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Diet and prey availability of the Black Wheatear *Oenanthe leucura* in the El Hodna region (M'Sila, Algeria)

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Abstract - The Black Wheatear *Oenanthe leucura* is distributed in the arid rocky landscapes of the Iberian Peninsula and North Africa. The species is insectivorous in the South of Europe, while its diet has not yet been studied in the North-African population. In this study, we looked into its prey choice and availability in the El Hodna area of M'Sila, Algeria. Prey availability was estimated during the breeding season 2020 by means of Pitfall traps, butterfly net, sweep net and sight hunting method. The prey groups consumed by the species in winter 2019 and spring 2020 were determined by using 219 faecal samples found on the different perches. Faecal samples analysis revealed 1656 prey items. The species' diet is dominated by insects, which may be related to the great abundance of this prey group in the habitat. The Black Wheatear's main food resources were ants, orthopterans and beetles. In the winter, the most consumed prey groups ranged in size from 7.31 to 13.25 mm, whereas in the spring, they ranged from 1.5 to 7.37 mm. The most abundant taxonomic group during the breeding season were insects (RA = 97.64%), and Hymenoptera was the most widely accessible (RA = 72.6%) in the habitat of the species because of the apparent abundance of ants (RA = 71.14%). We determined the Ivlev index (Li), which enables a comparison between the species' diet and the prey abundance in the habitat. According to the Ivlev Index, the Black Wheatear is an opportunistic bird, catching the majority of the area's available prey.

Keywords: Black Wheatear, food availability, diet, faecal samples, M'Sila, Algeria.

INTRODUCTION

Studies on the relationship between birds and habitat indicate that additional elements besides bioclimatic ones affect the availability of food resources (Morrison et al. 1990). Prey availability and diet composition can be compared to determine the prey groups inhabiting an ecosystem, and their abundances and distribution (Cooper & Whitmore 1990). Birds use various food resources, reflecting their different foraging and prey-capturing techniques

(Holmes 1986), which can explain why some prey are consumed more frequently than others (Cooper & Whitmore 1990). The species trophic ecology includes the evaluation of hunting techniques, foraging behaviours and potential prey types (Hutto 1990). Climate, seasonality, and the presence of other bird species in their core area may all have an impact on this (Brennan & Morrison 1990). This is the case with the Black Wheatear, *Oenanthe leucura*, for whom feeding strategy may be critical to survival in arid zones with low productivity (Hódar 1998).

The Black Wheatear is a sedentary species distributed in southwest Europe and northwest Africa (Ferguson-Lees 1960, Todó et al. 2009, Noguera et al. 2014, Aznar & Élbáñez-Agulleiro 2016, Estévanez 2021). Two subspecies can be recognized by their morphology (Vaurie 1959). The European subspecies *Oenanthe leucura leucura* is confined to Portugal, the southern three-quarters of Spain, while the African subspecies *Oenanthe leucura syenitica* is found in the Western Sahara, Morocco, Algeria, Tunisia, and Libya (Ferguson-Lees 1960). The European populations live in open, sunny locations that are more or less rocky and have little vegetation, and they frequently occupy arid regions (Ferguson-Lees 1960, Prodon 1985, Moreno 1997, Soler 1997, Ramírez & Soler 2004, Todó et al. 2009). The populations of North Africa are restricted to the southern Grand Atlas slopes and extend into the Saharan Atlas, where it is especially common in Algeria (Heim De Balsac & Mayaud 1962). It can be found in Algeria's high plateaus, the Tell, and the Oranais (Heim De Balsac & Mayaud 1962, Ledant et al. 1981, Isenmann & Moali 2000).

