TÜBİTAK

Turkish Journal of Zoology

http://journals.tubitak.gov.tr/zoology/

Research Article

Turk J Zool
(2018) 42: 207-217

doi:10.3906/zoo-1705-51

Comparative diet of hedgehogs (*Atelerix algirus*) in two localities in Kabylia, Algeria

Dalila DJENNOUNE[1,*], Faiza MARNICHE[2], Mansour AMROUN[1], Raphaël BOULAY[3]

[1]Laboratory of Ecology and Biology of Terrestrial Ecosystems, Department of Biology, University Mouloud Mammeri of Tizi-Ouzou, Tizi-Ouzou, Algeria

[2]Laboratory of Zoology, National Veterinary School of Algiers, Algiers, Algeria

[3]Research Institute of Insect Biology, University of Tours, Tours, France

Received: 24.05.2017 • **Accepted/Published Online:** 10.11.2017 • **Final Version:** 21.03.2018

Abstract: The present study is the first qualitative and quantitative analysis of the diet of Algerian hedgehogs (*Atelerix algirus*) in Kabylia, Algeria. The study was carried out between May and October 2014 and covered two different sites, Yakouren (a forested site) and Tizi-Rached (an agricultural site). In Yakouren, the analysis of droppings allowed us to identify 12,050 items grouped into 16 categories of eaten preys, while in Tizi-Rached, 13,543 items grouped into 13 categories of preys were identified. In both locations, the Hymenoptera category is the most eaten type of prey at a rate of 93% in Yakouren and 98% in Tizi-Rached. Moreover, the seasonal variation, the food selectivity, and comparative studies of the consumed categories between the two sites were analyzed in this study. In the Hymenoptera category, 99% of the consumed preys at both sites belonged to the family Formicidae. A deeper investigation revealed that 13 species were in that family in Yakouren and 11 species in Tizi-Rached. The species most consumed by the hedgehogs at both sites are Messor spp. at a rate of 49% in Yakouren and 91% in Tizi-Rached. In order to analyze the preference for some prey, a biochemical analysis of the energy intake was performed and discussed.

Key words: Diet, hedgehog, *Atelerix algirus*, food selectivity, seasonal variations, energy intake

1. Introduction

Understanding the trophic behavior of a given species is essential as it constitutes the first principle of animal ecology (Salas and Fuller, 1996). Many factors cause the study of diet to be of the utmost importance. It brings a better understanding of the nature of potential competitive interactions between sympatric species (Jaksic et al., 1992; Wiens, 1993), as well as how species food profiles influence the environment.

The study of the diet of insectivorous mammals has been the subject of several works. For instance, we can cite the case of the mole of Europe (Beolchini and Loy, 2004) and that of the shrew (Churchfield, 1982; Brahmi et al., 2012).

The hedgehog's diet has been the subject of numerous studies worldwide. In New Zealand, several studies have been conducted on the effect of hedgehog predation on the endemic fauna of the island ecosystems in which they were introduced (Brockie, 1959; Campbell, 1973; Chris et al., 2005; Jones and Norbury, 2011). We have also gathered information on some studies from Europe pertaining to the diet of the European hedgehog (Yalden, 1976; Wroot, 1984).

In Algeria, some works have been dedicated to the study of the Algerian hedgehog (*Atelerix algirus*). These works have focused on some aspects of trophic ecology but they remain very fragmentary. Indeed, the diet has not been thoroughly investigated. For instance, Doumandji and Doumandji (1992) studied the hedgehog's diet in the region of Algiers. Parasitological analysis was discussed in some works (Khaldi et al., 2012a, 2012b; Sakraoui et al., 2014). In the study of Khaldi et al. (2016), the recent anthropogenic introduction of the Algerian hedgehog (*Atelerix algirus*) in Europe was highlighted by molecular evidence support. Derouiche et al. (2016) investigated the genetic and phenotypic variation of North African hedgehog (*Atelerix algirus*) and the desert hedgehog (*Paraechinus aethiopicus*) in Algeria, using mitochondrial DNA and external morphological characters. Road mortality of the Algerian hedgehog *Atelerix algirus* in the Soummam Valley in Algeria was studied by Mouhoub-Sayah et al. (2009). To the best of our knowledge, there is no published work dealing with the diet of the hedgehog of Kabylia. The goal of our research is to enrich the Algerian hedgehog ecology corpus, particularly by bringing to light new elements pertaining to the diet of the hedgehog in

* Correspondence: dj_dalila@hotmail.fr

Kabylia. This study also aims at providing a quantitative analysis of food selectivity. The seasonal variation of the hedgehog diet for both sites is also discussed. Moreover, we discuss the energy value of a few species of Formicidae, namely *Messor* spp., which appear to be preferred by the hedgehog.

2. Materials and methods

2.1. Study sites

The fieldwork was carried out in two sites located in Kabylia, which is in the northern part of Algeria. The first site, Yakouren, is a forest location, located 46 km east of Tizi-Ouzou (36°4′N, 4°23′E). The altitude of this hardly anthropized forest varies from 512 m to 657 m, with several roads going through it. The site is also characterized by ravines and streams. *Quercus suber* is the dominant species of the forest's flora. We collected our samples in the southern portion of the forest, where the undergrowth is made up of several species such as *Myrtus communis*, *Genista tricuspidata*, *Pistacia lentiscus*, *Arbutus unedo*, *Calicotome spinosa*, *Alnus glutinosa*, and *Salix pedicellata*. The shrub layer is predominantly composed of *Ilex aquifolium* and *Rubus ulmifolius*. The second site, Tizi-Rached, is an agricultural ecosystem located 13 km east of Tizi-Ouzou (36°40′ N, 4°11′ E), at an average altitude of 300 m. The site is heavily visited by humans. Crops, including, among others, wheat, potatoes, beans, maize, and turnip, depending on the season, are abundant there. There are also other perennial crops such as the fig tree and the olive tree, as well as other naturally occurring varieties of vegetation, namely *Rubus ulmifolius*, *Fraxinus* sp., *Rosa sempervirens*, and *Genista tricuspidata*. The climate in both sites is of the Mediterranean type. During the study period (from May to October 2014), the temperature at the two sites varied between 13 °C and 25 °C in May, between 20 °C and 33 °C in August, and between 10 °C and 21 °C in November.

2.2. Prey availability

The estimation of hedgehog prey availability in both locations was determined by the pitfall traps method. They were filled to a third with soapy water, which allows for insects to get trapped in them. After 24 h, the contents of the traps were retrieved and poured into a plastic bottle filled with 70% alcohol. All the insects captured were identified and a representative sample was kept to be used as the reference collection. The traps were inserted during the dropping collection period, i.e. from May to October 2014. They represent the average prey availability.

