https://doi.org/10.48047/AFJBS.7.4.2025.1297-1309

African Journal of Biological Sciences

Journal homepage: http://www.afjbs.com

Research Paper Open Access

Study of the spatio-temporal diversity of Noctuids (Lepidoptera-Noctuidae) in the Biskra region (Northern Algerian Sahara).

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Volume 7, Issue 4,Apr 2025
Received: 15 Feb 2025
Accepted: 05 Mar 2025
Published: 05 Apr 2025

doi:10.48047/AFJBS.7.4.2025.1297-1309

Abstract

The present study on the diversity of noctuid moths (Lepidoptera-Noctuidae) carried out in three phœnicicultural sites in the Biskra region (northern Algerian Sahara) during the year 2022 - 2023, enabled us to inventory 26 noctuid moth species. They are divided into eight subfamilies, 12 tribes and 19 genera. Our results show that the El Outaya station has the highest number of species, with 25 taxa (55.25% of the total). The species *Agrotis ipsilon* and *Agrotis segetum* predominate at all study sites. *Caradrina flavirena* and *Caradrina claripalpis* come second, but these two taxa are practically absent from the Ain Benoui station. Monitoring of noctuid moth fluctuations shows that the Outaya and Sidi Okba stations have two main flight periods, the first in autumn and the second between the beginning of March and the end of April. At Sidi Okba, we observed an uninterrupted presence of moths, with intense adult activity during the autumn period.

Key words: Noctuid insects, Diversity, Date palm, Northern Sahara.

Résumé

La présente étude sur la diversité des noctuelles (Lepidoptera-Noctuidae) menée dans trois sites phœnicicoles de la région du Biskra (Sahara septentrional algérien) au cours de l'année 2022 – 2023, nous a permis d'inventorier 26 espèces de noctuelles. Elles sont réparties dans huit sous familles, 12 tribus et 19 genres. Nos résultats indiquent que la station d'El Outaya abrite le plus grand nombre d'espèces avec 25 taxons soit 55,25% de l'effectif totale. Les espèces *Agrotis ipsilon* et *Agrotis segetum* prédominent quelque soit le site d'étude. En deuxième position arrive les Caradrina représentées par *Caradrina flavirena* et *Caradrina claripalpis*, ces deux taxons sont pratiquement absents au niveau de la station d'Ain Benoui. Le suivi des fluctuations des noctuelles montre que pour le cas des stations de l'Outaya et Sidi Okba on observe deux principales périodes de vols, la première automnale et la deuxième intervient entre le début Mars et la fin Avril. A Sidi Okba on observe une présence ininterrompue des papillons avec une intense activité des adultes au cours de la période automnale.

Mots clés: Noctuelles, Diversité, Palmier dattier, Sahara septentrional.

INTRODUCTION

Of the 160,000 butterfly species known worldwide, around 35,000 are noctuids, making them the largest family in the order Lepidoptera (Fibiger, *et al*. 2010). Already in the late 1990s, the upper systematics of noctuid moth's sensu lato began to be reworked on the basis of morpho-anatomical studies (Holloway, 2011). Noctuid moths are heterocerans, and most of their imagos are nocturnal. Some of these species are considered pests in their caterpillar form. This family is of great economic importance, as it includes species that are characterized by extreme polyphagy and can attack all plant species, whether vegetable, floral, and ornamental or even spontaneous (Lafontaine et al., 2010). The order comprises between 155,100 and 174,233 described species (Robineau, 2011), divided into 120 families and 46 super-families (John, 2008), including almost 7,000 in Europe and 5,000 in France (Vincent, 2008). Research into molecular phylogeny (notably by Zahiri) led in 2011 and 2012 to a system of four families for this group (Euteliidae, Erebidae, Nolidae and Noctuidae) (Minet *et al*., 2012). Noctuid caterpillars are among the most damaging pests of greenhouse crops. These include *Autographa gamma*, *Chrysodeixis chalcites*, *Helicoverpa armigera*, *Laconobia oleracea*, *Mamestra brassicae*, *Spodoptera exigua* and *Spodoptera littoralis* (Barkou H *et al.*, 2017). According to El Fakhouri *et al* (2019).

In Algeria, there is very little work on Lepidoptera in general and noctuid moths in particular, we cite in particular the remarkable work of Barkou in 2017 who had established a list of 33 species of noctuid moths belong to nine (09) subfamilies: Acontiinae, Noctuinae, Acronictinae, Cuculliinae, Oncocnemidinae, Plusiinae, Heliothinae, Catocalinae and Euteliinae, 17 tribes and 32 genera.

