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Ministry of Higher Education and Scientific Research
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MEMORIAL

Submitted for the award of the
ACADEMIC MASTER'S DEGREE

FIELD: Biological Sciences

OPTION: Biology and Control of Insect Populations

*The life cycle of **Calopteryx haemorrhoidalis** in northeastern
Algeria (Khenchela) development types, growth ratio and
instar identification (Zygoptera: Calopterygidae)*

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Academic Year: 2023-2024



Acknowledgments



*In the name of God, the all-merciful, the most merciful
First of all, we thank ALLAH who has provided us with the
effort courage and willpower to accomplish and finalize this
work.*

*Our sincere thanks go first and foremost to our supervisor
Dr Ali ELAFRI, who gave us so much of his time to guide us
guide and accompany us throughout the period devoted to the
completion of this thesis. We are grateful to him for his
tolerance, patience, encouragement and encouragement and
invaluable advice.*

*Genuine and sincere gratitude goes for the respectable
members of the jury who have accepted to give time to read
and evaluate this humble work; namely, Dr. Halassi I and Dr.
Maamar H.*

Dedication

To the one whose name I carry to my role model in life, to the most precious person in my heart, my beloved father.

To the fountain of tenderness, Mother.

To Hatem, my brother, you have always been my biggest supporter in my studies, but today I am graduating and you are not there.

To my uncle, the lover of my heart and my second father Med Cherif. To my uncle's wife, my second mum

To my sisters Basma and Céline and Hadil

To my brother Mohammed, my heart's lover and my companion in my path

To my friends Jumana Achba, Manal Bouali, Zahra Bouzidi, Rania Boudraa, Rayen Madour, Salma Ferhati, Salima Ouannassi, Hamda Abbabssa.



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Abstract



Introduction

Introduction

Biodiversity is an ancient concept that culminated in the signing of the Convention on Biological Diversity at the Rio de Janeiro Conference in 1992. Biodiversity has now taken its place among the major global environmental issues **(Leveque and Monolo, 2001)**. The Convention on Biological Diversity defines biodiversity as "variability among living organisms from all sources, including ecosystems". Variability exists among living species from various sources, including marine and aquatic systems, as well as the ecological complexes they form. This encompasses diversity between species, and across ecosystems. Biological diversity is not evenly distributed across the biosphere **(Lévèque and Mounolou, 2001)**, with high biodiversity areas dubbed "hotspots" Hotspots of biodiversity. The list of hotspots includes 20-30 locations globally, including the Mediterranean basin and Algeria.

Algeria is a vast country with a rich palette of wetlands that is unique in the world, rich in flora and fauna, but scientifically little known. These aquatic environments are a haven for many aquatic organism that live and reproduce there. Among them aquatic insects, a group of invertebrates organism whose presence in an aquatic ecosystem, including hydro systems like rivers, streams, ponds, and wetlands, is paramount to the point that without insects several key ecosystem processes would be vastly affected (**Weisser and Siemann 2008;Yang & Gratton, 2014 ; Elango et al., 2021**).

Odonatan species (Dragonfly and Damselfly) are one the most fascinating insects, easy to observe, large in size, and often adorned with vibrant colors. They demonstrate remarkable aerial prowess, flying during warm and sunny days. Studying dragonflies is an exciting activity because there are always astonishing aspects to discover for those who wish to engage in patient and conscientious observation **(Dijkstra & Lewington, 2006)**. The life cycle of this taxon and the ecological diversity of the species make it relevant to study. It is important to note that although it is interesting to study species individually, the odonata taxon is often approached as a whole. Furthermore, the sensitivity of some species to the quality of larval habitats and water further enhances the interest in studying this group **(Grand & Boudot, 2006)**. The freshwater conditions of habitats and aquatic or semi-aquatic vegetation are generally responsible for the present assemblages. Disruptions to habitats or chemical pollution can generally influence the presence of certain species. All these criteria make odonata a stable and reliable indicator of hydro system quality **(D'Amico et al, 2004)**.

The Odonata order, the suborder Zygoptera, commonly referred to as damselflies, is characterized by their slender bodies, delicate wings that they typically hold closed over their bodies when at rest, and their eyes that are separated rather than touching. Zygoptera species are often found near slow-moving or still waters, where they lay their eggs and where their aquatic nymphs develop. The family Calopterygidae, within the Zygoptera suborder, is known for its large, brightly colored species. Members of this family exhibit a variety of mating and territorial behaviors, with males often displaying vibrant wing colors and patterns to attract females and deter rivals. One such species within the Calopterygidae family is *Calopteryx haemorrhoidalis*, the Copper Demoiselle. This species is native to the western Mediterranean region, including parts of Northeast Algeria. The Copper Demoiselle is particularly noted for its striking appearance: males with dark, metallic wings and a distinctive red area on the underside of their abdomen, and females with lighter, translucent wings. The life cycle of *Calopteryx haemorrhoidalis* is adapted to the specific environmental conditions of its habitat, making it an important species for studying the impacts of environmental changes on aquatic biodiversity. Numerous investigations have been undertaken to understand the Algerian odonata (**Sélys- Longchamps Longchamps, 1849; Sélys, 1865; 1866; 1871; 1902 ; Kolbe, 1885 ; Mclachlan 1897; Morton, 1905; Martin, 1910**). However many localities specially in semi-arid and Sharan region remain poorly investigated.

We aim in this study to investigate the life cycle of this species by studying their development types, growth ratio and instar identification in a semi-arid region Wad El-hamma Wilaya of Khenchela. This perennial watercourse is located 5 km from Khenchela down town, 14 km from Kais, and 2 km from Hammam Essalihine. The wad El-hamma flows continually and bypasses this area. The Wad El-hamma derives from the hot springs of Hammam Essalihine end destination is the entire Remila. The wad sub-watershed spans 35° to 35°30' N and 7° to 7°6'5"E, covering 37.5 km² and with an altitudes range from 850 to 1900 meters

This study is divided into three chapters

- Chapter one: Summary of the literature on Calopterygidae Family, species *Calopteryx haemorrhoidalis*
- Chapter two: Description of the study area.
- Chapter three: Results and discussion.

Finally, this manuscript is closed by a conclusion and some research perspectives.

Chapter one: Biology and Ecology of Calopterygida

1.1. Calopterygidae biology

The larvae of *Calopteryx* are typically found in rivers and larger creeks, where they attach themselves to aquatic plants, roots, and woody debris. Their development takes two to three years, with females generally requiring a longer development period compared to males. *Calopteryx* exhibit intricate courtship behavior, which has been extensively studied. Females lay their eggs in floating mats of vegetation, an aquatic Oviposition activity was observed on July to August however, it likely commences earlier and extends slightly beyond these dates., the flight period spans from May to September (Westfall and May 1996).

1.2. Classification of Calopterygidae

Order: **Odonata**

Suborder: **Zygoptera**

Family: **Calopterygidae**

Genus: **Calopteryx**

Species: *C. haemorrhoidalis*

Binomial name: *Calopteryx haemorrhoidalis* Vander Linden, 1825



Figure 01: photo of *Calopteryx haemorrhoidalis* female and male (Spain, 2014)

1.3. Morphology of Calopterygidae

1.3.1. Morphology of adults

1.3.1.1. The head:

The head of adult Calopterygidae is typically equipped with large compound eyes, allowing for acute vision during flight and hunting. These eyes are multifaceted, comprising numerous individual facets called ommatidia, which contribute to their exceptional visual acuity **(Corbet,1999)**. Additionally, the head features a pair of short antennae used for sensing chemical cues and environmental stimuli **(Paulson,2009)**

3.1.2. The thorax:

The thorax of Calopterygidae is robust and muscular, serving as the attachment site for the powerful flight muscles needed for aerial maneuverability **(Corbet,1999)**. It consists of three segments: the prothorax, mesothorax, and metathorax. Each segment bears a pair of legs, as well as a set of wings in the case of the mesothorax and metathorax **(Paulson,2009)**.

1.3.1.3. The legs:

Calopterygidae possess six legs, with each leg composed of several segments: the coxa, trochanter, femur, tibia, and tarsus. These legs are adapted for various functions, including walking, grasping prey, and perching on vegetation **(Corbet,1999)**. The tarsus often features specialized structures such as spines or claws, aiding in climbing and gripping **(Paulson,2009)**.

1.3.1.4. The wings:

The wings of Calopterygidae are membranous structures supported by a network of veins, providing both strength and flexibility during flight **(Corbet,1999)**. They exhibit striking iridescence, owing to microscopic structures on the wing surface that refract and reflect light **(Boudot & Kalkman,2015)**. The wingspan varies between species, with males typically possessing larger and more colorful wings than females **(Paulson,2009)**.

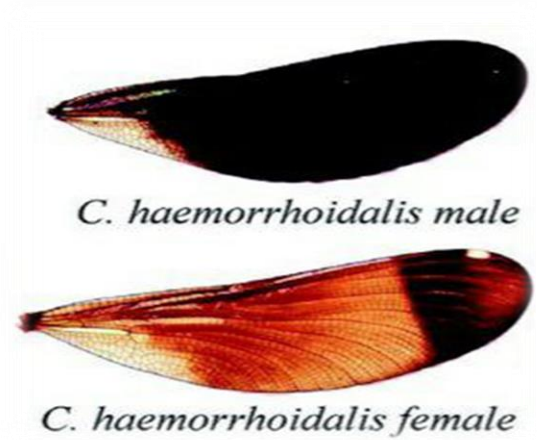


Figure 02: The wings of *C. haemorrhoidalis* male and female (Antonio Torralba-Burial,2008)

1.3.1.5. The abdomen:

The abdomen of Calopterygidae consists of several segments and houses vital internal organs, including the digestive, reproductive, and respiratory systems. In males, the abdomen may feature specialized structures such as claspers used during mating (Corbet,1999). Females possess an ovipositor at the tip of the abdomen, utilized for depositing eggs in suitable aquatic habitats (Paulson,2009).