2.3. The hedgehog's diet

The hedgehog's diet was analyzed by studying the composition of droppings. Fecal analysis was the preferred method as it would not require for animals to be sacrificed. It is also an easier method of gathering larger samples as opposed to that of animal slaughter or collecting carcasses (Fedriani and Kohn, 2001). In order to distinguish between the compositions of the fecal matter samples, we use a fieldwork guide that references the size, shape, and color of the droppings according to their compositions. We analyzed 120 samples of Algerian hedgehog droppings, 60 of them collected at Yakouren and the other 60 at Tizi-Rached. The samples were gathered between May and October 2014. Each sample was stored in a petri dish with ethanol, which rids the droppings of any pathogenic germs. We used a binocular microscope with 10 × 40 magnification to analyze the insects ingested by the hedgehog. Identification was done using diverse insect fragments (head, thorax, elytra, femurs, tibiae, and mandibles) retrieved from the droppings. The determination of the various fragments was carried out at the lowest possible taxonomic level. These fragments were classified first by orders, then by families, and finally by genera when possible, using different keys of determination. These keys of determination are given in the following references: for the Coleoptera, Perrier (1927) and Perrier and Delphy (1932); for the Hemiptera, Perrier (1979); for the Orthoptera, Chopard (1943), and for the Hymenoptera, Perrier (1940). As for the ants, determination was extended to the genus level with keys of determination for *Messor* (Cagniant and Espadaler, 1997), *Camponotus* (Cagniant, 1996), and *Crematogaster* (Cagniant, 2005).

2.4. Biochemical composition

The nutritional values of proteins, lipids, and sugars and the estimation of energy intake were determined by analyzing the biochemical composition of the ants. This analysis consisted of measuring the level of proteins, lipids, and carbohydrates for each species of ants consumed by the hedgehog. Three methods were used for this purpose.

Protein content (nitrogen level): the total nitrogen was determined by the Kjeldahl method. The organic nitrogen of the sample to be analyzed was mineralized by concentrated sulfuric acid in the presence of a catalyst. The ammoniacal nitrogen formed was displaced by sodium hydroxide and then dosed by titration (Jarrige, 1988).

Lipids content (fat matter): the fat matter was determined by the Soxhlet method. The crude fats corresponded to the substances extracted under reflux by a solvent (light petroleum) (Jarrige, 1988).

Total sugars content: the total sugars content was determined by the Bertrand method. The sugar proportion is made after defecation and hydrolysis by reduction of alkalino-cupic liqueur and valuation of cooper oxide formed, according to cupric-metrical analysis (Lecoq, 1965).

The energy intake is computed from the fact that 1 g of protein is equivalent to 4 kcal, 1 g of sugar is equivalent to 4 kcal, and 1 g of lipid is equivalent to 9 kcal.

2.5. Data analysis

In order to characterize the diet of the hedgehog on the basis of all collected droppings, we determined the number (N) of items for each identified category ingested by the hedgehogs. To estimate the taxonomic diversity, we used the following indices.

Relative abundance (RA %) is computed by the following formula:

RA (%) = n_i / N × 100, where n_i is the number of individuals of species i taken into account and N is the total number of individuals of all species (Ramade, 2008).

Frequency of occurrence was defined by the following formula (Dajoz, 2006):

C (%) = n_{fi} / N_f ×100, where n_{fi} is the number of droppings containing species i and N_f is the total number of droppings analyzed. Depending on the value of C, species i can be defined as ubiquitous if 75% ≤ C (%) ≤ 100%, regular if 25% ≤ C (%) ≤ 74%, accessory if 5% ≤ C (%) ≤ 24%, and rare if C (%) < 5% (Bigot and Bodot, 1973).

The Shannon–Weaver diversity index H′ is the measure of species diversity in a given population (Daget, 1976). Species diversity H′ is computed by the following formula (Dajoz, 2006):

$H' = -\sum_{i=1}^{N} n_i / N \log_2 (n_i / N)$, where N is the sum of the number of species and n_i is the size of the population of species i.

Equitability index J′ is calculated as the ratio $J' = H'/H'_{max}$ between observed diversity H′ and maximum diversity H'_{max}, which is the diversity observed in the theoretical case in which all the species have the same number of individuals (Ramade, 2008). The used formula is $H'_{max} = \log_2(S)$, where S denotes the total number of species composing a population (Blondel, 1979). The equitability index J′ varies from 0 to 1. When J′ is near 0, i.e. J′ < 0.5, this means that the individuals mostly tend to belong to a single species. When J′ approaches 1, it means that all species have the same abundance (Barbault, 1981).

Ivlev's index is used to measure the food choice. Symbolized by I, this index makes it possible to compare the relative abundance of the available prey species in the environment and the choice of prey consumed by the predator. It is calculated by the following formula: I = (r – p) / (r + p – 2rp), where r represents the prevalence of an item in the species' food spectrum and p the prevalence of the same item in the surrounding environment. The I index varies from –1 to 0 for a negative selection and from 0 to +1 for a positive selection (Jacobs, 1974). For both sites, we compared the relative proportions of animal orders in the environment with those observed in the diet.

To analyze the correlation between the relative abundance and the relative occurrence, the Spearman rank correlation was used. The chi-square test (χ^2) and the Mann–Whitney test were used to study the seasonal variation and to compare the two sites' results, respectively. This statistical analysis was performed using the XLSTAT software package.

3. Results

3.1. Diet

The analysis of the 120 droppings collected in the two sites allowed us to list 18 food categories. In the region of Yakouren, 12,050 preys were identified from 60 droppings. These items were classified into 16 categories grouped into five classes (Arachnida, Chilopoda, Diplopoda, Gastropoda, and Insecta). In the region of Tizi-Rached, 13,543 preys grouped into 13 categories were identified from 60 droppings grouped in four classes (Arachnida, Malacostraca, Diplopoda, and Insecta). The most frequently observed category is Hymenoptera. In Yakouren, 93% of the identified preys were Hymenoptera while in Tizi-Rached, it was 98%. The second most commonly consumed category is Coleoptera, but with very low percentages of 4% in Yakouren and of 1% in Tizi-Rached. The other categories identified are negligible and their total percentages do not exceed 1% in the two studied regions (Table). The number of preys contained by droppings between the two locations is not significantly different, as demonstrated by results obtained from the Mann–Whitney test: z = –0.145, P = 0.884.