The present work on the diversity of noctuids (Lepidoptera - Noctuiidae) was carried out for the first time in the Biskra region (northern Sahara). Three experimental stations were selected on the basis of their ecological characteristics and botanical diversity. These were El Outaya, Sidi Okba and Ain Ben Noui. The first involved the inventory and relative abundance of noctuid moth species. The second was devoted to studying fluctuations in noctuid moth populations at the three study sites.

MATERIALS AND METHODS.

Presentation of the study region.

The wilaya of Biskra is located in south-eastern Algeria, between the Aures region and the Ziban, in the eastern part of the northern Sahara. It lies at an altitude of 124m, with a latitude of 34.48°N and a longitude of 05.44°E. It is bordered to the north by the wilaya of Batna, to the northeast by that of M'Sila, to the south by the wilaya of El-Oued and to the south-west by that of Djelfa (Fig.1), and covers an area of 216712Km².

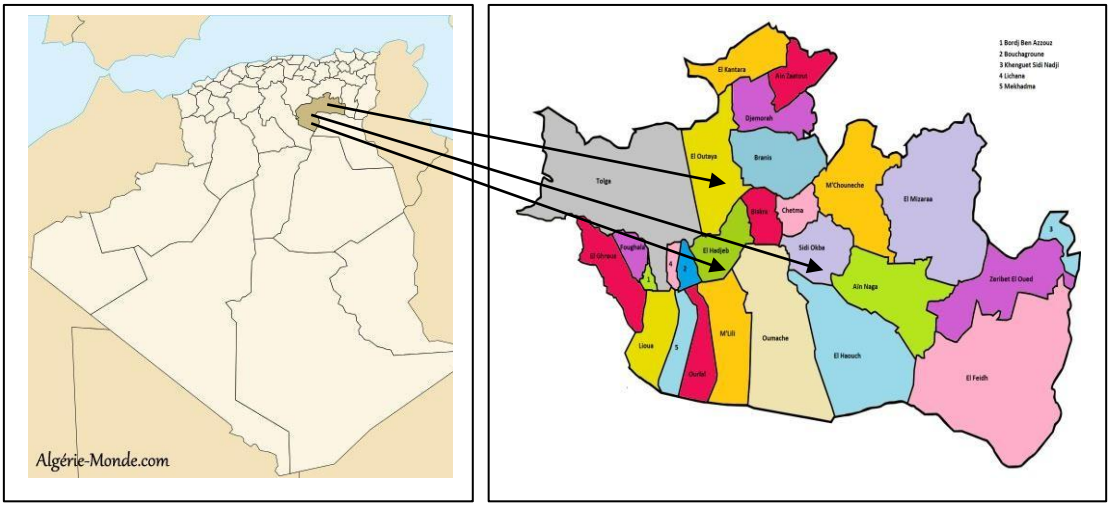

Figure: 1- Geographic map of the Wilaya of Biskra.

Description of study sites

The experiment was carried out between October 2022 and June 2023. We worked at three sites across the wilaya: El Outaya, Sidi Okba and Ain Benoui.

L'Outaya site.

El Outaya is a commune in the wilaya of Biskra (Algeria), located 25 kilometers to the northwest on Route Nationale 3 linking Biskra to the wilaya of Batna. It is located in the arid bioclimatic zone, 15 km from Biskra (Algeria). Bearing coordinates 35 02′ 00″ North, 5 36′ 00″ East, its surface area is 409.08 Km2.

Sidi Okba site.

The Sidi Okba region is located 20 km south-east of the city of Biskra (34°45' N; 5°54' E). It belongs to the Eastern Zab region, south of the Saharan Atlas, with its hot, dry desert climate, bordering the foothills of the Aures mountains. The site is characterized by a relief consisting of a plain in the northern zone (Ain Naga), which is relatively rugged and rocky, crossed by ephemeral streams. The region is located at 34.75° latitude and 5.9° longitude, with a total surface area of 254.55 km².

The study station is part of a cereal farm in SAADA, located on a spreading zone of Oued Djdi and Oued Biskra. It covers an area of 180 ha used to grow durum wheat (Var:VITRON). The farm is surrounded by traditional oases containing a variety of cultivated and spontaneous vegetation.

Ain Benoui El - Hadjeb site.

Our work was carried out at the experimental station of the Technical Institute for the Development of Saharan Agriculture (ITDAS), located in the region of Ain Ben Noui in the commune of El-Hadjeb, 7 km from the capital of the wilaya of Biskra on national road no. 46 (Fig. 1). Its geographical coordinates are: altitude (124 m), latitude (34° 44' North) and

longitude (5° 39' East). The overall surface area of the ITDAS palm grove is 20.4 ha, including 14 ha planted with date palms. The total number of palm trees is 1,630 (ITDAS, 2018).

