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BIOMETRIC AND DIET OF THE EUROPEAN STARLING (*STURNUS VULGARIS*) IN ITS ARID WINTERING AREAS OF NORTH AFRICA

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ABSTRACT. – Biometric and diet of the European starling (*Sturnus vulgaris* Linnaeus, 1758) in its wintering areas in northeastern Algeria was studied following the body measurements and analysis of 117 gizzard contents from November 2014 to February 2015 at three localities. The mean total body length was 20.55 ± 1.38 cm and the average total body mass was 62.58 ± 9.93 g. The study revealed that bird diet is very diverse and composed of three fractions: (i) a vegetable fraction with mainly olives and other vegetables; (ii) an animal fraction mainly composed by invertebrate preys; and (iii) an inert fraction formed by hairs, feathers, pebbles and fibers. The plant fraction was represented in all the analyzed gizzards and 59.82 % of them contain only plant items. The animal fraction was represented by 37 invertebrate prey taxa, divided into 4 classes. Insects dominated in numbers, mostly including Coleoptera and Hymenoptera, which cover 51.56 % and 35.87 %, respectively. No arthropod was overrepresented in terms of occurrence and there were differences between months and stations. The GLM analysis shows that the variation in animal prey numbers ingested was very highly significant according to bird length and body mass, wintering months and studied regions.

INTRODUCTION

The European starling is a Passeriformes bird, considered to be one of 114 species belonging to the Sturnidae family (Germain 2005). Originally native to Europe, its range has expanded depending on climate change and agriculture development (Berthold 1968). Human interventions allowed European starling to extend its range across all continents by moving between its wintering and breeding areas (Clergeau 1998). Lowe *et al.* (2007) considered it as one of the world's most invasive species and it is classified as Least Concern (Birdlife International 2016).

Heim de Balsac & Mayaud (1962) reported that this species moves between Europe and North Africa, where it is considered a regular wintering bird with variable numbers. It winters in bands from the East from Egypt to the West, the extreme south of Morocco through the Libyan littoral zone.

The European starling diet varies according to the geographical location, seasons and age (Germain 2005). The species adapts to the food resources of the environment and modifies its intake food according to the occupied area. During nesting, the European starling feeds mainly on insects, maintaining their numbers at a sustainable economic level. It feeds its young with tender and soft prey (Doumandji & Doumandji-Mitiche 1994). Clergeau (1989) indicated that the species has a dual status with respect to agriculture; it is considered in Eastern Europe as an auxiliary during reproduction, it is above all an insectivore that explores the meadows. Hanzak & Formanek (1981) pointed out that it is useful for agriculture since it consumes insects, worms and slugs in considerable quantities. During the wintering season, it becomes a real pest in Western Europe and the Mediterranean (Clergeau 1989). In very cold weather, it complements its diet with soft seeds taken from maize silage fodder for cattle or in plots recently planted in winter cereals where it collects the germinate seeds (Clergeau 2000). It has therefore been considered a problem species since the beginning of the 20th century and during the first part of this same century; it is mainly in North Africa where the species caused damage, especially in olive groves (Clergeau 1989).

Several authors have studied the composition of the European starling diet around the world (Lobb & Wood 1971, Taitt 1973, Coleman 1977, Moeed 1980, Feare & Gennity 1986, Trotta 2001, Rhymer 2012), which indicates that European starlings are omnivorous and feed on a wide variety of arthropods, arachnids, annelids, crustaceans and molluscs, as well as plants and fruits.

In wintering areas of the European starling, particularly in North Africa, the diet of this species is poorly documented and existing data are old (Heim de Balsac & Mayaud 1962, Etchecopar & Hue 1964). In Algeria, this bird is considered as scourge by executive decree n° 95-387 of 28 November 1995 (Decree of the Agriculture Ministry and issued by the National Institute of Plant Protection) and the main studies on its diet were conducted in the northern part of the country, where the climate is generally temperate. Relevant literature indicated the species is polyphagous with insectivorous tendency (Rahmouni-Berraï 2009, Berraï & Doumandji 2014, Djennas-Merrar *et al.* 2016). However, in the arid regions of the interior of the country, studies on the European starling are practically absent, despite the olive growing large extension in recent years with one million hectares of new plantations (ITAFV 2010) and whose maturity coincides with the arrival of wintering European starlings. To this end, knowledge of the biology and ecology of this species, especially its diet and its impact on olive tree crops, is of paramount importance. Knowing in particular that in the arid regions of North Africa, the constraining living conditions are different from those of the humid regions of the Mediterranean coast and its nesting area in Europe.

