

DIVERSITY AND DYNAMICS OF POTENTIAL PREY OF THE ALGERIAN NUTHATCH *SITTA LEDANTI* DURING THE BREEDING SEASON

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Abstract: This current study is focused on the trophic menu of the Algerian Nuthatch *Sitta ledanti* in the Guerrouch forest (Algeria). The sampling was done during the breeding season (from March to June 2018) of this bird. The results exposed the importance of Lepidopteran larvae on the diet of the Nuthatch. This taxa was the most diversified and abundant order with 20 species. The available prey associated with the Algerian Oak is more abundant during the incubation and the feeding young phases. These preys are much less present during the pre-laying and post-flight phases. During egg incubation and feeding, periods when the nuthatches' food and energy requirements are at their peak. The average size of prey available during the nesting period is 14.05 ± 7 mm. Potential prey sizes for Nuthatches, on average, are higher, more in advance of the breeding period. Geometridae are dominant during the incubation phase of the brood, represented mainly by the species *Operophtera brumata*. Caterpillars with a dominant green color are the most available for Nuthatches with a rate of 80 %. Short-haired Caterpillars make up the majority of the available caterpillar stock at 81.07%.

Keywords: *Sitta ledanti*, trophic menu, Algerian Oak, caterpillars, breeding period

INTRODUCTION

A detailed knowledge of diet is essential for many biology and ecology birds' studies. However, it is difficult to measure directly the diet of a species that has so far been highest breeding in artificial nest boxes, as is the case of the Algerian Nuthatch (Moulaï R., pers. observ.). Endemic to Algeria, *Sitta ledanti* has been the subject of few studies that allow us to presume its diet through the use of indirect inferences based on morphology (beak shape), or behavior (Gatter & Mattes, 1979; Bellatreche & Boubaker, 1995; Bougaham *et al.* 2017). Indeed, although previous studies have approached the subject of the foraging patterns, and feeding behavior of the species, these punctual works do not allow to identify, even to understand the relationship between the Algerian Nuthatch and its various prey species. Especially that, there is an extensive literature on invertebrate trapping techniques, particularly in relation to bird diet (e.g., Cooper & Witmore, 1990; Poulin *et al.*, 1994).

The Algerian Nuthatch during its foraging in breeding season seems to be insectivorous with a preference for folivorous caterpillars (Gatter & Mattes, 1979; Bellatreche & Boubaker, 1995; Moulaï *et al.*, 2017). Although the literature is rich in descriptive work on the food availability of different tits species (e.g., Gibb, 1950; Lack, 1955; Perrins, 1970; Van

Balen, 1973; Noordwijk *et al.* , 1995; Chabi *et al.* , 1995; Djenidi & Bouslama, 2004), and other insectivorous passerine species (Clere & Bretagnolle, 2001; Boudeffa *et al.* , 2014); no studies have yet been carried out on the diversity and dynamics of food availability of *Sitta ledanti* during its breeding season.

It is within this context that our approach, which aims to assess the diversity, structure and dynamics of potential prey of the Algerian Nuthatch according to the different phases of its breeding phenology.

MATERIAL AND METHODS

Study area

This study was carried out between 28 March and 21 June 2018 in the forest of Guerrouch (10860 ha) within the Taza National Park in Jijel (northeastern Algeria) (Fig 1). Only 3197 ha of this forest is included in the protected area. The climate of the region is wet and mild in winter. The main tree species include; Algerian oak (*Quercus canariensis*), afares oak (*Quercus afares*) and cork oak (*Quercus suber*), with a diverse undergrowth composed of tree heather (*Erica arborea*), arbutus (*Arbutus unedo*), common bracken (*Pteridium aquilinum*), common ivy (*Hedera algeriensis*), Diss (*Ampelodesma mauritanicus*), Kabyle Honeysuckle (*Lonicera kabylica*), Hairybroom (*Cytisus villosus*), and laurustine (*Viburnum tinus*) (Bellatrech, 1994).



Fig.1. Location of the Guerrouch forest (Algeria).

