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The :

Theme :

Current State Of Lepidoptera (Rhopalocera) Diversity In Biskra and EL M'Ghair

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Jury:

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Dedications

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TELLOUL Nada rayhan

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Introduction

Insects are among the most widespread and diverse animal groups on Earth, and this is hardly surprising considering that the number of insect species surpasses that of all other animal groups combined **(Maghni*&al.,* 2017)**. The order Lepidoptera, which ranks as the fourth largest order within the class Insecta, includes an estimated 112,000 to 225,000 species worldwide. These species exhibit a wide range of shapes, sizes, and colors. Lepidopterans play a vital role in the functioning of terrestrial ecosystems, acting as herbivores, pollinators, hosts for parasitoids, and prey for numerous vertebrates and invertebrates **(Brown, 2021)**. In addition, they are highly sensitive to pesticides, environmental disturbances, and climate change, particularly temperature fluctuations, which significantly affect migratory species **(Sparks *& al.,* 2007)**.

Although the importance of studying butterfly distribution in ecosystems may not be immediately evident, butterflies have long contributed to plant pollination and reproduction, making them an essential link in food webs and contributing to ecological balance**(Bonneil, 2005a).** Their ecological benefits extend beyond biology, agriculture, and the environment, reaching into sectors such as industry and ecotourism **(Nguku *&al.,* 2007)**. Furthermore, butterflies are recognized as excellent bioindicators of environmental health due to their sensitivity to habitat changes and pollution **(Villemey & Archaux, 2018)**.

In this study, we focused on the suborder Rhopalocera, commonly known as “day butterflies,” which is considered one of the most important groups within the order Lepidoptera **(Dajoz, 1974).**

Our objective was to contribute to the knowledge of butterfly diversity by studying two regions in southeastern Algeria, namely Biskra and El M’Ghair, which to our knowledge have not been the subject of specific studies on butterfly distribution. By exploring these areas, we aim to highlight the local biodiversity of butterflies and to enhance the understanding of the ecological and environmental factors influencing their distribution.

This thesis is structured into three main parts. The first part presents the general context of the study, along with an overview of butterflies and their ecological significance. The second part describes the study areas, the adopted methodology, and the analytical tools used. The third and final part includes the results obtained, their interpretation, and a discussion in light of the objectives set at the beginning of the research.

Chapter I: Bibliographic study about Lepidoptera (Rhopalocera)

1.1. General information

The scientific name Lepidoptera comes from the Greek: Lepis (lepidos), meaning "scale", and Pteron, meaning "wing", referring to wings covered with scales. Within this order, butterflies belonging to the suborder Rhopalocera, commonly known as day butterflies, are distinguished by their bright colors, diurnal activity, and characteristic morphology**(Chinery & Legrand, 1988)**. They typically rest with their wings held vertically together and possess antennae that end in a well-defined club shape. These insects belong to the phylum Arthropoda and the class Insecta **(Loyer & Petit, 1995)**. The classification system developed by Linnaeus over 250 years ago remains hierarchical, with species being the fundamental unit, grouping all individuals capable of interbreeding and sharing common traits **(Loyer & Petit, 1995).**

Day butterflies differ from one another not only in their adult forms but also in their developmental stages: egg, caterpillar, chrysalis, and cocoon **(Still, 1996).** The shape of their antennae, leg structures, and especially their behavior during rest are key criteria used to identify and classify them **(Laplanche & Corge, 2008; Still, 1996).**

1.2. Biology of Lepidoptera (Rhopalocera)

1.2.1. General morphology

According to **Bergerot (2011a),** the morphology of a butterfly, like any insect, is divided into three parts (head, thorax and abdomen). The head carries the sensory organs such as the antennae or the eye, the thorax carries the wings as well as the three pairs of legs. The abdomen contains many internal organs linked to physiological processes such as reproduction or digestion. Butterflies are characterized by two pairs of wings covered with scales and a proboscis allowing them to ensure the ingestion of nectar **(Fig. 1).**

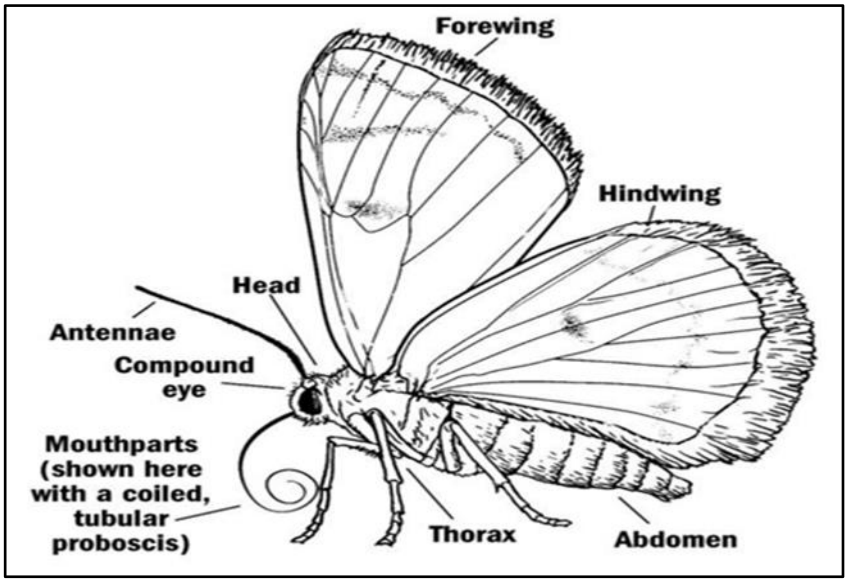

Figure 1: General morphology of Lepidoptera **(Waston, 2011)**.

1.2.1.1. Head

The head has a pair of compound eyes, a pair of antennae that end in a club in butterflies and in moths without a club, a proboscis through which the insect feeds on flower nectar, sap or even liquids from spoiled fruit **(Gwenale & Benedicte, 2005).** The ventral side of the head has the coiled proboscis of a sucking-licking type that only exists in the adult state, consisting of two gutters forming a canal used to suck up the nectar **(Bergerot *& al.,* 2012).**

According to **Rougeot & Viette (1978),** the antennae can be largely plumose (pectinate), toothed, ciliate, filiform, swollen and curved at the apex, fusiform, etc., and are swollen at the tip, which differentiates the butterflies from the moths which without swollen tips have filiform or plumose antennae. Moreover, they often differ considerably from one sex to another, but they are always better developed in the male than the female. They can reach a considerable length.

1.2.1.2. Thorax

Motor center of the body, it is composed of three segments. The prothorax, the mesothorax and the metathorax, and the motor elements namely the legs and the wings. The latter are composed of a thin chitinous membrane, covered with thousands of small flattened scales aligned like the tiles of a roof and attached to the wing membrane by a small pedicel **(Dozières & Valarcher, 2017).**

According to **Frahtia (2002),** these scales are modified hairs covered with an imperceptible waxy film, on which are present round colored ocelli whose number and color are characteristic of each species. The coloring of the scales is due to pigments (Physical coloring) and to phenomena of networks or thin blades (Optical coloring).

1.2.1.3. Abdomen

The final section that makes up the body of the insect is elongated and tube-like, made up of eight segments in males, while females possess only seven; three or four of these segments are significantly altered to create the outer components of the reproductive system. In many female insects, an ovipositor is present, which is utilized for depositing eggs **(Higgins, 1991a)**.The abdomen houses the digestive tract, the circulatory organs, a complex muscle system, as well as the organs responsible for excretion and reproduction (Laplanche & Corge, 2008).

1.2.1.4. Wings

The wings often stand out as the most magnificent aspect of a butterfly, with their embellishments and hues serving as critical factors for identification. It is vital to carefully examine the shape and arrangement of the designs and their variations on both sides and across the four wings. The form of butterfly wings varies significantly considering their primary purpose is flight. Some possess widely spaced, broad, rounded wings that facilitate long glides, while others feature narrow, somewhat angular wings, usually tailored for flapping movements **(Sterry & Mackay, 2005).**

1.2.2. Life cycle

According to **Bergerot (2011b),** the journey of a butterfly unfolds across four unique stages. Initially, it begins as an egg, serving as the foundation for embryonic growth, followed by the caterpillar phase. During thisperiod, the emphasis lies on accumulating energy and developing. Next, the stationary pupaappears, which is the stage of metamorphosis into an adult butterfly, ultimately resulting in theimago, the phase of spreading and species reproduction **(Fig. 2).** Typically, the entire cycle spans from 3to 12 months, but records show extremes of 21 days to 2 years **(Higgins, 1991b)**.