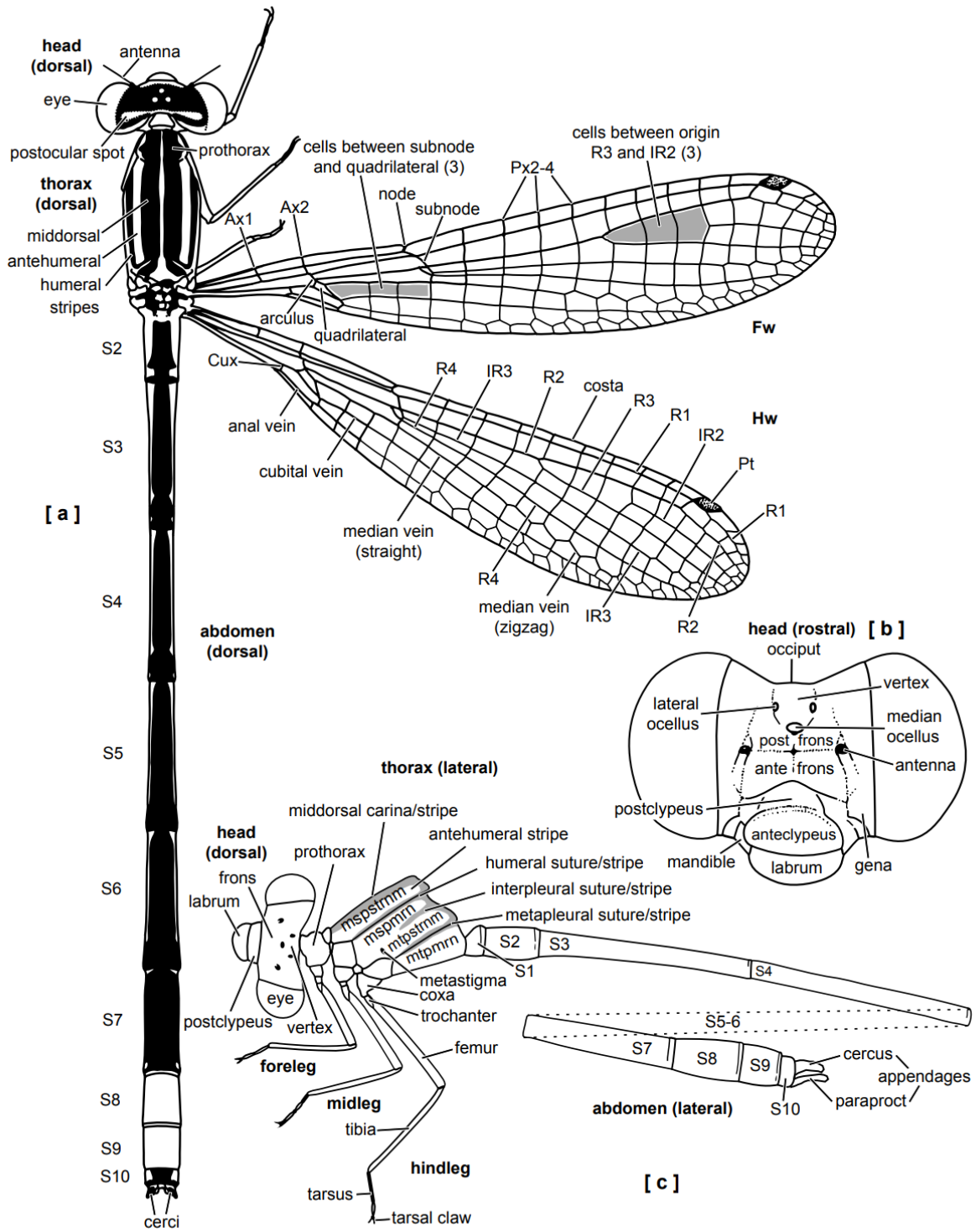


Fig. 2: Zygopteran morphology.

Figure 03: Zygoptera morphology (Suhling,2012)

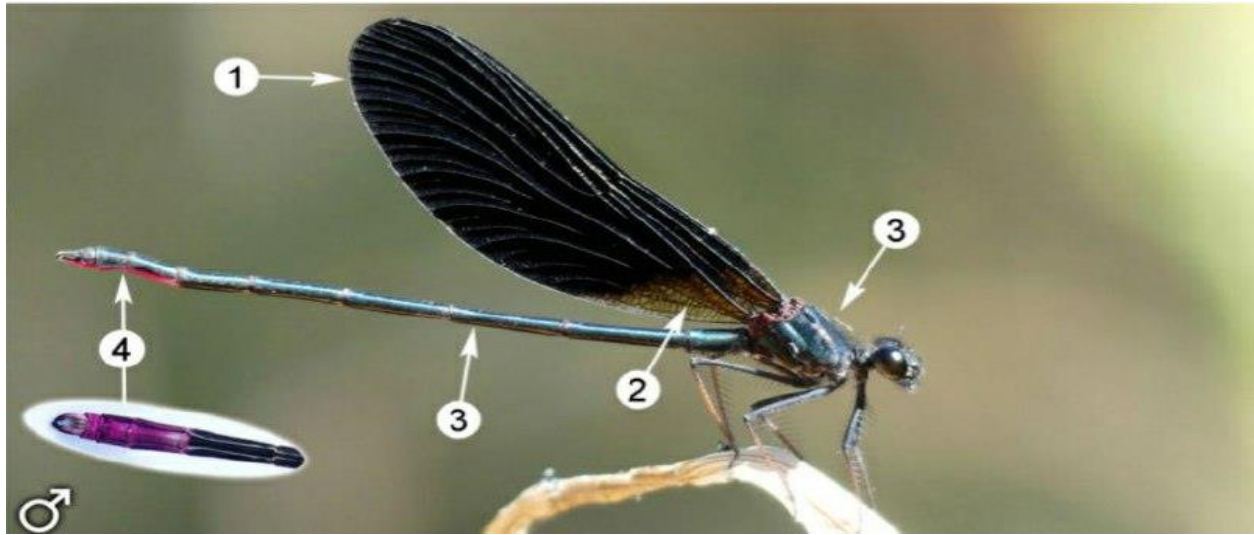


Figure 04: Morphology of *Calopteryx haemorrhoidalis*, male

Length: From 45 to 48 mm. Hindwing span: From 23 to 37 mm.

Male: 1. Wings are black. 2. Transparent wings base. 3. Dark thorax and abdomen with some reddish or bronze shades. 4. S8, S9 and S10 are bright red or pink underneath. Female: 5. Smoky brown wings. Darker and well outlined apex on the hindwings. 6. White pseudo pterostigma. 7. Metallic green or copper shades on the thorax and abdomen.

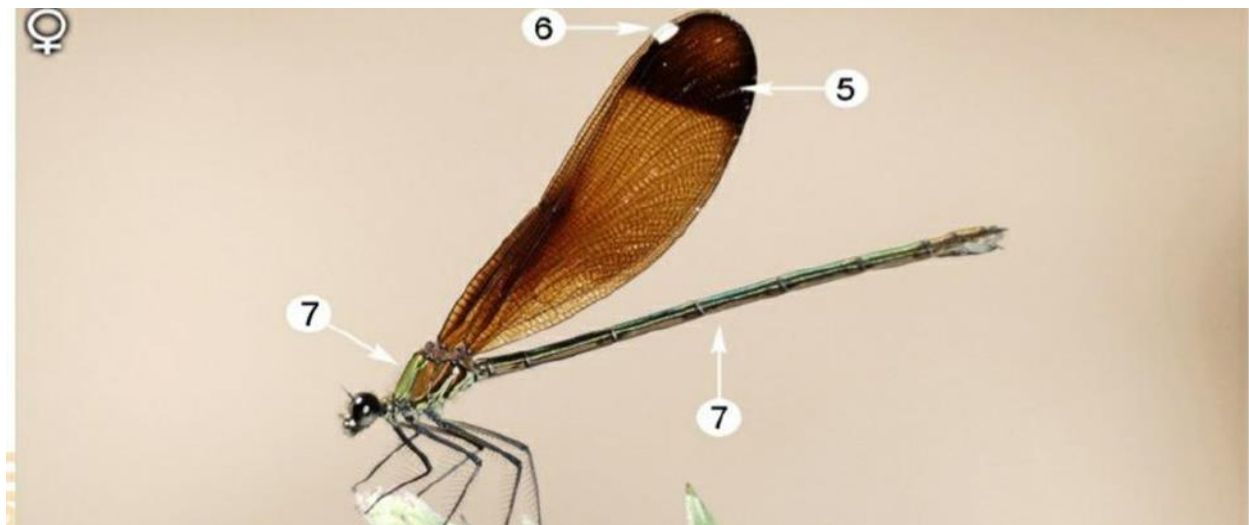


Figure 05: Morphology of *Calopteryx haemorrhoidalis*, female

1.3.2. Morphology of larvae

1.3.2.1. The head:

The head of Calopterygidae larvae, or nymphs, is equipped with large compound eyes, similar to those of adult individuals. These eyes aid in detecting prey and potential predators in their aquatic habitat (Corbet,1999). Additionally, the head features a pair of powerful mandibles used for capturing and consuming prey, as well as smaller appendages such as antennae and labial palps (Paulson,2009).



Figure 06: Headshot of *Calopteryx haemorrhoidalis* (Nouasri,2024)

1.3.2.2. The thorax:

The thorax of Calopterygidae larvae is relatively compact and consists of three segments, much like that of the adults. This region of the body bears three pairs of segmented legs, which are adapted for crawling and clinging to submerged vegetation (Corbet,1999). The thorax also houses the developing wing pads, which become more prominent as the larvae mature (Paulson,2009).

1.3.2.3. The abdomen:

The abdomen of Calopterygidae larvae is elongated and segmented, with each segment bearing a pair of gills for respiration in aquatic environments. These gills extract oxygen from the water, enabling the larvae to breathe while submerged (Corbet,1999). The abdomen also contains the digestive and reproductive organs, which develop as the larvae progress through their nymphal stages (Paulson,2009).

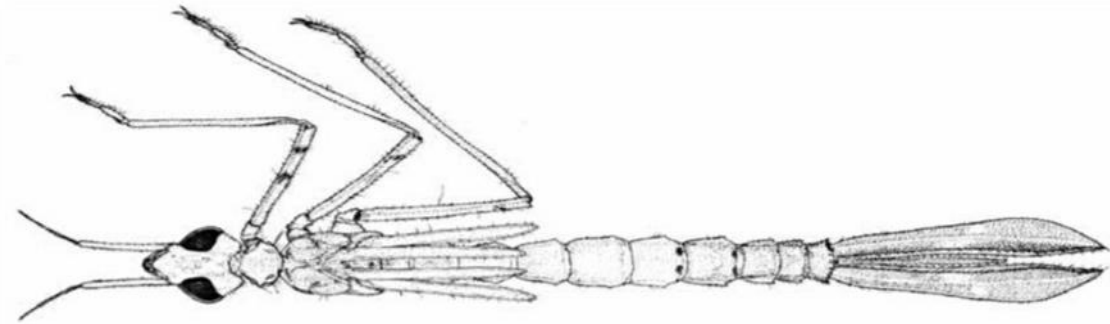


Figure 07: Morphology Calopterygidae of larvae (Roldan-Perez,1988)

