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WHAT DOES THE DIET OF THE COMMON STARLING (*STURNUS VULGARIS* LINNAEUS, 1758) IN THE ZIBAN OASIS (ALGERIA) INDICATE: PEST OR USEFUL IN AGRICULTURE?

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Abstract. The Common Starling (*Sturnus vulgaris*, L. 1758) is a migratory bird with a vast distribution throughout the Western Palearctic and beyond. It has gained notoriety as one of the most pernicious invaders globally due to its highly destructive nature. In Algeria, this species mostly affects olive tree plantations. We studied the diet of the Common Starling from October 2021 to February 2022 by dissecting the gizzards of 92 specimens from five localities in the Ziban region of Algeria. The investigation revealed a total of 708 prey items, consisting of animal and plant parts. The animal part was dominant, comprising 522 prey items that belonged to 42 species distributed among 27 families and 10 orders. Coleoptera were represented by 24 species in 14 families and were the most abundant order. The ant *Messor barbarus* and the beetle *Opatrum sabulosum* were the most consumed species. The plant part was represented by 9 species across 8 families and orders, with *Phoenix dactylifera* and *Olea europea* being the two most consumed species. Surprisingly, the European Starling menu also revealed 13 crop pests that were frequently present in its diet, such as the beetle *Opatrum sabulosum*, the fly *Bactrocera oleae*, and the moth *Plodia interpunctella.* The Shannon index (H' = 4.27) showed that the diet of the Common Starling was diverse, and the value of evenness (E = 0.75) showed that the sampling was relatively even. We highlight that the Common Starling's diet is very varied and changes based on the local food availability.

INTRODUCTION

The Common Starling (*Sturnus vulgaris* Linnaeus, 1758) is regarded as one of the most harmful invasive avian species in the world (Lowe et al. 2007). Globally, it is classified as a species of least concern (LC) by the IUCN Red List of Threatened Species (Birdlife International 2023). It winters in northern Algeria, between the Mediterranean Sea and the southern high plateaus (Chedad et al. 2022). In Algeria, it is considered a pest by Executive Decree No 95-387 of 28 November 1995 (decree of the Ministry of Agriculture and decree of the National Institute of Plant Protection). This species is not protected. On the other hand, the related Spotless Starling, *Sturnus unicolor*, is protected by Algerian Fiat (12-235) in relation to Executive Fiat 12-235 of 24 May 2012, establishing the list of protected non-domestic animal species. According to JORADP No 28 of 28 May 1989, the capture of the Common Starling is authorized. The role of the Common Starling in Algerian agricultural environments was debated by many authors (Doumandji and Merrar 1999; Djennas-Merrar and Doumandji 2003; Rahmouni-Berrai 2009; Berrai and Doumandji 2014; Merrar 2017; Farhi and Belhamra 2017; Bada et al. 2019).

Diet content studies are helpful in determining the composition of prey, prey abundance, and hunting strategies of birds (Torre et al. 2004). The Common Starling diet is of interest because it varies with geographical location, season, and age (Germain 2005). Its diet has been the subject of much research throughout the world, namely in Canterbury, New Zealand (Coleman 1977), Tunisia (Bortoli 1970), southeast England (Rhymer et al. 2012), Sialkot, Pakistan (Mahmood et al. 2013), and several localities throughout Algeria (Rahmouni-Berraï 2009;

Berraï and Doumandji 2014; Farhi and Belhamra 2017; Bada et al. 2019). Classified as omnivorous, the Common Starling consumes various types of invertebrates and vegetal matter; however, in winter, its diet depends mainly on plant material and can damage crops (Feare 1984). In Algeria, it is a real pest in all wintering areas. In the arid regions, Farhi and Belhamra (2017) found that olives and dates are consumed by starlings. In subhumid regions, it damages pistachio and olive crops (Merrar 2017). In semi-arid regions of Algeria, it mainly prefers olives (Bada et al. 2019).

Numerous global studies indicate that the Common Starling is responsible for agricultural losses due to crop damage. The objective of this research is to categorize the many animal and plant species that comprise the trophic diet of starlings from the arid Ziban area located in the northeast of Algeria. Additionally, it is important to demonstrate the detrimental impact on agricultural yields within the wintering habitats located in these regions.