Methodology

To carry out this study on noctuid moth diversity, we used light traps and sex pheromones. A light trap was placed at each station to trap the different species of noctuid moths. The trap in question consists of an attractant system made up of ultraviolet lamps (60 leds) which surround a plank rod about 40cm long, attached to an iron support and contained in a plastic container in which there is cotton soaked in ethyl acetate to kill the trapped insects. It is well known that the design of the trap and the physical qualities of the light radiation have a direct influence on the quality and quantity of the harvest.

Surveys are carried out every ten days, i.e. three times a month. The butterflies are collected in plastic pillboxes, on which the date and place of collection are indicated. Once in the laboratory, the butterflies are sorted and separated on the basis of a few morphological criteria, before being definitively identified on the basis of an examination of their genitalia (sclerotinized reproductive organ). In an Excel table, the moths identified are counted by species and by study site.

I - RESULTS

1 - Taxonomic inventory of Noctuids

The results of noctuid moth captures carried out in three biotopes of the Biskra region (northern Sahara) using light traps during the year 2022 - 2023 are grouped in the following table 1:

Table: 1- Species of noctuids caught in light traps in the Biskra region

Subfamilies	Tribes	Species of moths	Outaya	Ain Benouui	Sidi Okba
Acontiinae	Acontiini	*Acontia lucida* Hufnagel, 1766	x	x	x
Noctuiinae	Noctuini	*Agrotis ipsilon* Hufnagel, 1766	x	x	x
		Agrotis segetum Denis & Schiffermüller, 1775	x	x	x
		Agrotis trux Hübner, 1824	x	x	x
		Agrotis spinifera (Hübner, 1808	x		x
		Cerastis faceta Treischke, 1835	x	x	x
		Noctua pronuba Linnaeus, 1758	x	x	x
		Ochropleura leucogaster Freyer, 1831	x	x	x
		Hoplodrina ambigua Denis & Schiffermüller, 1775	x	x	x
	Hadenini	*Discestra trifolii* Hufnagel, 1766	x	x	x
	Caradrinini	*Caradrina claripalpis* Scopoli, 1763	x		x
		Caradrina flavirena Guenée, 1852	x		x
	Leucaniini	*Leucania loreyi* Duponchel, 1827	x	x	x
		Mythimna albipuncta Denis & Schiffermüller, 1775	x	x	x

Ipimorphinae	Prodeniini	*Spodoptera exigua* Hübner, 1803	x	x	x
		Spodoptera littoralis Boisduval, 1833	x		x
		Spodoptera cilium	x	x	
Acronictinae	Acronictini	*Agrochola lychnidis* Denis & Schiffermüller, 1775	x		
Spilomelinae	Spilomelini	*Papilta unionalis* Hübner, 1796	x		
Cuculliinae	Xylenini	*Lithophane leautieri* Boisduval, 1829		x	x
Heliothinae	Heliothini	*Helicoverpa armigera* Hubner, 1808	x		x
		Heliothis veriplaca Hufnagel, 1766	x	x	x
		Heliothis peltigera Denis and Schiffermuller, 1775)	x		x
Plusiinae	Argyrogrammatini	*Trichoplusia orichalcae* Fabricius, 1775	x		x
		Chrysodeixis chalcites Esper, 1789	x	x	x
	Plusiini	*Autographa gamma* Linnaeus, 1758	x	x	x
08	**12**	**26**	**25**	**17**	**23**

The results of an inventory of noctuid moths carried out at three stations in the wilaya of Biskra (northern Sahara), El-Outaya, Ain Benoui and Sidi Okba, over the course of 2022 - 2023, enabled us to identify 26 species of noctuid moth. They are divided into eight subfamilies, 12 tribes and 19 genera. The Noctuiinae subfamily predominates at all three stations, with 14 species at El Outaya and Sidi Okba and 11 taxa at Ain Benoui. In second place are the Ipimorphinae, Heliothinae and Plusiinae with three species each. Finally, the other subfamilies, Acronictinae, Spilomelinae and Cuculliinae, each have a single species (Tab. 1).

The histograms in Figure 2 show that the El Outaya station is home to the highest number of noctuid moths, with 25 taxa (55.25% of the total), followed by Sidi Okba with 23 species (27.56%). The Ain Benoui site is the least populated, with 17 species (17.19%).