The diet of the Black Wheatear has been so far studied only on the European subspecies in the South of Europe (Richardson 1965, Soler et al. 1983, Prodon 1985, Moreno et al. 1994, Hódar 1995, Moreno 1997, Soler 1997). The availability and captured prey, as well as the climatic conditions, would all affect the species' diet, which consists primarily of arthropods, vertebrates, and a low proportion of plants (Richardson 1965, Prodon 1985, Hódar 1995, Soler et al. 1995). However, no research has been done on the species' diet in the southern edge of the Mediterranean basin in North Africa. Indeed, the lack of information on the species' diet inhabiting open and non-forested areas is particularly linked to the difficulty of capturing and managing specimens in often low-density populations (Hódar 1998). The aim of this study is to describe for the first time the diet of the African subspecies of Black Wheatear in Algeria during the winter and breeding period. Thus, we examined the fluctuation in its diet over months and seasons, and compared prey availability to prey detected in the species' faeces.

MATERIALS AND METHODS

Study area

The study area is located 15 kilometers north of the Wilaya of M'Sila city center in the Boukhemissa region at a height of 500 meters (35°48'39.4"N, 004°32'56.4"E) (Fig. 1). The biogeographic sector of El Hodna, which has a continental climate and an arid bioclimatic stage. Winters are cold, and summers are hot and dry, with annual rainfall ranging from 100 to 250 mm (Le Houérou 1995, Le Houérou 2009). The average annual temperature is about 15.8 °C (Le Houérou 1995).

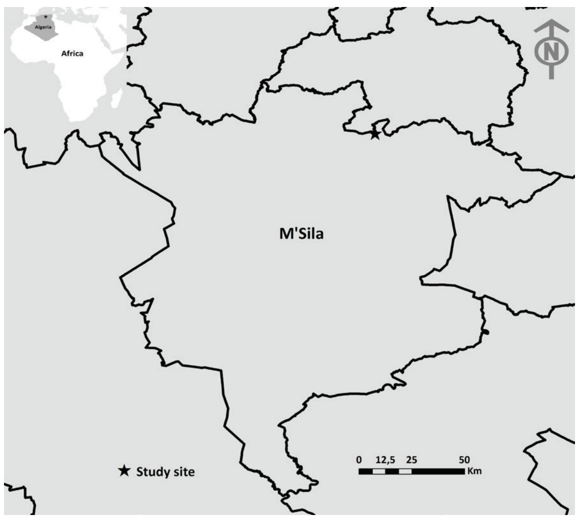

Figure 1. Schematic map of the geographical location of the study area.

Faecal collection

The diet study of the Black Wheatear was carried out by analysing faecal samples. Faecal samples were collected during two periods: in winter (from November 2019 to January 2020) and in spring (from March to May 2020). A total of 149 faecal samples were collected during the winter and 70 samples during the spring. The faecal samples were collected from different perches located in the different territories of the species (four territories). The perches were regularly cleaned each month in order to avoid the accumulation of faecal samples from the previous month. Collected faecal samples were placed in Eppendorf tubes on which the date and location were indicated.

Prey availability

The study of prey availability in Black Wheatear territories was conducted between March and May 2020. It coincided with the faecal sample collection during the spring period. We have applied four sampling methods in the immediate surroundings of the species perches. Pitfall traps were used to catch terrestrial arthropods (Cooper & Whitmore 1990). Additionally, some flying insects that land on the Pitfalls traps were captured using this technique (Benkhelil 1991). It is suitable for studying prey availability for this avian species, because the Black Wheatear captures most of its prey on the ground surface (Hòdar 1995). We were able to retrieve the contents of 15 Pitfall traps per month every 72 hours after they were deployed. In addition to the Pitfall traps, we sampled flying insects, such as butterflies and bees, using butterfly nets (Yi et al. 2012), and arthropods on plants using a sweep net (Cooper & Whitmore 1990). Furthermore, we used the sight hunting method, which consists in searching for the species with visual observation. It is thought that sight hunting is an appropriate technique for locating arthropods concealed beneath rocks, in cracks, or beneath vegetation (Winchester & Scudder 1993). The identification of arthropods was by referencing determination keys used for several taxonomic groups (Jones et al. 1990, Charrier 2002, Chinery 2005, Albouy & Richard 2017). Arthropod sampling defines the abundance and availability of prey in the habitat, which are used to determine the choice of prey consumed by the Black Wheatear.