The Shannon–Weaver index H′ was calculated for the two studied regions. The obtained values are low in both Yakouren (H′ = 0.48) and Tizi-Rached (H′ = 0.22). The equitability values J′ are less than 0.5 for the two studied regions, J′ = 0.12 in Yakouren and J′ = 0.05 in Tizi-Rached. These values reflect an imbalance between the numbers of preys consumed by the hedgehog. Analysis of frequency of occurrence was performed and is illustrated by Figure 1. For both sites, the results show that Hymenoptera species are present in all analyzed droppings. The second most dominant category in the two sites is Coleoptera, with a percentage of 88% in Yakouren, and 80% in Tizi-Rached. For the remaining categories, a difference between the two locations is noted. In Yakouren, the remaining categories are Orthoptera (52%); Araneae, Opiliones, and Homoptera (between 28% and 27%); and Dictyoptera (23%). The other categories do not exceed 10% of analyzed droppings. In Tizi-Rached, the remaining categories are successively Hemiptera (25%), Dermaptera (23%), and Blattodea, Araneae, Orthoptera, and Julida (between 18% and 13%). The other categories do not exceed 10% of analyzed droppings. The correlation between the relative abundance and the frequency of occurrence of the different

Table. Number of identified items (N) and relative abundance (RA%) of the different food categories identified in the diet of the Algerian hedgehog (*Atelerix algirus*) and Ivlev's selectivity values (I) for food categories consumed by the Algerian hedgehog in Yakouren and in Tizi-Rached. ("---": not found).

	Yakouren			Tizi-Rached		
Orders	N	RA%	(I)	N	RA%	(I)
Araneae	30	0.25	–0.724	11	0.08	–0.844
Acari	---	---	---	---	---	-1
Mesostigmata	---	---	---	---	---	-1
Opiliones	41	0.34	–0.433	1	0.01	–0.925
Prostigmata	---	---	–1	---	---	---
Sarcoptiformes	---	---	---	---	---	–1
Trombidiformes	---	---	-1	---	---	–1
Geophilomorpha	2	0.02	1	0	0.00	---
Scolopendres	---	---	---	---	---	–1
Julida	5	0.04	1	27	0.20	1
Pulmonata	2	0.02	1	0	0.00	---
Scutigeromorpha	---	---	---	---	---	–1
Stylommatophora	3	0.02	1	0	0.00	---
Blattodea	0	0.00	---	64	0.47	0.185
Coleoptera	532	4.40	0.740	149	1.10	1
Dermaptera	2	0.02	1	25	0.18	1
Dictyoptera	34	0.28	0.535	3	0.02	1
Diptera	---	---	–1	---	---	–1
Hemiptera	4	0.03	-0.675	26	0.19	0.667
Heteroptera	9	0.07	1	2	0.01	–0.591
Homoptera	87	0.72	0.789	9	0.07	–0.070
Hymenoptera	11249	93.10	0.108	13215	97.58	0.387
Isopoda	0	0.00	---	1	0.01	–0.443
Lepidoptera	1	0.01	–0.823	1	0.01	1
Mantodea	---	---	–1	---	---	---
Neuroptera	4	0.03	1	0	0.00	---
Orthoptera	45	0.37	0.043	9	0.07	–0.579
Psocoptera	---	---	---	---	---	–1
Thysanoptera	---	---	---	---	---	–1
Entomobryomorpha	---	---	–1	---	---	–1
Poduromorpha	---	---	---	---	---	–1

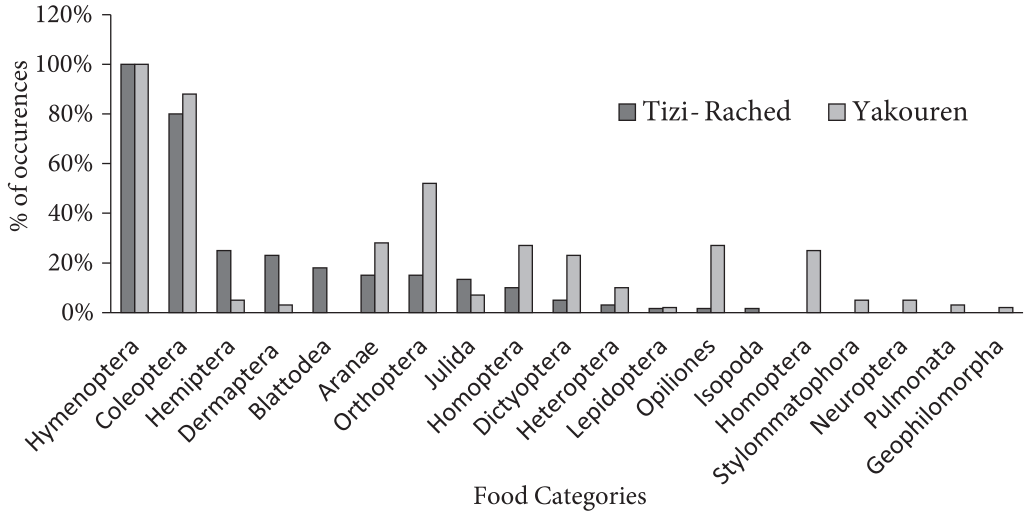

Figure 1. Occurrences of food categories consumed by the Algerian hedgehog in Yakouren and in Tizi-Rached.

food categories consumed by the hedgehog is significant according to the Spearman's correlation test: $r_s = 0.977$, $P < 0.0001$ in Yakouren; $r_s = 0.966$, $P < 0.0001$ in Tizi-Rached.

In light of these results, we performed a more in-depth analysis of the droppings to reveal the families of preys present. In the Hymenoptera category, 99% of the consumed preys in both sites belonged to the family Formicidae. In Yakouren, 13 species of Formicidae were identified, including *Messor* sp. (49%), *Camponotus* sp.1 (31%), *Crematogaster* sp. (14%), *Aphaenogaster* sp.1 (3%), *Tetramorium* sp. (1%), and other species that are very weakly represented with percentages much lower than 1%. In Tizi-Rached, the family of Formicidae is represented by 11 species: *Messor* sp. (91%), *Camponotus* sp.1 (4%), *Aphaenogaster* sp.1 and *Tapinoma* sp. (2%), and *Tetramorium* sp. (1%). Again, in Tizi-Rached, other species were rarely consumed by the Algerian hedgehog, amounting to a percentage not exceeding 1% (Figure 2).