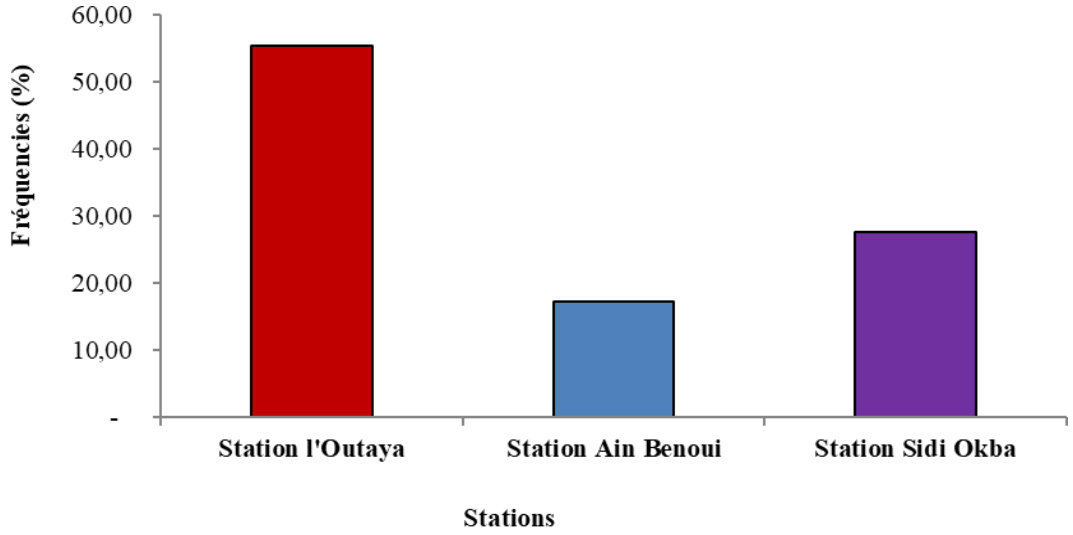

Figure: 2 - Proportions of populations of noctuids recorded in the three experimental stations.

2 - Relative abundance of Noctuids species at the three study sites.

Table: 3 - Abundances and frequencies of Noctuids species by study sites.

Species of moths	**Outaya**		**Ain Ben Noui**		**Sidi Okba**		**Total**	
	ni	AR	ni	AR	ni	AR	ni	AR
Acontia lucida	33	1,53	15	2,09	5	0,42	53	1,31
Agrochola lychnidis	3	0,14	0	-	0	-	3	0,07
Agrotis ipsilon	732	33,92	303	42,32	520	44,03	1555	38,35
Agrotis segetum	345	15,99	94	13,13	168	14,23	607	14,97
Agrotis spinifera	10	0,46	0	-	14	1,19	24	0,59
Agrotis trux	12	0,56	32	4,47	6	0,51	50	1,23
Autographa gamma	11	0,51	13	1,82	1	0,08	25	0,62
Caradrina claripalpis	122	5,65	0	-	17	1,44	139	3,43
Caradrina flavirena	203	9,41	0	-	10	0,85	213	5,25
Cerastis faceta	24	1,11	6	0,84	10	0,85	40	0,99
Chrysodeixis chalcites	5	0,23	5	0,70	8	0,68	18	0,44
Discestra trifolii	58	2,69	8	1,12	14	1,19	80	1,97
Helicoverpa armigera	16	0,74	0	-	8	0,68	24	0,59
Heliothis peltigera	25	1,16	0	-	6	0,51	31	0,76
Heliothis veriplaca	50	2,32	54	7,54	34	2,88	138	3,40
Hoplodrina ambigua	40	1,85	11	1,54	4	0,34	55	1,36
Leucania loreyi	12	0,56	11	1,54	16	1,35	39	0,96
Lithophane leautieri	0	-	1	0,14	2	0,17	3	0,07
Mythimna albipuncta	99	4,59	33	4,61	126	10,67	258	6,36
Noctua pronuba	52	2,41	5	0,70	7	0,59	64	1,58
Ochropleura leucogaster	11	0,51	11	1,54	17	1,44	39	0,96
Papilta unionalis	6	0,28	0	-	0	-	6	0,15
Spodoptera cilium	120	5,56	19	2,65	0	-	139	3,43
Spodoptera exigua	47	2,18	16	2,23	18	1,52	81	2,00
Spodoptera littoralis	7	0,32	0	-	3	0,25	10	0,25
Trichoplusia orichalcae	4	0,19	0	-	7	0,59	11	0,27
Espèces indéterminées	111	5,14	79	11,03	160	13,55	350	8,63
Total	**2158**	**100**	**716**	**100**	**1181**	**100**	**4055**	**100**