This study aims to describe the bodily conditions and food spectrum of the European starling with a qualitative and quantitative analysis of the items ingested and the variation of the diet composition according to time and space. The results of this work tend to elucidate the impact of European starling on the agro-system of olive trees and could thus lead to guidance for the management of the species in its wintering area in arid character.

MATERIALS AND METHODS

Study area: This work was conducted in the administrative department of Batna, located in the northeastern part of Algeria (35° to 36°N, 4° to 7°E), at the junction of the two Mountain Atlas: Tellian and Saharan Atlas (Fig. 1). European starling specimens examined were captured between November 2014 and February 2015, in three sites: (i) an olive grove of 5 ha (300 olive trees) in the village of Sefiane; (ii) an olive grove of 14 ha (185 olive trees) in Barika city; (iii) a dormitory erected in a cement factory, located 10 km south west of the many olive groves of Tilatou village. The main olive varieties cultivated in the region are Sigoise and Chemlel. The three sampled regions are belonging to three different bioclimatic scales: arid with fresh winter (Sefiane region 35°25'13"N, 5°35'25"E), arid with temperate winter (Barika region 35°17'48"N, 5°47'33"E) and arid with cold winter (Tilatou region 35°17'48"N, 5°47'33"E) (Madani 2008, Chafaa 2013).

In fact, the climate of the study area is dominated by aridity with dry, hot summers and relatively cold and slightly rainy winters. The climatic regime shows great irregularity with notably important variations from one year to another and from one month to another of the same year. In 2014 and 2015, the respective precipitation amounts of 258.03 mm and 327.69 mm were above the average recorded over 39 years (1976-2014). Compared to the same period, the average annual temperature in the region (14.54 °C) was below the respective annual average temperature for 2014 (16.3 °C) and 2015 (15.6 °C). In 2014, the lowest temperature (6.6 °C) was recorded in December and the hottest (27.5 °C) in August. In 2015, the lowest and warmest temperatures were noted in January (5.1 °C) and July (27.5 °C), respectively (Bouam et *al.* 2017, ONM 2015).

Bird catching and measuring method: During the wintering period of the European starling (November 2014 to February 2015), 117 individuals were captured: 68 in Tilatou, 19 in Sefiane and 30 in Barika. Bird specimens were kindly provided by the phytosanitary services and are derived from the catches made by olive growers authorized to fight against intrusions of these birds (official regulation of the National Institute of

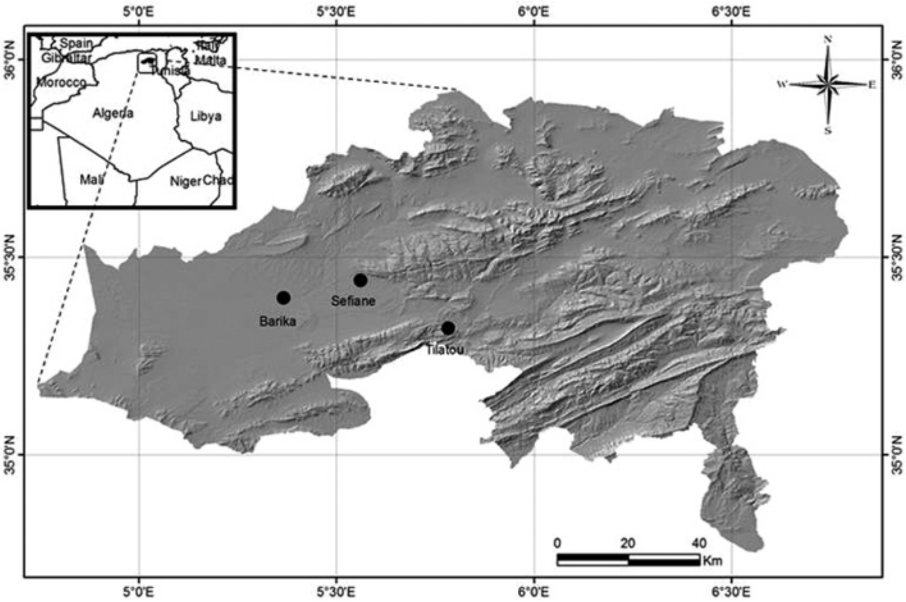

Fig. 1. – Location of the three study sites of the European starling (*Sturnus vulgaris*) in the north-eastern of Algeria.