Data collection

An arthropod trapping campaign was conducted in an area of about 300 ha, situated at an altitude of 750 m a.s.l and including Algerian oak tree on the north-western slope of the Guerrouch forest. We chose to carry out our sampling around 3 nests of *Sitta ledanti*. The sampling of potential prey began at the onset of the oak budburst period (toward the end of March). This period corresponds to the excavation of Nuthatch cavities. The three referenced nests were particularly followed in order to draw up a reproduction calendar for the species, in relation to the dynamics of potential prey during the breeding season.

A plastic tarp (2m X 2m) (as a tray) was placed randomly around 10 sampled trees of Algerian oak (preferred tree species for foraging of the Algerian Nuthatch) (Bellatreche & Boubaker, 1995; Mayache *et al.*, 2020). Each tree was sampled 5 times over a 4-months period, with traps set on the following dates; 28 March, 11 April, 3 / 15 May, and 21 June. These dates correspond to the main phases of the breeding phenology of the Algerian Nuthatch.

On the sampling methods of caterpillars, the three techniques (Branch samples, Frass production, Water basins) (Zandt, 1994), seem to be consumes much more time during the field season. The choice of our techniques depends mainly on the aim of the research; therefore, we have adopted two techniques that seem to be the most suitable for our study;

Beating the branches: consists of hitting the foliage of the tree vertically with a stick to make the invertebrates associated to the Algerian oak fall on to the beating tray placed under the beaten branches. For technical reasons, a ladder, extending to 4 m, was used to shake the branches from the lowest part of each tree crown.

Brushing: using a brush attached to the end of a handle, the bole and especially the junction zone “trunk – branch”, is rubbed. This zone is visited preferentially by the Nuthatch during the foraging period, as indicated by Bellatreche and Boubaker (1995).

Our sampling method is commonly used, but like other techniques, it is not free of bias, it nevertheless reflects as much the occurrence of arthropods (especially the caterpillar's timing) as their relative density, and captures depend on the foliage cover of the tree and its distance from the beating tray.

The contents of the samples were examined as a whole in two steps; first identification and taxonomic census of specimens, and second, hand-sorting of individuals according to size (for all specimens), dominant color, and hair intensity (only for caterpillars).

Concerning the size of taxa, class limits are determined and standardized in relation to the length of the beak (culmen), which measures on average 16 mm (Vielliard, 1978). In addition, the Sturge rule has been applied to identify the number of size classes and the class interval (Scherrer, 1984).

Sturge's Rule: $k = 1 + 3.322(\log_{10} n)$,

k is the number of classes,

n is the total number of examined items.

Data analysis

The normality distribution and homogeneity of data was checked. Non parametric test Kruskal-Wallis was done in order to compare both between abundances of arthropods orders observed during Algerian Nuthatch breeding and between abundances of preys according to the four phases of Algerian Nuthatch breeding. PCA analysis was performed to illustrate chronology of caterpillars (Lepidoptera) appearance in trophic menu of Algerian Nuthatch during breeding period. Statistical tests were performed using XLSTAT (2009.1.02).

RESULTS AND DISCUSSIONS

Algerian Nuthatch breeding calendar

According to our observations carried in the forest of Guerrouch. The breeding period of the Algerian Nuthatch extends from the first ten-days of April to the last ten days of May. The average date of the first egg laid was April 4. Hatching occurred around April 21. The chicks fledged on 16 May.

Taxonomic diversity and potential prey abundance

Totally, 352 individuals of arthropods associated with the Algerian oak, belonging to 13 orders, 39 families, and 65 species with quite varied numbers of contributions. The most plentiful potential prey is the caterpillar of *Operophtera brumata* (Tortricidae) (14.73%), followed by another caterpillar, *Tortricidae sp2* (10.76%), then we find with the same proportion (10.20%), *Machilis sp* (Machilidae) and the *Opliones, Leiobunum sp1* (Table 1).