According to Jacobs (1974), Ivlev's selectivity index (*Li*) compares the relative abundance of available prey consumed by the predator. It is expressed by the following formula:

$$Li = (r - p)/(r + p)$$

Where r is the prey number in the diet and p is the same prey number in the natural environment. The value of *Li* ranges from -1 to 0 for negative selection (for the least selected prey), and from 0 to +1 for positive selection (for the most selected prey) (Ivlev 1961, Jacobs 1974).

Faecal sample analysis and prey taxa identification

Each collected faecal sample was placed into a Petri dish with a few drops of water to aid in faecal sample dehusking, and then the separated fragments were arranged using entomological forceps (Belkacem et al. 2019, Zemouri et al. 2021). These fragments were observed and identified using an Olympus binocular stereo zoom Z410 (magnification range: 0.8–4.7 x 10). Then, in a different Petri dish lined with blotting paper, these fragments were gathered and organised according to category. By using multiple spider and insect guides and following identification keys, we were able to identify the prey taxa (Calver & Wooller 1982, Tatner 1983, Rarlph et al. 1985, Jones et al. 2001, Charrier 2002, Chinery 2005, Albouy & Richard 2017). We were able to identify some prey by using the collection of arthropods gathered from the species' foraging ranges. Prey was identified at the possible lowest taxonomic rank. We counted one prey item when we found a complete head, thorax, mandible, elytra, or chelicerae (Zemouri et al. 2021). Additionally, when legs and wings were observed, one prey item was also counted. The observation of seeds and floral rosettes in faecal samples revealed that the species had been consuming plant berries. By using a χ^2 test, the proportion of taxonomic groups of prey that Black Wheatear consumed was compared over the six-month period and the two seasons.

Diet diversity

To analyse our data, we applied various ecological indexes. First, we used the total richness (S), which is the number of prey taxa found in all collected faeces (Ramade 1984). Then, the mean richness (s) is equal to the average number of species in the N samples (Ramade 1984). The relative abundance (RA %) is the proportion of items belonging to each prey taxa (n_i) to all items belonging to all prey taxa (N) combined (Zaime & Gautier 1989). The frequency of occurrence (FO %) is the ratio expressed as a faecal number percentage containing the prey taxa to the total faecal number N (Dajoz 1982). We used Costello's (1990) graph representation to identify the prey groups selected by Black Wheatears. This graph uses the relative abundance (RA %) of prey groups observed in the species' diet in both the winter and the spring as the y-axis and the frequency of occurrence (FO %) as the x-axis. The Costello graph describes the predators' feeding strategies (specialist or generalist), the degree of diet homogeneity, and the prey groups' abundance (dominant or rare). Black Wheatear diet diversity was expressed by the Shannon-Weaver index (H' Clarke & Warwick 2001).

Similarity index

Sörensen's similarity index (1948) was used to compare the Black Wheatear's diet in the winter and spring as well as the relationship between prey availability and the species' diet. Sörensen's similarity quotient was calculated by the following formula:

$$Cs = (2j / (a + b)) \times 100$$

Where *Cs* is Sörensen's index, *a* and *b* are the prey taxa number present in samples a and b, and *j* is the prey taxa number common to both samples a and b.

Prey sizes

In the case of non-degraded taxa (complete prey items), prey size was directly determined. Incomplete prey items were indirectly measured by measuring undegraded arthropod parts such as heads, elytra, and thorax (seen Calver & Wooller 1982). These arthropod parts (fragments) were measured with graph paper to estimate the size of the whole prey. We used the χ^2 test to compare the prey proportions in each size class. To identify the number of size classes (*K*; Scherrer 1984), we applied Sturge's (1926) formula:

$$K = 1 + 3.322 (\log_{10} n)$$

Where *n* is the total number of individuals examined belonging to any of the prey items found. We then created *n* intervals of size classes with a range obtained by dividing the difference between the largest and smallest size values by the total number of classes found (*size class interval = largest size – smallest size/n*).