Plant Protection). They were usually captured at the end of the day; this ensured that they had finished feeding. Captures were done using shotguns, glue on olive branches containing olives (deposited on the ground) and ornithological nets. The collected specimens were put in plastic bags with the date and the capture site recorded, weighed and then frozen, and later thawed for laboratory analysis (Authorization of animal sacrifice for a scientific study n° 244/SRPV Batna/2018). A set of morphometric and biometric variables was measured on each individual collected according to the method described by Whitworth *et al*. (2009). These measurements included: the total body mass (in g), wingspan, lengths of body, beak, tail, head with beak and tarsus (in cm). The mass measurements were made using a precision balance (± 0.01 g) and a caliper (± 0.01 mm) for the length parameters. During the European starling dissection, we followed the method described by Yusufu & Bello (2004): the bird was first spread on the back in a dissection tray and fixed with pins. A pair of scissors was used to open the abdominal cavity after having completely removed its feathers. The digestive tract, from the gizzard to the end of the caecum, was then carefully removed and weighed. The volume of the digestive tract recovered (in ml) was calculated by the difference in volumes (± 1 ml) following immersion in a graduated cylinder containing a known initial volume of water. For the diet study of the bird, only the gizzard was recovered and stored in ethanol since it is the part that contains the main elements ingested and is relatively little altered. The rest of the untreated, very thin, digestive tract contained only very few identifiable elements. Once emptied and rinsed with distilled water, the contents of the gizzard was completely recovered by scraping with a spatula in a Petri dish in which a mixture of equal parts of 2 % of formalin and 70 % alcohol was added to ensure the asepsis according to the method described by Taitt (1973).

Item identification and counting: When identifying the elements contained in the gizzards, we started with the separation between the plant fragments, the animal and inert ones (hairs, pebbles, fibers and feathers). The vegetable fraction was identified from the nature of the different grains and pericarps encountered. Identification of invertebrate preys was based on the simultaneous recognition of several chitinous fragments such as heads, thorax, elytra, kernels, femurs, shins and mandibles (Chenchouni *et al*. 2015). The different animal items were identified by referring to different works (Perrier 1961, 1964, Zahradnik 1988, Barraud 1992, Auber 1999) and based on the collections of insect fragments available in the laboratory of ecology and environment (Batna 2 University, Algeria). For non-entomological prey, shells were the only criterion for identifying mollusks. Arachnids were distinguished from other prey by the presence of a cephalothorax with chelicerae, pedipalpes and forceps (Vachon 1952). The myriapods were recognizable by the large number of legs carried by the abdomen and fine pointed mandibles. Worms (e.g. annelids) are easily digestible and are therefore difficult to found in gizzards of insectivorous birds. However, plants are recognized by the remains of undigested cuticles.

The individual number of each species of insect and arachnid preys was determined primarily by counting head or thorax numbers. When counting elytra, mandibles and cerques, the number of left and right appendages was taken into consideration. The presence of several apices of shells makes it possible to count the individual numbers of ingested mollusks.

Data analysis: The data exploration was carried out by calculating averages with standard deviations, percentages, as well as by the calculation of the demographic parameters and ecological indices of the populations and prey communities: the number of animal prey by gizzard (N); the abundance frequency (relative abundance) calculated for animal preys ($Fi\% = n_i/N) \times 100$) corresponds to the percentage of the individual numbers of a considered prey taxa (n_i) relative to the total number of individuals recorded in a gizzard (N) (Dajoz 1985); the constancy frequency (occurrence) calculated for all ingested items ($C\% = Pi/P \times 100$) is calculated by the ratio of the number of records containing the prey taxon (Pi) to the total number of surveys (P) (Dajoz 1985). Depending on the value of (C%), prey taxa are considered constant (C) (C% is equal to or greater than 50%), accessories (Acc) (C% between 25 % and 49 %), accidental (Ac) (C% between 10 % and 25 %) and very accidental (Va) (C% less than 10%) (Bigot & Bodot 1973). Total species richness (S) is the number of animal prey species/taxa encountered at least once at the end of N surveys (Magurran 2004). The Shannon diversity index (H') is calculated for animal preys using the following formula (Magurran 2004): $H'\text{ (bits)} = -\sum(n_i/N)\ \mathrm{Log}_2\ (n_i/N)$, where n_i is the individual numbers of prey species/taxa and N is the total of individual numbers of all preys. The Pielou index (Evenness E): $E = H'/H'max$, where H' is the Shannon diversity index and H'max is the maximum diversity ($H'max = \mathrm{Log}_2\ S$); the values of E range from 0 (no prey item is equally represented) to 1 (all prey items are equally represented) (Magurran 2004).

