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« Biodiversity and Environment »

Title

**Studies of soil fauna according to an
altitudinal gradient in the Wilaya of El Tarf**

Supported on : 24/06/2024

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Dedication

Praise be to God for allowing me to reach this stage in my academic career.

*Following the example of tenderness, patience and eternal love, my dear mother **Boudellal**
Beya*

To my dear father for his encouragement, tenderness and support

Nacer Rezig

*To my brothers **Ala, Chamsse El-Din and Maher** who have always supported and
encouraged me during my university studies.*

*To my beautiful sister "**Warda**"*

*To my nieces **Rassil, Arwa and Ghazal Rezig** the buds of love and the secret of our
happiness.*

*To my dear friend who is a sister to me **Badi Halima***

*To my dear **Dr. Rizzi Hadia** who accompanied me throughout my studies with her advice and
her constant guidance*

*To our "heart" teacher, Mme. **Chettibi Ahlam** for her kindness and patience*

To all my friends who shared the university journey with me

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ABSTRACT

Soil is the most diverse habitat on Earth and contains a large assemblage of species; these species are called soil fauna. This fauna includes a wide range of organisms ranging from microorganisms such as bacteria and fungi to macro-organisms such as earthworms, arthropods (insects, spiders, and mites) and others all animals.

The present work aims to determine the diversity of soil fauna at 7 sites at different altitudinal levels in the Wilaya of El Tarf, namely: Lake Oubeira, douar Brabtia, the cork grove of Ain Khiair, Matrouha, Zitouna, Ain Karma and Bouhadjar during the different seasons from October 2023 to April 2024.

Our results show that 22 families of soil fauna distributed differently in the areas studied, where we found 13 families in Ain Karma which was the most diverse area, followed by Brabtia, the Subéra raie of Ain Khiair and Bouhadjar with 8 families, then Lake Oubeira, Matrouha and Zitouna with 7 families.

The diversity and distribution of soil fauna are the result of the complex interaction between local climatic conditions, altitude variations and physicochemical properties of the soil. Understanding these dynamics is crucial for the conservation and sustainable management of terrestrial ecosystems, because it allows predicting how biological communities may respond to environmental changes at different spatial and temporal scales.

Keywords: Soil, Soil fauna, Wilaya of El Tarf, Altitude, Biodiversity

RESUME

Le sol est l'habitat le plus diversifié sur Terre et contient un large assemblage d'espèces, ces espèces sont nommées la faune du sol. Cette faune regroupe un large éventail d'organismes allant des micro-organismes comme les bactéries et les champignons aux macro-organismes tels que les vers de terre, les arthropodes (insectes, araignées, acariens) et d'autres petits animaux.

Le présent travail vise à déterminer la diversité de la faune du sol au niveau de 7 sites à différents étages altitudinaux de la Wilaya d'El Tarf, à savoir : Lac Oubeira, douar Brabtia, la subéraie d'Ain Khia, Matrouha, Zitouna, Ain Karma et Bouhadjar pendant les différentes saisons d'octobre 2023 à avril 2024.

Notre résultat a été montré que 22 familles des faunes du sol réparties différemment sur les zones étudiées, où l'on retrouve 13 familles à Ain Karma qui était la zone la plus diversifiée, suivie de Brabtia, la Subéraie d'Ain Khia et Bouhadjar avec 8 familles, puis Lac Oubeira, Matrouha et Zitouna avec 7 familles.

La diversité et la répartition de la faune du sol sont le résultat de l'interaction complexe entre les conditions climatiques locales, les variations d'altitude et les propriétés physico-chimiques du sol. Comprendre cette dynamique est crucial pour la conservation et la gestion durable des écosystèmes terrestres, car elle permet de prédire comment les communautés biologiques peuvent réagir aux changements environnementaux à différentes échelles spatiales et temporelles.

Mots clés: Le sol, La faune du sol, Wilaya d'El Tarf, Altitude, Biodiversité.