MATERIALS AND METHODS

Study area

The study area is situated in the Northern Algerian Sahara at Biskra (34° 48' N, 05° 44'E), at the intersection between the Aurès Mountains and the Ziban region. It encompasses a total area of approximately 21,509.80 km^2. The climate is hot, with dry summers and peaks that reach 44 °C in July and moderate but dry winters (mean temperature of the coldest month = 6 °C), with an annual average rainfall of 149.7 mm (Farhi et al. 2019). The study area is defined as "orchards and oases", at altitudes ranging from 93 to 201 m (Table 1, Figure 1).

Data collection

There are several ways to investigate the diet of birds. The main ones are analysis of stomach contents, analysis of pellets, regurgitation of juvenile birds, faecal content examination of prey remains in the nest and around the feeding area, and direct observation (Duffy and Jackson 1986; Marti 1987; Blagosklonov 1987; Chedad et al. 2021). The most accurate method for analyzing bird diets, according to Rosenberg and Cooper (1990), is to analyze their digestive contents. This method has been widely used (Ababsa et al. 2011; Rahmouni-Berraï and Doumandji 2010; Farhi and Belhamra 2017; Bada et al. 2019).

During the wintering period between October 2021 and February 2022, 92 starlings were captured in the morning or evening with an ornithological mist net, which was placed at night in five study sites: 30 birds we caught in El Outaya, 10 in Sidi Okba, 25 in Ourellal, 10 in Ouled Djellal, and 17 in Tolga. The gizzard contents were analyzed by fixing an individual with pins in a dissection tray. The abdominal cavity was cut open with a pair of scissors from the cloacal hole to the neck. The gizzard was removed and stored in ethanol in different Petri dishes to count and separate the contents into two categories (plant and animal parts) (Tunhikum 2008; Rosenberg and Cooper 1990; Chenchouni et al. 2015). Stomach contents were fixed in 70% ethanol and subsequently determined under a stereomicroscope (Taitt 1973). The identification of invertebrate prey was based on a simultaneous analysis of chitinous parts and a comparison with insects and plants identified in the field. The various animal parts were identified by consulting Perrier's (1961) and Auber's (1999) guides. For prey other than insects, mollusc identification was based on the shells (Brown 2002). According to Vachon (1952), arachnids can be distinguished from other prey by the cephalothorax with chelicerae, pedipalpes, and forceps. Myriapods were distinguished by the presence of forcipulas attached to the first segment of the body (Kevan et al. 1989). Plant remains were identified by comparison with herbarium specimens collected at the study sites. The plant fraction was identified based on the nature of the different grains and pericarps encountered (pulps, cores, and seeds).

Table 1. Characteristics of study sites.

No	Study site	Latitude (North)	Longitude (East)	Elevation (m a.s.l.)	Cultivated species
1	El Outaya	34°55'58.38"	5°39'32.19"	201	*Olea europaea, Pistacia vera, Argania spinosa, Hordeum vulgare, Simmondsia chinensis, Moringa oleifera, Pyrus* spp., *Punica granatum,* Plasticulture
2	Sidi Okba	34°44'17.40"	5°53'22.20"	45	*Phoenix dactylifera, Olea europaea, Hordeum vulgare*, Plasticulture
3	Ourellal	34°35'14.27"	5°31'37.91"	93	*Olea europaea, Phoenix dactylifera, Ficus carica, Vitis vinifera*
4	Ouled Djellal	34°26'10.80"	5°6'5.40"	182	*Olea europaea*, *Phoenix dactylifera*
5	Tolga	34°54'39.86"	5°24'40.48"	192	*Olea europaea*, *Phoenix dactylifera*, *Hordeum vulgare, Citrus* spp., Plasticulture