In order to evaluate the impact of European starling feeding on animal prey, the food items were classified into five trophic categories: phytophagous, predatory, polyphagous, saprophagous and coprophagous.

We used a GLM (generalized linear model; Poisson-distributed error and a log link function) to test the variation of ingested prey number (animal fraction), according to morphometric/biometric parameters (body length, beak length and total body mass), the three studied sites (Sefiane, Barika and Tilatou) and the four months (November-February). Months were compared to December and regions were compared to Tilatou area. The results are considered statistically significant when $P < 0.05$. Statistical tests were performed using the R software (R Development Core Team 2014).

RESULTS

Morphometric and biometric variables of birds

Of the 117 specimens measured, the total body length averaged 20.55 ± 1.38 cm (min 15.00 and max 23.00 cm).

The average total body mass was 62.58 ± 9.93 g (min 37.87 and max 93.9 g). The average gizzard wet mass and volume were 7.16 ± 1.99 g (min 3.31 and max 13.56 g) and 7 ± 2.04 ml (min 3 and max 14 ml), respectively (Table I).

Global food spectrum

The analyzed gizzards of starlings contained three categories of food: a plant fraction, an animal fraction and inert elements. Plant part was mainly represented by olives (olive core and pulp) and other plants belonging to the families of Solanaceae (*Capsicum annuum*, *Solanum lycopersicum*) and Rutaceae (*Citrus sinensis*). The inert part included feathers, hairs, fibers and pebbles (Table II). The animal prey was represented by 37 species/taxa of invertebrate preys, representing 7 orders, 23 families and 37 different genera. Arthropod prey were the most abundant type of item, both in species/taxa numbers and in individual numbers. Ingested insects belonged to four orders and Coleoptera prey were the most represented with 13 families and 20 species/taxa. Among Coleoptera prey ingested, Scarabaeidae (20.94 %), Carabidae (14.13 %) and Curculionidae (6.02 %) predominated in numbers. The Hymenoptera order comes in second place and was mainly represented by Formicidae, in particular *Crematogaster scutellaris*.

Diet composition and structure

The diet of *S. vulgaris* showed a dominance of the plant fraction, 79 % of examined gizzards contained olive

Table I. – Morphometric and biometric variables of European starling in the arid regions of northeastern Algeria (N = 117).

Variables	Minimum	Maximum	Average ± SD
Wingspan (cm)	31.1	41.50	38.16 ± 1.58
Body length (cm)	17.50	25.30	20.55 ± 1.38
Length of the head and the beak (cm)	4.52	5.77	5.37 ± 0.68
Tail length (cm)	6.00	7.90	6.64 ± 0.34
Beak length (cm)	2.55	3.47	3.09 ± 0.17
Tarsal length (cm)	2.11	3.05	2.54 ± 0.27
Body mass (g)	37.87	93.9	62.58 ± 9.93
Digestive tract volume (ml)	3.00	14.00	7.00 ± 2.04
Digestive tract wet mass (g)	3.31	13.56	7.16 ± 1.99

Table II. – Systematic list, abundance frequency (Fi %), occurrence frequency (C %), occurrence scale (OS) and trophic status (TS) of animal preys ingested by European starling in northeastern Algeria. OS (Ac: accidental; Acc: accessory; C: constant; Va: very accidental); TS (Co: coprophagous; Ph: phytophagous; Po: polyphagous; Pr: predator; Sa: saprophagous); und.: undetermined taxa.