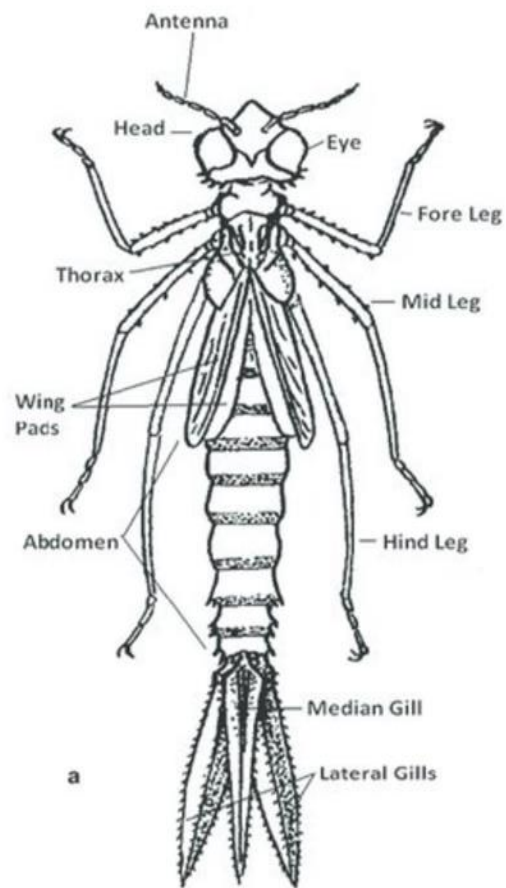


Figure 08: Morphology of larvae Zygoptera (Fraser,1919)



Figure 09: Morphology of larvae *Calopteryx haemorrhoidalis* (Nouasri,2024)

1.4. Ecology of Calopterygidae

1.4.1. Habitats

Calopteryx haemorrhoidalis is a species of flowing water habitats. The larvae live in aquatic vegetation, often near the bottom. Emergence occurs vertically or in retroversion on riparian vegetation or on emergent plants. The adult separates from the water during maturation. It is found along hedges, forest edges, in sunny and sheltered areas from the wind. Mature males typically stay along small rivers, often in areas where riparian vegetation is significant and highly tiered. Helophytes often grow in the stream bed itself. The species can colonize very small river sections, including gaps of a few meters in wooded streams. During drought periods, when streams dry up, adults often move to larger water bodies, sometimes rivers **(Alcock,1983)**.

➤ **Territorial Behavior:**

Male Calopterygidae often establish and defend territories along the edges of water bodies, where they engage in courtship displays and mate guarding to attract females and deter rival males **(Cordoba-Aguilar,2008)**. Territorial disputes among males may occur, leading to aggressive interactions and aerial battles to establish dominance over preferred territories **(Paulson,2009)**.

➤ **Environmental threats:**

The ecology of Calopterygidae is increasingly threatened by human activities such as habitat destruction, pollution, and climate change. Urbanization, agriculture, and industrialization have led to the loss and degradation of freshwater habitats, reducing the available resources for damselflies **(Corbet,1999)**. Pollution from agricultural runoff, sewage discharge, and chemical contaminants further deteriorates water quality, impacting the survival and reproduction of Calopterygidae populations **(Boudot & Kalkman,2015)**.

1.5. Life Cycle of Calopterygidae

1.5.1. Mating:

The Calopterygidae is an animal group known for its unique copulatory processes. Males transfer sperm from the ninth abdominal segment to the second and third segments where intromittent organs are present, adopting a unique copulatory wheel where the female mesostigmal plates are grabbed by the male anal appendices (**Alcock,1983**). Copulation takes place in two stages: sperm displacement and transfer. In brief mating's, males can displace almost all sperm from the female storage organs, unlike other species that mate for several hours. (**Córdoba-Aguilar,2003**), The Calopterygid species studied have a rhomboid penis head with two distal horns covered with pointing spines. Females have two sperm storage organs: the bursa copulatrix and the spermatheca (**Waage,1979& Miller,1987**). Two sperm displacement mechanisms have been described in this family: removal and sensory stimulation. During removal, the penis horns enter the spermatheca, while during stimulation, the medial part of the aedeagus deforms two vaginal plates with embedded mechanoreceptor sensilla, coordinating muscles surrounding the spermatheca and causing spermathecal sperm ejection. (**Miller,1987**).



Figure 10: Mating *Calopteryx haemorrhoidalis* (Gail Hampshire, 2011)

1.5.2. Egg laying:

The female lays her eggs alone, but the male always stays close to the female during egg-laying to protect her from other males. The female flies to aquatic plants in the male's territory.

She then begins to plant her eggs in the plants. If there are many males present, the female submerges completely in the water after a short time to continue planting her eggs. The female *Calopteryx hemorrhoidal* can remain underwater for just over an hour. She can do this because she is surrounded by an air bubble



Figure 11: *Calopteryx hemorrhoidal* - Egg-laying

1.5.3. The eggs

Are laid in the vegetation close to the surface. During hatching, the egg releases a prolarva that is unable to feed. This first larval stage, a little special and of very short duration, will quickly be followed by a more conventional larval stage during which the feeding becomes preponderant.

1.5.4. The larva

Is aquatic, it has a scary outer shell which gives it a certain rigidity but cannot change size. Each larval stage therefore ends with a moult in which the larval envelope is abandoned, allowing the animal to grow. The moults thus allow the growth and the gradual transformation of the larva into the final shape of the adult. The mounds are also repairable, because when a limb is lost, it can be regenerated to the next moult. The development of the *Calopteryx* larva lasts about one to two years depending on prey abundance and water temperature. The larva winters twice.

At the end of the last larval stage, the larva leaves water to emerge: this is the metamorphosis or

1.5.5. Imaginary moulting

The larva separates from its old envelope, then called exuvie. The mask disappears in adults. Exuvies are often found in vegetation on the edge of the sites where the larvae have lived. After a more or less long phase during which it can be found far from the water at sites rich in insects from which it feeds, the image will mature, then reproduce and die. During the courtship parade, the male presents the female's her retro-reflector to seduce her. Subspecies hybridization is common in locations where subspecies areas overlap. This is due to the fact that isolated populations have evolved genetically. The males defend their territory with pugnacity, especially near the place of laying. They attract females through a courtship

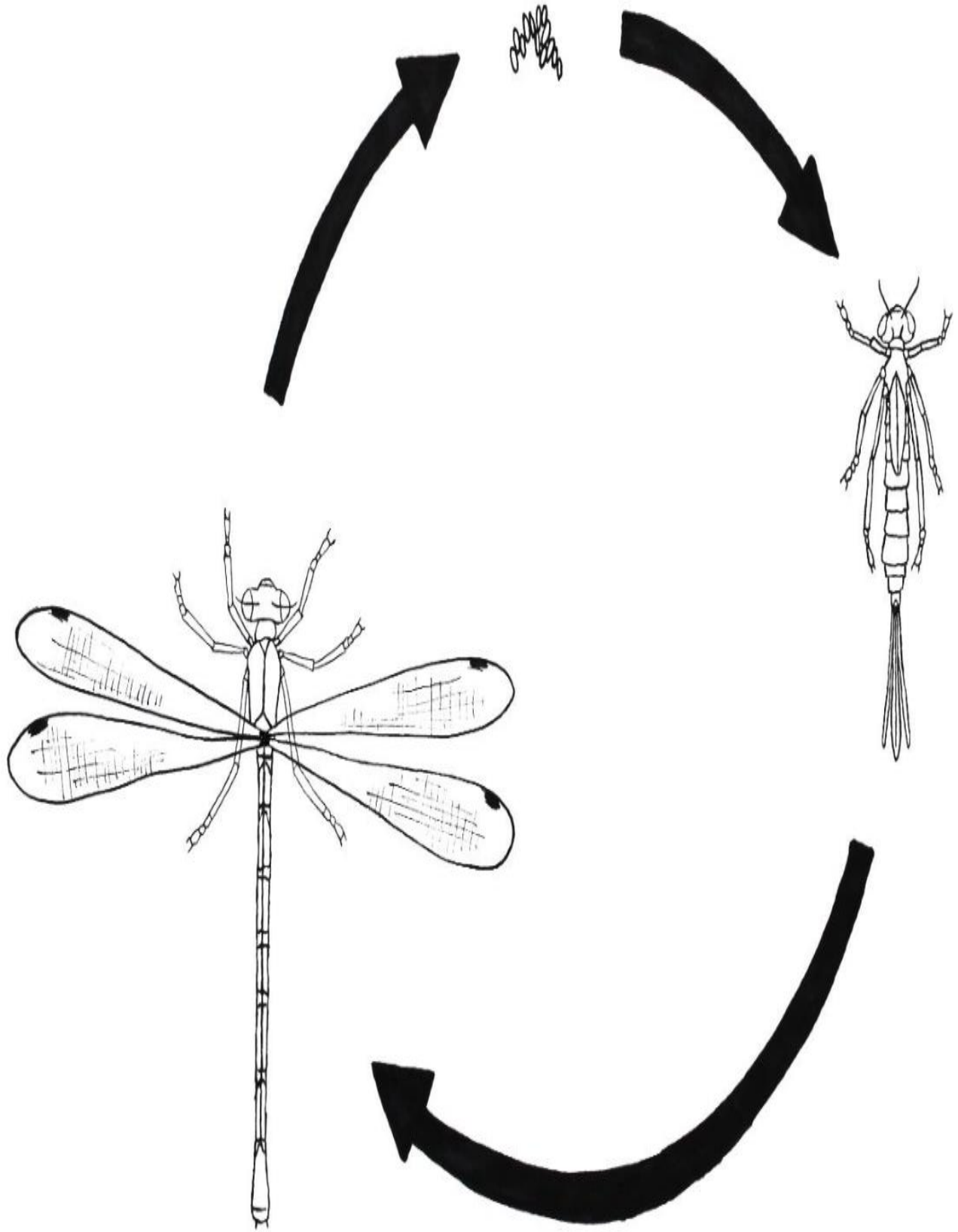


Figure 12 : life cycle zygoptera (Tanya Jayne Dann,2018)

Chapter two:
Presentation of the
study area and
Materials and
Methods

2.1 Geographical situation of the wilaya of khenchela

Khenchela wilaya is situated in northeastern Algeria, specifically in the Aurès region. In the Algerian administrative division, it is state number 40. It became visible as a state following the 1984 split. The states of Tebessa in the east, Oum El Bouaghi in the north, Batna in the west, Biskra and the valley (Wadi Souf) in the south are all represented by it as mediators. The city's name is thought to come from the name of the Berber queen Dehya's daughter, who the Arabs referred to as the priestess The Wilaya's total population was estimated at 414,550 on 12/31/2011(ANDI,2013). At a distance of roughly 600 km from Algiers

2.1.1Administrative framework

At present, the wilaya territory is made up of 21 communes grouped into 8 Daïra (including 05 Daïra created in 1990) (Bouafia,2015)

Table 01: Administrative division of the Wilaya of Khenchela

Daïra	Communes
Khenchela	Khenchela
El-hamma	El-hamma, Nsigha, Tamza, Baghai
Babar	Babar
Kais	Kais, Taouzient, Rmila
Ain Touila	Ain Touila, M'toussa
Bouhamama	Bouhamama,Chelia, Msara, Yabous
Chechar	Chechar, Djellal, Kheirane, Ouldja
O-Rechache	Ouled Rechache, Mahmel