RESULTS

Diet composition

The Black Wheatear diet was composed of arthropods (RA = 97.70%, n = 1618), vertebrates (RA = 0.42%, n = 7) and plants (RA = 1.88%, n = 31). In the faecal samples, 1656 prey items were found (1204 in winter, 452 in spring). Insects were the most abundant prey type (96.93% in winter, 85.84% in spring), followed by spiders (2.08% in winter, 8.19% in spring). Plants, reptiles and chilopods appeared in low numbers, notably in winter (plants = 0.65%, reptiles = 0.16%, chilopods = 0.16%) (Appendix 1).

The species diet composition varied between months (χ^2 test = 283.74, $p < 0.001$) and seasons (χ^2 test = 502.5, $p < 0.001$). In winter, ants were the most consumed prey by Black Wheatears (Fig. 2) because of the high presence of *Messor* sp. in the analysed faecal samples. A similar observation was made in spring, when *Tetramorium biskrensis* and *Messor* sp. dominated the studied faecal samples, and the ants were consistently the most frequently hunted by the species. Orthoptera, Curculionidae, and Carabidae were quite frequent in the species' diet in both the winter and the spring (Fig. 2). We should mention that Black Wheatears occasionally eat small plant berries and can prey upon small Lizards (Squamata).

Furthermore, the proportion of some better-digested prey items, such as larvae, might be under-detected with a bias towards more chitinous insects.

Relationship between availability and diet

The prey availability study revealed 1102 prey items grouped into 110 prey taxa. Insects were the most abundant (RA = 97.64%), followed by spiders (RA = 2%), gastropods (RA = 0.27%) and reptiles (RA = 0.09%). The Hymenoptera group has the highest availability (RA = 72.6%) in the habitat of the species. This dominance results from the abundance of the ant family (RA = 71.14%).

Selectivity indicated that the proportion of rejected prey (57.62%) was higher than the proportion of selected prey (42.37%) (Tab. 1). Prey groups such as ants, Tenebrionidae, Pentatomidae, Haliplidae and Chrysomelidae were negatively selected. Orthoptera, Cetoniidae, Carabidae, Buprestidae, Staphilinidae, Curculionidae and Oxyopidae were positively selected.

Diet diversity and potential prey

We were able to identify 76 prey taxa in the winter and 70 prey taxa in the spring from the 219 faecal samples we studied. The average number of prey taxa per faecal sample was larger than five in the spring compared to less than five in the winter (Tab. 2). The lowest value was recorded in November (2.51 ± 1.37). Black Wheatear diet in the spring was more diverse, especially between March and May (Tab. 2). In the winter, between November and December, it was less diversified. The minimum value was registered in November (H' = 1.81 bits).