الملخص

التربة هي الموائل الأكثر تنوعًا على وجه الأرض، وتحتوي على مجموعة كبيرة من الأنواع، وتسمى هذه الأنواع بحيوانات التربة. تشمل هذه الحيوانات مجموعة واسعة من الكائنات الحية تتراوح من الكائنات الحية الدقيقة مثل البكتيريا والفطريات إلى الكائنات الحية الكبيرة مثل ديدان الأرض والمفصليات (الحشرات والعناكب والعث) وغيرها من الحيوانات الصغيرة.

يهدف العمل الحالي إلى تحديد تنوع حيوانات التربة في 7 مواقع على مستويات ارتفاعية مختلفة بولاية الطارف، وهي: بحيرة أوبيرة، دوار برابطية، بستان الفلين عين خيار، مطروحه، الزيتونة، عين كرامة وبحجر خلال فترة مواسم مختلفة من أكتوبر 2023 إلى أبريل 2024.

أظهرت نتائجنا أن 22 عائلة من حيوانات التربة توزعت بشكل مختلف في المناطق المدروسة، حيث وجدنا 13 عائلة في عين كرامة التي كانت المنطقة الأكثر تنوعًا، تليها برابتيا، وسوبرا راي عين خيار وبوهاجر مع 8 عائلات، ثم بحيرة أوبيرا. ومطروحه والزيتونة وعددهم 7 عائلات.

إن تنوع الحيوانات الموجودة في التربة وتوزيعها هو نتيجة للتفاعل المعقد بين الظروف المناخية المحلية وتغيرات الارتفاع والخصائص الفيزيائية والكيميائية للتربة. يعد فهم هذه الديناميكيات أمرًا بالغ الأهمية للحفاظ على النظم البيئية الأرضية وإدارتها المستدامة، لأنه يسمح بالتنبؤ بكيفية استجابة المجتمعات البيولوجية للتغيرات البيئية على مستويات مكانية وزمانية مختلفة.

الكلمات المفتاحية: التربة، حيوانات التربة، ولاية الطارف، الارتفاع، التنوع البيولوجي.

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INTRODUCTION



INTRODUCTION

Biodiversity is currently a major issue in ecological research, both in terms of its role in ecosystems, its determinism and its valorization in the field of environmental conservation (Solbrig *et al.*, 1994).

Biodiversity is the life that surrounds us in all its forms. It is essential for all vital processes and services provided by the ecosystems of the planet. It is the result of several million years of evolution combined with centuries of human activity (gathering, demolition, agriculture, urbanization, etc.) (CDB, 2010). It refers to the variety within living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they form part. It is also diversity within species, between species and between ecosystems.

Algeria is characterized by a remarkable biodiversity linked to the diversity of its climate, geomorphology and ecosystems. Some ecosystems are of particular interest in terms of landscape and cultural richness of biodiversity.

Algeria has large forests (21% of the country's total area in 1830), and an exceptionally abundant, diverse and rich fauna. What, as evidenced today, is still alive and dynamic, therefore it represents a national and international heritage of invaluable value (DGF, 2004). Especially in the northern part of the country which is directly connected to the Mediterranean Sea, where these areas benefit from a very large environmental diversity of plants and animals. Among these regions we have the region of El Tarf.

El-Tarf is located in the far northeast of Algeria on the Tunisian border. It is characterized by its Mediterranean climate, which gives it an enormous natural wealth in various reliefs and altitudes. This wilaya contains a nature reserve recognized as a biosphere reserve by UNESCO in 1990, which is the ElKala National Park (PNEK).

The PNEK is considered a real jewel of the Mediterranean basin due to its rich biodiversity and the abundance of its natural resources. This biosphere is characterized by the presence of three "marine, lakes and forest" ecosystems, extending over eight communes of the wilaya of El-Tarf



INTRODUCTION

Soil is one of the most important reservoirs of biodiversity. Indeed, soil biodiversity corresponds, in many cases, to that observed above the surface of the soil (Heywood, 1995). So soil is the most diverse habitat on Earth and contains a wide assembly of species, these species are called soil fauna (Andrene, 1999).

The soil has many functions, since the main since the birth of mankind has been to feed people, it is a function oriented towards agricultural production. In this sense, the soil is first and foremost a medium of crops, to provide plants with water, air and nutrients, all necessary for good soil fertility.