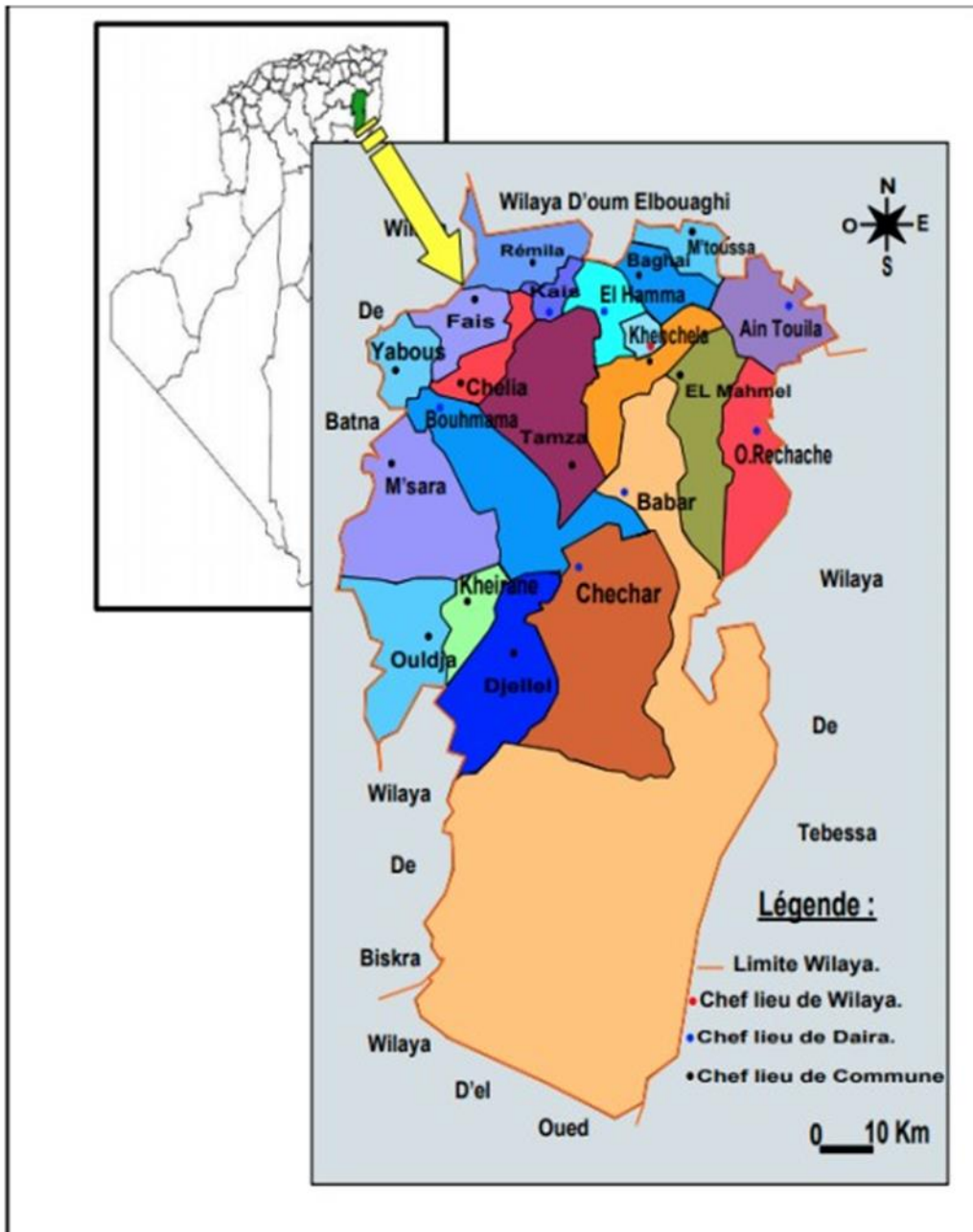


Figure 13: Administrative map of the Wilaya of Khenchela

2.1.2 Geography

The Khenchela region, spanning across a total area of 9715 square kilometers, is situated within the Hauts Plateau natural grouping, positioned in the central part of the national territory and flanked by the Telly Atlas to the north and the Saharan Atlas to the south. Its distinctive physical characteristics, shaped by the quaternary period uplift of the Aures, impart upon it a landscape reminiscent of the northern mountainous regions, rendering it unique among its counterparts. This diversity is evident in its varied terrain, encompassing Telly landscapes, such as the verdant Aures mountains in the west, high plains conducive to semi-arid cereal cultivation in the northern reaches, and steppe and Saharan landscapes characterized by barren, eroded mountains like the Nememchas in the east, interspersed with oases such as Siar, Khirane, and El Ouedja, as well as low plains like El Meita and Ouazerne. The region's agro-sylvo-pastoral focus is underscored by its allocation of 22% for agricultural use, 12% for forests, and 49% for steppe, according to (Anonymous, 2001).

2.2 Land use

2.2.1 Relief

The relief of the Wilaya is characterized by four main geographical features:

- a. Mountains** (covering 35% of the wilaya's surface area): To the west lie the towering peaks of the Aures massif, boasting the highest summit, Mount Chelia, reaching 2328 meters. In the central zone, the landscape is dominated by the Nememcha mountains, while in the northeast, the Tafrent mountains of Tafrent (Ain Touila) rise prominently.
- b. Plateau:** Found to the northeast, specifically in areas like Mahmel and Ouled Rechache.
- c. Plains:** The northern region is marked by the expansive Remila plain, while to the west, the high plains of Bouhmama and M'toussa stretch out.
- d. Steppe:** and Saharan rangelands, along with chotts: These encompass the southern expanse, covering nearly half of the wilaya's total surface area (49%). Comprised mostly of sandy soils, this region features depressions known as chotts and extends into a dune zone in the extreme south.

2.2.2 Soil and vegetation

In terms of soils and vegetation, Khenchela exhibits diverse characteristics across its regions:

a. Northern Plains: These areas boast a dense hydrographic network and deep, fertile soils. Natural vegetation primarily comprises Armoise (Chih), Helba (Artemesia Helba, Alba), Guettaf (Atriplex), Salsola, and jujube.

b. North-Western and Central Mountainous Zones: Within the Aures Mountains, soils tend to be humus-bearing or humus-bearing limestone, occasionally punctuated by bedrock outcrops. The Mahmel and Wad El-arab plateaus feature calcareous soils due to bedrock outcroppings. This region is rich in diverse flora, including forests of cedar, Aleppo pine, holm oak, cypress, black pine, ash, esparto grass, mug wort, jujube, R'Tem, acacia, juniper, and rosemary.

c. Eastern Nememcha Mountains: Here, the forest cover has degraded significantly, with bedrock outcroppings prevalent throughout the region, except for a small central strip with calcareous soils.

2.3 Climatic overview

Understanding climatology is crucial for comprehending precipitation patterns and their impact. By analyzing climatic data and parameters measured over a specific period, we can estimate various components of the water balance. This knowledge is essential for understanding surface hydraulic systems, influenced by parameters such as rainfall, temperature, evapotranspiration, infiltration, and runoff.

Algeria's geographical diversity gives rise to three distinct climatic zones: a Mediterranean climate in the north, a semi-arid climate in the interior, and an arid climate in the Sahara.

The Wilaya of Khenchela experiences three primary climatic conditions:

- **Central Mountainous Regions:** Winters are extremely harsh, while summers are moderate. This area typically has short, hot summers and long, very cold winters.
- **Southern Saharan Steppes:** Winters are moderate, while summers are hot and dry. This region experiences relatively milder winters compared to the mountainous areas, with scorching summers characterized by arid conditions.

- **Northern High Steppes:** Winters are very cold, while summers are dry. Areas like **(Djefali and Mefardji)** have intensely cold winters and comparatively cooler summers.

In Khenchela, summers are short, overall very hot, and winters are long, very cold, and partially cloudy. The climate remains dry throughout the year. Temperature variations typically range from 0°C to 33°C over the year, seldom dropping below -3°C or exceeding 38°C. Climate plays a pivotal role in shaping the distribution of living organisms **(Blondel,1979)**.

This section focuses on the extended hourly mean wind vector, including speed and direction, at 10 meters above ground level in Khenchela. Local topography and various factors significantly influence the observed wind at a specific location, leading to fluctuations in instantaneous wind speed and direction.

2.3.1 Wind

In Khenchela, the average hourly wind speed exhibits moderate seasonal variation throughout the year. The windiest period spans approximately 6.1 months, from November 8 to May 12, characterized by average wind speeds exceeding 12.5 kilometers per hour. February emerges as the windiest month, with an average hourly wind speed of 13.9 kilometers per hour.

Conversely, the calmest period spans around 5.9 months, from May 12 to November 8. August stands out as the calmest month, with a mean hourly wind speed of 11.0 kilometers per hour.

According to **(Robert,1982)**, wind plays a crucial role in insect flight and dispersal. It replaces the relatively saturated air in contact with evaporating surfaces with new layers of generally lower temperature and humidity. Consequently, insect activity can be significantly affected by wind, as noted by **(Dajoz,1982)**.

Table 02: Climatic data for average monthly wind speed (2010-2020) in (km/h)

Month Period	jan.	feb.	March	apr.	may.	Jun	july.	aug.	sep.	oct.	nov.	dec.
2010-2020	13.7	13.9	13.7	13.5	12.2	11.3	11.1	11.0	11.1	11.7	12.8	13.4

Source: (Khenchela weather station, 2020)

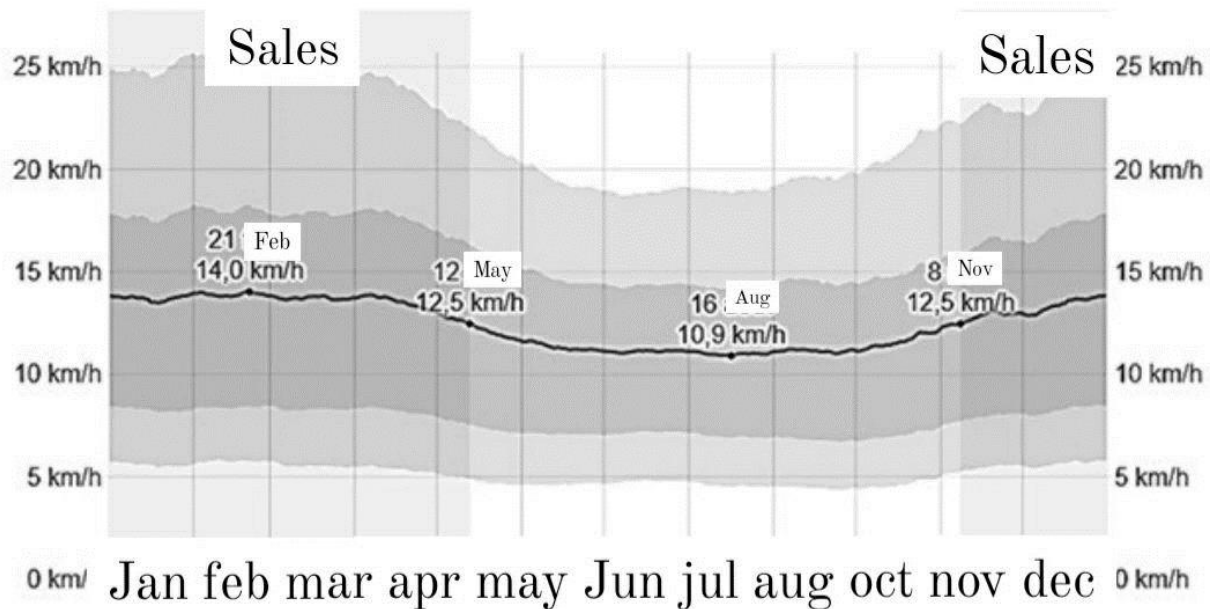


Figure14: Wind variations (monthly averages, minima and maxima)For the willaya of khenchela (2010-2020)

In Khenchela, the main average hourly wind direction exhibits variation throughout the year:

➤ **Winds from the North:**

- Most frequently observed for approximately 1.4 months, spanning from January 1 to February 13.
- Prevail for around 7.1 months, extending from February 21 to September 24.
- Also prevalent for 1.0 weeks, occurring from December 16 to December 23, peaking at 39% on February 3.