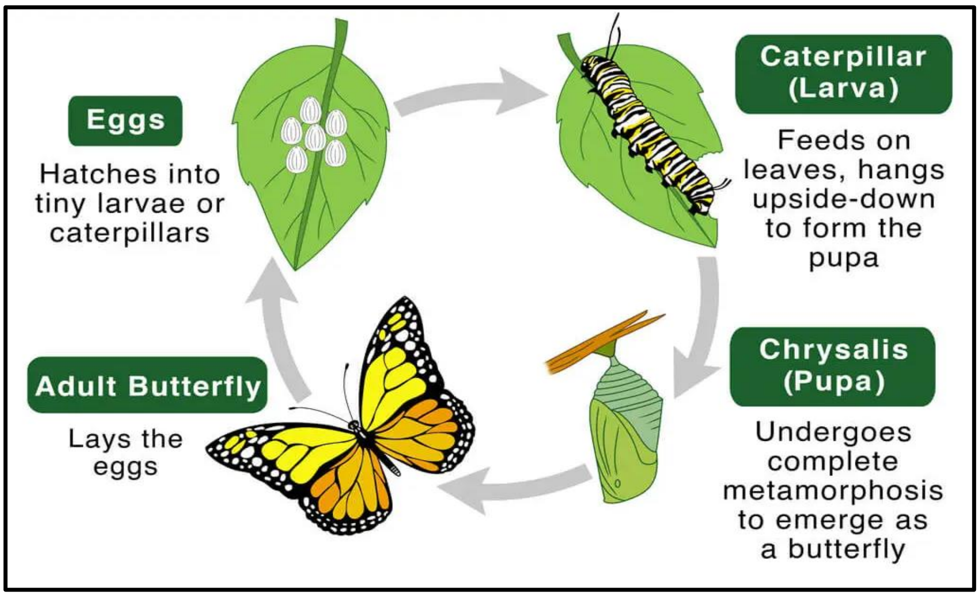

Figure 2: Life cycle of Lepidoptera **(Gullan & Cranston, 2014).**

1.2.2.1. Egg

Butterfly eggs are laid by females on host plants, providing nourishment for their caterpillars. These eggs, no larger than a pinhead, are positioned to hide from predators. Most butterflies produce 100-300 eggs, ranging from 0.5 to 3 mm in size. These eggs have the potential for embryonic development, which can take several days to weeks. Some species survive winter in egg form, initially pale but later adopting cryptic or vibrant colors (**Pierret &Marc, 2012).**

1.2.2.2. Caterpillar

The caterpillar, a tiny creature that transforms into a plant, feeds on its host plant, accumulating reserves for its transformation. It can increase its weight 100 times and molt four times to grow **(Pierret & Marc, 2012)**. Before each molt, the caterpillar stops feeding, becomes immobile, and the epidermal cells multiply to form a larger second skin. The caterpillar's development goes through larval stages linked to the molts necessary for growth **(Lepertel & Robert, 2000).** The larval life can last from three weeks to nine months in species that hibernate in the larval stage **(Beylagoun, 1998)**.

1.2.2.3. Chrysalis

The chrysalis, derived from the Greek word "chryso," signifies the end of a caterpillar's life, marking the transition to the mature butterfly (**Albouy, 2011)**. Once the caterpillar reaches its ideal size, it constructs a chrysalis using leaves or its own body. The chrysalis undergoes metamorphosis, creating new tissues and internal changes (**Genzales, 2019)**. The caterpillar's brain, eyes, antennae, mandibles, proboscis, digestive system, and reproductive organs emerge **(Pierret & Mollier, 2012)**. The chrysalis ruptures and becomes firm and rigid, lasting from a week to several months, depending on climatic conditions and species **(Bergerot *&al.,* 2012).**

1.2.2.4. Imago

The mature butterfly (imago) breaks free from the chrysalis and surfaces, waiting at least 4 hours before flying **(Genzales, 2019)**. The translucent skin of the chrysalis reveals its form, and the butterfly fills with air to rupture the chrysalis. Blood circulates through the wings to unfurl them **(Pierret & Mollier, 2012)**. Adult butterflies typically live one day to six months **(Warnock, 2004).**

1.2.3. Reproduction

Butterfly search for sexual partners begins with an approach flight, where males reach the female, who may or may not accept their invitation. Females signal their receptiveness by spreading their wings and emitting pheromones from the abdomen. The butterfly reproductive cycle includes courtship and copulation stages. During courtship, males perform reconnaissance flights to attract females, while females release their own pheromones **(Calvo, 2015)**. Males patrol breeding zones with "searching," characterized by anemotactic flight against the wind **(Félix & Anne, 2008)**.When the male finds the female, he emits approach pheromones that stop her attraction to other males. Mating can last from a few minutes to several hours **(Pierret & Mollier, 2012).**

1.2.4. Food (diets)

Lepidoptera caterpillars have varying diets based on their developmental stage. Somespecies are monophagous and obligate, while others are more generalist and feed on a widevariety of plants **(Loyer & Petit, 1995)**.Adult Lepidoptera primarily eat nectar, but some species also absorb othersubstances like liquids, water, dew, honey, saliva, sap, blood, mud, wet sand, sweat salt,excrement, and livestock urine (**Chinery, 1994**). Most adult Lepidoptera are nectarivorous and play acrucial role as pollinators. The pupa does not feed; it remains in a dormant state and relies. Entirely on the energy reserves accumulated during the larval stage to undergo metamorphosisinto an adult butterfly **(Loyer & Petit, 1995).**

1.2.5. Threats and diseases

Lepidoptera, a group of insects, are preyed upon by various animals including mammals, birds, reptiles, amphibians, insects, and spiders **(Bonneil, 2005b)**. They are captured in flight, on the ground, or when resting on plants. Their caterpillars are crucial in terrestrial food chains, representing an essential link in the ecosystem. Some consumers, such as birds, hedgehogs, toads... target eggs, chrysalises, caterpillars, and adult butterflies **(Suty, 2010).**

- **Parasitism:** is primarily caused by Tachinid and Ichneumon flies, while Cordycepsmilitaris fungus parasitizes caterpillars and chrysalides **(Roode *& al.,* 2019)**.
- **Predation:** Lepidoptera, including eggs, pupae, caterpillars, and adults, are crucial prey for various predators, including birds, hedgehogs, toads, bats, lizards, owls, beetles, hymenoptera, Hemiptera, dragonflies, ants, and flies. These enemies include beetles, hymenoptera, Hemiptera, dragonflies, ants, and flies **(Bonneil, 2005b).**

1.2.6. Defense mechanisms in Lepidoptera (Rhopalocera)

The eggs are shielded by their warning colors and camouflage, while some possess substances that hinder the development of parasite larvae. Several families cloak their eggs withs cales from the end of their abdomen **(Chinery, 1994).**

In terms of caterpillars, they too adopt the hue of their environment, concealing themselves in foliage or bark crevices, and feast primarily at night. Nonetheless, some exhibit brilliant colors that indicate their bad taste or toxicity **(Farndon & Chinery, 2000; Guilbot& Albouy, 2004).**

As for the stationary chrysalises, nearly all display cryptic colors that enable them to blend in to their surroundings. Adult butterflies, conversely, evade predators thanks to camouflage that varies from basic cryptic hues to intricate patterns Some species imitate dangerous animals, while others employ the shape of their wings, prolegs, and fake eyes to mislead predators. Contact with the irritating silks of both caterpillars and adults prove bothersome for humans and can even result in allergic reactions or poisoning.In adults, it is the hue of the wing scales that facilitates camouflage. Due to the sheer quantity of scales, the patterns they form can be infinitely diverse and remarkably intricate **(Chinery, 1994).**

1.3. Geographic distribution

The distribution of butterflies across the several sampled places is far from uniform. Numerous elements, including soil type, altitude, temperature, exposure to sunlight or shade (for sciaphilous species), and-above al-vegetation distribution, determine how suitable theirhabitat is.

Nonetheless, the host plant needs to be in a suitable microclimatic setting and besufficiently plentiful. In addition to the existence of sunny, warm, and wind-sheltered regions (such as bushes, groves, hedgerows, forest margins, and various terrains), this emphasizes thesignificance of plant structure and the surrounding flora. For many butterfly species, thesefrequently extremely stringent requirements severely restrict their options for habitat, renderingthem extremely vulnerable to even slight changes in their surroundings (Leraut, Patrice, 1992)**.**

1.4. Importance of biodiversity and roles of Lepidoptera in ecosystems

According to (Njue et al., 2023), Lepidoptera, the order of insects that includes butterflies and moths, play crucial roles in ecosystems. Their contributions span multiple ecological functions, below are their detailed roles:

a) Pollination: Butterflies (day-active) and moths (night-active) help pollinate flowers. Some plants, like yucca, depend entirely on specific moths.

b) Food source in food webs: Lepidoptera are key prey for birds, bats, reptiles, amphibians, small mammals, and predatory insects. Caterpillars are vital for many bird chicks.

c) Herbivory and plant control: Caterpillars feed on plants, helping control their growth. Some are natural weed controllers, while others can become harmful pests.

d) Nutrient cycling and decomposition: They enrich soil by consuming plants and decomposing organic materials like wool. Their waste and bodies boost soil nutrients.

e) Indicator species for ecosystem health: Their sensitivity to environmental changes makes them good indicators of habitat loss, climate change, and pollution.

f) Seed dispersal: Some species help spread seeds through their bodies or after digesting fruits.

