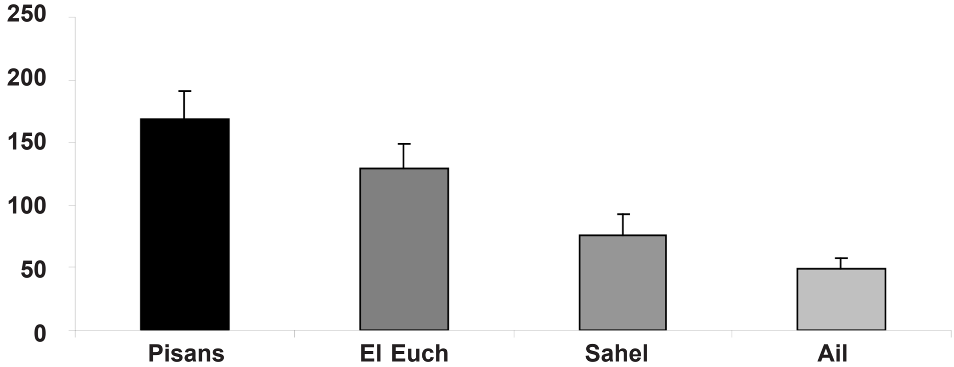

Fig. 3. Mean abundance of insects on Bejaia islands.

Fig. 3. Abundancia media de insectos en las islas de la región de Bugía.

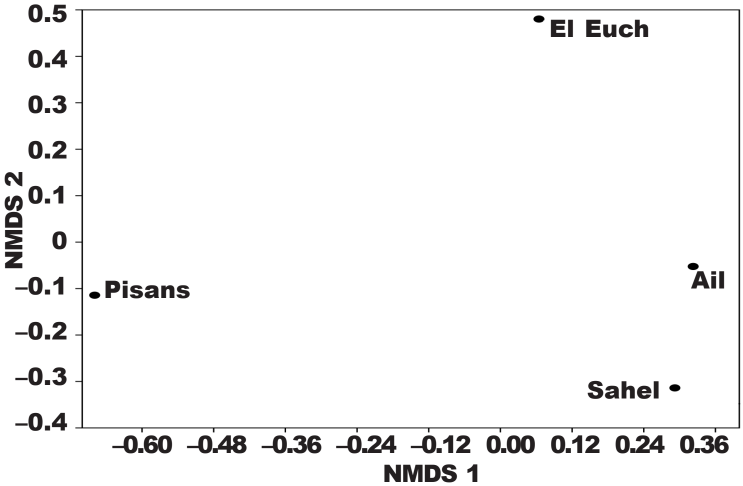

Fig. 4. Non–metric multidimensional scale (NMDS) of insects from Bejaia islands (stress = 0.013).

Fig. 4. Escala multidimensional no métrica (NMDS) de los insectos de las islas de la región de Bugía (estrés = 0,013).

uter), *Spergularia rubra* (L.), *Cleotephus myconis* (L.) etc. The sampling period, from April to July, seems to be favorable seasons for bees. In this sense, Coiffait–Gombault et al. (2016) attest that spring and early summer are the most favorable for bees, both in terms of abundance and species richness. Milla et al. (2010) consider this is due to the fact that the phenology of Mediterranean plant species enter dormancy or decrease their floridity during the summer in order to withstand water and heat stress.

Bejaia islands provide few families of Lepidoptera namely, Pieridae, Lyceanidae, Nymphalidae and Erebidae. We note the extreme reduction in number of species of the Lepidoptera population of Bejaia islands (8 species) compared to that of Jijel Islands (14 species) (Aissat and Moulai, 2016). Among butterflies, groups that use the widest host plant row are much richer in species than their specialized sister groups (Weincatner et al., 2006). Indeed, Yamamoto et al. (2007) demonstrated that the abundance of butterflies in island communities correlates well with their plant biomass. In our case, the species *Pieris rapae* (L., 1758) is the only common species that has been recorded on all islands. This species is widespread and very common in northern Africa (Tolman and Lewington, 1999).