Table 1

 Taxonomic diversity and abundance of the different preys available during the breeding period of the Algerian Nuthatch *Sitta ledanti* in the Guerrouch Algerian oak Stand (Algeria)

Orders	Families	Species	Ni	Fc%
<i>Stylomatophora</i>	<i>Limacidae</i>	<i>Limacidae sp</i>	3	0,85
<i>Opiliones</i>	<i>Sclerosomatidae</i>	<i>Leiobunum sp1</i>	36	10,20
		<i>Leiobunum sp2</i>	4	1,13
<i>Araneae</i>	<i>Zoridae</i>	<i>Zoridae sp</i>	2	0,57
	<i>Segestriidae</i>	<i>Segestria sp</i>	1	0,28
	<i>Dictynidae</i>	<i>Dictynidae sp</i>	2	0,57
	<i>Agelenidae</i>	<i>Tegenaria sp</i>	1	0,28
	<i>Lycosidae</i>	<i>Pardosa sp</i>	1	0,28
		<i>Hogna sp</i>	2	0,57
	<i>Ctenzidae</i>	<i>Cteniza sp</i>	1	0,28
<i>Oecobiidae</i>	<i>Uroctea durandi</i>	1	0,28	
<i>Isopoda</i>	<i>Oniscidae</i>	<i>Oniscus sp</i>	1	0,28
<i>Archaeognatha</i>	<i>Machilidae</i>	<i>Machilis sp</i>	36	10,20
<i>Julidae</i>	<i>Julidae</i>	<i>Julidae sp1</i>	10	2,83
<i>Plecoptera</i>	<i>Perliidae</i>	<i>Perla sp</i>	1	0,28
<i>Blattodea</i>	<i>Ectobiidae</i>	<i>Ecotobius sp</i>	1	0,28
<i>Orthoptera</i>	<i>Tettigoniidae</i>	<i>Ephippiger sp</i>	10	2,83
<i>Hemiptera</i>	<i>Cydnidae</i>	<i>Adomerus bigutatus</i>	1	0,28
	<i>Pentatomidae</i>	<i>Pentatomidae sp1</i>	1	0,28
	<i>Miridae</i>	<i>Miridae sp</i>	2	0,57
<i>Coleoptera</i>	<i>Carabidae</i>	<i>Laemostenus sp1</i>	1	0,28
		<i>Trechinae sp</i>	1	0,28
	<i>Staphylinidae</i>	<i>Ocypus olens</i>	1	0,28
	<i>Geotrupidae</i>	<i>Geotrupidae sp1</i>	1	0,28
	<i>Nitidulidae</i>	<i>Nitidulidae sp1</i>	1	0,28
	<i>Scarabeidae</i>	<i>Amphimallon sp</i>	1	0,28
	<i>Bostrichidae</i>	<i>Neoterius sp</i>	1	0,28
	<i>Ptinidae</i>	<i>Ptinus sp</i>	2	0,57
		<i>Cantharis obscura</i>	4	1,13
	<i>Cantharidae</i>	<i>Maltinus sp</i>	1	0,28
		<i>Cantharidae sp1</i>	1	0,28
		<i>Cantharidae sp2</i>	1	0,28
		<i>Cantharidae sp3</i>	1	0,28
		<i>Cantharidae sp4</i>	1	0,28
	<i>Curculionidae</i>	<i>Polydrusus sp1</i>	28	7,93
		<i>Polydrusus sp2</i>	3	0,85
	<i>Cerambycidae</i>	<i>Cerambycidae sp</i>	2	0,57
<i>Anobiidae</i>	<i>Anobiidae sp</i>	1	0,28	
<i>Lepidoptera (Caterpillars)</i>	<i>Geometridae</i>	<i>Operophtera brumata</i>	52	14,73
		<i>Geometridae sp 1</i>	1	0,28
		<i>Geometridae sp 2</i>	16	4,53
		<i>Geometridae sp 3</i>	8	2,27
		<i>Geometridae sp 4</i>	1	0,28
	<i>Tortricidae</i>	<i>Tortrix viridana</i>	5	1,42
		<i>Tortricidae sp1</i>	7	1,98
		<i>Tortricidae sp2</i>	38	10,76
		<i>Tortricidae sp3</i>	11	3,12
	<i>Noctuidae</i>	<i>Allophys sp</i>	1	0,28
		<i>Cosmia sp</i>	2	0,57
		<i>Noctuidae sp1</i>	4	1,13
		<i>Noctuidae sp2</i>	2	0,57
		<i>Noctuidae sp3</i>	3	0,85
		<i>Noctuidae sp4</i>	1	0,28
	<i>Noctuidae</i>	<i>Noctuidae sp5</i>	10	2,83
<i>Crambidae</i>		<i>Crambidae sp1</i>	3	0,85
<i>Pyralidae</i>	<i>Pyralidae sp1</i>	1	0,28	
	<i>Pyralidae sp2</i>	2	0,57	
<i>Notodontidae</i>	<i>Thaumetopoea sp</i>	1	0,28	
<i>Hymenoptera</i>	<i>Apoidea</i>	<i>Apoidea sp</i>	1	0,28
<i>Formicidae</i>	<i>Crematogaster scutellaris</i>	8	2,27	
	<i>Camponotus sp</i>	2	0,57	
	<i>Formicidae sp</i>	1	0,28	