Soil biological activity is closely related to biomass, i.e. the amount of living organic matter present in the soil (Benslama, 1998).

Soil fauna and its diversity are widely recognized for their participation in the physical, chemical and biological processes involved in the functioning and evolution of natural soils (Barrios, 2007 and Lavelle *et al.*, 2006).

According to (Bachelier, 1978), the role of soil fauna is important in the genesis and dynamics of soils, promoting the overall biological activity of the soil, as it indirectly promotes its structure. But the number of such soil fauna can also have a more direct effect on this structure, either by closely amalgaming the decomposing plant debris with the mineral part of the soil, or, like other animals, by facilitating the deep penetration of organic matter throughout the food chains.

The porosity, structure, water retention power and even the nature and saturation of the soil absorbent complex can be completely altered by animal life.

In the Wilaya of El Tarf, there are several sites or each has its own characteristics. Some of them are considered wetlands such as Lake Oubeira and others are considered forest areas, such as Douar Brabtia, Ain Khiar Suberaie and Zitouna. Others, on the other hand, are classified as steppe areas for agriculture, such as Matrouha, Ain Karma and Bouhadjar.

The objectives of this study are to know the richness of soil fauna in seven different sites of El Tarf namely: “Lake Oubeira, Douar Brabtia, the subarea of Ain Khiar, Matrouh, Zitouna, Ain Karma and Bouhajar” and how does the altitude change affect soil biodiversity?

The present work will therefore focus on the following four chapters:



INTRODUCTION

- ✓ The first chapter presents general information on the soil and elements on the diversity of pedofauna;

- ✓ The second chapter represents the experimental part, which includes the presentation of the study area, a description of the methodology, biological material, field sampling methods and methods used in the laboratory;

- ✓ The third chapter summarizes the results achieved during the study period;

- ✓ The fourth discussion chapter;

- ✓ And we will end with a conclusion.

Chapter I: Generality



Chapter I: Generality

I. The Soil

I.1. Soil Definition

The soil is a formation of the surface, it constitutes the essential element of the biotopes specific to continental ecosystems. Their ensemble, called the Pedosphere, is the result of the interaction of two biospheric compartments: the atmosphere and the surface layers of the lithosphere (Manneville *et al.*, 1999).

The soil is the upper layer of the terrestrial crust of mobile structure and variable thickness, more or less coloured by humus. The result of the slow and progressive transformation of the underlying parent rock, under the influence of physical, chemical and biological factors. (Manneville *et al.*, 1999).

I.2. Pedogenesis

The soil is the mobile surface layer of the Earth's lithosphere, with a variable thickness of a few centimeters to several meters resulting from the transformation of the underlying parent rock, under the influence of various physical, chemical and biological processes. (Demolon, 1932; 1966; in Samai, 2017). It consists of a mixture of mineral and organic materials, which serves as a support and natural medium for the growth of plants (Legros, 2007; in samai, 2017). This layer, also called paedological coverage, is the resulting over time of several genetic factors the mother rock on which the soil developed (Boulaine, 1989; in Samai, 2017).

Soil is a complex system of different raw materials interacting with each other. Soil properties result from the effect of all these interactions (Mac Carthy *et al.*, 1990; in Samai, 2017). It is the interface between the atmosphere, hydrosphere, lithosphere and living organisms.

I.3. Soil constituents

According to (Buttler, 1992), a volume of soil consists of solids, liquids and gases:



I.3.1. The solid phase

It contains mineral and organic elements: The mineral elements are directly the result of the mechanical disintegration and chemical decomposition of the rocks of the substrate or of the supplied materials, alluvions, colluvions and wind deposits, distinguished as: sand (2mm-50um), lemons (50um-20um) and clay (<2um).

The proportions of the latter define the soil texture and the ways in which these elementary particles are assembled represent the structure. The organic elements of the soil are composed of organic debris: animal waste (détritius, wax,...), vegetable waste (leaves, branches, tree trunk roots) which constitute the largest mass (**Roland, 1988**).

I.3.2. Liquid phase

It is the volume that partially or completely fills the open spaces (pores) included between the solid particles of the soil. It is composed of water and mineral or organic substances soluble in water. The presence of water in the soil is of fundamental importance for various reasons, namely: (**Roland, 1988**).