Phyla / Class	Order / Family	Genera / Species	Fi %	C%	OS	TS
Mollusca	Stylommatophora					
Gastropoda	Hygromiidae	Hygromiidae und.	4.19	4.27	Va	Ph
	Zonitidae	*Oxychilus hydatinus*	0.26	0.85	Va	Ph
	Chondrinidae	*Abida secale*	1.05	3.41	Va	Ph
	Helicidea	*Helicigona lopicida*	0.26	0.85	Va	Ph
	Sphincterochilidae	*Sphincterochila candidissima*	0.26	0.85	Va	Ph
Arthropoda	Und.					
Arachnida	Arachnida und.	Arachnida und.	0.79	2.56	Va	Pr
Myriapoda	Chilopoda und.					
	Chilopoda und.	Chilopoda und.	0.26	0.85	Va	Pr
	Coleoptera		51.56			
		Chlaenius sp.	0.52	1.70	Va	Pr
		Carabus sp.	3.14	1.70	Va	Pr
	Carabidae	*Macrothorax morbillosus*	0.26	0.85	Va	Pr
		Feronia sp.	2.88	8.54	Va	Pr
		Carabidae und.	7.33	12.82	Ac	Pr
	Staphylinidae	*Staphylinus* sp.	0.26	0.85	Va	Po
	Silphidae	*Silpha* sp.	0.52	1.70	Va	Co
	Geotrupidae	*Geotrupes* sp.	0.52	1.70	Va	Sa
		Rhyzotrogus sp.	1.05	3.41	Va	Sa
	Scarabaeidae	*Aphodius* sp.	2.09	5.08	Va	Sa
		Scarabaeidae und.	17.80	20.51	Ac	Sa
	Tenebrionidae	*Tenebrionidae* und.	1.57	4.27	Va	Ph
	Chrysomelidae	Chrysomelidae und.	0.26	0.85	Va	Ph
		Timarcha sp.	0.52	1.70	Va	ph
Insecta	Curculionidae	Curculionidae und.	6.02	8.54	Va	Ph
	Histeridae	*Hister* sp.	0.26	0.85	Va	Pr
	Coccinellidae	*Simiadalia bipunctata*	0.26	0.85	Va	Pr
	Buprestidae	Buprestidae und.	0.26	0.85	Va	Ph
	Elateridae	*Athous* sp.	0.26	0.85	Va	Ph
	Coleoptera und.	Coleoptera und.	10.73	19.65	Ac	/
	Hymenoptera		35.87			
		Tapinoma nigerimum	0.52	1.70	Va	Pr

Table II. – Continued.

Phyla Class	Order Family	Genera / Species	Fi %	C%	OS	TS
		Messor barbara	0.79	1.70	Va	Po
		Pheidole pallidula	1.05	3.41	Va	Po
	Formicidae	*Crematogaster scutellaris*	8.90	3.41	Va	Ph
		Monomorium salomonis	1.05	3.41	Va	Pr
		Cataglyphis bicolor	1.83	5.12	Va	Pr
		Crematogaster sp.	0.79	2.56	Va	Ph
		Formicidae und.	20.94	13.67	Ac	/
	Dermaptera					
	Forficulidae	*Forficula auricularia*	0.26	0.85	Va	Po
	Orthoptera					
	Gryllidae	Gryllidae und.	0.26	0.85	Va	Ph
Olive	Pulp			79.00	C	
	Core			16.23	Ac	
Other plants	Other plants			69.23	C	
Feathers	Feathers			28.20	Acc	
Hairs	Hairs			65.81	C	
Fibers	Fibers			35.04	Acc	
Pebbles	Pebbles			18.80	Ac	

Table III. – Average numbers of animal preys by gizzard and diversity evaluation of prey populations ingested by the European starling in the north-eastern Algeria.

	Tilatou (N = 68)	Sefiane (N = 19)	Barika (N = 30)	Global (N =117)
Total prey number	194	91	97	382
Average number of preys/gizzard	2.85 ± 0.70	4.79 ± 0.89	3.23 ± 0.97	3.26 ± 0.84
Total specific richness (S)	28	19	18	37
Shannon index (H')	3.41	3.83	3.19	3.83
Maximum diversity (H'_{max})	4.81	4.25	4.17	5.20
Evenness (E)	0.71	0.74	0.76	0.73

Table IV. – Results of the generalized linear model GLM testing the variation of animal prey number contained in European starling gizzards in North-East Algeria, according to the biometric conditions of the bird and the spatiotemporal variation (*: P < 0.05, **: P < 0.01 and ***: P < 0.001)

	Estimate	Std. Error	z value	*P* (> |z|)	*Significance*
(Intercept)	–1.710166	1.421291	–1.203	0.228880	
Sefiane region	0.399316	0.172065	2.321	0.020302	*
Barika region	0.404829	0.147602	2.743	0.006093	**
November	–3.462583	1.011001	–3.425	0.000615	***
January	–0.234974	0.155413	–1.512	0.130552	
February	–0.995092	0.194880	–5.106	3.29×10^{-7}	***
Body length (cm)	–0.235529	0.039184	–6.011	1.85×10^{-9}	***
Beak length (cm)	1.321717	0.358320	3.689	0.000225	***
Body mass (g)	0.056720	0.004929	11.508	$< 2 \times 10^{-16}$	***
Null deviance	1104.6				
Residual deviance	847.2				
AIC	1026				

pulp. A total of 59.82 % of analyzed gizzards contained only plant items. Other plants were represented by 69.23 % of occurrence frequency, whereas the olive cores were only found in 16.23 % of the examined gizzards. The animal fraction was present in 39.31 % of the analyzed contents. Inert elements had an occurrence frequency of 92.13 % (Fig. 2A).