Analysis of the results of noctuid fluctuations, reported in Table 2, gives a total of 26 species identified. The species *Agrotis ipsilon* and *Agrotis segetum* predominate at all study sites. *Agrotis ipsilon* (1,555 individuals) and *Agrotis segetum* (607 individuals) accounted for 38.35% and 14.97% respectively of the total population. The Outaya site is the most frequented by these two noctuid moths. In second place come the Caradrina moths,

represented by *Caradrina flavirena* and *Caradrina claripalpis*, with a total of 213 and 139 individuals respectively, i.e. 5.25% and 3.43%. The Outaya site still has the highest number of individuals, with 203 and 122 respectively. It should also be noted that these two taxa are practically absent from the Ain Benoui station. They are followed by the *Mythimna albipuncta* noctuid moth with 258 individuals (6.36%). Unlike the other noctuid moths mentioned, this species is much more frequent at the Sidi Okba site, with no fewer than 126 individuals captured, representing 10.67% of the total noctuid moth population recorded at the site. The species *Spodoptera cilium* (absent from the Sidi Okba site) and *Heliothis veriplaca* ranked sixth, with 139 and 138 individuals respectively, representing 3.43% and 3.40% of the total population. Finally, the other species show insignificant activity, with only isolated individuals captured at the three stations, ranging in number from 03 to 60 individuals. Indeterminate species, of which there are 14 taxa, account for 8.63% of the total population, and number no more than 350 individuals at the three stations.

3 – Fluctuations in Noctuid populations.

3.1 - Outaya site.

In Outaya, the appearance of Noctuids occurs from the first ten days of October with a number of 120 individuals captured in the traps. Analysis of the curve in Figure 3 indicates the presence of two main flight periods. The first autumn period extends from October 10 to December 10 and records a capture peak of 262 individuals noted during our survey on November 20. We then see a drop in populations that will continue throughout the winter. This is probably a period of laying and larvae that coincides with the availability of food offered by the various market garden crops established in the region. Indeed, during our surveys, we observed several noctuid larvae on tomato leaves. The second period of flight activity occurs between the beginning of March and the end of April and records a peak of capture of 217 individuals noted towards the end of March. A gradual drop in populations is observed throughout the month of April where a minimum of 39 individuals was noted towards the end of the same month. The flight activity of noctuids was very low during the month of May as shown by the negligible number of captures which varies between 31 and 38 butterflies.

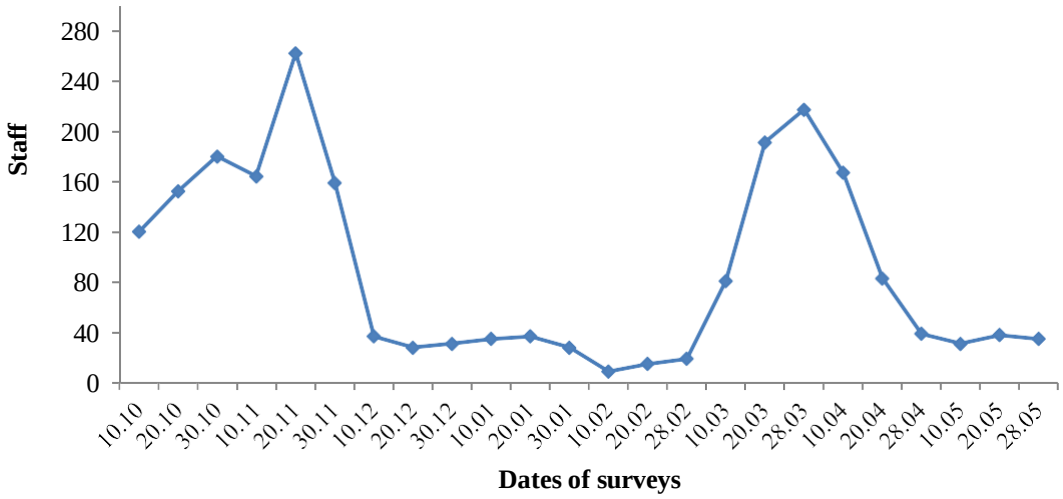

Figure: 3 - Spatio-temporal evolution of populations of noctuids listed in L'Outaye in 2023.

3.2 - Ain Benoui site

In the case of the Ain Benoui station, there are always two noctuid flight periods. The first is the most important, extending from October to December. The first adult moths were caught around the start of our experiment (65 individuals). Moth populations gradually increased, reaching a first peak of 110 individuals (15.36%) during our October 30 survey. After a slight drop in populations (71 individuals caught), a resumption of captures was observed during the second half of November, reaching a second peak of 139 individuals around the 20th of the same month, representing 19.27% of the total number of moths caught. This was followed by a sharp drop in the number of moths caught, to a minimum of 21 around the 20th of December (2.93%). A total absence of moths and captures was observed throughout January and February. This is probably due to the egg-laying and larval phases of the noctuid moths, insofar as this is a period when vegetable crops are expanding in the region. This hypothesis may be justified by the emergence of noctuid pupae and the resumption of flights from March 20 onwards. A flight peak of 56 moths was recorded on March 28, representing 7.82% of the total number of moths (Fig. 4).