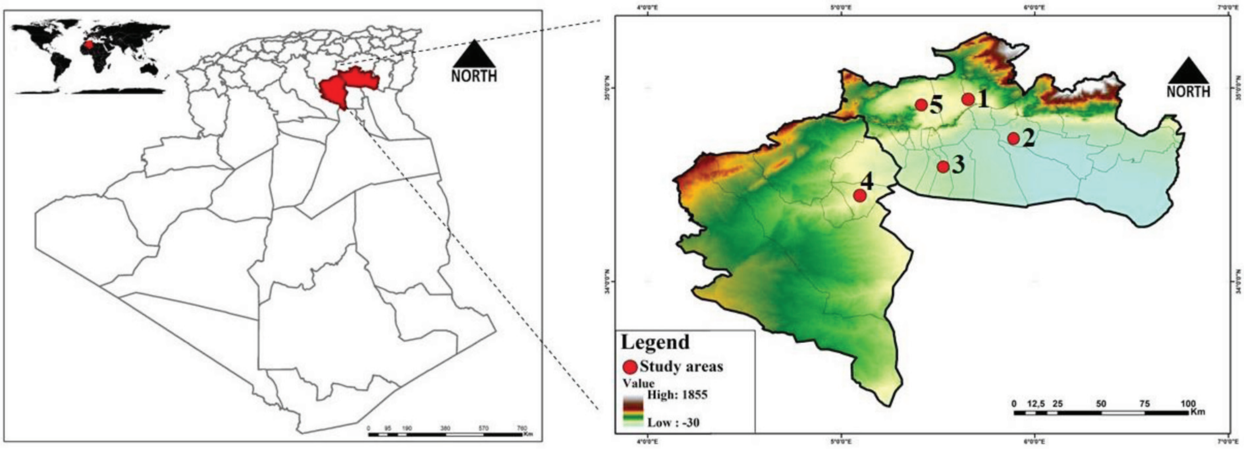

Figure 1. Geography situations in study sites: 1: El Outaya, 2: Sidi Okba, 3: Ourellal, 4: Ouled Djellal, 5: Tolga.

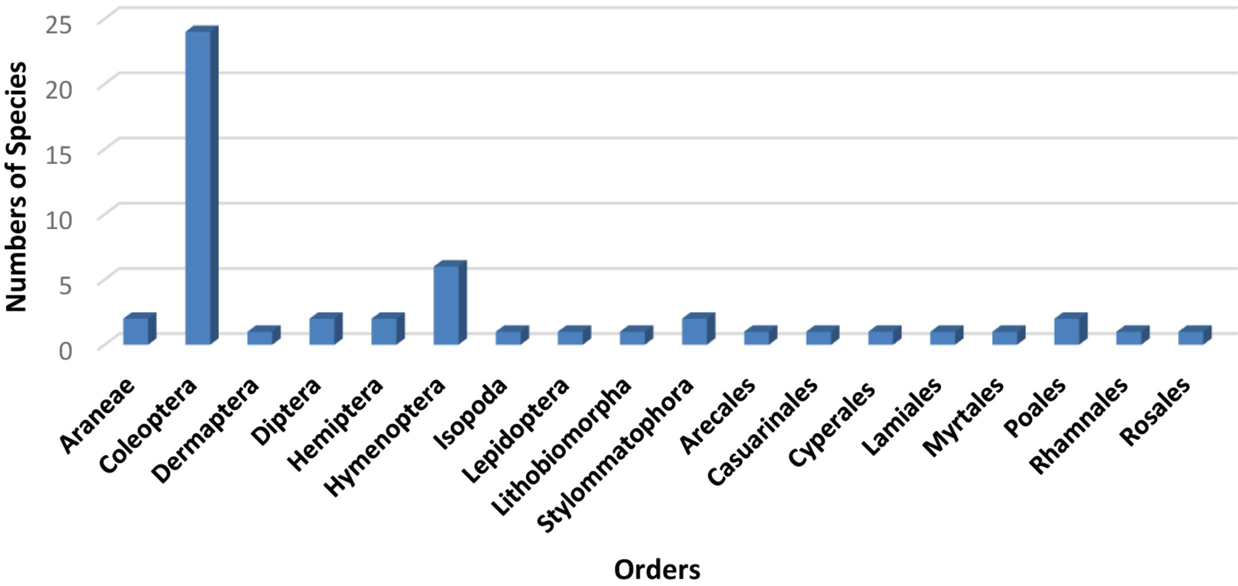

Figure 2. Number of orders and species (animal and plant) found in the Common Starling diet in the Ziban region.