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Chapter II: Materials & Methods

2.1. Presentation of the studies regions

2.1.1. Geographical location

The Biskra region (34°47′ to 34°53′N, 5°46′ to 5°39′E) is located in the northern part of the large sedimentary basin formed by the southern foothills of the Saharan Atlas and the northern fringe of the Sahara. It lies 425 km southeast of Algiers. Biskra serves as the gateway to the Saharan region, situated in the eastern part of the country at the foot of the southern slope of the Aurès massif, at the confluence of two valleys crossing the massif. The region stretches toward the Chott Melghir area in the southeast and the eastern Erg in the southwest. Its average altitude is 98 meters, and it covers an area of 21,671.2 km² **(A.N.I.R.F, 2010)** .

El M'Ghair is an Algerian wilaya (province) officially established in 2019, after previously being designated as a delegated wilaya in 2015. Located in the Algerian Sahara, it lies at coordinates 33°56′50″N, 5°55′20″E and covers a total area of 8,835 km². It shares borders with Biskra Province to the north; El Oued and Touggourt Provinces to the east; Ouled Djellal Province to the west; and Ouargla and Touggourt Provinces to the south **(Yousfi, 2017)** **(Fig. 3).**

Figure 3: Geographical locations of Biskra and El M'Ghair **(google earth, 2025).**

2.1.1. Climatic factors

According to (Dajoz, 1974), climatic factors have significant effects on the physiology, distribution, and behavior of animals, particularly insects. The data we collected from the study site reflect this influence **https://www.tutiempo.net/.**

2.1.1.1. Temperature

Temperature is a major limiting factor because it regulates all metabolic processes and thereby influences the distribution of all species and communities of organisms within the biosphere **(Ramade, 1991).**

Table 1 illustrates the average monthly temperatures for the wilayas of Biskra and El M'Ghair over the period 2015–2024, highlighting notable climatic differences between the two regions. In Biskra, the lowest average temperature was recorded in January, reaching approximately 12.43°C. In contrast, El M'Ghair, characterized by a more arid Saharan climate, generally experiences colder nighttime temperatures during winter, often dropping below 11.26°C, making the cold season slightly more intense despite its shorter duration.

On the other hand, July stands out as the hottest month in both wilayas. In Biskra, average temperatures reached 35.92°C during the period 2015–2024. In comparison, El M'Ghair typically records slightly higher summer temperatures, with July averaging 35.41°C, indicating a generally intense and prolonged summer heat in both regions. El M'Ghair also maintains slightly higher values in certain months, such as May and September.

Table 1: Average monthly temperature in the wilayas of Biskra and El M'Ghair during the period (2015-2024)

Months / wilayas	J	F	M	A	M	J	J	A	S	O	N	D
Biskra	**12.43**	14.42	17.85	22.14	26.92	32.92	**35.92**	34.5	29.98	24.09	17.66	13.62
El M'Ghir	**11.26**	13.82	17.59	21.95	27.07	32.66	**35.41**	34.18	30.08	23.88	16.83	12.46

2.1.1.2. Precipitation

Precipitation influences the pace of animal maturation, their lifespan, and reproductive capabilities **(Dajoz, 1971).** It is characterized as the yearly volume of water that falls within a given area, measured in millimetres **(Järvisalo & Saris, 1975).** This serves as a crucial ecological element not only for the operation and dispersion of terrestrial ecosystems but also for certain freshwater ecosystems like ephemeral ponds and lakes **(Ramade, 1991).**

During the period 2015-2024, the Biskra region recorded its highest average monthly rainfall in September, with 14.57 mm, and the lowest in July, at 0.30 mm, resulting in an annual average rainfall of 87.49 mm. In contrast, the El Mghair region experienced its peak average rainfall earlier in the year, during April, with 11.88 mm, while July also recorded the lowest rainfall at only 0.07 mm, leading to a significantly lower annual average of 50.22 mm. This comparison highlights that Biskra generally receives more rainfall throughout the year than El M’Ghair, with a more pronounced peak in early autumn, whereas El M’Ghair's rainfall is more limited and peaks in spring **(Tab. 2)**.

Table 2: Average monthly precipitation in the wailayas of Biskra and El M'Ghair during the period (2015-2024)

Months / wilayas	J	F	M	A	M	J	J	A	S	O	N	D
Biskra	1.31	4.36	8.55	14.4	13.1	3.07	**0.3**	1.67	**14.57**	8.66	4.29	4.21
El M’Ghir	0.25	7.31	4.44	**11.88**	2.79	0.2	**0.07**	0.66	11.27	2.64	7.16	1.55

2.1.1.3. Winds

Air movement is a significant atmospheric parameter regarded as one of the most defining features of climate **(Seltzer, 1946).** It indicates that air movement diminishes the activity of airborne insects **(Ramade, 1991).**

The table shows that, during the period 2015-2024, the lowest monthly average wind speed in the wilaya of Biskra was recorded in December, with a value of 11.45 km/h, while the highest average wind speed occurred in March, reaching 16.44 km/h. In comparison, in the wilaya of El M'Ghair during the same period, the lowest wind speed was observed in January, with 8.47 km/h, whereas the strongest winds were recorded in April, at 13.36 km/h **(Tab. 3)**.

This comparison indicates that Biskra generally experiences higher average wind speeds than El M'Ghair throughout the year, with its peak occurring earlier in the spring, while El M'Ghair exhibits milder wind conditions overall.

Table 3: Average monthly Winds in the wilayas of Biskra and El M'Ghair during the period (2015- 2024)

Months / wilayas	J	F	M	A	M	J	J	A	S	O	N	D
Biskra	13.96	14.44	**16.44**	15.05	15.41	15.15	12.69	11.63	11.78	11.99	13.4	**11.45**
El M'Ghir	**8.47**	9.69	11.56	**13.36**	12.55	13.11	11.83	11.27	10.49	8.93	8.8	8.63

2.1.2. Climatic summary

2.1.2.1. Ombrothermic diagram of Bagnouls and Gaussen

The analysis of the diagrams shows that in the wilayas of Biskra and El M'Ghair, the dry period extends throughout the entire year during the period from 2015 to 2024 **(Fig 4 and 5).**

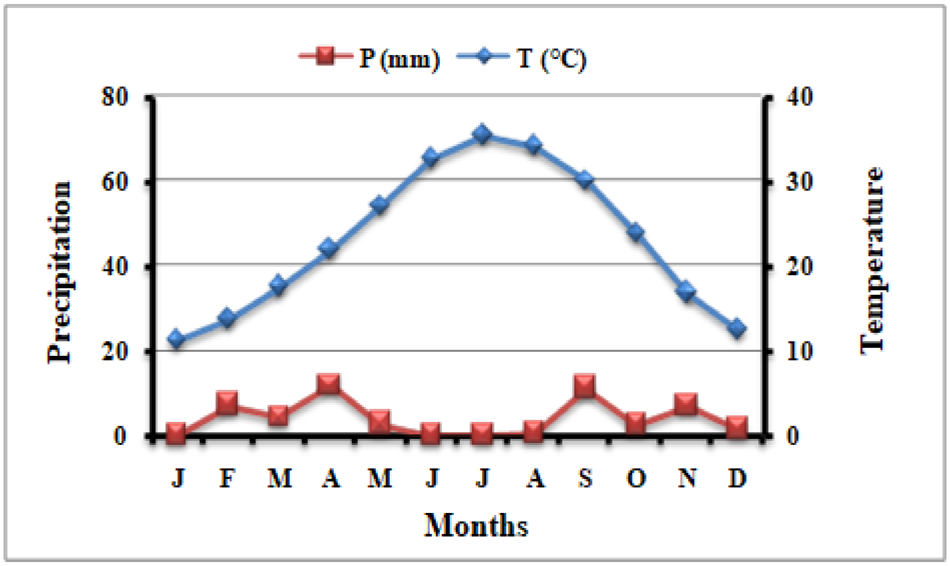

Figure 4: Ombrothermic diagram of Bagnouls and Gaussen for the wilaya of El M'Ghair during the period 2015-2024