The presence of large colonies of the yellow–legged gull *Larus michahellis* Naumann 1840, is not without impact on the island ecosystem, particularly on the flora; permanent trampling which creates areas of bare land with intense erosion, modification of the physico–chemical nature of the soil (droppings, corpses. etc.), which leads to the expansion of ruderal plants and the establishment of allochthonous taxa, leading to a regression of native phytocenoses (Vidal, 1998; Bonnet et al., 1999). Consequently, the presence of the colonies of this gull in most of the islands of the Bejaia region allows a real diversity of dipterans, which develop on debris and decomposing animal corpses.

The diversity of a stand has at least two aspects. The first is the number of species present, usually species. But the species richness of a stand is only an imperfect measure of

Table 3. SIMPER analysis of species that contribute more to dissimilarity between the species assemblages of the four islands: Ad, average dissimilarity; %C, percentage of contribution; %A, percentage of accumulation.

Tabla 3. Análisis SIMPER de las especies que más contribuyen a la disimilaridad entre grupos de especies en las cuatro islas: Ad, promedio de disimilitud; %C, porcentaje de contribución; %A, porcentaje de acumulación.

				Average			
Species	**Ad**	**%C**	**%A**	**Pisans**	**El Euch**	**Sahel**	**Ail**
Cassida viridis (L., 1767)	7.111	9.422	9.42	59	101	0	3
Pheidole pallidula (Nyl., 1849)	5.244	6.955	16.37	86	0	50	31
Delia sp.	4.708	6.239	22.61	90	8	0	5
Cassida sanguinosa (Suff.,1844)	4.531	6.005	28.62	0	78	0	1
Megatoma undata (L.,1758)	3.882	5.145	33.76	71	11	2	0
Crematogaster scutellaris (Ol., 1792)	2.487	3.297	37.06	35	0	20	0
Tapinoma simrothi (Krausse, 1911)	2.285	3.028	40.09	0	0	30	18
Dasytes sp.	2.257	2.992	43.08	0	0	30	15
Psylliodes sp. 1	2.215	2.936	46.01	1	38	0	0
Cicadella sp. 1	2.139	2.835	48.85	13	35	2	3
Camponotus ruber (Emery,1925)	1.761	2.333	51.18	0	8	23	0

diversity and does not take into account the other aspect of diversity which is the numerical importance of each species. For our case, the values of Shannon–Weaver diversity, are high at Bejaia islands, the values of the diversity index in descending order, are H' = 3.34 bits for the island of Pisans, H' = 3.12 bits for the island of El Euch, H' = 3.07 bits for the Ail Islet and H' = 2.97 bits for Sahel Islet. The differences observed between the different islands are related to several parameters, we can cite in order of importance, the nature and richness of the vegetation cover, the area of the islands, the distance from the mainland and finally the intensity of exogenous disturbances, whether of human origin or related to the presence of seabird colonies (McArthur and Wilson, 1967; Vidal, 1998; Ponel and Andrieu–Ponel, 1998).

Various mathematical tools have been proposed to try to evaluate this aspect of diversity, which translates, along with the number of species, their more or less equitable distribution. The equitability index (E) is the most commonly used (Remade, 1984). The study of equitability shows that the numbers of insect species captured on the islands of the Bejaia region have very high equitability values ($0.77 \leq E \leq 0.87$), with the maximum value recorded for Ail Islet (0.87). Moreover, although the general entomological structure is balanced for the majority of the islands studied, which can be explained by a balance between the rate of colonization and the rate of extinction (Mc Arthur and Wilson, 1967), it is favored by the proximity of the shoreline.

The non–metric multidimensional scaling (NMDS) analysis, which considers not only species richness but also their abundance on each island, clearly shows significant differences in the composition of insect species assemblages between the different islands. Eleven (11) insect species are responsible for 50 % dissimilarity between the four islands of the Bejaia region. In general, these differences are explained by the abundance of certain

Table 4. Overall contribution of the most important taxa to diversity: Gd%, percentage of global diversity; * value greater than or equal to the threshold considered.