➤ **Winds from the West:**

- The dominant direction for about 1.1 weeks, from February 13 to February 21.
- Prevail for approximately 1.7 months, lasting from October 24 to December 16.

- Additionally observed for 1.3 weeks, spanning from December 23 to January 1, reaching a maximum percentage of 38% on December 27.

➤ **Winds from the South:**

- Most commonly experienced for around 1.0 months, occurring from September 24 to October 24, peaking at 33% on October 14.

These variations in wind direction provide insight into the seasonal patterns and prevailing atmospheric conditions in Khenchela throughout the year.

2.3.2 Temperature

Air temperature is an important factor conditioning the ecology and biogeography of all living beings in the biosphere. It is an essential ecological factor, since its influence is constantly felt by insects (**Dajoz,2006**). Temperature appears to be the most important factor in the emergence of bees to collect pollen (**Louveaux,1958**).

Average monthly temperatures over 10 years (2010 to 2020) are shown in the table below:

Table 03: Climatic data on average monthly temperatures (2010-2020)

	jan.	feb.	march.	apr.	may.	jun.	july.	Aug.	sep.	oct.	nov.	dec.
Max	10°C	11°C	14°C	18°C	24°C	29°C	33°C	32°C	27°C	21°C	15°C	11°C
Avg	4°C	5°C	8°C	12°C	17°C	22°C	26°C	25°C	20°C	15°C	9°C	5°C
Min	0°C	1°C	3°C	6°C	10°C	15°C	17°C	17°C	14°C	10°C	4°C	1°C

Source: (Khenchela weather station, 2020)

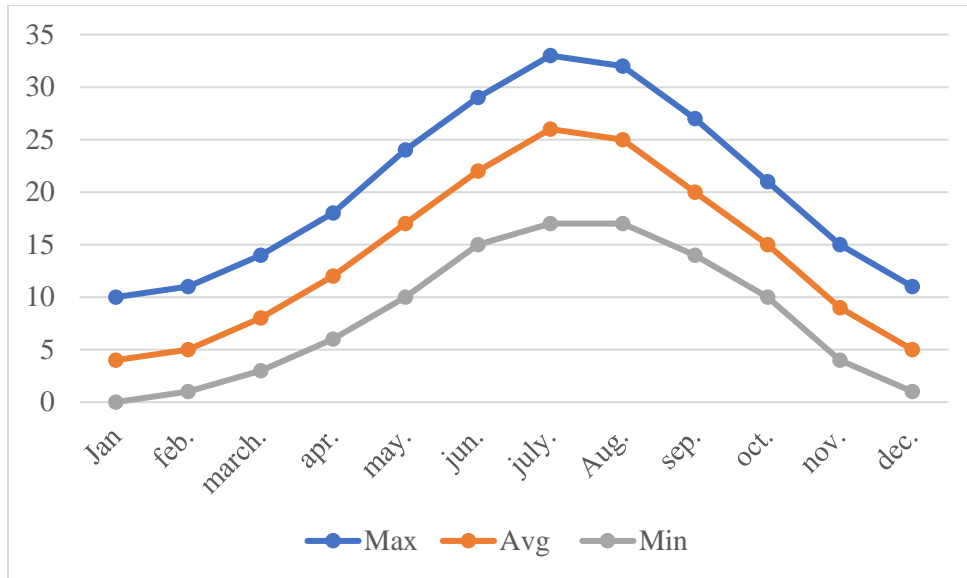


Figure 15: Variations in mean, minimum and maximum monthly temperatures

For the willaya of khenchela (2010-2020)

The very hot season in Khenchela spans 2.9 months, starting from June 12 and ending on September 9. During this period, the average daily maximum temperature exceeds 28°C. July stands out as the hottest month, with an average maximum temperature of 33°C and a minimum of 17°C.

Conversely, the cold season persists for 4.0 months, commencing from November 18 and extending to March 16. Throughout this period, the average daily maximum temperature remains below 14°C. January marks the coldest month of the year, with an average minimum temperature of -0°C and a maximum of 10°C.

2.3.3 Precipitation

Precipitation in Khenchela is influenced by two main factors: hypsometric distribution and relief. According to the average annual precipitation map of eastern Algeria by (A.N.R.H 1993), the western region of Khenchela is characterized as a dry area, with average annual precipitation ranging from 250 to 400 mm, varying along a north-south gradient.

Rainfall plays a crucial role in the development of living organisms, particularly affecting the foraging behavior of bees, as noted by (Schua1952) cited by (Grasse,1968). (Ramade,2009) defines precipitation as the total amount of rainfall, hail, and snow received per unit area and unit time. It stands as a fundamental ecological factor, influencing the functioning and distribution of terrestrial ecosystems, as well as certain limnic ecosystems like temporary ponds, lakes, and brackish lagoons prone to periods of drying up.

Table 04: Climatic precipitation data for the period (2010-2020)

Month \ Precipitation	jan.	feb.	March	apr.	may.	Jun	july.	aug.	sep.	oct.	nov.	dec.
Rainfall (mm)	25,9	21,2	27,8	32,1	34,9	23,2	9,4	16,3	30,3	25,6	25,1	21,7
Snow in (mm)	38,8	23,7	5,7	1,6	0,0	0,0	0,0	0,0	0,0	0,0	1,1	16,5

Source : (khenchela 2020 weather station)

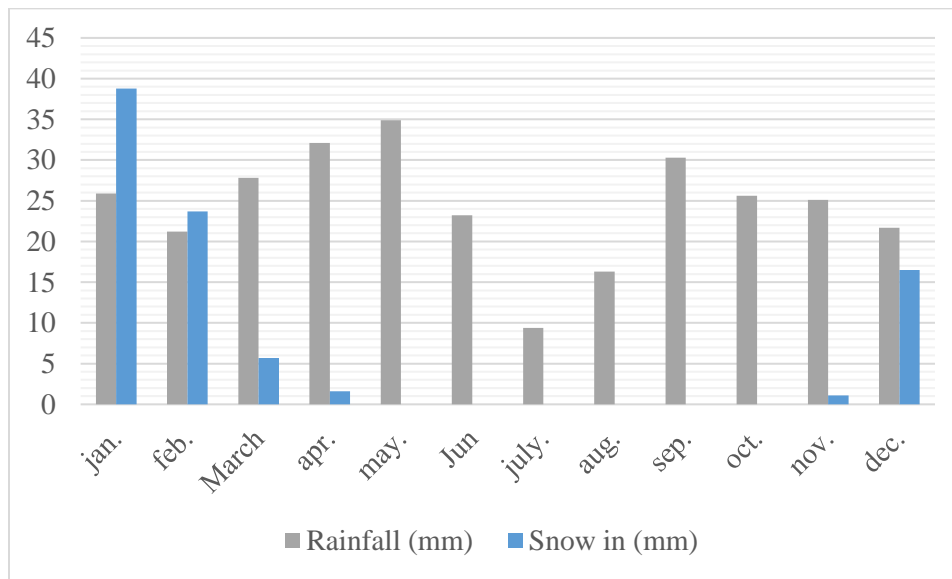


Figure 16: Precipitation for the period 2010-2020 in the Khenchela region

Here is the precipitation and snowfall data for Khenchela:

Precipitation:

- The wettest month in Khenchela is May, with an average rainfall of 35 millimeters.
- The least rainy month in Khenchela is July, with an average rainfall of 9 millimeters.

Snowfall:

- The snowy period of the year lasts 1.5 months, from December 23 to February 9, with a sliding 31-day snowfall of at least 25 millimeters.
- The snowiest month in Khenchela is January, with an average snowfall of 39 millimeters.
- The snow-free period of the year lasts 10 months, from February 9 to December 23. The smallest snowfall occurs around August 2, with an average total accumulation of 0 millimetres.

3. Study Site and Observation Stations

3.1. Site Presentation

The town of El-hamma is situated 5 km away from the capital of the wilaya of Khenchela, 14 km from the commune of Kais, and 2 km from Hammam Essalihine. It is bordered by the continuously flowing Wad El-hamma. This river originates from the thermal springs of Hammam Essalihine and flows uninterrupted until it reaches its final destination, the Remila.

The Wadi El-hamma sub-watershed is positioned between latitude 35° and $35^{\circ}30'$ N, and longitude 7° and $7^{\circ}6'5''$ E, encompassing a surface area of 37.5 km^2 . It is characterized by altitudes ranging from 850 m to 1900 m.