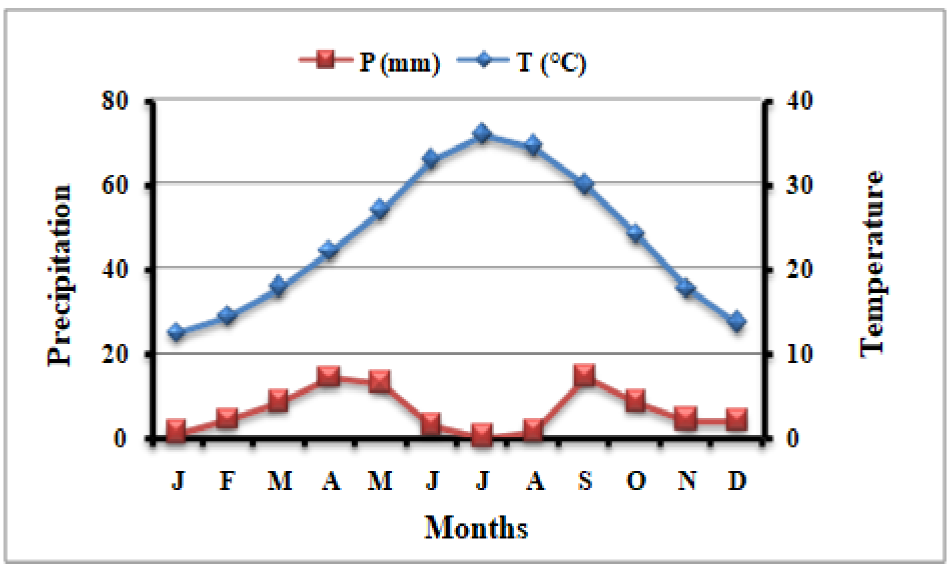

Figure 5: Ombrothermic diagram of Bagnouls and Gaussen for the wilaya of Biskra during the period 2015-2024

2.1.2.2. Emberger's rainfall climagram

Emberger constructed a climagram using Q_2 on the y-axis and the average of the minimum temperatures of the coldest month (m) on the x-axis. In general, for Algeria, the simplified formula proposed by **(Stewart, 1969)** is used: $\mathbf{Q_2 = 3.43 \times P / (M - m)}$ where:

P: Annual precipitation (mm)

M – m: Thermal amplitude (°C)

Based on climatic data from the period 2015-2024, the bioclimatic classification of the studied regions places both Biskra and El-Meghair within the Saharan bioclimatic stage with hot winters. The Q_2 index was calculated at 11.46 for Biskra and 7.13 for El-Meghair, confirming the arid nature of these areas. The lower Q_2 value observed in El-Meghair indicates a more pronounced desert climate compared to Biskra, highlighting regional variations in humidity and aridity within the northern Saharan zone **(Fig.6)**.

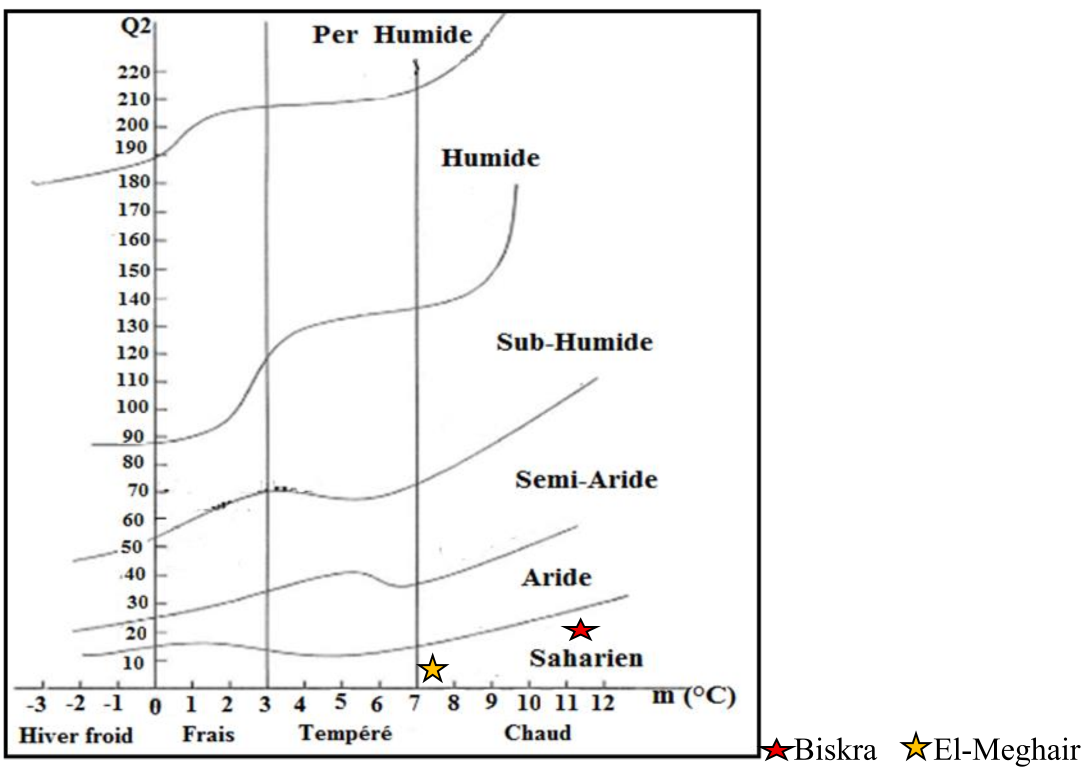

Figure 6: Location of the wilayas of Biskra and El M'Gair on Emberger's Climagram

2.2. Materials and working methods

2.2.1. In the study sites

✓ ***Site I (in Biskra):*** This is a traditionally planted station, located at coordinates 34°42′33.5″N and 5°16′51.4″E in the commune of **Elghrous**. It covers an estimated area of 2 hectares and is characterized by the presence of a wadi (wadi Leghrous). The soil is sandy in nature, and irrigation is carried out through a drip system. The station includes 95 date palm trees (85 Deglet Nour, 2 Ghars, 4 Dokkar, and 4 Degla-Beida), along with some cultivated plants such as alfalfa (*Medicago sativa L.*) and mint (*Mentha aquatica L.*). Several species of fruit trees are also present, including 12 pomegranate trees (*Punica granatum*), 10 lemon trees (*Citrus limon*), 4 medlar trees (*Crataegus azarolus*), 7 fig trees *(Ficus carica*), and 6 olive trees *(Olea europaea*). Among the spontaneous herbaceous plants recorded on the site are Bermuda grass (*Cynodondactylon* .), prickly lettuce (*Lactuca serriola*), and Avena sterilis **(Fig. 7)**.

Figure 7: General view of the study site in Elghrous **(Original)**

✓ ***Site II (in El M'Ghair):*** This is a traditional agricultural station located at the coordinates 33°30′00″N and 6°01′00″E in the municipality of **Djamaa**. It covers an area of approximately two hectares, with sandy soil and is irrigated through a system of water channels. The station includes 250 date palms, among which there are 100 Deglet Nour palms, 40 Ghars palms, and 32 Degla Beida palms. In addition, various cultivated plants are present, such as parsley, lettuce, and spinach, along with vegetables like beetroot, pepper, onion, garlic, and carrot. Several types of trees are also found in the station, including 6 grapevines, 10 fig trees, 10 pomegranate trees, and 2 apricot trees. Among the spontaneous wild plants that grow naturally are *Rumex* (sorrel), *Phragmites* (reed), and *Galium aparine* (cleavers) **(Fig. 8)**.

Figure 8: General view of the study site in Djamaa **(Original)**

We conducted this study over a four-month period, from February to April 2025, involving a weekly survey of diurnal butterflies at two distinct sites: El-Ghrous and Djamaâ. Butterfly specimens were collected once per week throughout this period.

2.2.3. Sampling methods for Lepidoptera

The method used at the two study sites to sample Lepidoptera is sweeping with a sweep net. This is a tool used to collect low-mobility insects found in grasses or bushes **(Lamotte, & Bourlière, 1969)**. It consists of a metal ring with a diameter of 40 to 50 cm **(Fig. 9)**, attached to a strong, fine-meshed cloth bag about 1 meter deep **(Benkhelil, 1991).** This technique involves random sampling of vegetation. The net should be swept through the full height of the vegetation, brushing the ground with up-and-down motions to ensure comprehensive insect capture. The speed of the strokes is crucial, as it helps catch insects that might other wiseescape, particularly those near the roots. The sudden motion startles the insects, causing them to fall into the net **(Lamotte, & Bourlière, 1969).**

Lepidoptera are collected after every series of 10 quick, short, and precise strokes-each stroke corresponding to a step and a lift-with each sweep covering about 1 m^2 of surface area **(Moussa, 2005).** This method is easy to apply using simple equipment and is effective in capturing both flying insects and those resting on low vegetation **(Bouzid, 2003).** The contents of the net are transferred into a Petri dish, where the date and location are recorded before sending the samples to the laboratory for identification.