3.2. Seasonal variation

There is no significant difference in the different dietary categories identified in the hedgehog's diet between seasons in the two regions ($\chi^2 = 3.008$, ddl = 32, P = 1 in

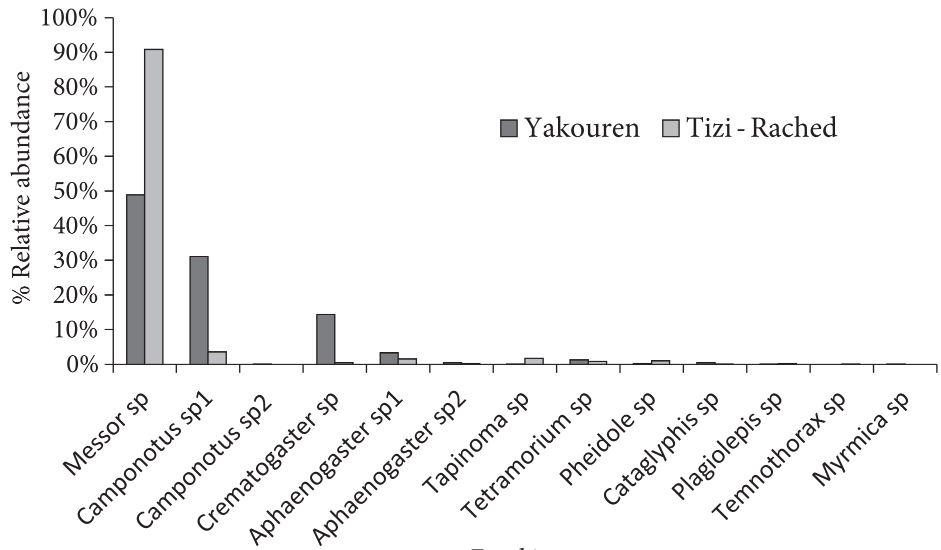

Figure 2. Relative abundance of Formicidae species consumed by the Algerian hedgehog in Yakouren and in Tizi-Rached.

Yakouren and χ^2 = 3.220, ddl = 26, P = 1 in Tizi-Rached). The Hymenoptera dominated during all three seasons of spring, summer, and autumn with a percentage between 93% and 94% in Yakouren and a percentage between 97% and 98% in Tizi-Rached (Figures 3 and 4).

The Shannon–Weaver diversity index H′ was calculated for each season and for each studied region. In Yakouren, the highest value of this index was in the spring with H′ = 0.52. In opposition, the lowest value recorded was in autumn with H′ = 0.41. The values of the equitability index J′ are low for all seasons, the maximum being obtained in spring (J′ = 0.12) and the minimum in autumn (J′ = 0.10). At Tizi-Rached, the values of the Shannon–Weaver diversity index are lower. The highest value was obtained during summer with H′ = 0.30 and the lowest value was observed during autumn with H′ = 0.10. The values of the indices obtained are less than 0.50, the maximum obtained being in summer with J′ = 0.07 and the minimum in autumn with J′ = 0.03.

3.3. Food availability

The inventory of food availability at both sites was completed during the period of the study. In Yakouren, 3 classes were identified: Insecta (94%), Arachnida (3%), and Collembola (3%). These classes were then divided into 14 orders. Hymenoptera was the most predominant order with a percentage of 92%. Other orders were present with low percentages (between 1% and 3%). They are: Araneae, Opiliones, Prostigmata, Trombidiformes, Coleoptera, Dictyoptera, Diptera, Hemiptera, Homoptera, Lepidoptera, Mantodea, Orthoptera, and Entomobryomorpha. The

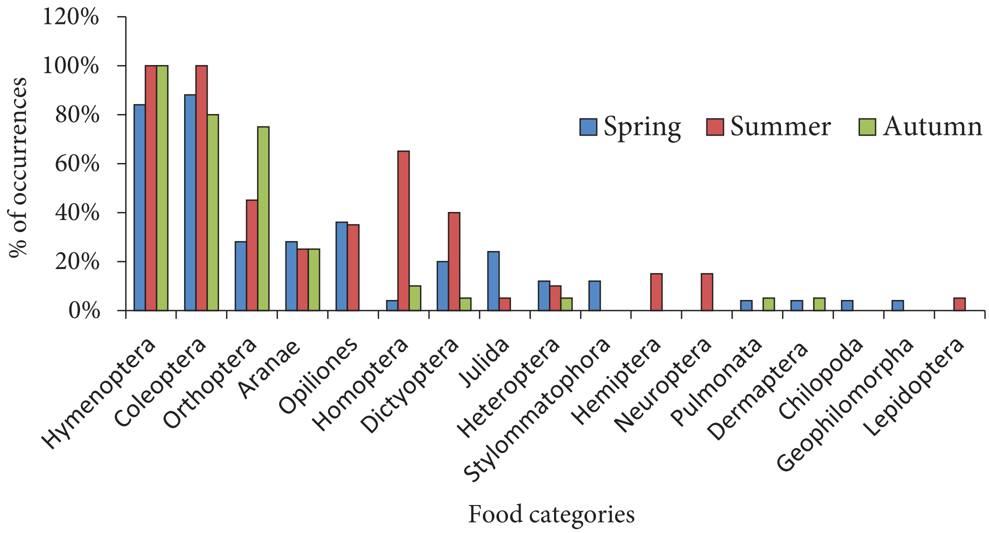

Figure 3. Seasonal variation among the different food categories of the Algerian hedgehog in Yakouren.

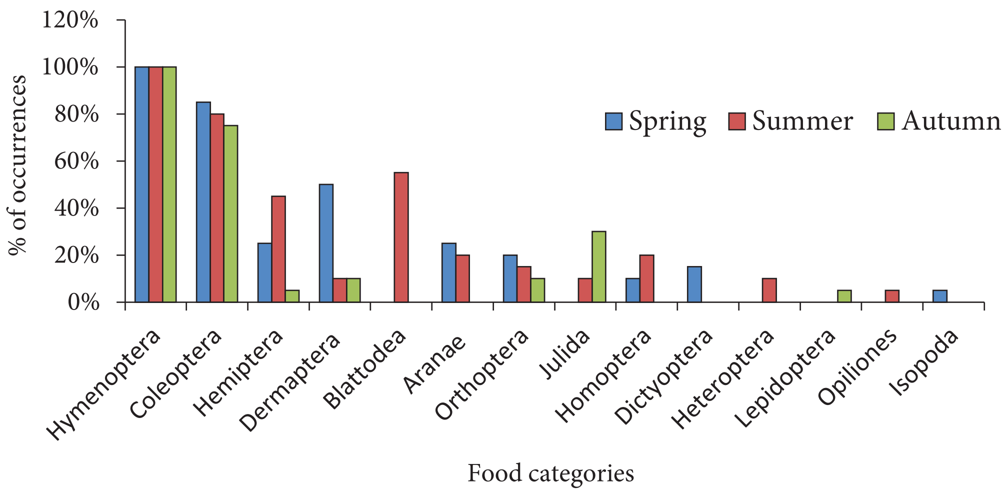

Figure 4. Seasonal variation among the different food categories of the Algerian hedgehog in Tizi-Rached.