	<i>Cynipidae</i>	<i>Cynipidae sp1</i>	1	0,28
		<i>Cynipidae sp2</i>	1	0,28
	<i>Braconidae</i>	<i>Braconidae sp</i>	1	0,28

Our results reveal that available food supply for the Algerian Nuthatch is relatively extensive. Twenty species of caterpillars (*Lepidoptera*) were constantly recorded in the sampled plot (31%), followed by *Coleoptera* with 19 species (28%). Spiders come in third place with 8 species (12%). The rest of the

available resources are composed by *Hymenoptera* (11%), *Hemiptera* (5%), *Opiliones* (3%). Next come *Archaeognatha*, *Julidae*, *Orthoptera*, *Blattoptera*, *Stylommatophora*, *Plecopterans* and *Isopoda* with respectively 1% for each order (Fig.2).

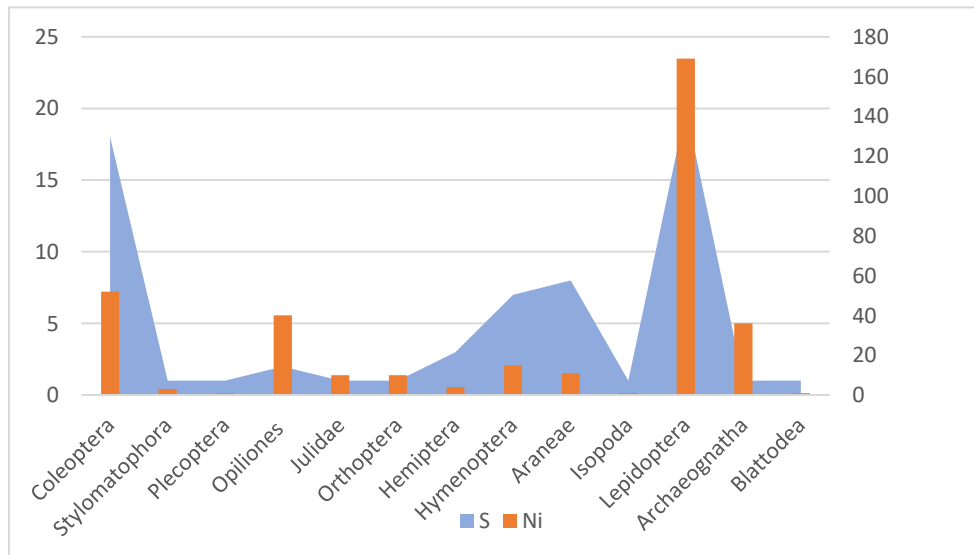


Fig. 2. Diversity and abundance of potential prey of the Algerian Nuthatch *Sitta ledanti* in the Guerrouch Algerian oak stand during the breeding period.

In terms of abundance, *Lepidoptera* caterpillars predominate with a rate of 48%, followed by Beetles with 15% of individuals caught. The other orders, more or less abundant, are represented by: *Opiliones* (11%),

Archaeognaths (10%), *Hymenoptera* (4%) and Spiders (3%) (Fig.3). But, no significant difference in abundances between these arthropods orders was noted ($K= 18.132$, $p\text{-value}= 0.112$).