Data analysis

The data were analyzed using several indexes. Total richness (S) is the total number of species (Blondel 1975) found in the digestive tract. Mean richness (Sm) is the average number of species (Ramade 1984) contained in a given gizzard. Relative abundance (AR%) is the ratio of the number of individuals of a prey species (nor) to the total number of individuals of all species (N) (Zaime and Gautier 1989). The Shannon-Weaver (H') diversity index is given by the formula: $H' = - \sum qi \log_2 qi$, where qi is the relative frequency of species i (Blondel et al. 1973). The equitability index (E) is the ratio of observed diversity (H') to maximum diversity (H' max) (Blondel 1979). The maximum diversity is represented by the following formula: $H' max. = \log_2 S$, where S is total richness. The values of E range from 0 (no prey item is equally represented) to 1 (all prey items are equally represented).

RESULTS

The analysis of Common Starlings' gizzards enabled us to identify 708 prey items divided into two categories: the animal component with 42 species and the vegetable component with 9 species. The animal category was represented by molluscs and arthropods, where we identified 522 prey items, including 42 species, distributed across 27 families and 10 orders (Figure 2). Insects were the most representative group. The families Formicidae, Carabidae, and Scarabaeidae were best represented with six, five, and four species, respectively. We also noted that the ant *Messor barbarus* was the most consumed of all specimens (220 individuals). For plants, we recovered 186 fractions containing nine species distributed over eight families and orders. The Common Starling consumes several species of plants, preferably *Olea europaea* (with 52 cores and pulps) and *Phoenix dactylifera* (with 51 cores and pulps).

Table 2. Systematic list, abundance frequency (Fi%), and occurrence frequency (C%) of animal preys ingested by Common Starlings in the Ziban region (Biskra, northeast Algeria).

Type	Orders	Families	Species	*N*	Fi%	C%	Scale
Animalia	Stylommatophora	Enidae	*Mastus pupa*	7	0.99	40	Co.
		Helicidae	*Loxana alabastrites*	4	0.56	20	Acc.
	Araneae	Thomisidae	*Ozyptila* spp.	5	0.71	40	Co.
			Ceratinopsis spp.	1	0.14	20	Acc.
	Lithobiomorpha	Lithobiidae	*Eupolybothrus nudicornis*	4	0.56	40	Co.
	Isopoda	Armadillidiidae	*Armadillidium vulgare*	3	0.42	60	Cos.
	Hemiptera	Pentatomidae	*Nezara viridula*	4	0.56	60	Cos.
			Pyrrhocoris apterus	4	0.56	20	Acc.
	Dermaptera	Forficulidae	*Forficula auricularia*	6	0.85	40	Co.
	Lepidoptera	Pyralidae	*Plodia interpunctella*	19	2.68	60	Cos.
	Hymenoptera	Formicidae	*Camponotus thoracicus*	6	0.85	40	Co.
			Crematogaster scutellaris	13	1.84	60	Cos.
			Tetramorium biskrensis	3	0.42	60	Cos.
			Messor barbarus	220	31.07	80	Omn.
			Tapinoma nigerrimum	4	0.56	40	Co.
			Formica incerta	1	0.14	20	Acc.
	Coleoptera	Tenebrionidae	*Pimelia payraudi*	4	0.56	20	Acc.
			Opatrum sabulosum	29	4.10	80	Omn.
		Scarabaeidae	*Aphodius* spp.	14	1.98	60	Cos.
			Onthophagu spp.	4	0.56	60	Cos.
			Tropinota squalida	5	0.71	60	Cos.
			Acrossus rufipes	20	2.82	40	Co.
		Elateridae	*Athou* spp.	6	0.85	60	Cos.
			Agriotes lineatus	9	1.27	60	Cos.
		Dermestidae	*Dermestes* spp.	6	0.85	60	Cos.
		Chrysomelidae	*Oulema melanopus*	7	0.99	40	Co.
		Geotrupidae	*Geotrupes* spp.	3	0.42	40	Co.
		Silphidae	*Silpha obscura*	10	1.41	60	Cos.
		Anobiidae	*Stegobium* spp.	1	0.14	20	Acc.
		Staphylinidae	*Oxytelus* spp.	10	1.41	20	Acc.
		Carabidae	*Brachinus* spp.	20	2.82	60	Cos.
			Zabrus spp.	10	1.41	40	Co.
			Pterostichus madidus	3	0.42	20	Acc.
			Acinopus spp.	2	0.28	40	Co.
			Amara aenea	1	0.14	20	Acc.
		Histeridae	*Hister* spp.	4	0.56	60	Cos.
		Chrysomlidae	*Labidostomis* spp.	2	0.28	40	Co.
		Curculionidae	*Otiorhynchus cribricollis*	4	0.56	20	Acc.
		Coccinellidae	*Coccinella septempunctata*	1	0.14	20	Acc.
			Coccinella undecimpunctata	1	0.14	20	Acc.
	Diptera	Tephritidea	*Bactrocera oleae*	39	5.51	60	Cos.
		Drosophilidae	*Cyclorrhapha* spp.	3	0.42	20	Acc.
Plantae	Arecales	Arecaceae	*Phoenix dactylifera*	51	7.20	100	Omn.
	Lamiales	Oleaceae	*Olea europaea*	52	7.34	80	Omn.
	Rhamnales	Vitaceae	*Vitis vinifera*	6	0.85	60	Cos.
	Myrtales	Punicaceae	*Punica granatum*	2	0.28	20	Acc.
	Rosales	Rhamnaceae	*Zizuphus spina*	13	1.84	20	Acc.
	Poales	Poaceae	*Triticum aestivum*	3	0.42	20	Acc.
			Sorghum bicolor	36	5.08	20	Acc.
	Cyperales	Poaceae	*Cynodon dactylon*	12	1.69	60	Cos.
	Casuarinales	Casuarinaceae	*Casuarina equisetifolia*	11	1.55	40	Co.
Total	18 orders	35 families	51 species	708	100.00	/	/