*Tabla 4. Contribución global de los taxones más importantes a la diversidad: Gd%, porcentaje de biodiversidad global; * valor superior o igual al umbral considerado.*

Bejaia insect species	**Gd%**	**0.05**	**0.001**
Lixus (Ortholixus) angustus (Herbst, 1795)	1.58		*
Dasytes sp.	2.53		*
Megatoma undata (L.,1758)	3.91		*
Cassida viridis (L., 1767)	5.90	*	
Cassida sanguinosa (Suff.,1844)	3.75		*
Camponotus ruber (Emery,1925)	1.92		*
Cataglyphis bicolor (Fab., 1793)	2.23		*
Lasius flavus (Fab., 1823)	1.10		*
Crematogaster scutellaris (Ol., 1792)	2.92		*
Tapinoma simrothi (Krausse, 1911)	2.65		*
Pheidole pallidula (Nyl., 1849)	7.37	*	
Plagiolepsis shmitzii (Forel, 1895)	1.37		*
Halictus quadricinctus (Fab., 1777)	1.10		*
Apis mellifera (L., 1767)	1.92		*
Delia sp.	4.46		*
Anthomyia sp.	1.04		*
Musca domestica (L., 1758)	1.10		*
Fannia sp.	1.68		*

Table 5. Values of Sorensen's similarity coefficient applied to insect species of Bejaia islands.

Tabla 5. Valores del coeficiente de similitud de Sorensen aplicados a las especies de insectos de las islas de la región de Bugía.

Bejaia Islands	**Pisans Island**	**El Euch Island**	**Sahel Islet**	**Ail Islet**
Pisans Island	100	45.37	15.53	27.72
El Euch Island		100	30.23	26.19
Sahel Islet			100	32.35
Ail Islet				100

species on only a few islands. For example, the abundance of Coleoptera species on some islands (*Cassida viridis* (L.), *Cassida sanguinosus* (Suff., 1844), *Megatoma undanta* (L.), *Dasites* sp., *Psylloides* sp. 1 and *Cicadella* sp. 2) is probably related to the availability of easily exploitable food resources. According to Jaenike (1990), most phytophagous insects are specialists, so each new plant species present in a given island effectively forms a new resource unit. For ants, this disparity in numbers may be related to the nature of the soil on these four islands. Indeed, the islands of the west coast of Bejaia are characterized by their rocky structures, which is a brake to the installation of certain species. On the other hand, other species need only a stone, dead branches, or little depth to install their nests, as for example *Plagiolepis schmitzii* (Forel, 1895), *Tetramorium biskrense* (Forel, 1904), *Pheidole pallidula* (Nyl.), *Tapinoma simrothi* (Krausse, 1911), *Camponotus ruber* (Emery, 1925). The dominant species are very rare and account for a maximum of 13 % in the Bejaia islands. The species encountered in Bejaia islands are thus seldom ubiquitous and seem to be generally attached to a single island. This particularity can favor the use of these species as indicators on the state of the environment in which they were collected.

Using Sorensen's similarity coefficient between the four islands shows that the two islands, Pisans and El Euch, have the highest similarity values (45.37 %). From the point of view of specific richness, Bejaia islands present different species richness ($34 \leq S \leq 71$) that share few common species (eight species). These differences may be related to the particularities of each island (habitat heterogeneity, vegetation diversity, distance from the mainland, elevation, soil type). It is interesting to point out here the importance of the vegetation similarity between Bejaia islands, which is equal to 59 % (Benhamiche and Moulai, 2012), which can explain in part the common species between islands. To give just this example of Coleopterans, an order obviously important on the different islands studied, its species are characterized by a highly developed monophagy (Fadda et al., 2004), which leads us to reasonably believe that the presence of an identical flora on all our islands will attract a priori the same entomological cortege of Coleoptera, and this may be valid for the different orders of insects.

Conclusion

This study constitutes the first contribution to the knowledge of insect diversity in Bejaia islands (Algeria). We have recorded 112 species in Bejaia islands. Pisans Island is the most diverse, while Ail Islet is the poorest. Insect composition assemblages on Bejaia islands are significantly different. Eleven (11) insect species are responsible for more than 50 % of this dissimilarity. *Cassida viridis* and *Pheidole pallidula* explained more than 13 % of the diversity of all islands. Pisans and El Euch Island are the closest in terms of insect similarity. These data can be a milestone in the short– or medium–term monitoring of insect assemblages of these small islands depending on the evolution of certain disturbing factors such as nesting pairs of yellow–legged gulls and human frequentation.