- Water is the essential element for soil fertility, because their presence makes possible chemical reactions between various constituents of the soil, and the birth of neoformations of molecules either mineral or organic.
- Water is the only solvent in the soil and the only carrier of various substances. Only the movement of water causes the translocation of both dissolved and suspended substances

I.3.3. The gas phase

It occupies the free spaces left between the solid particles of the soil and which are not filled by the liquid phase, the gas phase is composed of gases as well as air: water vapour and O₂, CO₂, N. These gases come from the alteration of rocks, the decomposition of organic matter and human input. These soil constituents are organized as we move to higher levels of organization in aggregates (**Roland, 1988**).



I.4. The characteristics of the soil

I.4.1. Physical characteristics

I.4.1.1. The texture

It is the granulometric composition of the soil, i.e. the proportion of each of its solid constituents that have different sizes. It depends on the nature of the fragments of the mother rock and the minerals derived from its decomposition which contains the mineral fraction. The granulometric analysis allows to distinguish enlarged elements: stone (more than 2mm), gravel (2 to 20 mm), fine elements: sand (2mm to 20 u), the lower limit of its sand is also 50 u including some classification of granulometry and lemon (between 20 um or 50 um), clay (< 2 u) (**Benslama-Zanache, 1998**).

I.4.1.2. The structure

This is the way different particles of the soil are organized. The isolated particles, once assembled, appear as larger particles "bushes" and there are several types of structures: granular, angular, prismatic and lamellar (**Benslama-Zanache, 1998**).

I.4.1.3. Porosity

The porosity of a horizon is an essential notion for everything related to water reserve, fluid circulation (water and air) and rooting possibilities. Unfortunately, its components (volume, dimension, organization of voids) are not truly accessible to the macromorphological description on the ground, the porosity can be approached and quantified seriously only by appropriate physical techniques (laboratory measurement) or by observations and measurements on thin blades (micro-morphology and image analysis) avoiding the artifacts related to the drying of samples (**Benslama-Zanache, 1998**).

I.4.1.4. The atmosphere of the soil

When the pores are not full of water, the soil area is confined, the solid parts obstructing exchanges with the outdoor air. The porosity of the soil and its distribution therefore largely condition the gas exchanges between the ground and the atmosphere.

Despite the difficulties of its measurement, the composition of the ground air is not the same as that of the ambient air (**Benslama, 1996**).



I.4.1.5. Soil ventilation

It is a more complex phenomenon due to the nature of a porous system whose cavities are occupied in fluctuating proportions by water and air. As long as adequate ventilation ensures free circulation of oxygen in the soil, asphyxiation of neither micro-organisms nor roots to be feared, respiratory activity is morally assured (**Duchaufour, 1977**).

I.4.2. Physicochemical characteristics

I.4.2.1. pH

The pH notion important measures soil acidity on a scale of 1 to 14, a medium is neutral when its pH is 7. Below it is acidic, above it is basic or alkaline. Calcareous soils are generally basic, while sandy or very rich in organic matter are rather acidic. Most plants accommodate to a pH around neutrality (6 to 7.5), but some require acidic soil (acidophilic plants) or, on the contrary, limestone (**Duchaufour, 1977**).

I.4.2.2. The absorbent complex

The term "absorbent complex" refers to the set of colloids (in the broad sense of the term, humic and clay compounds) with negative charges capable of holding cations in the so-called interchangeable form, i.e. can be replaced by other cations, under certain precise conditions. (**Duchaufour, 2001**).

I.5. Soil solution

La réserve en eau du sol assure la quasi-totalité des besoins en eau de la plante : selon les espèces végétales, il faut de 250 à 800 litres d'eau pour un kilo de matière organique sèche. Par ailleurs l'eau dissout les éléments nutritifs pour constituer la solution du sol. L'alimentation du végétales s'effectue à partir de la solution du sol. Elle assure la lixiviation des cations lors de la pédogénèse elle est le siège de nombreuses processus de solubilisation, ou d'insolubilisation par rapport aux constituants solides qui traduisent souvent une évolution à long terme. (**Benslama-Zanache, 1998**).