Scale (Omn.: omnipresent; Cos.: constant; Co.: common; Acc.: accidental).

Four species are considered omnipresent (representing 7.55%) in the diet of the Common Starling: two animal species (*Messor barbarus* and *Opatrum sabulosum*) and two plant species (*Phoenix dactylifera* and *Olea europaea*). As for the other species, they are divided into three categories: accidental, constant, and common, which represent 35.85%, 32.08%, and 24.85%, respectively (Table 2).

We have recorded 13 crop pests that are constantly present in the trophic menu of the starling, including *Plodia interpunctella*, *Bactrocera oleae* and *Opatrum sabulosum*, which cause huge damage to the crops of dates, olives and cereals (Table 3).

The Shannon diversity index (H′) and evenness (E) of the diet of Common Starlings in the Ziban region for five study sites are summarized in Table 4.

The value of Shannon's index (H') was estimated at 4.27, indicating that the diet of the Common Starling in the Ziban region can be classified as diversified with a high balance between the individual numbers of sampled species (E = 0.75). However, this index took values between 2.23 and 4.28 at different study sites. The most important value averages were recorded in Ourellal (4.28 bits) and Tolga (3.68 bits).

DISCUSSION

The Common Starling is essentially omnivorous and opportunistic in its food selection, feeding on a wide variety of plant and animal material (Craig 2020). In our study, the animal part consumed was 4.6 times higher than the plant fraction during the wintering period in the southeast of Algeria. Similar findings were reported from Poland (Central Europe) during the nesting season where the animal part consumed was 5 times higher than the vegetal one (Gromadzki 1969).

The diet of the Common Starling has been largely discussed in Algeria and through the species distribution area; it is dominated by animal prey, represented mainly by insects and especially by the orders Coleoptera and Hymenoptera. The results of our study are similar to those recorded by Farhi and Belhamra (2017) in the same area, who indicated that the Coleoptera order is the most abundant in the Common Starling food menu. Bada et

Table 3. List of crop pests with occurrence status in the trophic menu of the Common Starling.