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References

Aissat, L., 2019. Nestedness pattern and the influence of geographical factors on Algerian breeding birds, *International Journal of Environmental Studies*, 77: 547–554, Doi: 10.1080/00207233.2019.1690248

Aissat, L., Moulai, R., 2016. Analysis of Insect Diversity of Three Islets in the North–East of Algeria. *Journal of Entomological Research Society*, 18(2): 1–21.

Auber, L., 1999. *Atlas des Coléoptères de France, Belgique et Suisse*. Tome I. Ed. Boubée, Paris.

Benhamiche, S., Moulai, R., 2012. Analyse des phytocénoses des systèmes insulaires des régions de Bejaia et de Jijel (Algérie) en présence du Goéland leucophée, *Larus-michahellis*. *Revue d'Écologie (Terre et Vie),* 67: 375–397, https://www.persee.fr/doc/revec_0249-7395_2012_num_67_4_1653

Bernard, F.,1958. *Les fourmis (Hymeoptera, Formicidae)*. Ed. Masson et Cie, Paris.

Bonnet, V., Vidale, E., Medail, F., Tatoni, T., 1999. Analyse diachronique des changements floristiques sur un archipel Méditerranéen périurbain (Iles du Frioul, Marseille). *Revue d'Écologie (Terre Vie),* 54: 3–18.

Chopard, L., 1943. *Faune de l'empire Français (Orthoptéroides de l'Afrique du Nord)*. TomeI. Ed. Larose, Paris.

Coiffait–Gombault, C., Crouzet, N., Morison, N., Guilbaud, L., Vaissiere, B., 2016. Diversitéde abeilles sauvages (Hymenoptera: Apoidea) de l'île de Porquerolles (France, Var). *Scientific Reports of Port–Cros National Park*, 30: 95–143.

Delvare, G., Aberlenc, H. P., 1989. *Les insectes d'frique et d'Amérique tropicale. Clé pour la reconnaissance des familles*. Ed. CIRAD, France.

Duplan, L., 1952. *La région de Bougie*. 19ème congrès Geol. Inter. Mong. Rég., 1ère série, 17, Alger.

Fadda, S., Orgeas, J., Ponel, P., Dutoit, T., 2004. Organisation et distribution des communautés de coléoptères dans les interfaces steppe–friches postculturales en Crau. *Ecologia Mediterranea*, 30(1): 85–104, https://www.persee.fr/doc/ecmed_0153-8756_2004_num_30_1_1497

Gotileb, A., Hollender, Y., Mendelik, Y., 2011. Gardening in the desert changes bee communities and pollination network characteristics. *Basic and Applied Ecology*, 12: 310–320, Doi: 10.1016/j.baae.2010.12.003

Hammer O., Harper, D. A. T., Ryan, P. D., 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis. *Paleontologia Electronica,* 4: 1–9, http://paleo electronica.org/2001_1/past/ issue1_01.htm

Hussein, A. A., Baaloudj, A., Benhamiche–hanifi, S., Lassouane, N., Moulai, R., 2021. Does seabeards guano affect plant physiology in insular ecosystem?. *Studia Universitatis "Vasile Goldis" Arad, Seria Stiintele Vietii (Life Sciences Series)*, 31(1): 11–22.

Jaenike, J., 1990. Host specialization in phytophagous insects. *Annual Review of Ecology, Evolution, and Systematics,* 21: 243–273.

Kuhlman, M., 2009. Patterns of diversity, endemism and distribution of bees (Insecta: Hymenoptera, Anthophila) in southern Africa. *South Africa of Botany*, 75: 726–738, Doi: 10.1016/j.sajb.2009.06.016

Lam Hoai, T., Lasserre, G., Amanieu, M., 1987. Utilisation de la diversite pour decider du choix des especes a retenir dans un lot faunistique. Suivi du zooplancton dans la station de Meze (etang de Thau) de 1982 a 1985. *Acta Oecologica Oecologia Generalis,* 81: 17–28.

Legendre, L., Legendre, P., 1984. *Ecologie numérique. Tome 1: le traitement multiple des données écologiques*. Masson, Paris et les press de l'Université de Quebec.