Figure 9: Sweep net **(Original)**

2.2.4. Method of transporting Lepidoptera

When a butterfly is captured in the field, it is immediately placed in a "papillote," a small triangular paper wrap adapted to the size of the insect, with its wings carefully folded over its back **(Fig. 10)**. The papillote is closed by folding in both sides **(Olsoufieff, 1935).** These papillotes are then stored in a box. This method protects the very fragile butterflies from shocks during transport and from contact with other specimens collected later. It is possible to keep butterflies alive in these papillotes for the duration of the fieldwork. Once back at the lab or home, the insects are euthanized by freezing. However, this technique is considered less than ideal, as it may still cause slight damage to the specimens **(Franck, 2013).**

Figure 10: Method of transporting Lepidoptera **(Original)**

2.2.5. In the laboratory

The observation of the collected insects is often carried out using a binocular magnifying glass. Some species can be identified on site, but most require more detailed study in the laboratory.

Our collected specimens were identified by **Mrs. Diabe-Dighiche (Researcher at CRSTRA).**

2.3. Ecological indices

According to **Lellouche & Lazar (1974)**, the analysis of biological data expressed in quantitative terms can be interpreted using ecological indices to assess the structure and diversity of a given community.

2.3.1. Composition indices

a. Species Richness (S): Species Richness refers to the total number of butterfly species recorded in a particular habitat or sampling site. It provides a primary measure of biodiversity (**Ramade, 1991**).

b. Mean richness (Sm) : Mean richness <<< Sm >> is the average number of species in each survey**(Blondel, 1979).**

$$Sm = Ni / R$$

Sm: mean richness

Ni: number of species sampled

R: total number of surveys

c. Relative Abundance (Ar): It is expressed as a percentage and allows for the evaluation of the number of individuals of a species, category, class, or order (Ni) in relation to the total number of individuals of all species combined in a faunistic inventory (**Faurie *& al.,* 2003**). It is calculated using the following formula:

$$Ar\ (\%) = ni / N \times 100$$

Where :

- ***ni* :** is the number of individuals of species *i*
- ***N*:** is the total number of individuals of all recorded species

Interpretation of Ar values:

- **Species is rare and scattered :** Ar < 5%
- **Species is uncommon :** 5% <Ar ≤ 20%
- **Species is common :** 20% <Ar ≤ 40%
- **Species is dominant:** Ar ≥ 40%

2.3.2. Structural indices

a. Shannon-Weaver Diversity Index (H'): According to **Ramade (1990)**, it is necessary to combine the relative abundance of species with the total richness in order to obtain a mathematical expression of the general Shannon diversity index. It is given by the following formula:

$$H' = -\sum_{i=1}^{s} p_i \log_2 p_i$$

Where :

- ***pi* :** is the relative abundance of the species and pi = ni / N."

This index has ecological significance only if it is calculated for a community of species performing the same function within the biocenosis **(Faurie *& al.,* 2003)**.

d. Evenness (E): Evenness is the ratio of the observed diversity (H') to the theoretical maximum diversity (H' max) (**Barbault, 1981)**. It is given by the following formula:

$$E = H / H'max$$

The value of E ranges between 0 and 1. A value close to 1 indicates a highly balanced butterfly community, whereas a value near 0 suggests dominance by one specie **(Ramade, 2003).**

d. Occurrence frequency (F %): It is the ratio, expressed as a percentage, of the number of surveys containing the species (Pi) under consideration to the total number of surveys (P) **(Dajoz, 1974)**. According to **Faurie *& al.,* (2003)**, it is defined as follows:

$$F\ \% = (Pi \times 100)/P$$

Where :

- ***F%:*** Occurrence frequency
- ***Pi :*** Number of surveys containing the studied species
- ***P:*** Total number of surveys conducted

Based on the value of F %, the following categories are distinguished (**Dajoz, 1974)**:

- **Omnipresent species :** if F = 100%
- **Constant species :** if 75% ≤ F < 100%
- **Regular species :** if 50% ≤ F < 75%
- **Accessory species :** if 25% ≤ F < 50%
- **Accidental species :** if 5% ≤ F < 25%

These ecological indices will be applied to the data collected from different sampling sites in order to assess the composition, dominance patterns, and overall diversity of butterfly communities within the study area. They will help in comparing ecological conditions across habitats and understanding the environmental factors influencing butterfly distribution.

Chapter III : Results and Discussion

The results of the inventory of Lepidoptera captured in the regions of El Ghrous and El M'Ghair during a three months sampling period are presented in the table below.

Table 4: Liste of species collected in the regions of El Ghrous and Djamaa from February to April 2025

Family	Species	Number	Ar%	F%
Nymphalidae	*Venessa cardui* (Linné, 1758)	8	2.13	13.89
	Boloria sp.	1	0.27	2.7
	Melitaea phoebe(Denis & Schiffermüller, 1775)	7	1.86	28.80
	Melitaea deserticola (Oberthür, 1909)	21	5.59	25.00
	***Danaus chrysippus* (Linné, 1758)**	**96**	**25.53**	**75.00**
	Melitaea aetherie Hübner, 1826	16	4.26	30.56
Peiridae	*Euchloe crameri* Butler, 1869	25	6.65	27.78
	Euchloe simplonia (Freyer, 1829).	22	5.85	25.00
	***Pieris rapae* (Linné, 1758)**	**87**	**23.14**	**88.89**
	Colias philodice Godart, 1819	22	5.85	25.00
	Colias crocea (Fourcroy, 1785)	17	4.52	16.67
Gelechiidae	*Tuta absoluta* (Meyrick, 1917)	8	2.13	11.11
Arctiidae	*Utetheisa pulchella* (Linné, 1758)	15	3.99	30.56
Lycaena	*Phlaeas americana* (Linnaeus, 1761)	18	4.79	36.11
Hesperiidae	*Carcharodus alceae* (Esper, 1780)	13	3.46	11.11

During the study period, a total of 376 individuals were obtained, represented by 15 species of diurnal butterflies were recorded, divided into 6 families. The Nymphalidae family is the richest with 6 species, followed by the Pieridae with 5 species. The families Gelechiidae, Arctiidae, Lycaenidae, and Hesperiidae showed the lowest representation, each with only one species.

Habitat heterogeneity and quality play a very important role in the presence and persistence of Rhopalocera populations, as the sites richest in diversity and Rhopalocera presence are those with a heterogeneous landscape **(Gonseth, 1994 & Frahtia, 2005)**. These results are similar to those recorded in a study conducted by **(Ghemmaz, 2015)** in a citrus orchard in Boufarik, which reported a richness of 15 rhopalocera species distributed across 4 families. The Pieridae and Nymphalidae were each represented by 5 species. Compared with studies carried out by order, the Lepidoptera order was represented by 31 species and 11 families reported in different localities of the Biskra region by **Deghiche-Diab (2016)**.**(Zeghti et al., 2016)** in the Ouargla region recorded the presence of 8 species represented by 7 families.

1 Ecological Indices

1.1 Composition indices

1.1.1 Species Richness (S)

According to Table 4, the total richness of the lepidoptera collected in the study regions is equal to 15 species. However, it is worth noting the absence of the Satyridae and Papilionidae families from the list of families recorded in the study sites. These families include nine species, representing 12.5% of the total number of butterflies recorded in Algeria, which currently includes 120 known species **(Tennent, 2006).** Compared to the study conducted in Sebkhet Sejoumi in Tunis, **(Mohamed et al., 2019**) reported 12 species of butterflies*: Bena bicolorana, Lygephila viciae, Rhodometra sacraria, Carcharodus tripolinus, Vanessa atalanta, Vanessa cardui, Lycaena phlaeas, Cigaritis siphax, Colias crocea, Pontia daplidice, Pieris rapae*, and *Papilio machaon mauretanica*

In addition, in the study **(Deghiche Diab, 2015)** carried out in the Biskra region indicated a richness of 148 species belonging to 82 families, from which the most important species were Coccinella septempunctata, Psyllobara viaintiduopunctata, Polistes gallicus, Megascolia maculata, and Sphaerophoria scripta, whereas in the work established by **(Deghiche Diab, 2020)**, indicated the importance of Lepidoptera order that ranked the third position with 10 species and 6 families.