order Hymenoptera is divided into 4 families. The family Formicidae is the most dominant with a percentage of 99%. Other families are weakly represented with a single individual. In the dominant family of Formicidae, we identified 11 species. The two main species identified were *Cataglyphis viaticus*, which is the most dominant at 68%, and *Crematogaster laestrygon*, at 12%. Other species do not exceed 10%. These other species include *Aphaenogaster dipilis*, *Aphaenogaster sardoa*, *Camponotus alii*, *Crematogaster scutellaris*, *Crematogaster* sp., *Messor barbara*, *Plagiolepis barbara*, *Tetramorium sericeiventris*, and *Tetramorium sumiliev*. The values of the Shannon–Weaver diversity and equitability indices are H′ = 2.34 and J′ = 0.43, respectively.

In Tizi-Rached, we determined 5 classes. Insecta was the most dominant class (97%), followed by Arachnida (2%). Other classes are represented in very low percentages. These five classes are divided into 20 orders. Among these orders, Hymenoptera is dominant (95%). Diptera and Araneae are present at percentages of 2% and 1%, respectively. Other orders are present in low percentages. They are Acari, Mesostigmata, Opiliones, Sarcoptiformes, Trombidiformes, Scolopendres, Scutigeromorpha, Blattodea, Hemiptera, Heteroptera, Homoptera, Orthoptera, Psocoptera, Thysanoptera, Isopoda, Entomobryomorpha, and Poduromorpha. Hymenoptera contains 7 families. Again, Formicidae is the most dominant (99%), and other families are represented in very low percentages. The family Formicidae includes 20 species. *Messor barbara* is the most dominant species at 38%, followed by *Pheidole pallidula* (35%), *Tetramorium sumiliev* (8%), *Plagiolepis barbara* (5%), *Tapinoma nigerrimum* (4%), *Aphaenogaster sardoa* (3%), *Aphaenogaster dipili* (2%), *Aphaenogaster testaceo pilosa* (2%), *Cataglyphis viaticus* (1%), and *Tetramorium caespitium* (1%). Other species are very poorly represented (*Aphaenogaster* sp., *Crematogaster auberti*, *Crematogaster laestrygon*, *Crematogaster scutellaris*, *Crematogaster* sp., *Messor* sp., *Plagiolepis* sp., *Temnothorax* sp., *Tetramorium sericeiventris*, and *Monomorium salomonis*). The values of the Shannon–Weaver diversity and equitability indices are H′ = 2.83 and J′ = 0.41, respectively.

3.4. Food selectivity

The selectivity index values are reported in the Table for both locations. In Yakouren, we recorded 7 orders in feces that were not caught by traps. The value of the corresponding Ivlev index is +1. These orders are Geophilomorpha, Julida, Pulmonata, Stylommatophora, Dermaptera, Heteroptera, and Neuroptera. Four orders that were present in both the droppings and the environment were identified. These orders all have positive Ivlev index values, ranging between 0.04 and 0.074. These orders are Coleoptera (I = 0.74), Dictyoptera (I = 0.53), Homoptera (I = 0.73), Hymenoptera (I = 0.11), and Orthoptera (I = 0.04). In Tizi-Rached, we found 5 orders that were consumed by the hedgehog but were absent from the environment. The corresponding Ivlev index value is therefore equal to +1. These orders are Coleoptera, Dermaptera, Dictyoptera, Julida, and Lepidoptera. Three of the identified orders have a positive Ivlev index value. These orders are Blattodea (I = 0.18), Hemiptera (I = 0.66), and Hymenoptera (I = 0.39).

3.5. Biochemical characteristics of some ant species

As seen in the previous results, the study demonstrates that individuals of the family Formicidae are the most frequently consumed in the diet of the hedgehog. In order to understand the hedgehog's preference for Formicidae, it is crucial to carry out an analysis of the biochemical components, which reveals the nutritive qualities of some species of ants. To perform this study, we analyzed a few species of ants, in particular *Messor* sp., which is the most dominant, using a set of biochemical methods. This analysis makes it possible to demonstrate the different nutritive values of proteins, lipids, and carbohydrates. The results obtained show that *Messor* sp. is very rich in proteins (72.74%), is low in lipids (5.05%), and does not contain carbohydrates. For the other species, *Cataglyphis* sp., *Tapinoma* sp., and *Pheidole* sp., due to the small amount of samples that were available for analysis, only the protein levels could be determined. The results showed that *Pheidole* sp. contains the most protein (77%), followed by *Cataglyphis* sp. (73.18%) and *Tapinoma* sp. (48.31%). Data concerning the energy values of the different biochemical components of *Messor* sp. are detailed as follows: the protein energy value is 290.96 kcal/dry matter %, the lipid energy value is 45.45 kcal/dry matter %, and the carbohydrate energy value is zero. Thus, the total energy value of these three biochemical components in *Messor* sp. equals 336.41 kcal/dry matter %.

4. Discussion

It is clear from our results that arthropods are the main prey species of the Algerian hedgehog (*Atelerix algirus*). In Yakouren, among the five classes of arthropods identified, the class of insects is predominant. The same observation is true in Tizi-Rached, where this class is predominant over the four other identified classes. These results generally correspond to those reported by Doumandji and Doumandji (1992), Mouhoub-Sayah (2009), and Khaldi (2014). The food spectrum in the hedgehog's diet is very restricted. The Algerian hedgehog mainly displays insectivorous habits.

This behavior is found in other insectivorous animals such as the Algerian shrew (Brahmi et al., 2012) and the European shrew (Churchfield, 1982), which feed mainly on Hymenoptera and Coleoptera, respectively. On the other hand, the diet of the hedgehog differs from that of the mole, which feeds mainly on earthworms and larvae (Beolchini and Loy, 2004).