Pests	Occurrence	Trophic status	Crop damage
Nezara viridula	Cos.	Phytophagous (F.A.O. 2016)	Legumes + Plasticulture
Forficula auricularia	Cos.	Omnivorous (F.A.O. 2016)	Vegetable garden
Plodia interpunctella	Cos.	Phytophagous (F.A.O. 2016)	Dates (Bouka et al. 2001)
Opatrum sabulosum	Omn.	Saprophagous (Gallo and Pekár 1999)	Cereals + Grapes (Chernej 2005)
Aphodius spp.	Acc.	Coprophagous (El Aichar 2014)	Cereals (El Aichar 2014)
Athous spp.	Cos.	Phytophagous (Platia 2006)	Cereals (Dajoz 2003)
Agriotes lineatus	Cos.	Phytophagous (Simone et al. 2011)	Potato + Placticulture + Cereals (Dajoz 2003)
Oulema melanopus	Cos.	Phytophagous (Gallo and Pekár 1999)	Cereals (Ulrich et al. 2004)
Silpha obscura	Cos.	Predator (Gallo and Pekár 1999)	Cereals + Potato (Konieczna et al. 2019)
Zabrus spp.	Cos.	Phytophagous (Dajoz 2002)	Cereals (Roume 2011)
Pterostichus madidus	Cos.	Predator (Johnson and Cameron 1969)	Grassland + Cereals (Tălmaciu et al. 2016)
Acinopus spp.	Co.	Predator (Brague-Bouragba et al. 2007)	Cereals (Brague-Bouragba et al. 2007)
Bactrocera oleae	Cos.	Phytophagous (F.A.O. 2016)	Olives up to 15% of the yield's losses (Rossini et al. 2022)

Occurrence: Omn.: omnipresent; Cos.: constant; Co.: common; Acc.: accidental.

Table 4. Shannon's index (H') and evenness (E) of common starling captured for each station (Ziban region) during 2021–2022.

Study site	Specific richness	Individual number	Shannon-Weaver index (H')	Maximum diversity (H'max)	Evenness (E)
El Outaya (N = 30)	45	462	3.55	5.55	0.65
Ourellal (N = 25)	27	100	4.28	4.75	0.90
Tolga (N = 17)	19	55	3.68	4.25	0.87
Ouled Djellal (N = 10)	14	76	3.07	3.81	0.81
Sidi Okba (N = 10)	6	15	2.23	2.58	0.86
Total (N = 92)	51	708	4.27	5.73	0.75

N: number of individuals of *Sturnus vulgaris*.

al. (2019) reported that the species consumes an important quantity of animal prey over the wintering period. A quarter of the insects consumed were Coleoptera and Hymenoptera in Batna region of northern Algeria.

However, in Algiers (northern part of Algeria), Berraï (2015) and Djennas-Merrar et al. (2016) noted that Hymenoptera, primarily ants, predominate in the diet of Common Starlings, followed by Coleoptera. This is probably due to their large abundance in the foraging area during the wintering period of the Common Starling in Algeria (Coleman 1974; Paton et al. 2005; Bada et al. 2019). However, Rhymer et al. (2012) reported that Tipulidae larvae are the primary dietary item for nestling Common Starlings on lowland farmland. In this study, we also noted two invertebrate species that are omnipresent in the diet of the Common Starling. Some are easier to catch, such as *Opatrum sabulosum*, while others are numerous, such as social insects. In the case of Hymenoptera, such as *Messor barbarous*, they are appreciated because they are relatively soft. According to Rahmouni-Berraï and Doumandji (2010), social insects such as *Messor barbarus* are heavily ingested by Common Starlings. Also, Bada et al. (2019) mentioned that the richness, accessibility, and simplicity of capture of Coleoptera and Hymenoptera in the wild are probably the causes of their consumption patterns.