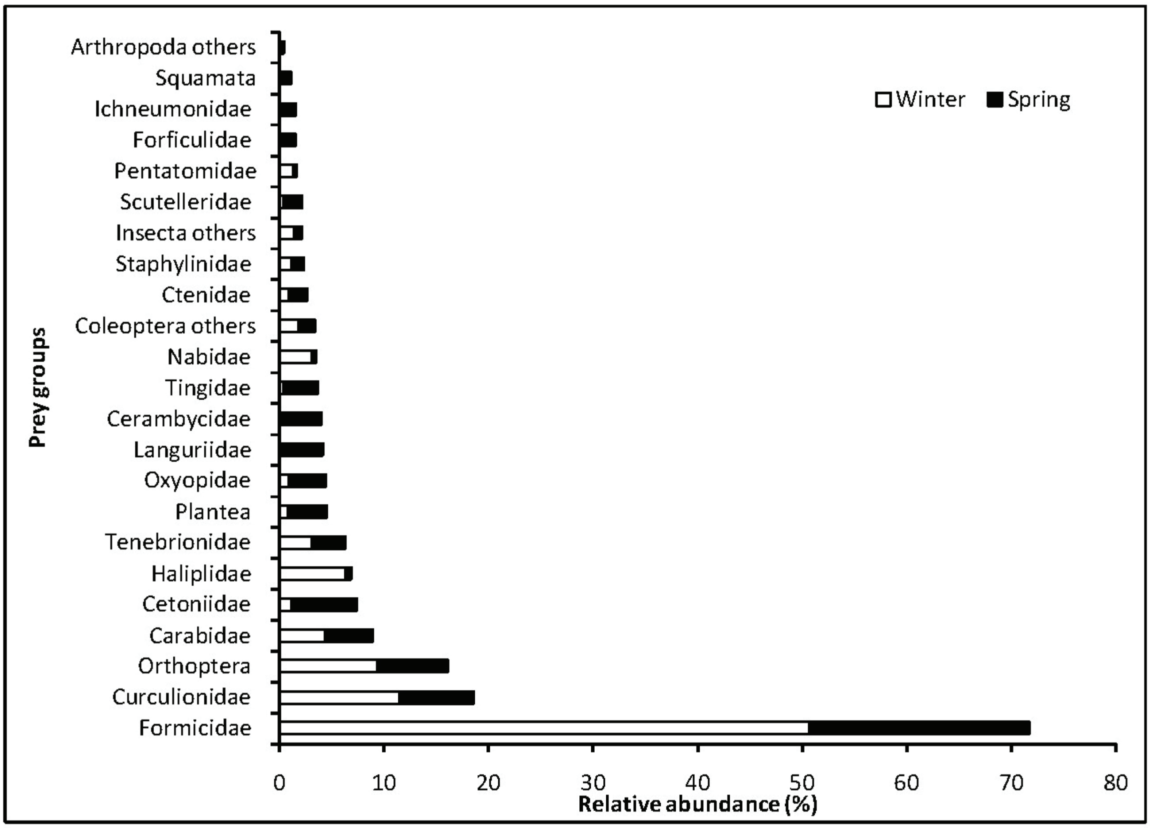

Figure 2. Black Wheatear diet composition in the M'Sila region.

Table 1. Selectivity values for the different prey groups found in the diet of Black Wheatear in M'sila region.

	March	April	May	All months
Curculionidae	0.76	0.17	0.8	0.63
Carabidae	0.8	0.82	1	0.86
Staphylinidae	0.6	0	0	0.75
Haliplidae	1	-1	-0.2	-0.57
Cerambycidae	-1	0	0	-1
Chrysomelidae	1	-1	-0.14	-0.17
Elateridae	1	0	0	1
Coleoptera	1	0	1	1
Tenebrionidae	0.08	-0.69	0.38	-0.08
Scarabaeidae	0	0	-1	-1
Cetoniidae	0.86	1	1	0.89
Attelabidae	1	0	1	1
Hydrophilidae	0	-1	0	-1
Buprestidae	1	1	0.78	0.83
Hymenoptera	0	-1	0	-1
Formicidae	-0.71	-0.60	-0.87	-0.74
Apidae	0.2	-1	-1	-0.45
Vespidae	0	1	0	1
Ichneumonidae	1	1	0	0.56
Pentatomidae	1	-1	1	-0.33
Miridae	-1	0	-1	-1
Nabidae	1	0	0	1
Tingidae	1	1	1	1
Pyrrochoridae	-1	-1	-1	-1
Scutelleridae	1	1	1	1
Orthoptera	0.78	1	0.92	0.9
Acrididae	-1	-1	-1	-1
Diptera	-1	-1	-1	-1
Forficulidae	0	0	1	1
Carcinophoridae	0	0	1	1
Lepidoptera	-0.53	1	0.87	0.24
Trichoptera	0	1	0	1
Araneae	0	0	1	0.33
Oxyopidae	1	0.82	1	0.9
Ctenidae	1	0.2	0.67	0.54
Agelenidae	1	-1	1	0.33
Salticidae	-1	0	-1	-1
Lycosidae	-1	-1	0	-1
Philodromidae	0	-1	0	-1
Scytodidae	0	0	-1	-1
Thomicidae	0	0	-1	-1
Araneidae	-1	0	0	-1
Solifugae	0	0	-1	-1
Bithudae	0	1	0	1
Squamata	1	0	1	1
Plantea	0	0	1	1
Nemonycidae	-1	-1	0	-1
Oedemeridae	-1	-1	0	-1
Anthicidae	-1	-1	-1	-1
Nutidilidae	-1	0	0	-1

Dermestidae	0	-1	0	-1
Zopheridae	0	-1	-1	-1
Cleridae	0	0	-1	-1
Melyridae	-1	0	0	-1
Sphecidae	-1	0	0	-1
Halticidae	-1	0	0	-1
Pompilidae	-1	-1	0	-1
Meridae	-1	0	0	-1
Cicadellidae	-1	-1	-1	-1

Table 2. Black Wheatear diet ecological indices in the M'Sila region.