The order of insects that the Algerian hedgehog consumes the most is Hymenoptera in both Yakouren and Tizi-Rached. At the two sites, Coleoptera is the second most consumed, though rather infrequently so. These results are consistent with those reported in other works carried out in Algeria on the diet of the Algerian hedgehog (Doumandji and Doumandji, 1992; Mouhoub-Sayah, 2009; Khaldi, 2014). Mouhoub-Sayah (2009) and Khaldi (2014) asserted that the diet of the hedgehogs in Djurdjura National Park is 69% made up of Hymenoptera, while this is 72% in Soumam Valley and 94% in the Algiers region.

Most of the investigations on the diet of the European hedgehog (*Erinaceus europaeus*) show that Coleoptera is dominant. In New Zealand, it was observed that Coleoptera were present in 81% of the 192 analyzed intestines of hedgehogs living in various wetland habitats (Chris et al., 2005). Also in New Zealand, the results of Jones and Norbury (2011) showed that Coleoptera species were found in 94% of the analyzed feces of hedgehogs from arid habitats. In England, studies concluded that Coleoptera was the most eaten order by the European hedgehog. Yalden (1976) and Reeve (1994) noted that 73% of 137 analyzed stomachs showed the presence of Coleoptera.

We think it is worth noting that data regarding the hedgehog's feeding habits are quite limited. To the best of our knowledge, the only data available in the literature pertain to the frequency different orders in hedgehog stomach contents or feces. In this case, the order most frequently encountered in the stomach contents is Coleoptera. This information does not take into consideration in what proportion Coleoptera prey species are found in stomach contents or feces.

The results obtained on the composition of the food spectrum of the Algerian hedgehog are different from those of the European hedgehog. The Algerian hedgehog displays a heavy reliance on Hymenoptera as food. Indeed, the consumption of Hymenoptera by hedgehogs is quite large in both of the regions studied. However, we were able to observe a high frequency of occurrence of Coleoptera in the droppings, with a few items in each dropping. We can conclude that the dominance of Hymenoptera is due to its high availability in the environment as compared to the availability of Coleoptera, which is very low in Yakouren and almost nonexistent in Tizi-Rached. We also found that Formicidae is the most consumed family by the hedgehog. This difference in the trophic diet of the European hedgehog and that of the Algerian hedgehog may be explained by the availability or the abundance of Formicidae. In New Zealand, only 37 species of ants have been listed in the entire country (Don, 2007). On the other hand, in the Tizi-Rached region alone, we have already found 20 species in the pitfall traps that we buried in the ground ourselves. This means that in Tizi-Rached alone there is more than 50% of the number of species found throughout the entirety of New Zealand. This indicates that the abundance of ant species in Algeria may be an explanation for the hedgehogs consuming a lot of Hymenoptera.

As we discovered, ants are very much appreciated by the hedgehogs of Algeria, which consume several species of ants. In Yakouren, we listed 13 species, while in Tizi-Rached we listed 11 species. *Messor* sp. is the most consumed species at both sites.

A similar study of the diet of the hedgehog of Algeria was carried out by Derdoukh et al. (2012). These authors considered two sites located in the Mitidja region, which is a low-lying plain, whereas in our case we considered different sites located in the mountainous region of Kabylia. The results obtained by these authors are in agreement with our results. Indeed, the preference of the hedgehog of Algeria for ants was also underlined by these authors. *Messor barbara* is the prey most dominant in the diet of hedgehog in their two stations (at Baraki 87.03% and at Soumâa 51.21%).

As pointed out by Doumandji and Doumandji (1992), this species is considered to be detrimental to cereals. *Messor* sp. is found in all open-air environments, including crops, gardens, pasture, and forest clearings, but virtually never under the vegetation cover (Cagniant and Espadaler, 1997). The high consumption of the *Messor* species in Tizi-Rached is due to the fact that this genus is very abundant in this agricultural zone, which is characterized by the various crops, varying across the seasons. In Yakouren, in addition to *Messor* sp., *Camponotus* sp. was largely eaten. This is due to the fact that Yakouren is a forest region, and that, according to Cagniant (1970), *Camponotus* sp. is more of a forest type of ant.

According to Doumandji and Doumandji (1992), the Algerian hedgehog has a preference for hymenopteran insects and particularly ants. Along with gathering data on the rate at which a certain type of food appears, we looked at the energy value of a few species of Formicidae, namely *Messor* sp., which appears to be preferred by the hedgehog. The biochemical analysis carried out on the most dominant *Messor* species shows that this genus is very rich in protein and low in lipid with no carbohydrate. These results are in agreement with those of Rothman et al. (2014), who reported a study on the average nutrient concentration of different orders of insects. The concentration of proteins is higher than that of lipids in all orders. The energy intake that we obtained for *Messor* sp. is about 336.41 kcal/dry mass %. This result is consistent with what was reported by Rumpold and Schlüter (2013), who asserted that *Messor* sp. nutritional value is between 391 kcal/100 g and 566.36

kcal/100 g. The hedgehog's preference for *Messor* sp. may be influenced by the relatively high energy intake it provides, even though other species do provide more energy.

Moreover, the choice of *Messor* sp. as prey may be linked to the activity of the ants. Delalande (1985) studied the periods of activity of certain species of ants in the Mediterranean region. *Messor* sp. is mostly active from 1900 to 0200 hours, as well as from 0800 to 1000 hours.

While it is known that the protein values of *Pheidole* sp. and *Cataglyphis* sp. are also high, *Cataglyphis* sp. is a diurnal species (Delalande, 1985), which could explain the fact that it is not eaten as much by the hedgehog. However, *Pheidole* sp. is active during the night (Delalande, 1985). Why it is not preferred by the hedgehog remains unclear.

Abundance, quality, and ease of capture are the determining factors for the hedgehog's prey selection. The preference of the Algerian hedgehog for a given prey indicates an adaptation to the variation in environmental conditions. It should be noted that ants secrete alkaloids (Co et al., 2003). These molecules can often be of very acute toxicity. The consumption of ants could consequently be harmful to the hedgehog.

Studying the seasonal variations during spring, summer, and autumn in the hedgehog's diet would therefore be very relevant, as it could provide additional information helpful in understanding the matter further. Note that in winter the hedgehog would be hibernating. To the best of our knowledge, there is no study concerning the seasonal variation in the diet of the Algerian hedgehog. Overall, though, for all three seasons studied, which correspond to when the hedgehog is active, there is not a clearly marked variation in diet, as demonstrated by the chi-square test. This is likely due to the fact that Hymenoptera and Coleoptera are mainly predominant during all three seasons, both in Yakouren and Tizi-Rached. Nevertheless, it should be noted that there are differences in the consumption of certain orders depending on the season. Changes in the food supply in a given environment are linked to climatic variations, namely a drop in temperature and an increase in rainfall, which naturally lead to major changes in feeding behaviors (Mouhoub-Sayah, 2009). In Yakouren, we noticed that Orthoptera was more consumed in autumn, in third place after Hymenoptera and Coleoptera. The reason for this is that Orthoptera species are less active during this period because of unfavorable climatic conditions. They therefore become easier to prey on for the hedgehog (Moussi, 2012). During summer, however, the order Homoptera is the third most consumed prey, after Hymenoptera and Coleoptera. Indeed, this order is very abundant in this season. Spring is the season when there is the most diversity in the hedgehog's diet; almost all the identified orders were consumed during that period.