3.2. Observation stations

For the study of our area, we collected data from Ten stations (Figure17)

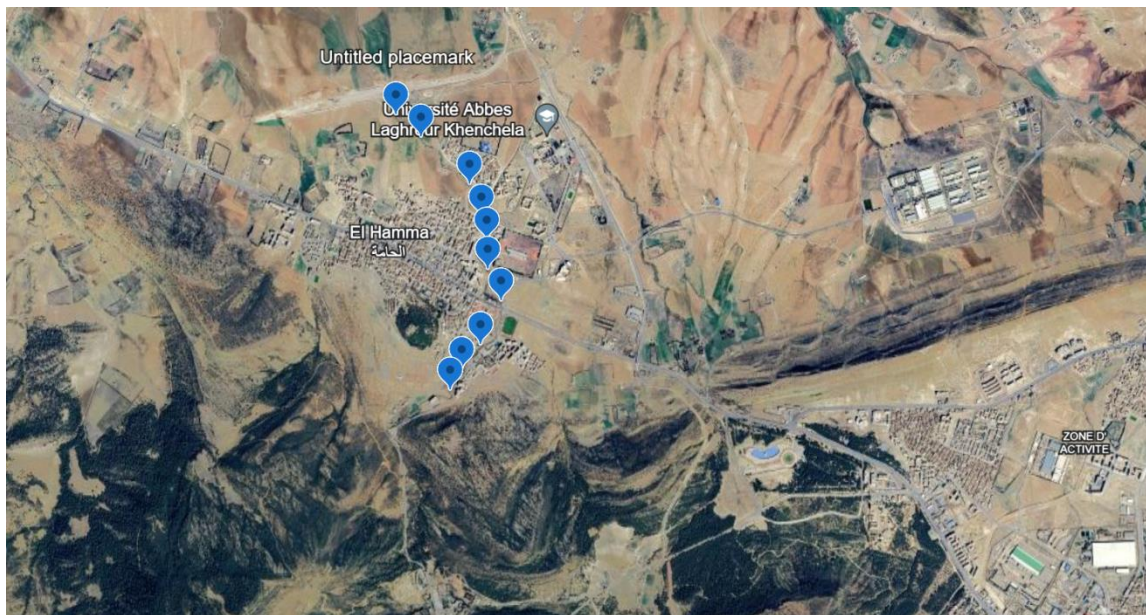


Figure 17: Location of study site and stations

3.3. Materials

To effectively study odonates, field equipment is essential for collecting, observing, and recording data on their behavior in various habitats. For every field excursion, it's necessary for the surveyor to assemble the following gear: [list equipment].

3.3.1. Entomological netting

Typically consists of a handle ranging from 1 to 2 meters in length, with a metal ring attached at one end measuring between 30 to 50 centimeters in diameter. The net itself is usually constructed from nylon or polyester material, forming a pouch that is transparent. This transparency is crucial as it allows researchers to easily locate and observe captured insects within the net.



Figure 18: Entomological netting

3.3.2. A fine-mesh

Sieve is an essential tool for sorting out the larvae of other aquatic insects from samples collected during odonate field studies



Figure 19: A fine-mesh

3.3.3. Entomological forceps:

They allow better handling of specimens to avoid direct contact.



Figure 20: Entomological forceps

3.3.4. A mercury thermometer

Is a device used to measure temperature using mercury as the medium. It consists of a glass tube filled with mercury and a metal ring to contain the mercury. The mercury expands or contracts in the tube as the temperature changes, causing its position to change. The level of mercury is read on the thermometer scale to determine the temperature



Figure 21: A mercury thermometer

3.3.5. Camera:

To obtain photos of aquatic habitats and their environment, as well as uncaptured species, but also to preserve evidence of the presence of a particular species.



Figure 22: camera

3.4. These items are used in the laboratory

for various tasks related to the study of odonates:

- Optical microscope: To examine the anatomical details of odonate specimens, such as reproductive organs or microscopic structures
- Binocular loupe: For a more detailed observation of the external characteristics of specimens, including their morphology and coloration.
- Notebook and graph paper: To record detailed observations, measurements, and drawings of specimens, as well as to take notes during experiment.
- Collection vials: To store specimens collected in the field before examination in the laboratory.
- Labels: To label specimens with information such as date and location of collection, as well as unique identification numbers.

- Additional notebook: Used as a laboratory journal to record details of experiments and analyses.
- Petri dishes: To culture odonate specimens or to prepare samples for further analysis.
- Dissection box: To prepare specimens by gently removing unnecessary parts or preparing them for further examination.
- Hemolysis tubes or dry tubes: Used to store tissue or fluid samples for biochemical or genetic analyses
- 70% ethanol: For preserving odonate specimens, keeping them in a preserved state for long-term studies.
- Entomological pins: To pin specimens onto boards or other surfaces for examination or presentation.
- Polystyrene plates: Can be used as a support to pin specimens or to organize entomological pins and other small materials during laboratory analysis.



Figure 23: laboratory equipment (Bouhlala , 2023)

3.5 Study methodology

3.5.1 In the field

The survey methodology for this dragonfly study involves selecting sites where dragonflies are abundant and thriving, and where sampling is essential. Site selection criteria include accessibility (proximity to roads, safety, and sparse vegetation). Throughout the study period (from February 22, 2024, to May 2024), we conducted 10 sampling occasions. Each visit lasted between 8 and 10 hours on average, or approximately two hours, thanks to favorable weather conditions. Optimal weather conditions for the surveys included: no wind or wind speeds less than 20 km/h, no rain, temperature between 20 and 30°C, and as clear a sky as possible (cloud cover should not exceed 75%) (Lebrasseur, 2013).

3.5.2. In the laboratory:

Collecting Odonata involves several steps:

- Killing the specimens: It's important to kill the Odonata specimens first. This is typically done using methods such as freezing or immersion in ethanol.
- Preparing the specimens: After being killed, the specimens are pricked on the thorax with appropriately sized entomological pins. Their backs are then affixed to a polystyrene board covered with millimeter-thick paper.
- Drying and mounting: Once prepared, the specimens are dried and mounted on entomological pins. They are carefully labeled with information about the species, location, and date of collection.
- Storage: Mounted specimens should be stored in a dry, pest-free environment to ensure their preservation.
- Record keeping: It's crucial to keep a detailed record of the collection process to track the specimens and the information gathered about them. This record helps in further research and analysis.

The method for studying Odonata larvae in the laboratory under the microscope involves the following steps:

- Microscope setup: Set up an optical microscope with both low-magnification (10X or 20X) and high-magnification (40X or 100X) objectives, along with a light source.

- Preparation of larva: Place a larva on a microscope slide with a small amount of water.
- Initial observation: Use the low-magnification objective to locate the larva and adjust the focus.
- Detailed examination: Utilize the high-magnification objective to examine the morphological features of the larva, including the head, body, legs, and gills.
- Documentation: Take photos and notes of the observed features and make measurements, such as shape, size, number, and position of appendages (caudal gills) and other structures.
- Repeat: Repeat steps 2 to 5 for each larva, taking care not to damage the specimens.
- Comparison: Compare the characteristics of the observed larvae with identification keys, such as the guide by **(Grand and Boudout,2006)**.
- Documentation of results: Document the study results, including observed characteristics and confirmed identifications.



Figure 24: Measuring the *Calopteryx haemorrhoidalis* larva **(Nouasri,2024)**



Figure 25: Display on polystyrene board (Elafri,2023)

3.6. Data analysis

3.6.1. Determination of Larval Stages:

Identification of different larval stages is accomplished using the standard method devised by **(Dyar,1890)**, which relies on the frequency distribution of head width. By constructing a histogram of head widths, discontinuities in growth between successive stages are revealed as gaps in the frequency distribution. Peaks in the histogram indicate transitions between successive stages. This approach was detailed by **(Lamelas-López et al, 2017)**, whose study focused on larval development and growth ratios of Odonata in the Azores.

3.6.2 Determining the adult stages

Calopteryx haemorrhoidalis requires a thorough examination of its physical and biological development using a set of criteria such as changes in color, body size, and wing characteristics. Samples are collected from various locations and at different times to ensure comprehensive study. Indicators of maturity include body color, size, wing length, thorax width, and abdomen length. Additionally, mating and flight behavior are observed, with high activity in flight and territory defense reflecting the behavior of mature males. Microscopic examination is used to inspect fine structures like reproductive organs, and chemical analysis is conducted to analyze hormones that change with maturity stages. This process also relies on reviewing existing scientific literature, such as **(Corbet,1999)** which studied the behavior and ecology of dragonflies, **(Askew,2004)**

Chapter three: Results and discussion

4. Results and discussion

4.1 General finding

During our fieldwork (4 sampling occasion between 22-04-2024 and 11-5-2024) we recorded the presence of tow groups of aquatic insects. Firstly, the *Ephemeridae* family constitutes the largest portion 46% of the total studied insects larvae (138 lrvae). Secondly, the odonatan species with 54% of the recorded lrvae. This odonatan species was constituted with 3 families and two suborders (*Zygoptera* and *Anisoptera*) (**Table 5, figure 26**):

- *Calopteryx haemorrhoidalis*: accounting for 64 larvae which indicates a good presence of this type.
- *Anisoptera*: with 55 larvae, indicates a significant presence of this type in the studied environment.
- *Platycnemis*: Comprising 13% of the total insects (40 larvae), it is the least abundant species.

Table 5: Number of aquatic macroinvertebrates recorded at Wad El-hamma between 4/22/2024 and 5/11/2024

Ephemeridae family	Odonata family		Anisoptera
	Zygoptera		
138	<i>Calopteryx haemorrhoidalis</i>	<i>Platycnemis subdilata</i>	55
	64	40	

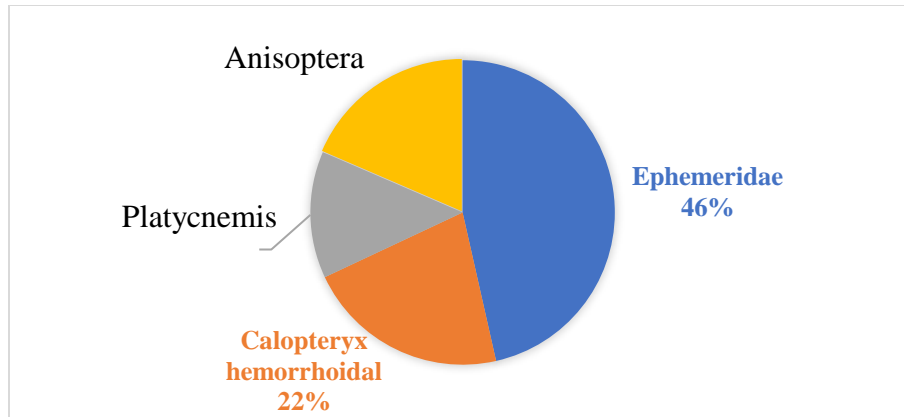


Figure 26: Structure of larvae population

4.2 Spatio-temporal variation

The analysis shows that the insect *Calopteryx haemorrhoidalis* is significantly present in Wad El-hamma, with 26 individuals recorded in the first group and 38 individuals in the second group on 11-05-2024, totaling 64 individuals (figure 26). This substantial presence indicates that Wad El-hamma provides a suitable environment for the growth and reproduction of this insect species. These results suggest that the environmental conditions in the valley, such as water quality and the availability of aquatic plants, are conducive to supporting the life of *Calopteryx haemorrhoidalis*. According to (Samraoui and Menai,1999), the historical distribution of this species in Algeria includes several areas: Cercle de la Calle (Sélys,1849), Bône (Sélys,1871), Constantine, Le Tarf, Oubeïra (McLachlan,1897), Biskra (Martin,1901), Biskra, Laghouat (Sélys,1902), Sebdou (Morton,1905), Bône, La Calle, El Guerra, Batna (Martin,1910), Hammam D’Hira (Ris,1913), Mascara (Longin Navas,1922), Azazga, Mascara (Lacroix,1925), Numidia (Samraoui and Corbet,2000), Mechroha, Collo, Jijel, Batna, Tlemcen, Drea (Menai,2005). This species is also found in the province of Khenchela (Bouhlala Kh,2023) indicating its wide distribution in clean and suitable aquatic environments.