	November	December	January	March	April	May
Nº faecal	35	68	46	23	18	29
Prey identified	21	51	41	41	37	39
Prey measured	16	39	31	25	22	21
Prey size (mm)	10.09 ± 2.39	10.15 ± 2.19	8.72 ± 2.88	10.01 ± 2.30	8.99 ± 2.18	11.01 ± 2.74
Mean richness	2.51 ± 1.37	4.16 ± 2.50	5.56 ± 1.98	4.60 ± 2.53	5 ± 1.87	5.24 ± 2.14
Diversity H' (bits)	1.81	3.04	4.32	4.37	4.27	4.53

There are six potential prey groups identified by the Black Wheatear diet graphic (Fig. 3). The species tends to capture more of the ants both in winter as well as in spring (Fig. 3). Other important prey groups were Orthoptera, Curculionidae, Carabidae, Haliplidae and Cetoniidae. However, Lepidoptera (RA = 5.09%, FO = 24.28%) contribute to a larger part of the species' diet in spring.

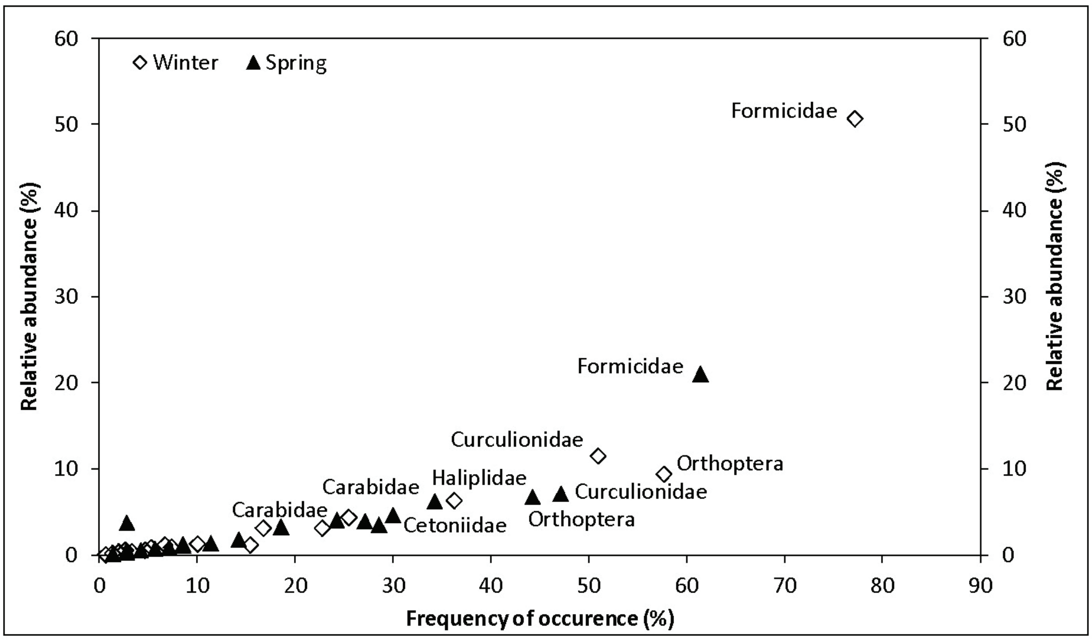

Figure 3. Costello's graphical representation of potential prey of Black Wheatear.

Diet similarity

During the breeding season, Sörensen's similarity coefficient showed a low similarity (15.55%) between prey availability and the species' diet. The species' diet in winter was different from that noted in spring (49.31%). Between the months of the same season, there were many similarities, especially between April and May for spring (57.5%) and between December and January for winter (50%) respectively.