Coleoptera were the most abundant animal prey in the bird gizzards (56.51 %), followed by Hymenoptera with 35.87 %. Other prey orders (Stylommatophora, Arachnida, Chilopoda, Dermaptera and Orthoptera) were only represented by low frequencies, not exceeding 10 % (Fig. 2B). It should be noted that among insect species identified, European starling consumes a greater prey which is characterized by a phytophagous diet with an abundance frequency (Fi %) of 40 %. Predator prey were noted with 34.28 %, while saprophagous and coprophagous prey had a total abundance frequency of 14.28 % and polyphagous was 11.42 % (Fig. 2C).

Diversity and spatiotemporal variation in the number of ingested prey

The global food spectrum in terms of animal prey was consisting of 37 species/taxa. The Tilatou (cold winter) was best represented with S = 28 species, while the Barika (temperate winter) and Sefiane (fresh winter) are recorded with 18 and 19 species/taxa, respectively. The average number of prey items per gizzard was 2.85 ± 0.70 at Tilatou, 3.23 ± 0.97 at Barika and 4.79 ± 0.89 at Sefiane. The values of the Shannon

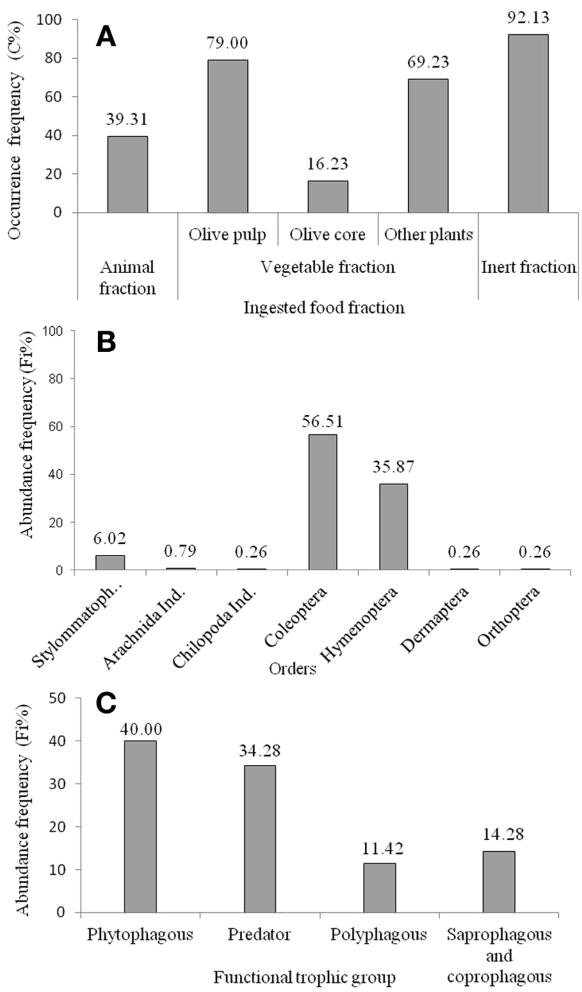

Fig. 2. – Proportions of food categories ingested by European starling in the North-East of Algeria. Occurrence frequencies of items C % (**A**), abundances of prey orders Fi % (**B**) and abundance frequencies Fi % of preys according to their trophic categories (**C**).

index (H') were 3.41 bits for Tilatou, 3.83 for Sefiane and 3.19 for Barika. Equitability (E) tends to unity (greater than 70 %) in the three sites studied with a relatively higher value in Barika (0.76) (Table III).

The number of ingested preys showed large variation depending on the biometric parameters of the bird, the studied regions and months (Table IV). The GLM highlights a statistically significant variation between all these parameters. Indeed, the change in the number of ingested prey based on body length, beak length and total body mass was statistically very highly significant ($P < 0.0001$). Also, the variation between regions showed the variation in Barika was statistically very significant ($P = 0.0061$) and significant in Sefiane ($P = 0.020$). The variation in November and February were very highly significant ($P < 0.0001$) and no significant variation was observed for January. The bird classes with a total body length between 21 and 23 cm, a beak length between 3 and 3.5 cm and a total body mass between 80 and 90 g ingested the highest number of animal prey during December and at Barika region (Fig. 3A-E).