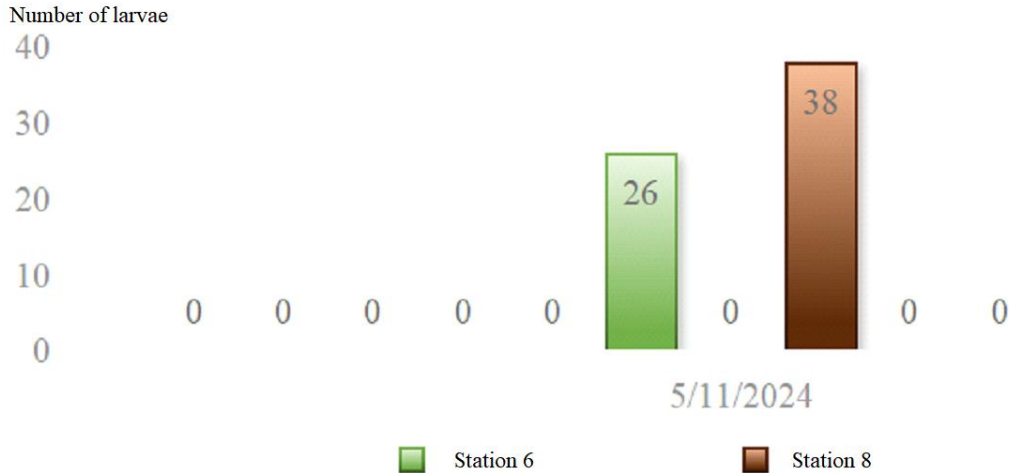


Figure 27: The distribution of *Calopteryx hemorrhoidalis* across ten stations

4.3. Water temperature and larvae occurrence

Water temperature at Wad El-hamma recorded at ten station (S1 to S8) between 4/22/2024 and 5/11/2024 were relatively stable with slight variations between the dates and different stations. The temperatures ranged from approximately 25.5°C at station S10 to around 24.5°C at stations S5 (figure 28). The highest temperatures were recorded at 5/11/2024 with 25 °C. The data indicates a general increase in temperatures from 29-04-2024 to 11-05-2024. This rise in temperature could be linked to the appearance of *Calopteryx hemorrhoidalis* at stations S6 and S8 on 11-05-2024 (figure 29), as the optimal temperature for the growth and reproduction of these insects appears to be between 23°C and 25°C .A study by (Chovanec & Waringer,2001) found that the most prevalent species in the Danube River preferred water temperatures between 20-25 degrees Celsius, as these conditions were ideal for larval development. Similarly, (Hassall & Thompson,2008) indicated that dragonflies in the United Kingdom benefit from warmer temperatures, with optimal water temperatures for most species ranging between 22-28 degrees Celsius. Additionally, a study by (De Block & Stoks,2005) examined the relationship between water temperature and growth rates in larvae, finding that the optimal water temperature for larval growth was around 24 degrees Celsius. It should be noted that the temperatures at stations S6 and S8 did not differ significantly from the other stations, The factors other than temperature that may influence the presence of *Calopteryx haemorrhoidalis* could include habitat quality,

water flow rate, presence of aquatic vegetation, and water pollution levels. Previous studies have suggested that habitat degradation, such as loss of vegetation cover or alteration of stream morphology, can negatively impact the abundance and distribution of Calopteryx species (Boudot et al,2007). Additionally, water quality parameters such as dissolved oxygen levels, pH, and nutrient concentrations can also affect the suitability of habitats for these insects (Hassall et al,2017). Furthermore, interactions with predators, competition with other species, and availability of suitable breeding sites are important factors influencing the presence and abundance of Calopteryx species (Hassall & Thompson,2008). Thus, a comprehensive understanding of these various factors is essential for assessing the ecological requirements and conservation needs of Calopteryx haemorrhoidalis populations.

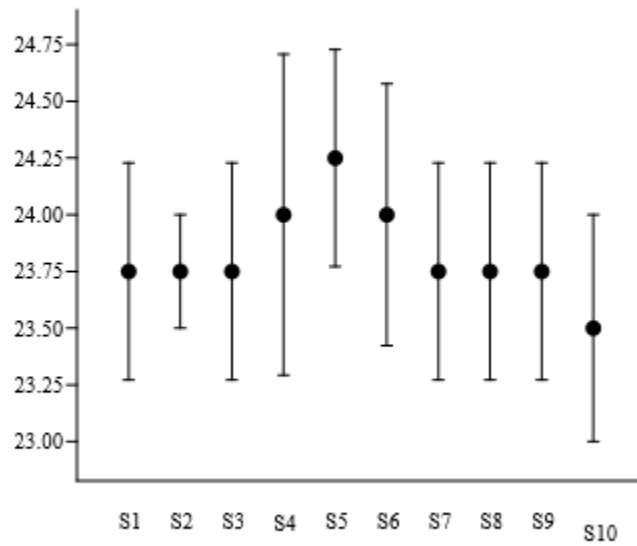


Figure 28: Temporel evolution of water temperature recorded at each station of larval collection

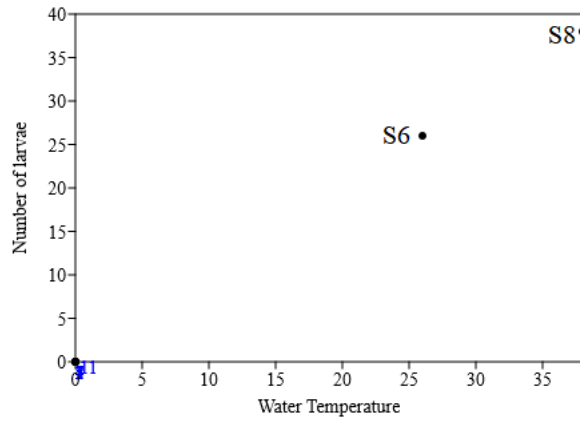


Figure 29: Impact of water temperature on larval observation

4.4 Larval stadia variation

Distribution of specimens of *Calopteryx haemorrhoidalis* across different developmental stages, with quantities for each stage:

- F1: This stage has 2 specimens. It represents the earliest stage of development with a head size of 1 mm, an abdomen of 3.5 to 5 mm, antennae of 1.5 to 2 mm, and a caudal blade of 3 to 5 mm.
- F2: There are no specimens in this stage. The F2 stage would have a head size of 1.5 mm, an 8 mm abdomen, 2 mm antennae, and a 4 mm caudal blade.
- F3: This stage has the highest number of specimens, totaling 40. The F3 stage is characterized by a head size of 2 mm, an abdomen length of 6 to 7 mm, antennae of 2 mm, and a caudal blade of 4.5 to 6 mm.
- F4: There are 5 specimens in this stage. The F4 stage features a head size of 2.5 mm, an 8 mm abdomen, 2 mm antennae, and a 6 mm caudal blade.
- F5: This stage includes 7 specimens. The F5 stage has a head size of 3.8 mm, an abdomen length of 11 to 13 mm, antennae of 3.2 to 3.7 mm, and a caudal blade of 7.8 to 8.2 mm.
- F6: There are 10 specimens in this stage. The F6 stage is characterized by a head size of 4 mm, an abdomen length of 12 to 18 mm, antennae of 5 to 6.5 mm, and a caudal blade of 11 to 12 mm.
- F0: This stage, representing the imago (adult) stage, has no specimens recorded. The F0 stage would have a head size of 4 mm, an abdomen length of 11 to 18 mm, antennae of 5 to 6.5 mm, and a caudal blade of 11 to 12 mm.

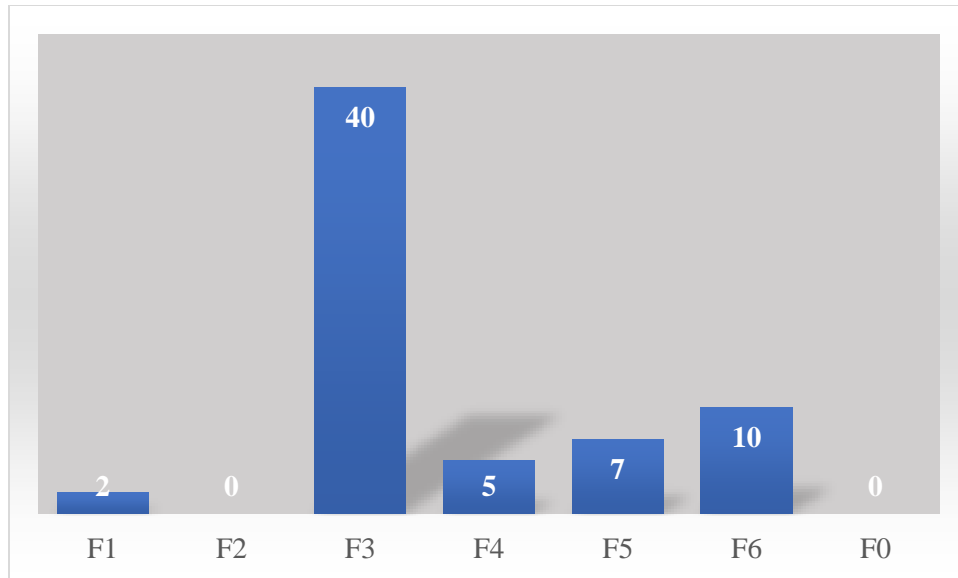


Figure 30: The developmental stages of *Calopteryx haemorrhoidalis*

Our study reveals that the larval stage of *Calopteryx haemorrhoidalis* is ubiquitous in almost all surveys, despite their minor concern and non-endemic nature. For the restoration of our Zygoptera population at each station in the study area, the species *Calopteryx haemorrhoidalis* is cosmopolitan, with its presence strongly linked to ecological conditions such as clean, well-oxygenated water devoid of pollution and fairly rapid currents, as well as behavioral conditions such as male territorial behavior, defending an area of about 5 m² for around twenty days, as described by **(Grand and Boudot,2006)**. For the Calopterygidae family, *Calopteryx haemorrhoidalis* **(Vander Linden,1825)** is characterized by males having a shiny reddish-brown to black body, while females have a shiny brown to green body with metallic coppery reflections. The undersides of the last three abdominal segments of males are vivid red. Wings are predominantly reddish-black, somewhat smoky, and marked with a brown spot or bar towards the apex in females **(Grand and Boudot,2006)**. Males exhibit territorial and satellite behavior, with a courtship display involving hovering and wing fluttering, abdomen raised to display the caudal appendages. The species occupies watercourses and fast-flowing microhabitats from high altitudes down to sea level **(Samraoui and Corbet,2000)**. The autochthonous nature of odonates poses a challenge in studies relying on the adult component of dragonflies, which scientifically cannot fully represent the analysis of odonate components. Therefore, the search for larval stages and exuviae remains the only tools to determine population structure and describe its characterization. At least once contacted, the latter proposal represents the majority of species comprising our