Prey sizes

The prey size consumed by the species varies between 1.5 (Languriidae sp.) and 25 mm (*Anisolabis maritima*) (Fig. 4). The prey average size was 9.71 mm (SD = 2.88) in the winter and 10.15 mm (SD = 2.56) in the spring. The average prey size varied little from month to month (Appendix 1). However, the smallest prey were consumed in January and April, with an average size of 8.99 mm (SD = 2.18).

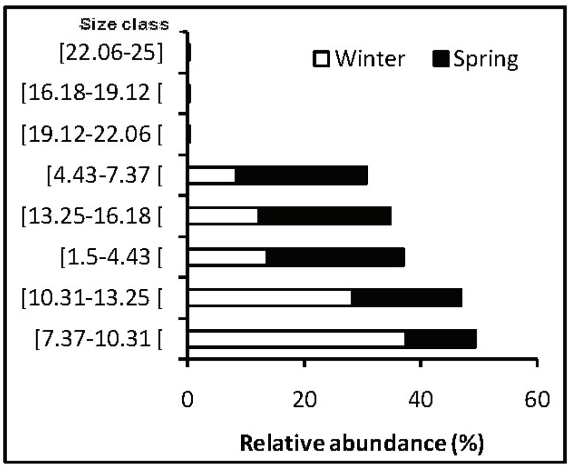

Figure 4. Size class of prey taxa found in the faecal of Black Wheatear.

The prey sizes consumed varied slightly over the course of the six months (χ^2 test = 40, df = 25, P = 0.017), but not significantly between the two seasons (χ^2 test = 32, df = 24, P = 0.127). The majority of prey eaten by Black Wheatears had a size ranging between 7.31 and 13.25 mm the most during the winter (Fig. 4). They were represented especially by *Messor* sp., for which we identified two main size averages (size 1 = 9 mm, size 2 = 12 mm) depending on the cast (workers, queen, etc.), and *Tropinota hirta* (13 mm). On the other hand, in the spring (Fig. 4), smaller size prey (between 1.5 and 7.37 mm), such *Tetramorium biskrensis*, were more frequent in the species' diet (7 mm).

DISCUSSION

Insects dominate the Black Wheatear diet in M'Sila region in winter as well as in spring. Our results confirm what has been found in the South of Europe, where the subspecies *Oenanthe leucura leucura* is considered an insectivorous bird (Picot-Lapeyrouse 1790, Witherby et al. 1938, Géroudet 1963, Ferguson-Lees 1960, Voos 1960, Richardson 1965, Hódar 1995), and expand the current knowledge to a wider geographical area. In M'Sila, the Black Wheatear also consumed different prey taxa, including spiders, chilopods, reptiles and plants. The species in southern Europe also consumes berries from a range of plants, such as *Asparagus acutifolius*, *Berberis hispanica*, *Rhamnus alpinus*, *Rubus idaeus*, *Olea* sp., *Smilax aspera*, *Capparis spinosa* and *Myrtus communis* (Picot-Lapeyrouse 1790, Witherby et al. 1938, Blanchet & Heldt 1951, Ferguson-Lees 1960, Voos 1960, Géroudet 1963, Richardson 1965, Prodon 1985, Hódar 1993, 1994). According to Hódar (1993), these various plant berries will be essential food sources in dry ecosystems. In the M'Sila region, reptiles make up a small amount of the species' diet. Hymenoptera, Orthoptera, and Coleoptera make up the majority of the species' diet in the M'Sila region. Our findings concur with those from France and Spain in southern Europe (Picot-Lapeyrouse 1790, Voos 1960, Richardson 1965, Hódar 1995). Ants dominate the species' diet both in winter and in spring, similar to other populations observed in its distribution area (Witherby et al. 1938, Voos 1960, Richardson 1965, Hódar 1995). This is a result of their great availability and abundance in the surroundings of the species' territories. Ants are more available and abundant in dryland (Hódar 1995), for example, reaching 71.14%

of the total number of arthropods caught in Pitfall traps in M'Sila. Therefore, ants serve as a significant source of prey for birds of the genus *Oenanthe* in dryland (Cramp 1988). Ants are not listed as the Black Wheatear's prey species in southern France (Prodon 1985). According to the latter author, this bird catches more beetles and Orthoptera in the late summer, as well as caterpillars while feeding young chicks and other arthropod groups like butterflies, spiders, hymenoptera and Scolopendridae. In our study, Diptera were found in lower numbers in the Black Wheatear's diet than Witherby et al. (1938), which reported this category of insects among the prey that predominated in the diet of the European subspecies *Oenanthe leucura leucura*.