I.6. The different horizons of the ground

I.6.1. Horizon O

This horizon is organic (rich in humus) and contains partially decomposed plant residues that are almost unrecognizable in the soil. It contains 30% organic matter (Annonyme, 2024).

I.6.2. Horizon A

It contains organic matter and minerals. In rare cases, it is caused by the penetration of organic matter into the soil in the form of soluble components. However, in general, this is the result of a mechanical mixture of living organisms (worms, insects) in the soil, or in the case of cultivated soils, this can materialize at the intervention of tools (Annonyme, 2024).

I.6.3 Horizon B

It is rich in various constituents: clay, iron, organic matter, calcium carbonate, etc.

These components come mainly from the washing of percolation waters (rainwater, irrigation water) of the upper horizons, in particular the O horizon, which is characterized by their color, structure, nature of composition and granulometry (Annonyme, 2024).

I.5.4. Horizon C

It is caused by the alteration of the rocky substrate. Its conversion is still limited, so its original characteristics (litage, schistosity, mineral) are still very obvious (Annonyme, 2024).

I.6.5. Horizon R

It corresponds to a hard rock substrate (granite, limestone, gravel, etc.) (Figure 01). All soils do not necessarily have the same organization. Some horizons may be more or less important, some may be absent.

There are thus soils that are poorly developed, poorly thick, and poorly structured in horizons. The more the soil moves, the thicker the terrain is. Therefore, pediatricians distinguish several types of soils that reflect different stages of development. The differentiation of the soil does not depend on its age: a poorly differentiated soil may be older than a recent and highly differential soil. For example, a limestone soil has very few horizons and certain factors (such as steep slopes) can promote erosion and hinder soil differentiation (Annonyme, 2024).

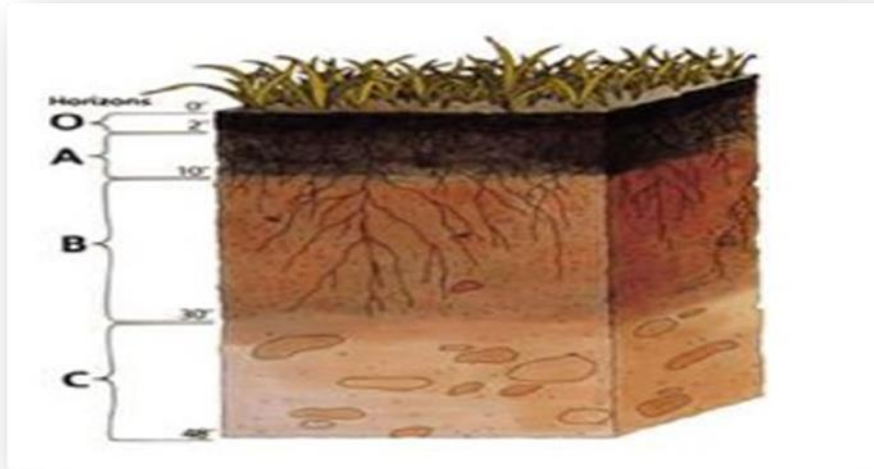


Figure 01: The different horizons of a soil profile (Annonyme, 2024).

I.7. The biological component of the soil

All levels of the food chain are found in soils, with the exception of photosynthetic organisms, which are limited to the surface of the soil. Decomposers, on the other hand, are very abundant there; they transform organic matter and mineralize it. This diversity of trophic levels can be found within the same taxonomic group: for example, we find fungivorous, bacteriovoric, herbivore or predator nematodes that are distinguished by the shape of the mouthpieces. In Mediterranean environments, climatic and paedological conditions have a strong effect on reducing the dynamics of community succession (Véla and Benhouhou, 2007). The policies implemented and adopted have led to the degradation of the agroecosystems for which the current attempts are to restore the functions (Boudiaf Nait Kaci *et al.*, 2014).

II. Soil fauna

II.1. Definition of soil fauna

The pedofauna or soil fauna is the whole of wildlife carrying out all or part of its life cycle in the soil. The behavior of these organisms responds to the constraints imposed on the soil, and the intensity and nature of these constraints are closely linked to their size, access to water and nutrients (Benjamin, 2010).