In Tizi-Rached, summer is the most diversified season in terms of prey. Blattodea is eaten only in the summer at a relatively high rate, although still below those of Hymenoptera and Coleoptera. Conversely, Dermaptera is often consumed in the spring but rarely consumed in the summer. This reflects the hedgehog's ability to adapt its food requirements to the prey availability in its habitat.

The results show that, in Yakouren, there are 12 orders with positive values of the selectivity index, and in Tizi-Rached there are 8 orders with positive values of that same index. This difference is probably due to the availability of the orders in the environment. Note that the majority of orders in Tizi-Rached with a positive selectivity index are also present in Yakouren. However, there are some differences between the two sites. Some orders with a positive selectivity index in one site are assigned a negative index in the other site and vice versa.

The orders that have the maximum selectivity index (+1) in the two sites are Dermaptera and Julida. After that, orders with an important index value are Coleoptera and Dictyoptera. The work carried out on the selectivity of the European hedgehog by Jones and Norbury (2011) showed that the prey most sought after by the European hedgehog belong to the orders of Dermaptera and Coleoptera. This is in line with our results. According to Wroot (1984) and Reeve (1994), the reason for the European hedgehog's dietary preference for Dermaptera is unclear, as this order has a relatively low energy content compared to other types of food. Indeed, Rumpold and Schlüter (2013) showed that Lepidoptera, which is the least preferred type of food, has the highest energy value (508.89 kcal/100 g). The energy values of Coleoptera and Hymenoptera are also significant at 490.30 kcal/100 g and 484.45 kcal/100 g, respectively. Hymenoptera does have a positive index, but it is quite low considering that Hymenoptera is the most consumed order in the hedgehog's diet. This can be explained by its high abundance in the environment. In other words, the hedgehog of Algeria consumes food in relation to its abundance.

It should however be noted that the availability as well as the methods used are subject to biases. Indeed, pitfall traps remain insufficient for a more in-depth measure of availability. This is mainly due to the fact that surface fauna in motion, such as Hymenoptera, has a higher chance of being captured in pitfall traps than other less active or flying types of prey. The study that we performed allowed us to highlight a part of the ecology of the Algerian hedgehog. In spite of limitations from lack of data on prey availability, some solid conclusions can be drawn.

We conclude that the diet of the Algerian hedgehog relies mainly on Hymenoptera, particularly on ants. However, the hedgehog of Algeria does not hesitate to consume other types of preys such as Coleoptera, depending on the availability of such prey. This is valid for the two studied sites. We also noticed that the diet of the hedgehog varies mainly depending on the availability of the prey species during the seasons. It is our opinion that further research should be directed towards gathering data on prey availability by diversifying the types of traps used to capture prey. Another research direction that we are suggesting is biochemical analysis of all of the prey species consumed by the hedgehog. This could provide a clearer understanding of the Algerian hedgehog's preference, if any, for some prey species according to their energy contribution.

Acknowledgments

The authors are grateful to the Editor and the three anonymous referees for their constructive comments and valuable suggestions, which improved the quality of the paper. This work was funded by the Laboratory of Ecology and Biology of Terrestrial Ecosystems (LEBIOT), University Mouloud Mammeri, Tizi-Ouzou, Algeria. The authors therefore acknowledge technical and financial support from LEBIOT. The authors also thank Emmanuelle Martel for help in correcting language errors.

References

Barbault R (1981). Ecologie des populations et des peuplements. Paris, Franch: Ed. Masson.

Beolchini F, Loy A (2004). Diet of syntopic moles *Talpa romana* and *Talpa europaea* in central Italy. Mamm Biol 2: 140-144.

Bigot L, Bodot P (1973). Contribution à l'étude biocénotique de la garrigue à Quercus coccifera. Composition biotique du peuplement des invertébrés. Vie Milieu 23: 229-249 (in French).

Blondel J (1979). Ecologie et biogéographie. Paris, France: Ed. Masson (in French).

Brahmi K , Aulagnier S, Slimani S, Mann CS, Doumandji S, Baziz B (2012). Diet of the Greater white-toothed shrew *Crocidura russula* (Mammalia: Soricidae) in Grande Kabylie (Algeria). Ital J Zool 79: 239-245.

Brockie RE (1959). Observations of the food of the hedgehog (*Erinaceus europaeus L.*) in New Zealand. New Zeal J Sci 2: 121-136.

Cagniant H (1970). Deuxième liste de fourmis d'Algérie, récoltées principalement en forêt (Deuxième partie). Bulletin de la Société d'Histoire Naturelle de Toulouse 106: 28-40 (in French).

Cagniant H (1996). Les *Camponotus* du Maroc (Hymenoptera: Formicidae). Ann Soc Entomol Fr 32: 87-100 (in French).

Cagniant H (2005). Les *Crematogaster* du Maroc (Hymenoptera: Formicidae), Clé de détermination et commentaires. Orsis 20: 7-12 (in French).

Cagniant H, Espadaler X (1997). Le genre *Messor* au Maroc (Hymenoptera: Formicidae). Ann Soc Entomol Fr 33: 419-434 (in French).

Campbell PA (1973). The feeding behaviour of the hedgehog (*Erinaceus europaeus L.*) in pasture land in New Zealand. Proceedings of the New Zealand Ecological Society 20: 35-40.

Chopard L (1943). Faune de l'Empire français :I. Orthoptéroïdes de l'Afrique du Nord. Paris, France: Ed. Librairie Larose (in French).

Chris J, Kisten M, Mark S (2005). Diet of hedgehogs (*Erinaceus europaeus*) in the upper Waitaki Basin, New Zealand: implications for conservation. New Zeal J Ecol 29: 29-35.

Churchfield S (1982). Food availability and the diet of the common shrew, *Sorex araneus,* in Britain. J Anim Ecol 51: 15-28.

Co JE, Jones TH, Hafetz A, Tinaut A, Senelling RR (2003). The comparative exocrine chemistry of mine Old World species of *Messor* (Formicidae: Myrmicinae). Biochem Syst Ecol 31: 367-373.