The Orthoptera, Oxyopidae, and Cetoniidae prey groups had the greatest positive selection, according to the calculated Ivlev selectivity index. The Black Wheatear consumed most of these prey types during the breeding season in M'Sila; this suggests that its diet is very diversified and demonstrates the generalist hunting strategy of the species (Hódar 1995). The choice of orthopterans as a food source is likely due to their high nutritional content (Ueckertet al. 1972, Belovesky & Slade 1993, Hódar 1995). The species also chose the Oxyopidae group (lynx spiders) since they can be found frequently, concealed in small rock crevices in arid regions and are very simple to catch (Polchaninova 2012). Despite their overall abundance in the faecal sample during this period, the ant groups were negatively selected. This fact might be related to the great diversity of prey and the fact that ants were not a good food source during this time (Hódar 1995), as parents must provide profitable prey for their broods (Royama 1970). The species consumes a large number of available prey as a result, saving energy while searching for food (Vignes 2011).

The prey number per faecal varies between months and seasons. There was a large difference in the prey type appearance in each faecal sample. Each faecal sample contained a variety of prey taxa, with *Messor* sp. (RA = 48.59%, FO = 32.61%) being the most consumed in the winter and *Tetramorium biskrensis* (RA = 8.63%, FO = 12.33%) and *Messor* sp. (RA = 7.96%, FO = 11.38%) in the spring. The fluctuations in the diversity index (H'), especially in winter, are explained by the abundance of some prey in the faecal samples. In fact, the springtime diet of the Black Wheatear in the M'Sila region was more diversified than the wintertime diet. This difference might come from the fact that parents need to feed their nestlings with profitable and varied prey during the breeding season (Royama 1970, Peris 1980, Hódar 1995). Another possible explanation is that the difference between the winter and spring diets might be influenced by climatic factors, as the rise in temperature during the spring could lead to the emergence of additional insect groups (Boudeffa 2015). It might possibly be connected to how dryland birds forage, catching numerous arthropods that walk on the ground (Hódar 1995).

Regarding the prey size results, the species tends to consume smaller prey in the spring than in the winter. The abundance of prey species such as *Messor* sp. (size 1 = 9 mm, size 2 = 12 mm) and *Tropinota hirta* (13 mm) appears to be related to the importance of prey sizes between 7.31 and 13.25 mm in its diet in winter. In the spring, *Tetramorium biskrensis*, the most abundant species of ants, was also the most important prey with sizes smaller than 7.37 mm in the species' diet. In Spain, *Messor bouvieri* (size = 8-9 mm) and *Camponotus foreli* (size = 10-14 mm) are the two ant species that constitute the majority of the Black Wheatear's diet (Hódar 1995). Ants are exceptionally well adapted to high and low temperatures since they are protected in their underground nests. Therefore, they become abundant prey whenever the conditions are suitable (Hódar 1995).

Conclusion

The Black Wheatear's diet contained a significant amount of ants in the M'Sila region of Algeria, which may be explained by the overall abundance of this prey group. Nonetheless, the ant group was negatively selected in the diet, likely in favour of prey with a higher nutritional content. The species adopted an alternative feeding strategy, catching the most available prey groups in the territory's surroundings when the main food source's availability decreases. Some prey groups might be abundant but less available to the Wheatears. Orthopterans, spiders (Oxyopidae) and beetles (Cetoniidae) become more significant in the species' diet during the breeding season while being less common in the habitat. Therefore, the availability of some prey groups and the local climate may play a significant role in determining the composition of the Black Wheatear's diet in the M'Sila region. In the future, it would be interesting to examine the diet composition of both adults and nestlings in order to gain a better understanding of the species' diet at different life stages.

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