Lomolino, M. V., Smith, G. A., 2003. Prairie dog towns as islands: applications of island biogeography and landscape ecology for conserving non–volant terrestrial vertebrate. *Global Ecology and Biogeography*, 12(4): 275–286, https://www.jstor.org/stable/3697490

Lomolino, M. V., Weiser, M. D., 2001. Towards a more general species–area relationship: diversity on all islands, great and small. *Journal of Biogeography*, 28(4): 431–445, https://www.jstor.org/stable/i234183

Magnanou, E., 2005. Micromammifère Helminthes et insularité: Evolution des traits de vie du rat noir (Muridae) et des deux musaraignes (Corcidurinae) sur les îles ouest–méditerranéennes. PhD thesis, Montpellier University, France.

Mc Arthur, R. H., Wilson, E. O., 1967. *The Theory of Island Biogeography. Monographs in Population Biology, no. 1.* Princeton University Press, Princeton, NJ.

Milla, R., Castro–Diez, P., Montserrat–Marti, G., 2010. Phenology of Mediterranean woody plants from NE Spain: Synchrony, seasonality, and relationships among phenophases. *Flora–Morphology, Distribution, Functional Ecology of Plants*, 205: 190–199, Doi: 10.1016/j.flora.2009.01.006

Perrier, R., 1935. *La faune de la France. Tome IV: Hémiptères, Anoploures, Mallophages et Lépidoptères*. Delagrave, Paris.

– 1961. *La faune de la France. Tome V: Les Coléoptères 2ème Partie*. Delagrave, Paris.

– 1963. *La faune de la France. Tome VIII: Les Diptères*. Delagrave, Paris. Perrier,

– 1964. La *faune de la France. Tome VI: Les Coléoptères 1ère Partie*. Delagrave, Paris.

Plateaux–Quéner, C., 1972. La *biologie des abeilles primitives*. Masson et Cie, Paris.

Ponel, P., Pasetti, L., 2012. Les arthropodes des îlots du cap corse, une diversité insoupçonnée. *Natura*, 28: 1–9.

Ponel, P., Andrieu–Ponel, V., 1998. Eléments pour un inventaire des arthropodes des îles satellites du Parc national de Port–Cros: Bagaud, Gabinière, Rascas. *Travaux Scientifiques du Parc national de Port–Cros*, 17: 81–90.

Portevin, G., 1924. Ce *qu'il faut savoir des insectes. Volume III. Orthoptères; Hyménoptères; Diptères et insectes inférieurs*. Paul Lechevalier, Paris.

Ramade, F., 1984. *Eléments d'écologie: Ecologie fondamentale*. Ed. Mc Graw–Hill, Paris.

Solomon, S. E., Mikheyev, L., 2005. The ant (Hymenoptera: Formicidae) fauna of Cocos island, Costa Rica, *Florida Entomologist*, 88(44): 415–423, https://www.jstor.org/stable/3496634

Tolman, T., Lewington, R., 1999. *Guide des papillons d'Europe et d'Afrique du Nord*. Delâchaux et Niestlés, Paris.

Vidal, E., 1998. Organisation des phytocénoses en milieu insulaire méditerranéen perturbé. Analyse des inters relations entre les colonies de Goélands leucophées et la végétation des îles de Marseille. PhD thesis, Aix–Marseille University, France.

Vela, E., 2016. Contribution of the PIM initiative to the knowledge of small islands plant biodiversity in Algeria. In: *XV OPTIMA, the Organization for the Phyto–Taxonomic Investigation of the Mediterranean Area Meeting, from 6–11 Juin 2016*: 1–46. Montpellier University, France.

Weincatner, E., Wahlberg, N., Nylin, S., 2006. Dynamics of host plant use and species diversity in *Polygonia* butterflies (Nymphalidae). *Journal of Evolutionary Biology,* 1–6, Doi: 10.1111/j.1420-9101.2005.01009.x

Yamamoto, N., Yokoyama, J., Etkawata, M., 2007. Relative resource abundance explains butterfly biodiversity in island communities. *Proceedings of the National Academy of Sciences, US*A, 104: 10524–10529, Doi: 10.1073/pnas.0701583104