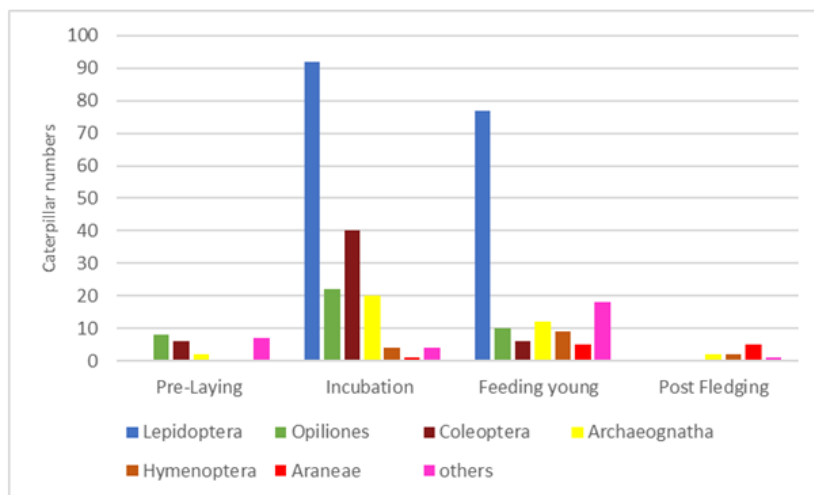


Fig. 3. Abundance of prey available for the Algerian Nuthatch and associated to the Algerian oak in the Guerrouch forest during each phase of the breeding season. (Algeria).

Our results revealed that there was a significant difference in abundances of prey between the four phases of *Sitta ledanti* breeding ($K= 12.611$, $p\text{-value}= 0.006$). We note that during this breeding period, the available prey associated to the Algerian Oak is more abundant during the incubation and the feeding young phases. These preys are much less present during the

pre-laying and post-fledging phases (Bonferroni test: $CD= 19$, $p\text{-value}= 0.0083$). Before excavation of cavities, Algerian oaks are not yet in leaf (beginning of budburst) and average temperatures are not high enough, which leads to a lower diversity and abundance of available arthropods. The same trend is observed from mid-May, the period corresponding to

the nest -robbing of the young Nuthatches, when the arthropod fauna is less present. This may be related to two main reasons, the first is due to the absence of butterfly caterpillars, since the latter have evolved to the chrysalis or adult butterfly, and the second is probably related to the decrease in the stock of arthropods, especially caterpillars, because of predation (mainly insectivorous birds) and other mortality factors.

During egg incubation and feeding, periods when the Nuthatch's food and energy requirements are at their peak. We note the predominance of *Lepidoptera* caterpillars which must have an undeniable supply for the adults and the chick. Other available preys appear in a significant number during these two phenological phases, these are the Coleoptera (notably *Polydrusus sp1*), Opiliones, Machilidae (Archaeognatha). The Opiliones represented essentially by *Leiobunum sp1* (Fig.10) are quite present on the trunk of the Algerian oak, on the main branches and even on the twigs. Several beak loads of food formed by *Machilis sp* had been observed (Fig.11). They are very accessible food for the Nuthatches, since they reside on the mosses and in the wrinkles of the trunk bark, which they often climb up and down. The indigestible chitinous parts of the beetles and other insects can replace the caterpillars, and the bird's stomach quickly becomes full. They allow Nuthatches to feel full more often and are less likely to overeat (Thiollay, 1976). On the other hand, it seems reasonable to suppose that Nuthatches are obliged to adapt to a qualitative and quantitative change in food resources that depends largely on the evolution of climatic factors, notably temperature, but

also on the phenology of the host tree and to a lesser extent on the intensity of competition from other insectivorous birds, especially cavernicolous birds.

Evolution of available prey size during the breeding period of *Sitta ledanti*

Potential prey sizes varied from 2mm for *Dictynidae sp* to 45mm for *Allophyes sp*. The average size of items identified during the nesting period was 14.05±7 mm.