1.1.2 Relative Abundance (Ar)

According to the **abundance graph 11 and Table 4**, the relative abundance values vary from one species to another. In both regions, the dominant species is *Danaus chrysippus* with a relative abundance equal to 25.53%. He is followed by *Pieris rapae* with 23.14%. The other species correspond to low percentages between 0.27% to 6.65%.

The abundance of *Danaus chrysippus* and *Pieris rapae* is probably related to climatic conditions as well as the presence of their host plants or prey, which favor their development. The presence of flowering plants in a plot favors the maintenance and multiplication of several specie (**Bertolaccini et al.,2011**).

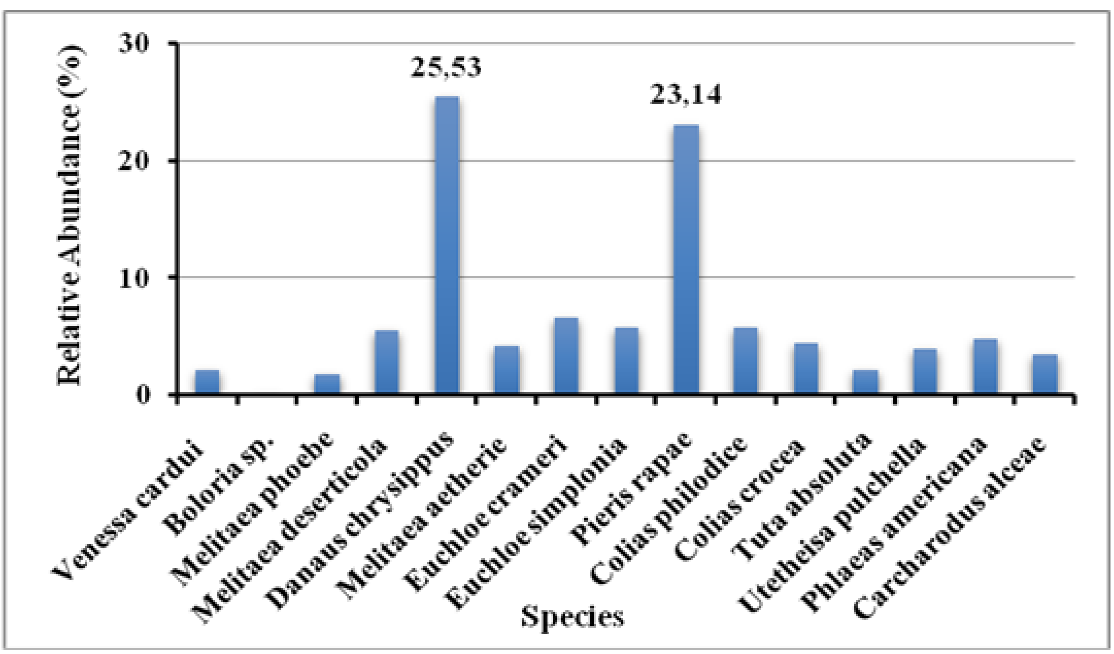

Figure 11: Relative abundance of Lepidoptera collected by order in the regions of Djamaa and El-Ghrous during the period from February to April 2025

On the other hand **(Bouras, 2019),** mentioned that the most captured species in Ouargla are *Pyrausta aurata* (Ar = 24.4%), *Eulamprotes atrella* (Ar = 28.1%), and *Tuta absoluta* (Ar = 17.2%). Whereas **(Achoura & Belhamra, 2010)** noted that the order Lepidoptera, with a rate of 14.7%, included 7 captured species, notably *Pieris napi* and *Pieris rapae* in the Biskra region. For the study in Tunis, the dominant species is *Pieris rapae* with a relative abundance of 15.52%, and the lowest is *Vanessa atalanta* with 4.7% **(Mohamed et al., 2019).**

1.1.3 Occurrence frequency

In the entire recorded entomofauna, we were able to distinguish four main groups **(Fig 13 & Tab. 4)**. Among the 15 species of Lepidoptera retained, 8 are accidental species, representing **53%.** Accessory species are in second position with 4 species, representing **27%**. The sporadic species represent **7%**, and constant species are represented by 2 species, comprising **13%**.

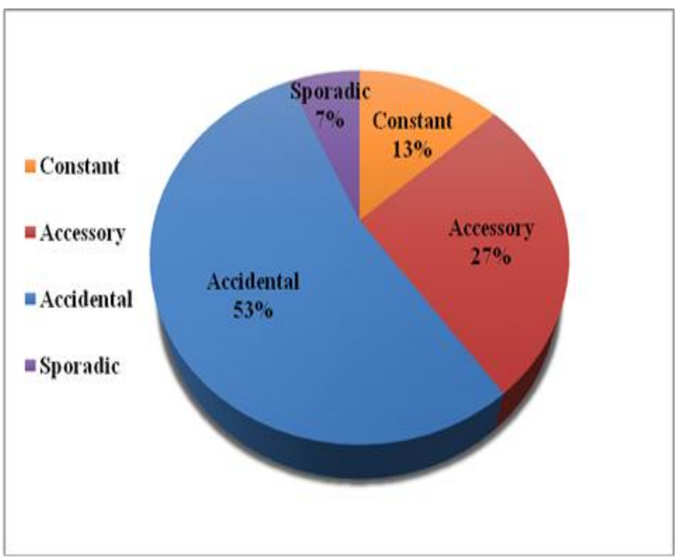

Figure 12: Frequency of Lepidoptera collected by order in the rigons of El-Ghrous and Djamaa during the period from February to April 2025

The presence of a large number of accidental species can be explained by the fact that between one survey and another, a species may complete its development cycle. Our results are comparable to those obtained by **(Deghiche, 2014)**in a palm grove in Biskra, where the constant species are represented by 5 species (54.05% to 72.97%), 12 sporadic species (2.7% to 8.11%), 30 accessory species, and more than half of the trapped species (80 species) are classified as accidental.

1.2 . Structural indices

1.2.1. Shannon-Weaver Index (H')

According to **Table 4**, the value of the Shannon diversity index obtained in the two regions is equal to **0.82**. It is worth mentioning that these values are relatively low (H'max = 3.9), which is typical for Saharan zones in our case. Our results are slightly lower than those reported by **(Bousbia, 2010)** , who recorded H' values ranging between 2.27 and 4.99 across all study stations following the use of Barber pots, mowing, and colored traps methods. Our results differ significantly from those reported by **(Zeghti et al., 2015)**, who worked in a station in the Ouargla region and recorded much lower values ranging between 0.68 and 2.53, justified by a relatively low sampling effort compared to that of the present study. The results reported by **(Kacha et al., 2017)** for forest environments in the north of the country vary between 2.12 and 2.73. Moreover,**(Zeghti, 2020)**. Noted that the diversity of Lepidoptera stations in Algeria is relatively high, approaching 3.17. Even in India, values range between 2.07 and 2.33 **(Elanchezhian et al., 2014).**

1.2.2 Evenness (E)

The equitability of the Lepidoptera collected in the two regions is equal to **0.2**, is less than 1. This leads us to say that the distribution of Lepidoptera species is low, whereas a value near 0 suggests dominance by one species. In results of **(Zeghti et al., 2016)** recorded that the Lepidoptera inventoried in the Ouargla region tend towards balance ($0.74 \leq E \leq 0.88$). The same is true for those noted by **(Zeghti et al., 2015)** in the same study region ($0.68 \leq E \leq 0.76$).

(Bousbia, 2010) noted an equitability value ranging between 0.76 and 0.88 in the Robbah, El-Ogla, and Sidi Mestour stations. Moreover, **(Bouras, 2019)** recorded that the Lepidoptera inventoried in the Ouargla region tend towards balance ($0.5 \leq E \leq 0.9$).

2 The relationship between climatic factors and population number

2.1 . Temperature

Based on the results of our study, the data show **(Fig13)** a general positive correlation between temperature and butterfly diversity, with the number of species increasing as temperatures rise, particularly during the period from March to April. In this phase, while temperatures rose from 15°C in February to 19.6°C in March, there was no significant change in the number of individuals, which only slightly decreased from 120 to 112. This suggests that butterflies in the studied area demonstrate a clear ability to adapt to slight temperature variations, making moderate drops in temperature not significantly impactful on their diversity and distribution.

Further support for the idea that high temperatures strongly influence butterfly abundance and diversity comes from similar findings in other regions. For example, the peak of butterfly diversity was recorded in June, when temperatures reached approximately 30°C. In the region of Batna **, (Bougrara, 2020)** reported that elevated temperatures contributed to accelerating the butterfly life cycle and increasing their feeding and reproductive activity, resulting in a noticeable rise in their numbers. Similarly,(**Kechi, 2019)** , in a study conducted in the High Plateaus, observed that butterfly activity peaked during periods of high temperature and flower abundance, particularly in May and June. These findings support the hypothesis that temperature plays a key role in determining the seasonal distribution and species richness of butterflies, including in Biskra and El M'ghair.