Generality

The soil fauna is in balance. All relationships, most easily observable in large terrestrial or aquatic species, exist within soil biocenoses: predation, parasitism, symbiosis, etc. Each species occupies its own niche and therefore plays a special role in the global exchange of energy and material in the soil. However, that balance is fragile. Most often, these animals are eurybytes, which means that they are extremely sensitive to small variations in pH, humidity, temperature, ventilation or soil mineral and organic content.

II.2. Soil fauna classification

II.2.1. Microfauna

With a length of between (< 0.2 mm), it mainly gathers microorganisms that need liquid water to live. Protozoa are found to be large consumers of bacteria; they induce the maintenance of the youth of bacterial populations, which must reproduce to combat this predation. We can also observe Metazoaries, essentially Nematodes (worms without segmentation), who intervene in the first phase of the decomposition of plants by breaking them, which then facilitates the action of bacteria and fungi. They also participate in the braking of horizons, activating the rise of mineral elements to the surface (**Gobât *et al.*, 1998; Martins *et al.*, 2015**)

II.2.2. Mesofauna

This category of invertebrates includes the majority of Nematodes, Acarians, Collemboles, and Protours, whose length varies between 0.2 and 4mm with a diameter of 0.1 to 2mm. Young larvae of macro arthropods typically fall into this category (**Nadama, 2006**).

II.2.3. Macrofauna

It can be easily spotted with the naked eye, especially because its size ranges from 4 to 80 mm, it mainly occupies the surface layers, grouping earthworms, some molluscs, arachnids, crustaceans and myriapods. The earthworms or lombrics have a primary role in brassing the different horizons, they ingest the soil that they throw away elsewhere bringing organic elements down. Their activity also improves soil ventilation and permeability.

Finally, their substantial biomass constitutes a reserve of nitrogen for the soil (**Nadama, 2006 ; Machado *et al.*, 2009**).



II.2.4. Megafauna

This class represents vertebrates that have a size exceeding 80 mm in length. They act on the soil by digging their galleries, reptiles, digging mammals such as peasants, prairie dogs, marmots, also earthworm-like amphibians, and apod and digging reptile (Gobat *et al.*, 1998; Peres, 2003). (Figure 02)