DISCUSSION

Biometry of the European starling is discussed by several authors, whether in Algeria or elsewhere in the world. Our results globally agree with those reported in the literature for all measured variables (body length, wingspan, tarsal, beak and tail lengths), whether in North America where the species has been introduced (Kessel 1957, Cabe 1993, Johnson & Givens 2009), in Europe (original nesting area) (Heinzel *et al*. 2004) or in North Africa considered as a wintering area (Heim de Balsac & Mayaud 1962, Etchecopar & Hue 1964, Rahmouni-Berraï 2009). However, the total body mass was slightly lower in our study area than that reported in the literature, notably by Cabe (1993) in North America. This could be due to the fact that our studied specimens are migrants that have crossed the Mediterranean, which would have negatively influenced their body mass after their movement. Similarly, a difference in total body mass was noted compared to the specimens explored by Rahmouni-Berraï (2009) in northern Algeria at an average 400 km in the North humid bioclimat and where environmental conditions are more favorable, and in particular food availability.

The European starling diet is dominated by the vegetable fraction which is omnipresent in all analyzed bird gizzards. Also, more than half of these gizzards contained no animal prey. In its introduced range, whether in Australia, South Africa, New Zealand, North America, or Southern and Western Europe and where European starling is sedentary, the plant part still predominates in the species diet during winter and autumn (Karasov 1996, Starck 1999). During periods of cold weather, European starling may resort to a wholly vegetarian diet and need to consume a large quantity of such food to meet their metabolic requirements (Taitt 1973).

In addition, the olive pulp has a high occurrence frequency in the studied gizzards; this is due to the fact that the European starling migration coincides with the fruiting period of the olive trees in the studied areas. The low presence of olive cores in the studied gizzards is probably due to the fact that the bird prefers the large-caliber olive (e.g. Sigoise) that it does not swallow entirely on the one hand (lack of cores in gizzards); on the other hand probably because this olive variety is the most cultivated in the study area. In Tunisia, olives swallowed whole occupy three quarters of the diet of European starlings (Bortoli 1970). It should be noted that in the current study, the European starling also consumes other plants, such as Solanaceae and Rutaceae probably harvested at public dumps, frequent visiting places of these birds in North-eastern Algeria (Berraï 2015). It is also possible that these plants were taken accidentally in the olive frequented