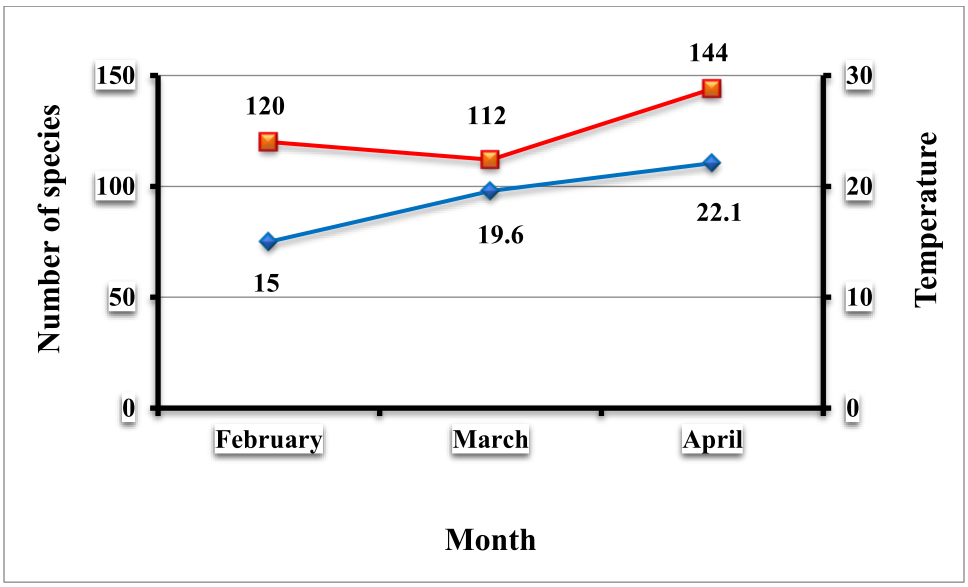

Figure 13: Relationship between species number and temperature

2.2 Winds

The minimum capture is recorded in March (Ni = 112) where V = 17 km/h.**(Fig 14)** This means that wind intensity affected butterfly capture, and the value decreased as wind intensity increased and increased as wind intensity decreased. There is therefore a clear relationship between hunting and wind. The low occurrence of species recorded during March can be explained by the fact that very low temperatures, wind, or rain slow down the feeding process, especially in herbivorous species, and thus predation and parasitism **(Coutin, 1988).** A regression analysis by (**Vandenbosch, 2003)** shows that population fluctuations are closely linked to climate changes over short (El Niño) and longer (Pacific Decadal Oscillation) timescales.

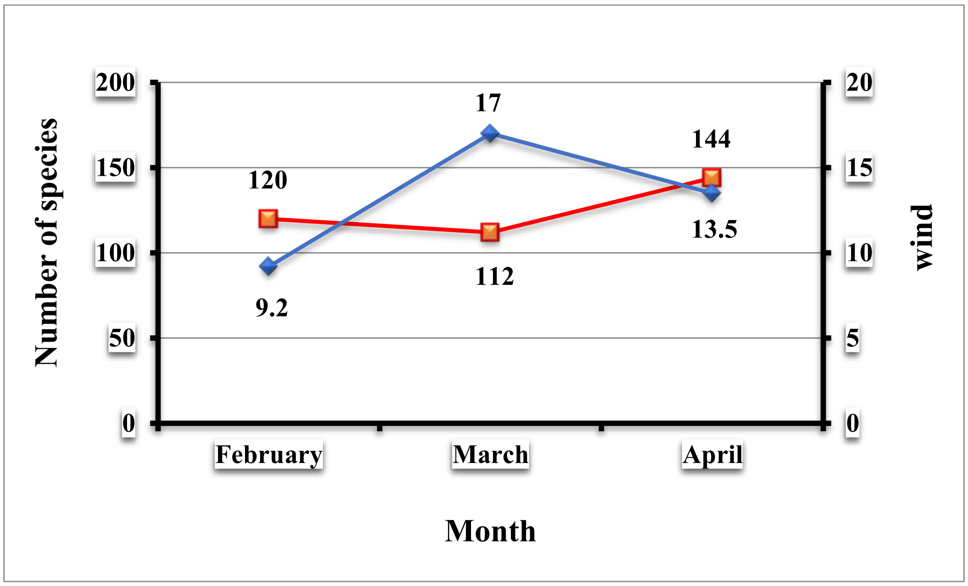

Figure 14: Relationship between species number and winds

Conclusion

The results of this study are; a total of 376 individuals were obtained, represented by 15 species identified (Species Richness), belonging to six families, with Nymphalidae and Pieridae being the most prominent.

The relative abundance values vary from one species to another. In both regions, the dominant species is *Danaus chrysippus* with a relative abundance equal to 25.53%. He is followed by *Pieris rapae* with 23.14% were the most common and widespread in both sites, reflecting their strong adaptation to local climatic conditions and close association with host plants available in the studied environment.

Among the 15 species of Lepidoptera retained, 8 are accidental species, representing 53%. Accessory species are in second position with 4 species, representing 27%. The sporadic species represent 7%, and constant species are represented by 2 species, comprising 13%.

The value of the Shannon diversity index (H') obtained is equal to 0.82. It is worth mentioning that these values are relatively low (H'max = 3.9), which is typical for Saharan zones in our case. The equitability of the Lepidoptera collected is equal to 0.2, is less than 1. This leads us to say that the distribution of Lepidoptera species is low, whereas a value near 0 suggests dominance by one species.

The results of the study indicate that the slight decrease in temperature did not significantly affect the number of butterflies, demonstrating their ability to adapt. In contrast, strong winds contributed to a clear decline in individual counts, confirming the negative impact of wind on butterfly activity.

In light of these results, the study recommends extending such research to cover longer time frames and more ecologically diverse regions, to ensure a more comprehensive understanding of butterfly distribution and seasonal dynamics. It also emphasizes the importance of preserving natural habitats, limiting unplanned urban expansion, and promoting reforestation and the expansion of green spaces in semi-arid areas, due to their direct impact on supporting biodiversity and the sustainability of vulnerable species.

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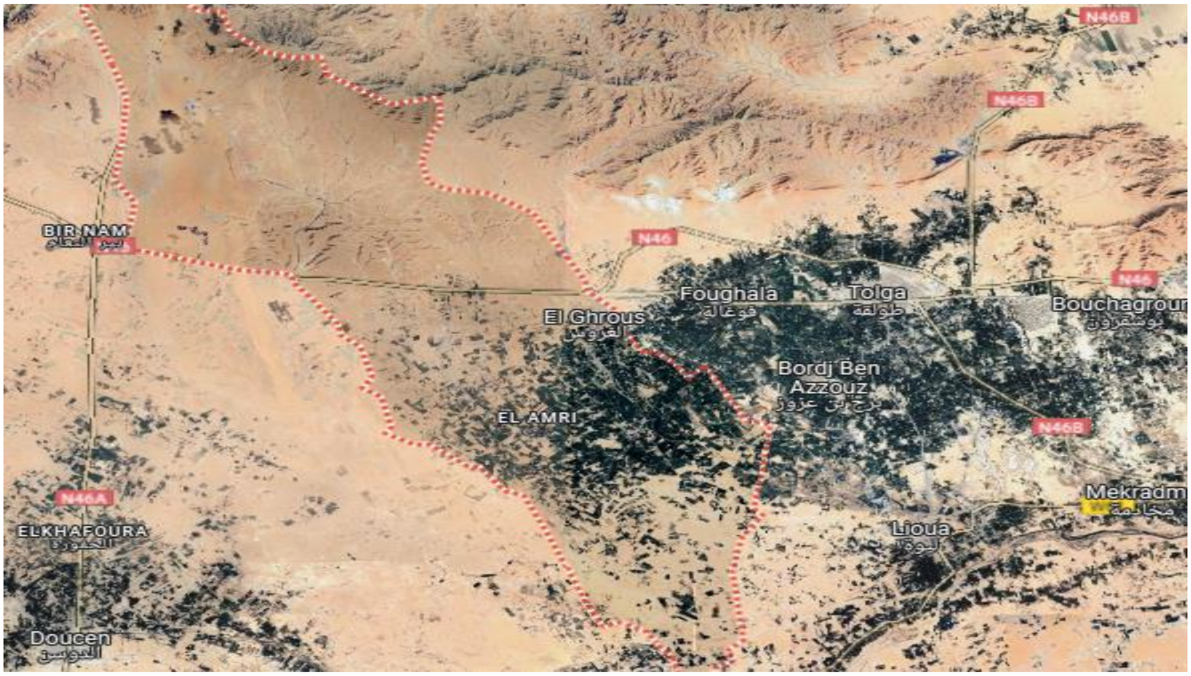
Annexes