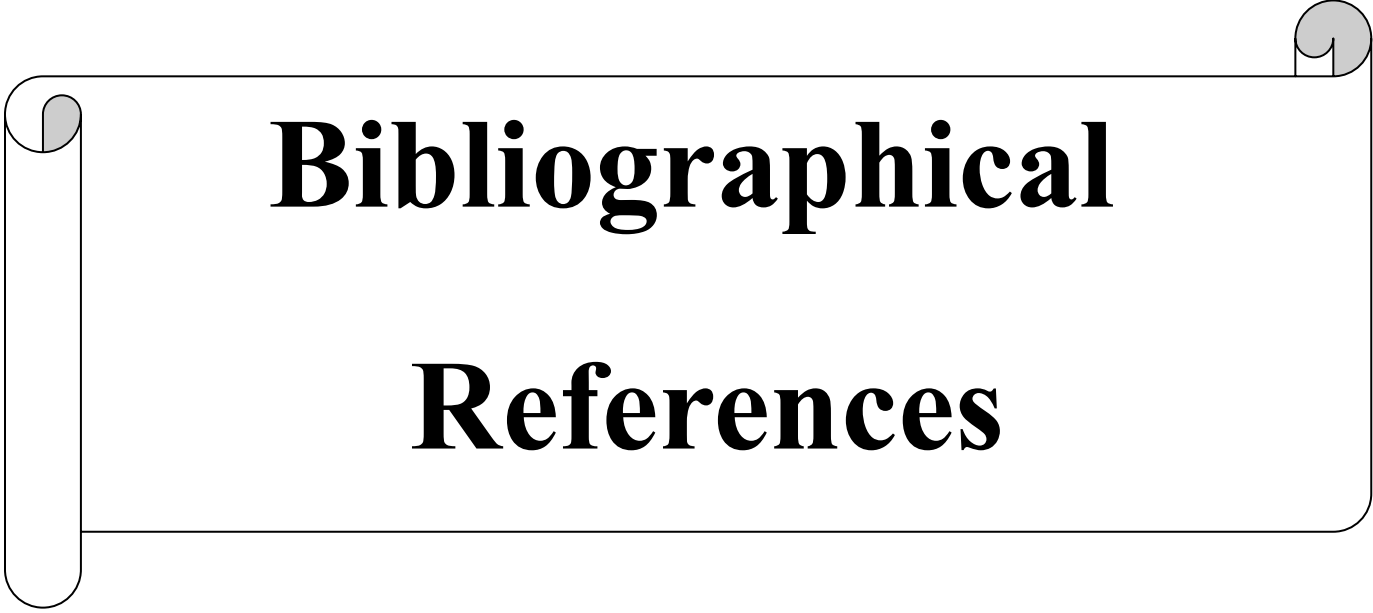
ecosystem. A comprehensive study of *Calopteryx haemorrhoidalis* has undertaken a meticulous examination of its developmental trajectory from larval stages to adulthood. Spanning seven discernible stages, ranging from the initial larval phase to the mature adult stage, the research has intricately elucidated the morphological characteristics and precise measurements of crucial anatomical features such as the head, abdomen, caudal blade, and antennae. A noteworthy revelation from this study lies in the distribution pattern of specimens across these developmental stages, unraveling intriguing variations. Particularly, the intermediate F3 stage emerges as the most prevalent, implying of an extended period of development during this phase. However, the absence of specimens in both the F2 and F0 stages.



Conclusion

Conclusion

In conclusion, this thesis has delved into the intricate world of *Calopteryx haemorrhoidalis*, shedding light on its developmental stages, ecological preferences, and distribution patterns. Through meticulous examination, it has become evident that *Calopteryx haemorrhoidalis*, despite being non-endemic and of minor concern, plays a significant role in freshwater ecosystems. Its presence is strongly linked to environmental factors such as clean, well-oxygenated water and rapid currents, highlighting its adaptability and ecological significance. Furthermore, this study emphasizes the importance of considering both larval and adult stages in ecological research, given the challenges posed by the autochthonous nature of odonates. By understanding the behavior, population dynamics, and habitat requirements of *Calopteryx haemorrhoidalis*, we can better inform conservation efforts aimed at preserving freshwater biodiversity. As we look to the future, further research into the interactions between *Calopteryx haemorrhoidalis* and its environment will be crucial for developing effective management strategies and safeguarding the health of aquatic ecosystems. By continuing to explore the biology and ecology of *Calopteryx haemorrhoidalis*, we can strive towards a more comprehensive understanding of its role in freshwater ecosystems and work towards its conservation for generations to come.

A decorative graphic of a scroll with a black outline and grey shading on the top and bottom edges, framing the text.

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Abstract

Abstract:

This study investigates the presence and ecological preferences of *Calopteryx haemorrhoidalis* in the wetland of Wad El-hamma, located in Khenchela, northeastern Algeria, within the semi-arid bioclimatic stage. Field surveys were conducted at ten stations over four sampling occasions from April 22, 2024, to May 11, 2024. The study revealed that *Calopteryx haemorrhoidalis* is prevalent in the area, thriving in clean, well-oxygenated waters with rapid currents. During the fieldwork, two groups of aquatic insects were recorded. The Ephemeroidea family constituted 46% of the total studied insect larvae (138 larvae), while Odonata species made up 54% of the recorded larvae. This Odonata group included three families and two suborders (Zygoptera and Anisoptera). Specifically, *Calopteryx haemorrhoidalis* accounted for 64 larvae, indicating a significant presence, followed by Anisoptera with 55 larvae, and *Platycnemis* with 40 larvae. The study meticulously examined the developmental stages of *Calopteryx haemorrhoidalis* from larval stages to adulthood, spanning seven stages. It described the morphological characteristics and measurements of key anatomical features. The distribution pattern showed that the intermediate F3 stage was the most prevalent, suggesting an extended developmental period, while the F2 and F0 stages were absent. Results indicated that the optimal temperature for the growth and reproduction of these insects ranges between 23°C and 25°C. The study emphasizes the importance of considering both larval and adult stages in ecological research to fully understand the role of *Calopteryx haemorrhoidalis* in freshwater ecosystems. The findings underscore the need for continued conservation efforts to preserve their habitats and ensure the health of aquatic ecosystems in El-hamma.

Key words: *Calopteryx haemorrhoidalis*, Wad El-hamma, Ecosystem.

Résumé

Cette étude examine la présence et les préférences écologiques de *Calopteryx haemorrhoidalis* dans la zone humide de Oued El Hamma, située à Khenchela, au nord-est de l'Algérie, dans un stade bioclimatique semi-aride. Des relevés de terrain ont été effectués dans dix stations au cours de quatre périodes d'échantillonnage, du 22 avril 2024 au 11 mai 2024. L'étude a révélé que *Calopteryx haemorrhoidalis* est répandu dans la région, prospérant dans des eaux propres, bien oxygénées et avec des courants rapides. Au cours du travail de terrain, deux groupes d'insectes aquatiques ont été recensés. La famille des Éphéméridés constituait 46% des larves d'insectes étudiées (138 larves), tandis que les espèces d'Odonates représentaient 54% des larves enregistrées. Ce groupe d'odonates comprenait trois familles et deux sous-ordres (Zygoptères et Anisoptères). Plus précisément, *Calopteryx haemorrhoidalis* représentait 64 larves, indiquant une présence significative, suivie par les Anisoptères avec 55 larves, et *Platycnemis* avec 40 larves. L'étude a minutieusement examiné les stades de développement de *Calopteryx haemorrhoidalis* de l'état larvaire à l'âge adulte, couvrant sept stades. Elle a décrit les caractéristiques morphologiques et les mesures des principales caractéristiques anatomiques. Le modèle de distribution a montré que le stade intermédiaire F3 était le plus répandu, suggérant une période de développement prolongée, tandis que les stades F2 et F0 étaient absents. Les résultats ont indiqué que la température optimale pour la croissance et la reproduction de ces insectes se situe entre 23°C et 25°C. L'étude souligne l'importance de considérer à la fois les stades larvaires et adultes dans la recherche écologique pour comprendre pleinement le rôle de *Calopteryx haemorrhoidalis* dans les écosystèmes d'eau douce. Les résultats soulignent la nécessité de poursuivre les efforts de conservation pour préserver leurs habitats et garantir la santé des écosystèmes aquatiques à El Hamma.

Mot clés : *Calopteryx haemorrhoidalis*, El Oued El Hamma, Ecosystème.

الملخص :

حققت هذه الدراسة في وجود وتفضيلات البيئة لحشرة *Calopteryx haemorrhoidalis* في مستنقع وادي الحامة في ولاية خنشلة، الواقعة في شمال شرق الجزائر ضمن المرحلة البيئية شبه الجافة. تم إجراء مسوحات ميدانية في عشر محطات على مدى أربع جولات من 2024-04-22 إلى 2024-05-11. كشفت الدراسة أن *Calopteryx haemorrhoidalis* شائعة في المنطقة، حيث تزدهر في المياه النظيفة والمشبعة بالأكسجين ذات التيارات السريعة. خلال العمل الميداني، تم تسجيل مجموعتين من الحشرات المائية. شكلت عائلة Ephemerae نسبة 46% من مجموع يرقات الحشرات المدروسة (138 يرقة)، بينما شكلت أنواع Odonata نسبة 54% من اليرقات المسجلة. تألفت مجموعة Odonata هذه من ثلاث عائلات ورتبتين فرعيتين (Anisoptera و Zygoptera). بشكل خاص، شكلت *Calopteryx haemorrhoidalis* 64 يرقة، مما يشير إلى وجود كبير، تلتها Anisoptera بـ 55 يرقة، و *Platycnemis* بـ 40 يرقة. بحثت الدراسة بعناية في مراحل نمو *Calopteryx haemorrhoidalis* من مراحل اليرقات إلى مرحلة البلوغ، متضمنة سبع مراحل. وُصفت خصائصها المورفولوجية وقياسات السمات التشريحية الأساسية. أظهرت نمط التوزيع أن المرحلة F3 المتوسطة كانت الأكثر شيوعًا، مما يشير إلى فترة تطوير ممتدة، في حين غابت المرحلتان F2 و F0. تظهر النتائج أن درجات الحرارة المثلى لنمو وتكاثر هذه الحشرات تتراوح بين 23°C و 25°C. تؤكد الدراسة على أهمية النظر في كل من المراحل اليرقية والبالغة في البحث البيئي لفهم الدور الكامل لحشرة *Calopteryx haemorrhoidalis* في النظم البيئية للمياه العذبة. تبرز النتائج الحاجة إلى استمرار جهود الحفاظ على الموائل وضمان صحة النظم البيئية المائية في الحامة.

الكلمات المفتاحية: النظم البيئية المائية *Calopteryx haemorrhoidalis* واد الحامة