Daget J (1976). Les modèles mathématiques en *écologie*. Paris, France: Ed. Masson (in French).

Dajoz R (2006). Précis d'écologie. 8th ed. Paris, France: Dunod (in French).

Delalande C (1985). Rythmes d'activité de quelques espèces de fourmis en région méditerranéenne (Hy, Formicidae). Act Colloq Insect S 2: 303-318.

Derdoukh W, Guerzou A, Baziz-Neffah F, Khoudour A, Dahou M, Meribai A, Doumandji S (2012). Election of preys by *Atelerix algirus* in two stations of Mitidja (Algeria). International Journal of Bio-Technology and Research 2: 51-62.

Derouiche L, Bouhadad R, Fernandes C (2016). Mitochondrial DNA and morphological analysis of hedgehogs (Eulipotyphla: Erinaceidae) in Algeria. Biochem Syst Ecol 64: 57-64.

Don W (2007). Ants of New Zealand. Dunedin, New Zealand: Otago University Press.

Doumandji S, Doumandji A (1992). Note sur le régime alimentaire du Hérisson d'Algérie, (*Erinaceus algirus*), dans la banlieue d'Alger. Mammalia 56: 318-321 (in French).

Fedriani JM, Kohn MH (2001). Genotyping faeces link individuals to their diet. Ecol Lett 4: 477-483.

Jacobs J (1974). Quantitative measurement of food selection: a modification of the forage ratio and Ivlev's electivity index. Oecologia 14: 413-417.

Jaksic FM, Feinsinger P, Jimenez JE (1992). A long-term study on the dynamics of guild structure among predatory vertebrates at a semi-arid Neotropical site. Oikos 67: 87-96.

Jarrige R (1988). Alimentation des bovins, ovins et caprins. Paris, France: Ed. Institut National de Recherche en Agronomie (in French).

Jones C, Norbury G (2011). Feeding selectivity of introduced hedgehogs *Erinaceus europaeus* in a dryland habitat, South Island, New Zealand. Acta Theriol 56: 45-51.

Khaldi M (2014). Les endoparasites et les ectoparasites des hérissons *Atelerix algirus* (Lereboullet, 1842) et *Paraechinus aethiopicus* (Mammalia, Erinacidae) et aperçu sur leur écologie trophique dans le bassin de Hodna (Algérie). PhD, Ecole Nationale Supérieure Agronomique, El-Harrach, Algiers, Algeria.

Khaldi M, Ribas A, Barech G, Hugot JP, Benyettou M, Albane L, Arrizabalaga A, Nicolas V (2016). Molecular evidence supports recent anthropogenic introduction of the Algerian hedgehog *Atelerix algirus* in Spain, Balearic and Canary Islands from North Africa. Mammalia 80: 313-320.

Khaldi M, Socolovschi C, Benyettou M, Barech G, Biche M, Kernif T, Raoult D, Parola P (2012a). Rickettsiae in arthropods collected from the North African Hedgehog (*Atelerix algirus*) and the desert hedgehog (*Paraechinus aethiopicus*) in Algeria. Comp Immunol Microb 35: 117-122.

Khaldi M, Torres J, Sams B, Miquel J, Biche M, Benyettou M, Barech G, Benelkadi HA, Ribas A (2012b). Endoparasites (helminths and coccidians) in the hedgehogs *Atelerix algirus* and *Paraechinus aethiopicus* from Algeria. Afr Zool 47: 48-54.

Lecoq R (1965). Manuel d'analyses alimentaires et d'expertises usuelles. Vol. 2. Paris, France: Ed. Doin (in French).

Mouhoub-Sayah C (2009). Ecophysiologie du Hérisson d'Algérie *Atelerix algirus* Lereboullet, 1842 (Mammalia, Insectivora) dans quelques stations du Djurdjura et dans la vallée de la Soummam. PhD, Ecole Nationale Supérieure Agronomique, El-Harrach, Algiers, Algeria (in French).

Mouhoub-Sayah C, Robin JP, Pevet P, Monecke S, Doumandji S, Saboureau M (2009). Road mortality of the Algerian Hedgehog (*Atelerix algirus*) in the Soummam valley (Algeria). Rev Ecol-Terre Vie 64: 145–156.

Moussi A (2012). Analyse systématique et étude bio-écologique de la faune des acridiens (Orthoptera, Acridomorpha) de la région de Biskra. PhD, University Mohamed Mentouri, Constantine, Algeria (in French).

Perrier R (1927). La faune de la France illustrée. V. Coleoptera. Paris, France: Ed. Delagrave (in French).

Perrier R (1940). La faune de la France. VIII. Hymenoptera. Paris, France: Ed. Delagrave (in French).

Perrier R (1979). La faune de la France illustrée. IV. Hemipteres. Anploures. Mallophages. Lepidopteres. Paris, France: Ed. Delagrave (in French).

Perrier R, Delphy F (1932). La faune de la France illustrée. VI. Coleoptera. Paris, France: Ed. Delagrave (in French).

Ramade F (2008). Dictionnaire encyclopédique des sciences de la nature et de la biodiversité. Paris, France: Ed. Dunod (in French).

Reeve NJ (1994). Hedgehogs. 1st ed. London, UK: T. & A. D. Poyser Ltd.

Rothman JM, Raubenheimer D, Brye MAH, Takahashi M, Gilbert CC (2014). Nutritional contributions of insects to primate diets: implications for primate evolution. J Hum Evol 71: 59-69.

Rumpold BA, Schlüter OK (2013). Nutritional composition and safety aspects of edible insects. Mol Nutr Food Res 57: 802-823.

Sakraoui F, Boukheroufa M, Sakraoui W, Madoui MEB (2014). Ectoparasitic ecology of Algerian hedgehog *Atelerix algirus* (Lereboullet, 1842) (Erinaceidae, Mammalia) in some localities of Edough Montain (Annaba, Northest Algeria). Advances in Environmental Biology 8: 217-221.

Salas LA, Fuller TK (1996). Diet of the lowland tapir (*Tapirus terrestris* L.) in the Tabaro River valley, southern Venezuela. Can J Zool 74: 1444-1451.

Wiens JA (1993). Fat times, lean times and competition among predators. Trends Ecol Evol 8: 348-349.

Wroot AJ (1984). Feeding ecology of the European hedgehog, *Erinaceus europaeus*. PhD, University of London, London, UK.

Yalden DW (1976). The food of the hedgehog in England. Acta Theriol 21: 401-424.