Annex 1: Individuals of the family Pieridae collected during the study

Annex 2: The most abundant species during the study period (*Danaus chrysippus)*

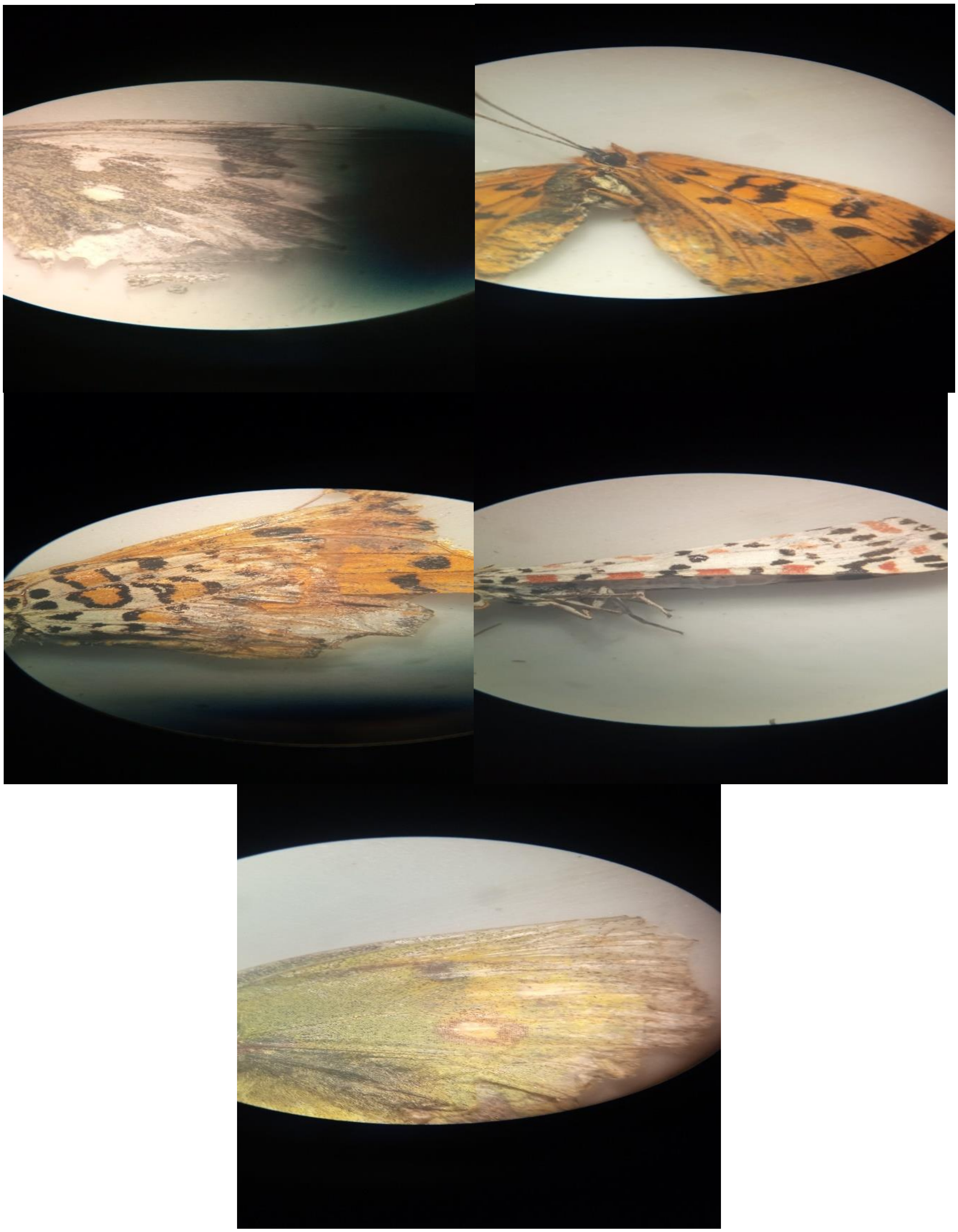
Annex 3 : Geographical locations of the study areas



Geographical location of El-Ghrous

Geographical location of Djamaa

Annex 4: Microscopic images for identification



Abstract

Our objective is to study the diversity of diurnal butterflies (Rhopalocera) in two semi-arid regions of southeastern Algeria: El Gharrous (Biskra) and Djamaa (El M'Ghair), during the period from February to April . Using the sweep net method for butterfly collection, we obtained a total of 376 individuals distributed across 15 species belonging to six families, with a predominance of the Nymphalidae and Pieridae families. *Danaus chrysippus* and *Pieris rapae* were identified as the dominant species. For ecological indices, species richness (S) was equal to 15 species, and relative abundance (Ar%) was 25.53% and 23.14% for *Danaus chrysippus* and *Pieris rapae* respectively. The Shannon-Weaver diversity index (H') was 0.8, and evenness (E) was 0.2. The results revealed a low to moderate diversity, influenced by climatic conditions, especially wind. According to the results of our study, the data show that temperature did not significantly affect butterfly numbers, whereas wind influenced both their abundance and diversity. It was recorded that 53% of the species were accidental, 27% were accessory, and only 13% were constant species.

Keywords: Lepidoptera, Rhopalocera, wind, bioindicators

Résumé

Notre objectif consiste à étudier la diversité des papillons diurnes (Rhopalocera) dans deux régions semi-arides du sud-est de l'Algérie : El Gharrous (Biskra) et Djamaa (El M'Ghair), durant la période de février à Avril. À l'aide de la méthode du filet fauchoir pour la collecte des papillons, on obtient un total de 376 individus répartis en 15 espèces appartenant à six familles, avec une prédominance des familles Nymphalidae et Pieridae. *Danaus chrysippus* et *Pieris rapae* ont été identifiées comme les espèces dominantes. Pour les indices écologiques on obtient : la richesse spécifique (S) égale à 15 espèces, l'abondance relative (Ar%) égale à 25,53% et 23,14% pour les espèces *Danaus chrysippus* et *Pieris rapae* respectivement, l'indice de Shannon-Weaver (H') et l'équité (E) égale à 0,8 et 0,2 respectivement. Les résultats ont révélé une diversité faible à modérée, influencée par les conditions climatiques, surtout le vent. Selon les résultats de notre étude, les données montrent que la température n'a pas significativement affecté le nombre de papillons, tandis que le vent a influencé à la fois leur abondance et leur diversité. Car on enregistre que 53% sont des espèces accidentelles, 27 % des espèces accessoires et des espèces constantes avec 13 % seulement.

Mots clés : Lépidoptères, Rhopalocères, vent, Bioindicateurs.

الملخص

هدفنا هو دراسة تنوع الفراشات النهارية (Rhopalocera) في منطقتين شبه جافتين في الجنوب الشرقي للجزائر: الغروس (بسكرة) والجامعة (المغير)، خلال الفترة من فبراير إلى أفريل. باستخدام طريقة الشبكة (الفراش) لجمع الفراشات، تم الحصول على ما مجموعه 376 فردًا موزعين على 15 نوعًا ينتمون إلى ست عائلات، مع هيمنة لعائلتي Nymphalidae وPieridae. تم تحديد نوعي *Danaus chrysippus* و*Pieris rapae* كأكثر الأنواع سيطرة. بالنسبة للمؤشرات البيئية، كانت الثروة النوعية (S) تساوي 15 نوعًا، ونسبة الوفرة النسبية (Ar%) بلغت 25.53٪ و23.14٪ لنوعي *Danaus chrysippus* و*Pieris rapae* على التوالي، بينما بلغ مؤشر شانون-ويفر 0.8 (H') ومؤشر التكافؤ 0.2 (E). كشفت النتائج عن تنوع ضعيف إلى معتدل، متأثر بالظروف المناخية، خاصة الرياح. ووفقًا لنتائج دراستنا، تُظهر البيانات أن درجات الحرارة لم تؤثر بشكل كبير على عدد الفراشات، في حين أن الرياح أثرت على وفرتها وتنوعها. إذ نُسجّل أن 53٪ من الأنواع كانت عرضية، و27٪ أنواع ثانوية، و13٪ فقط أنواع دائمة.

الكلمات المفتاحية: حرشفيات الأجنحة، الفراشات النهارية، الرياح، مؤشرات حيوية.

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