The use of the Sturge rule, has brought out (09) size classes of (05mm) intervals (Table 2). The size class (in mm): [5-10[is the largest in number of individuals during the pre-laying phase with 47.62%. During the incubation phase, the class [10-15[(38.51%) comes in first position, it is mainly represented by *Operophtera brumata*. It is followed by the size class [5-10[(35.06%). During the nestling feeding, Algerian Nuthatches have to face greater prey size of the order [20-25[(43.06%), represented mainly by the caterpillars of *Tortricidae sp2* and *Tortricidae sp3*. The size of the most available prey (50%) during the post-fledging phase varies between [20-25] mm, represented mainly by Spiders (*Cteniza sp*, and *Uroctea durandi*) (Table 2).

We note that the prey sizes available to the Nuthatches are on average greater, more in advance of the breeding season. This is generally related to the evolution of the size of potential prey taxa following the post-embryonic development that these arthropods undergo as a result of the increase in temperature during the breeding period.

Table 2

Numbers and frequencies of size classes (in mm) of potential prey of *Sitta ledanti* associated to Algerian oaks in the forest of Guerrouch (Algeria)

Prey size (mm)	Pre-Laying		Incubation		Feeding young		Post Fledging	
	Ni	Fc %	Ni	Fc%	Ni	Fc%	Ni	Fc%
[0-5[	3	14,29	4	2.30	16	11,11	2	14.29
[5-10[	10	47,62	61	35.06	10	6,94		
[10-15[	2	9,52	67	38.51	20	13,89	2	14.29
[15-20[	4	19,05	34	19.54	14	9,72	3	21.43
[20-25[	2	9,52	8	4.60	62	43,06	7	50.00
[25-30[					2	1,39		
[30-35[					14	9,72		
[35-40[					5	3,47		
[40-45]					1	0,69		
Total	21		174		144		14	

A definite correlation was obtained between the bill length (16mm) and the size of available prey, where we were able to identify three prey groups (Table 3);

-Micro-prey: smaller than 16/2 mm (< 8mm) corresponds to a widespread class in the sampled plot (31.73%). It is essentially made up of *Opiliones*, Beetles and *Hymenoptera*.

- Macro prey: greater than 16 mm. They are mainly composed of Lepidopteran Caterpillars, Spiders, and *Archaeognatha*. This is the most abundant size class in the study area with 41.08 %.

-Meso-prey: sizes between 8mm and 16mm, consisting of various potential prey taxa, with a contribution of 27.2%.

Table 3

Numbers and frequency of sizes (in mm) of prey available according to the length of the beak of the Algerian Nuthatch during the breeding period in the forest of Guerrouch (Algeria)

	Ni	Fc %
≤8	112	31.73
8<... ≤16	96	27.20
16<	145	41.08

Total	353	100%
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Caterpillars (Lepidoptera)

The distribution of taxonomic affiliations of caterpillars is not uniform, both in terms of the number of individuals caught and their availability along the breeding period of the Algerian Nuthatch (Fig. 4).

The amounts of caterpillars collected during the incubation phase were usually composed by *Geometridae* (Fig.8), and most of it was produced by *Operophtera brumata*. Their numbers increasing constantly during the first weeks, then decreasing, mainly due to leaving the tree for pupation. *Tortricidae*

caterpillars occupy the second rank in the composition of prey availability during the same phase. Then, they record their peak during the first days of the feeding phase. In the same way *Noctuidae* (Fig.9) peak coincided with the period of rearing young chicks.

Caterpillars of *Notodontidae* appear in low numbers during the incubation phase, while *Pyrilidae*, newly hatched larvae, with a low abundance, mark their outbreak during the feeding of young Nuthatches. Crambidae caterpillars are poorly represented during the both stages (Fig.4).