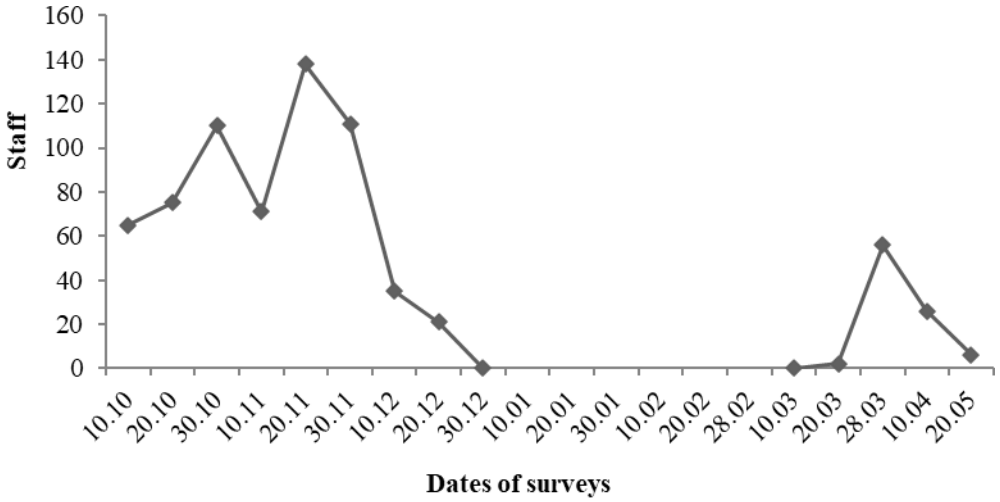

Figure: 4 - Spatio-temporal evolution of populations of noctuids listed in à Ain Benoui en 2023**.**

3.3 - Sidi Okba site

At the Sidi Okba site, we observed an uninterrupted presence of Noctuids. As at the previous two sites, two main flight periods were observed. The first is the most important, from the start of our experiment to the end of January. The second occurs from early February to the end of our study. The first moths were caught during our first survey, totalling 75 individuals (6.34%). A first peak of 162 individuals (13.69%) was recorded around the 20th of October. After a slight drop in catches towards the end of October, flights resumed, reaching a second peak of 129 individuals (10.90% of the total). This was followed by a gradual drop in flights, reaching a minimum of 14 individuals (1.18%) towards the end of January. The second period was marked by two main peaks of lesser importance. The first, totalling 73 individuals (6.17%), was recorded on February 28, and the second, 37 individuals (3.13%), on April 28. Finally, it should be noted that only 27 butterflies were caught in May, representing no more than 1.27% of the total number caught (Fig. 5).

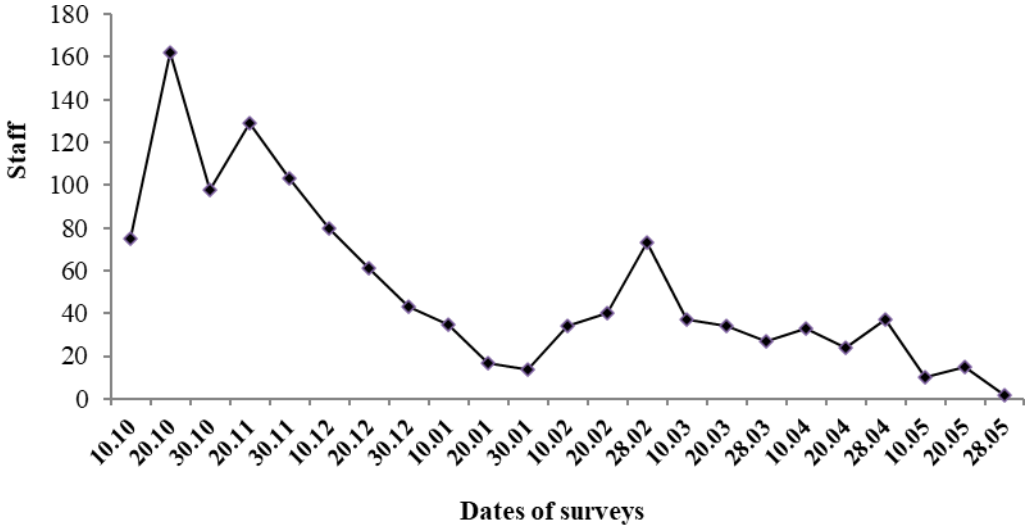

Figure : 5 - Spatio-temporal evolution of populations of noctuids listed in Sidi Okba en 2024.