Kontogeorgos et al. (2019) suggested that prey size is another important factor in the feeding habits and behaviour of predator species. Comprehending the dietary preferences of birds is essential for knowing their function in agriculture, particularly for the management of insects and plants (Farhi et al. 2016). The trophic menu of starlings, for instance, consistently includes various organisms such as *Plodia interpunctella*, a globally recognized insect pest that infests stored-products and processed food commodities. The insect pest discussed in the study conducted by Mohandass et al. (2007) has the capability to infest a wide range of items and is considered to be of significant economic importance in the context of processed food. In our research, it was shown that *Opatrums abulosum*, a widely distributed species, has polyphagous behaviour and demonstrates a vast variety of food preferences (Chernej 2005). This pest has been found to inflict substantial harm to several agricultural plant species (Medvedev 1968). Additionally, *Bactrocera oleae*, with a population of 39 individuals, is a prominent predator of the olive tree and a significant frugivorous monophage. This species exclusively feeds on olives, making it a major pest. The resulting damage inflicted by *Bactrocera oleae* is frequently substantial and diverse (Didier and Guyot 2012).

Apart from animal prey, plants are also consumed by Common Starlings, where *Olea europaea* and *Phoenix dactylifera* were omnipresent and dominated the plant part of the diet, as mentioned by Farhi and Belhamra (2017) in the Ziban oasis. This finding is most likely explained by the synchronization between the arrival of the European Starling and the period of production of dates and olives in the region (Edwards et al. 2014; Berraï and Doumandji 2014; Djennas-Merrar et al. 2016; Berraï et al. 2017; Bada et al. 2019). During winter, *Sturnus vulgaris* primarily consumes plants and can damage crops (Feare 1984). One of the principal elements affecting the diet of Common Starlings is the time of the year (Williamson and Gray 1975), which can justify the intense feeding of starlings so that they can replenish their depleted reserves during the journey to the wintering range.

We found that the species consumes numerous quantities of olives and dates while it is wintering. Bada et al. (2019) also found a high frequency of olive pulp in the wintering period, when the weather is cold, to satisfy their metabolic needs. The Common Starling may switch to a vegetarian diet and need to eat a lot of plant food. In its breeding habitat, it searches for fruits high in simple sugars and complex carbs, while in its wintering environment, it attacks plants high in fat, like dates, olives, and lentisk fruits (Taitt 1973; Berraï and Doumandji 2014; Merrar 2017).

Sturnus vulgaris is considered a primary pest of olive crops in Algeria (Djennas-Merrar 2002; Berrai et al. 2017), especially between December and February. Also, its wintering was considered a crop problem in many parts of the world because it damages plants (Tyler and Kannenberg 1980; Mahmood et al. 2013). Another interesting result in this study is the diversity, richness and balance in the trophic menu of the Common Starling, which corroborates the results of Farhi and Belhamra (2017) and Rahmouni-Berraï (2009). It indicates that the Common Starling is an omnivore, a conclusion reached by both old and recent studies conducted in Algeria and other countries. This bird must modify its diet in accordance with food availability, which is in turn influenced by climatic circumstances. Due to the harsh and wide-ranging environment of arid regions, the feeding behaviour of this species varies seasonally in terms of diversity and composition and follows seasonal and local trends in prey species abundance (Coleman 1977). The findings presented by Farhi and Belhamra (2017) demonstrate that the Commons Starling is a generalist species and displays opportunistic behaviour, thus being able to adapt to various environmental conditions.

CONCLUSION

Birds in arid regions must adapt their diets to the wide-ranging environment, which in turn depends on climatic factors. This study set out to gain a better insight into the trophic behaviour of the Common Starling in the Ziban oasis (northeast of Algeria). During its wintering, it was shown that this species is omnivorous and causes huge losses on olive trees and palm dates, as is the case in our study areas and in many regions of Algeria. Two insects (*Messor barbarus* and *Opatrums abulosum*) were the most common in its diet. In addition, we noted a significant presence of other insect pests that cause crop losses, such as *Plodia interpunctella* and *Bactrocera oleae*. For the vegetal part, two plants (*Phoenix dactylifera* and *Olea europaea*) are the most consumed by the starling. To contextualize this study, it is imperative to undertake supplementary research in adjacent regions with varying ecological conditions. This endeavour aims to evaluate the potential losses or gains that may arise from the consumption of certain detrimental insects by this species. Additionally, it seeks to identify solutions to better manage these populations.

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Conflicts of interest

The co-authors report no conflicts of interest.

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Data Availability

The data used to support the findings of this study are included within the article.

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