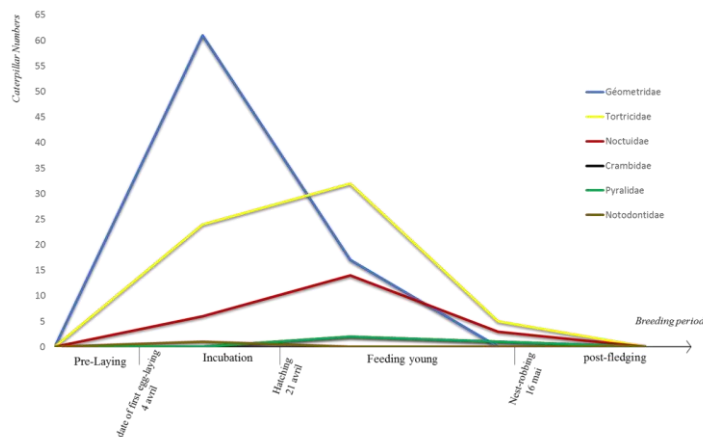


Fig. 4. Variations in number of caterpillars during the breeding period of the Algerian Nuthatch.

According to the results reported by PCA analysis (mainly the axis1 which holding 75.04% of information), the chronology of caterpillar appearance was categorized into 3 main classes. The first gathering the main available prey: *Geometridae* and *Tortricidae* which were positively and significantly correlated to chronology of appearance (1.694 and 1.617

respectively). The second class gathering secondary (alternative) available prey: *Noctuidae* which was negatively correlated with value of -0.068 . And the third class gathering occasional prey: *Notodontidae*, *Crambidae*, *Pyrilidae* which were negatively and highly correlated (-1.17 , -1.036 , 1.036 respectively) (Fig.5).

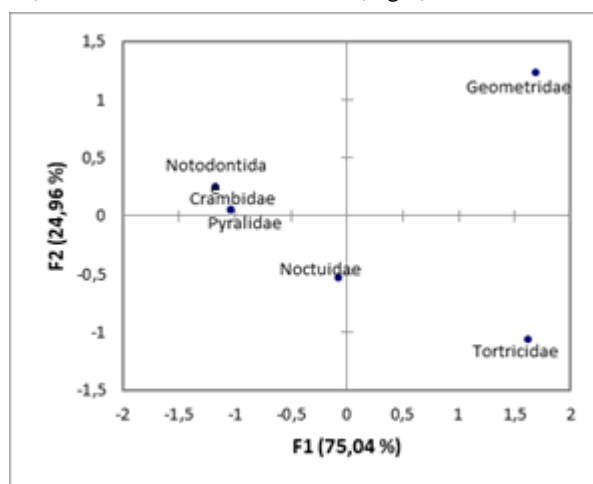


Fig. 5. PCA map illustrating caterpillars (Lepidoptera) appearance in trophic menu of Algerian Nuthatch during breeding period.

The broods of the three breeding pairs took an average of 42 days from the beginning of the laying of the first egg (4 April) to the time their young leave the nest (16 May). On average, the caterpillars take 40

days from hatching to pupation (Perrin, 1991). The availability of caterpillar’s supply occurred during the incubation phase (mainly from the male nuthatch to the female nuthatch incubating the eggs). But also, during

the first days of the feeding phase of the young Nuthatches (Fig.4). The maximum food demand of young Algerian Nuthatches is very close to that noted in the great tit *Parus major*, and usually occurs when the nestling are about 10 days old (Van Balen, 1973). However, our results show a slight mismatch with the caterpillars' peak and the maximum food demand of young Algerian Nuthatch. Perrin (1970) showed that early broods had an appreciable advantage over late broods. As the birds breed earlier, they were more likely to raise young.

Available caterpillar colors

Four categories of dominant colors have been identified. These colors are Green, Red, Brown and Other. Caterpillars with a dominant green color are the most available for Nuthatches with a rate of 80%, followed by those with a red color (10.65%). The other colors are less present (Fig.6). According to our observations of the contributions to the nests, the caterpillars of green color are the most noticed in the Nuthatch beaked. These caterpillars certainly frequent oak leaves. The green color protects the caterpillars from predators via their homochromy with the color of the leaves.