4 - Diversity indices

In order to characterize the specific diversity of Noctuid moth populations at the three study sites in 2023, we calculated several ecological parameters, in particular abundance, Shannon index (H'), equitability index (E), Simpson index and Fisher_alpha index. The results are reported in Table 4.

Table: 4 - Abundance and diversity indices of Noctuids listed at L'Outaya, Ain Benoui and Sidi Okba.

Study stations	Settings	X	XI	XII	I	II	III	IV	V
El -Outaya	Abundances	452	585	96	100	43	489	289	104
	Shannon_H	2,17	1,57	1,42	0,93	1,42	2,15	2,07	2,17
	Equitability_J	0,78	0,59	0,72	0,51	0,79	0,74	0,73	0,87
	Simpson 1-D	0,84	0,67	0,68	0,48	1,42	0,84	0,82	0,85
Ain Benoui	Abundances	250	320	56	0	0	58	26	6.00
	Shannon_H	2,20	1,56	0,82	0	0	1,90	1,86	1,01
	Equitability_J	0,81	0,59	0,51	0	0	0,86	0,95	0,92
	Simpson 1-D	0,84	0,66	0,39	0	0	0,80	0,83	0,61
Sidi Okba	Abundances	335	232	184	66	147	98	94	27
	Shannon_H	1,84	1,59	1,20	1,44	1,38	2,69	2,21	1,78
	Equitability_J	0,68	0,64	0,57	0,62	0,59	0,93	0,80	0,91
	Simpson 1-D	1,84	0,70	0,57	0,61	0,62	0,92	0,82	0,91

4.1 - Shannon diversity and equitability index

Noctuid abundance was highest at the Outaya site, with a total of 2,158 individuals, followed by Sidi Okba with 1,183. The Ain Benoui station was the least populated, with only 710 individuals caught. For the first two sites, the highest number of noctuid moths was recorded in November, with 585 and 320 individuals respectively. In the case of the Ain Benoui station, the highest number of noctuid moths was recorded in October, with 335 individuals. The monthly diversity indices were not very different at the three stations, and evolved in much the same way. They ranged from 0.93 to 2.17 at Outaya, from 0 to 2.20 at Ain Benoui and from 1.20 to 2.69. In general, diversity is highest in October for the first two sites and in March for the Ain Benoui station. Whatever the site, it does not exceed 2.69 bits, and is considered to be more or less low, except in October for the first two stations and in March for Sidi Okba.

Generally speaking, equitability varies between 0.51 and 0.93 at the three experimental stations, and therefore tends towards 1. In this case, we say that the population is represented by a close number of individuals, and that no species dominates. The environment is then said to be in ecological equilibrium.

4.2 - Simpson's index.

Simpson's index is the probability that two randomly selected individuals in a stand belong to the same species. The closer it is to 1, the more homogeneous the stand. It varies from 0.48 in January to 0.87 in May at Outaya, from 0.39 in December to 0.84 in October at Ain Benoui and, finally, from 0.57 in December to 0.92 in March at Sidi Okba. It should be remembered that Simpson's diversity index gives greater weight to abundant species than to rare ones. It therefore reflects the codominance of several species, insofar as it tends towards 1 at Outaya, Ain Benoui and Sidi Okba.

Discussion

The inventory of noctuid moths carried out as part of this study is characterized by a total of 4055 individuals captured, representing eight subfamilies, 12 tribes, 19 genera and 26 species of noctuid moths. The El Outaya station is home to the largest number of species, with 25 taxa (55.25% of the total), followed by Sidi Okba with 23 species (27.56%). The Ain Benoui site is the least populated, with 17 species (17.19%). Barkou in 2017 drew up a list of 33 noctuid species belonging to nine (09) subfamilies: Acontiinae, Noctuinae, Acronictinae, Cuculliinae, Oncocnemidinae, Plusiinae, Heliothinae, Catocalinae and Euteliinae, which comprise 17 tribes and 32 genera. Dih *et al* (1987) inventoried 10 species of noctuid moths in the Algerian region. In 1991, Zouaoui studied the population dynamics of noctuid moths in market garden crops in the Staouali and Boumerdes regions, estimating the damage caused by the species *Spodoptera littoralis* Boisduval. Other studies have been carried out by several Algerian authors in certain localities along the Algerian coast (Hasnaoui, 1989; Djebaili, 1992; Maouche and Sakhri, 1993).