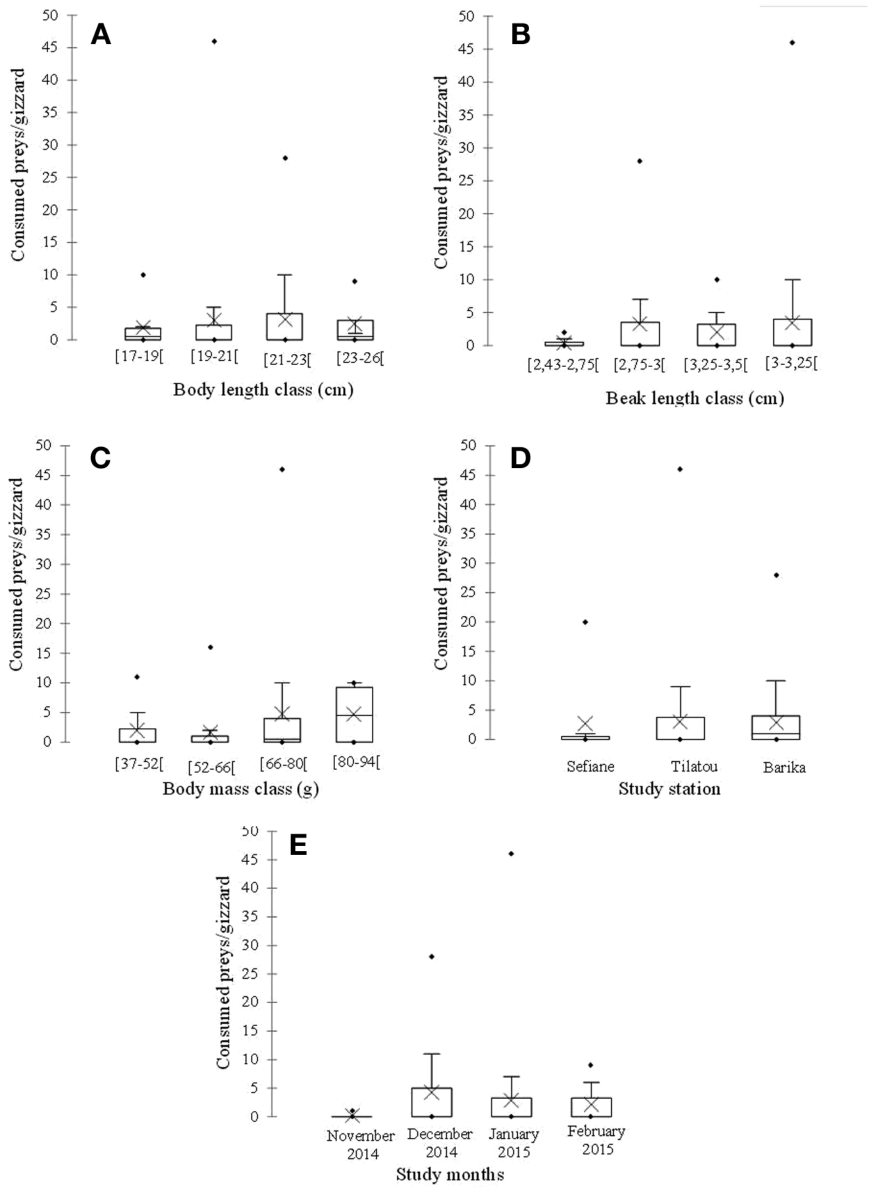

Fig. 3. – Variation in the prey number ingested by the European starling in the North-East of Algeria according to the biometric factors: body length (**A**), beak length (**B**), body mass (**C**), study regions (**D**), months (**E**) (cross = mean value).

groves. Berraï (2015) indicated that the plants most used by European starling are the olive tree and the pistachio tree. The food choice of this eclectic and opportunistic bird is probably influenced by the availability of food in the environment (Isotti 1997).

Among the insects ingested by the European starling, Coleoptera and Hymenoptera alone accounted for 3/4 of prey. Our results showed that Scarabaeidae were most ingested, followed by Carabidae, Coleoptera and Curculionidae. When searching for prey, the species feeds mainly on insects that move on the ground and that they hunt on the lookout. This phenomenon and the dominance of Hymenoptera, mostly ants, in the diet of European starling has been much reported in the literature (Moeed 1980, Fischl & Caccamise 1987, Djennas-Merrar 2002-2016, Rahmouni-Berraï 2009, Berraï 2015). The consumption pattern of Coleoptera and Hymenoptera is likely due to their abundance, availability and ease of capture in the wild. The calculated values of Shannon diversity index show that ingested prey were generally diversified and evenly distributed across the three study areas. This would again show that European starling is a species with an eclectic and opportunistic tendency that adapts to the food supply of the environment.

Otherwise, the number of animal preys ingested by European starling varied according to body and beak lengths, as well as body mass. Gibb (1955) reported that bird-dependent factors, such as height, beak length and age of individuals, affect the qualitative and quantitative predation variation in insectivorous birds.

We noted also a less intense prey consumption in the arid region with cold winters (Tilatou) compared to arid regions with cool (Sefiane) or temperate (Barika) winters. In fact, the harsh winter temperatures in the same arid climate condition the invertebrate activity, especially insects that become little available and accessible preys. Wolda (1983) highlighted that the seasonal insect distribution is usually controlled by three factors: the available resources, temperature and precipitation.

In the studied arid wintering areas, the temporal variation in the number of ingested preys mainly depends on the arrival and departure periods. According to Williamson & Gray (1975), the time of year is one of the main factors influencing the diet of European starlings. Indeed, the arrival of wintering birds coincides with November and December, which can justify the intense food activity of starlings in order to be able to reconstitute their depleted reserves during the journey undertaken towards their wintering area (Djennas-Merrar 2002). In February, the number of ingested prey decreased significantly due to the number of rainy days in the region. European starlings would have returned to a greater olive consumption, the animal prey being little available in rainy weather. Tinbergen (1981) showed that the feeding frequencies are lower during rainy days. Furthermore, the uneven climate during the winter period in arid regions would force these birds to adapt their diet to environmental conditions, including the availability of animal prey which is depending on the climate type.

As is the case in most of its global distribution, as well as in the humid regions of northern Algeria, the European starling is an eclectic frugivorous species during its wintering in the arid regions of North Africa. Throughout its wintering period, the species consumes a large quantity of olives with a very marked presence of animal prey. The climate of arid regions, rigorous and wide variations compel the bird to adapt its diet according to food availability, itself conditioned by climatic conditions. A true economic assessment of the balance between the damage caused to olive production and the limitation of certain invertebrate populations considered pests is required. This assessment would result from a clearer view of the conservation of the species in the arid regions of North Africa, especially in Algeria, where the species is considered a primary pest of olive crops and control campaigns are conducted using all possible means to limit its populations and its damage. In the long term, this may pose a real problem for the regional dynamics of the European starling populations.

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