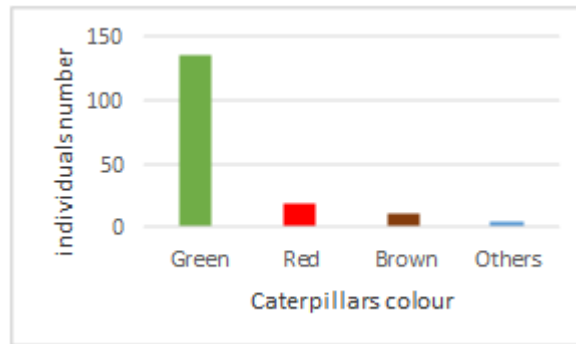


Fig. 6. Distribution of available caterpillars according to color during the breeding period of the Algerian Nuthatch.

Intensity of hairiness of available caterpillars

The dorsal hairs of some caterpillars can function as a physical defense against predator's attacks (Greeney *et al.*, 2012; Battisti *et al.*, 2013). In our study, three degrees of caterpillar hairiness were recorded for the available caterpillars; Slightly-haired, short-haired and long-haired species (shaggy) (Fig.7). Short-haired

caterpillars constitute the majority of the available caterpillar stock with 81.07%. They are represented mainly by the *Geometridae* in first place, followed by the *Tortricidae* in second place. The only shaggy species captured (Strong Hairy) is *Thaumetopoea sp.* While, no smooth species are reported in the study plot.

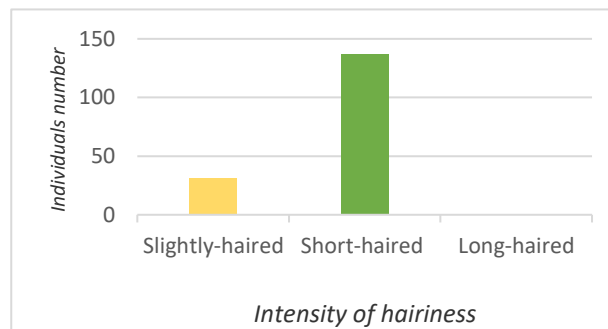


Fig. 7. Distribution of available caterpillars according to the intensity of hairiness during the breeding period of the Algerian Nuthatch.



Fig. 8. *Sitta ledanti* bringing a *Geometridae* caterpillar to their young (© Riadh Moulai).



Fig. 9. *Sitta ledanti* bringing a *Noctuidae* caterpillar (© Riadh Moulai).



Fig. 10. *Sitta ledanti* bringing a *Leiobunum sp1* to the nest (© Riadh Moulai).



Fig. 11. *Sitta ledanti* Male bringing a *Machilis sp* (© Mohamed-Ali DAKHLI).

CONCLUSION

This study is the first contribution of the trophic ecology description of *Sitta ledanti* in its habitat. In the future, it would be advisable to repeat the same study in other forest stands (Afares oak, or Atlas cedar...) where the Algerian nuthatch exists, as well as in other Algerian oak forests where the nuthatch does not exist, in order to better explain the nuthatch's relationship with its preys during the spring season. Also, it would be useful to take into account the contribution in biomass of the potential prey of the Nuthatch during the breeding period, and to evaluate with precision the

nature of the prey consumed and the impact that variations in the structure of the prey could have on the success of the broods and this, according to the seasons and the environment.

ACKNOWLEDGEMENT

First of all, we would like to thank the General Direction of Scientific Research and Technological Development -DGRSDT (MESRS) for its support and assistance throughout the preparation of this work. Also, we would like to thank warmly Mrs. Lylia Bedouhane (director of the Taza National Park), and

her staff (Engineers and forestry agents) for putting all the necessary means at our disposal for the good progress of our research.

AUTHORS CONTRIBUTION

Conceptualization, MEA. Mayache, R. Moulai; Methodology, MEA. Mayache, L. Temagoult, and R. Moulai; Data collection MEA. Mayache, L. Temagoult; Data validation, R. Moulai, M. Barra; Data processing; MEA. Mayache, R. Moulai, M. Barra; Writing—original draft preparation, MEA. Mayache, R. Moulai; Writing—review and editing, MEA. Mayache, R. Moulai.

FUNDING

This research received no external funding. The research is a Ph.D. study project performed in the Laboratory of Applied Zoology and Animal Ecophysiology (LZA), Faculty of Natural and Life Sciences, A.Mira University of Bejaia, Algeria.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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