Our results show that *Agrotis ipsilon* and *Agrotis segetum* predominate at all study sites. In second place come the Caradrina species, represented by *Caradrina flavirena* and *Caradrina claripalpis*, both of which are practically absent from the Ain Benoui station. According to Da-Wei Zhang *et al* (2022), chlorantraniliprole has good potential for the management of

Agrotis ipsilon and *Agrotis segetum* Noctuid moths at long range, tested using an attract-and-kill strategy.

A study of Noctuid moth fluctuations shows that in the Outaya site, noctuid moths appear from the first dekad of October. Two main flight periods are observed: the first is autumnal, from October 10 to December 10. This is followed by an egg-laying and larval period that coincides with the availability of food from the various market-garden crops grown in the region. The second flight period takes place between the beginning of March and the end of April. The Ain Benoui site also has two noctuid flight periods. The first is very important, extending from October to December, with two main peaks, the first recorded during our October 30 survey and the second noted on the 20th of the same month. After a total absence of moths during January and February, coinciding with the egg-laying and larval phases of the noctuid moths, a resumption of flights was observed from March 20 onwards. At the Sidi Okba site, noctuid moths were present without interruption. As at the previous two sites, two main flight periods were observed. The autumn period is the most important, extending from the start of our experiment to the end of January, and recording two peaks. The second is less important, with a single peak of no more than 73 individuals recorded towards the end of February. According to Manley 2008, noctuid moth larvae can survive in small numbers in more northerly areas, provided winters are mild.

According to a study conducted in 1994 and 1995 by INRA Duclos in Guadeloupe and ORSTOM, based on pheromone trapping monitoring, rainfall increases the abundance of moths captured, with the two flights of greatest intensity occurring precisely during the rainy season. Rainfall increases the abundance of moths captured, with the two flights of greatest intensity occurring precisely during the rainy season.

In order to characterize the specific diversity of Noctuid moth populations at the three study sites in 2023, we calculated several ecological parameters, in particular abundance, Shannon index (H'), equitability index (E), Simpson index and Fisher_alpha index. The monthly diversity indices differ little between the three stations and evolve in much the same way. They range from 0.93 to 2.17 at Outaya, from 0 to 2.20 at Ain Benoui and from 1.20 to 2.69. Generally speaking, equitability varies between 0.51 and 0.93 at the three experimental stations and therefore tends towards 1. In this case, we say that the population is represented by a number of close individuals and that no species dominates. The environment is then said to be in ecological equilibrium.

The H' index can then be taken to indicate a diversification of ecological niches in terms of insect species, and a homogeneity of insect populations (Calu, 2020). The more varied the number of species, the higher the Shannon index. According to Blondel (1979), the greater the H' index, the more diverse the community.

A Simpson index value of 0 indicates maximum diversity. A value of 1 indicates minimum diversity. In fact, it varies from 0.48 in January to 0.87 in May at Outaya, from 0.39 in December to 0.84 in October at the Ain Benoui site and, finally, from 0.57 in December to 0.92 in March at the Sidi Okba station.

Conclusion

In the light of the results obtained, our study has enabled us to highlight the biodiversity of noctuid moths in the Biskra region (northern Sahara), characterized by its climate specific to the regions of southern Algeria. 26 species of noctuid moths were recorded, divided into eight subfamilies, 12 tribes and 19 genera. Of the three sites chosen for this study, El Outaya had

the highest number of species, with 26 taxa (55.25% of the total), followed by Sidi Okba with 23 species (27.56%). The Ain Benoui site is the least populated, with just 17 species. The species *Agrotis ipsilon* and *Agrotis segetum* predominate at all study sites. Caradrina species, represented by *Caradrina flavirena* and *Caradrina claripalpis*, come second, but are absent from the Ain Benoui station. They are followed by *Mythimna albipuncta*, which shows intense activity at the Sidi Okba site. Two main flight periods are observed during the Noctuid moth cycle at the Outaya and Ain Ben Noui stations: one in autumn is the most important, and the other in spring of lesser importance. At Sidi Okba, on the other hand, Noctuid moths are present without interruption. In general, the absence of adults in winter corresponds to the egg-laying and larval phase of noctuid moths. In fact, this period coincides with the availability of food from the various market garden crops and other spontaneous plants growing in the region.

In perspective, it is essential to continue the inventory using the genitalia technique and to explore other biotopes that may harbor new species. It is also important to conduct in-depth studies on the bioecology of the different species of Noctuids in order to devise control strategies tailored to each pest, taking into account the presence of their natural enemies. Moreover, it would be wise to monitor the larvae of different species and identify their host plants.

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