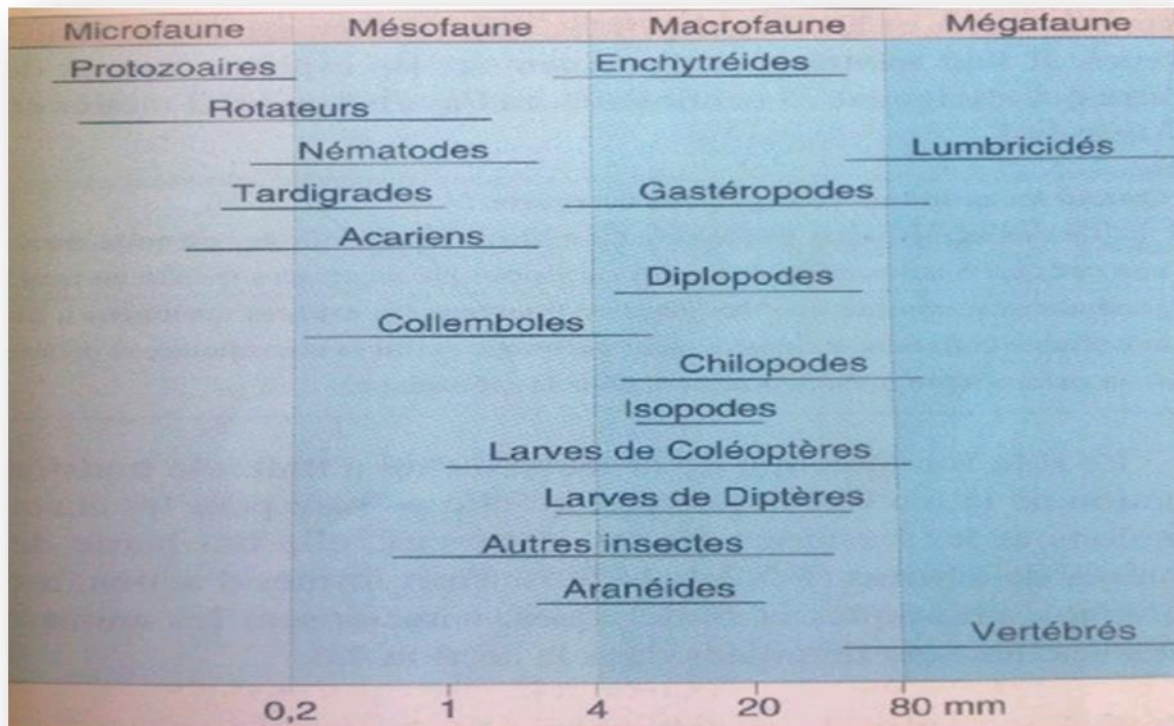


Figure 02: Classification of soil fauna by size (Gobat *et al.*, 1998)

III. Ecological importance of soil fauna

Soil fauna plays a decisive role in various processes of soil evolution. Thus, according to (Dejean *et al.*, 1986), the most important role played by soil invertebrates is their contribution to the degradation and mineralization processes of the organic macro-particles of the lithium, and thus to the rapid recycling of the minerals contained in the litium; they play a mechanical role in the nutrient cycle by fragmenting and ingesting the materials from the lithum, thus



Generality

facilitating their biodegradation. This biodegradation facilitates the action of microorganisms that break down and mineralize debris (Lavelle *et al.*, 1994). Reducing soil fauna could reduce the quantity and quality of carbon reserves in the soil and ultimately lead to the degradation of its physical and chemical properties. Soil organisms provide ecosystem services.

III.1. Action of Fauna on the soil

Soil microfauna exercises a triple mechanical, chemical and biological action on soils. These three actions participate both in soil formation (pedogenesis) and in the maintenance of soil fertility.

III.1.1. Mechanical action

Animals in the soil fragment organic matter. Earthworms roughly fragment them. Then, in order, myriapods, collemboles, molluscs and, finally, nematodes proceed to a more and more fine fragmentation. This fragmentation has the effect of significantly increasing the area of attack of organic matter by bacteria and soil fungi. The passage of organic matter into the digestive tract of these animals has the effect of mixing it with various intestinal secretions, with humic colloids or cytophageal jelly. This is followed by the formation of stable aggregates, the most notable of which are those left by the lombrics. (Girard *et al.*, 2005) All these animals participate in the active transport of organic matter through the horizons of the soil. In addition, by digging, these animals improve soil ventilation as well as water circulation. It is estimated that earthworms alone provide more than 50% of the macroporosity in the soil, whereas mechanical work (work) would provide only a quarter of it.

III.1.2. Chemical action

Earthworms do not merely distribute organic matter in the profile of a soil. Because calcium is essential to their metabolism, earthworms also circulate this element. It is believed that these animals, by raising this element to the upper layers, are opposed to washing and, consequently, to decalcification of the soil. The strawberries are very rich in potassium, ammonia, phosphorus and magnesium. These elements are mostly better interchangeable and better assimilable when they have passed through their digestive tract than when they are



Generality

adsorbed on the argilo-humic colloids. Soil fauna plays a fundamental role as an intermediary between soil and plant. (Girard *et al.*, 2005)

III.1.3. Biological action

All animals in the soil are necessarily microphytophages. The reason for this is that the food that these animals eat must be covered with bacteria, myceliums or cyanobacteria. It is certain that many of these microorganisms are destroyed by the digestive processes (mostly saprophytes). But it is also likely that other of these organisms, not destroyed, are stimulated during this transit. This is probably the case with humidifying microflora organisms, since humus is found to form more quickly from animal feces than from plant debris that has not undergone intestinal transit. (Girard *et al.*, 2005)

Chapter II: Material and Methods



Chapter II: Material and Methods

I. Description of the study area: La willaya d'El Tarf

I.1. Geographical location

El Tarf has a total area of 2,904 km², and is bordered by the Mediterranean Sea to the north, Tunisia (Governorate of Jendouba) to the east, Souk Ahras (Guglielmo), and Annaba (Annaba). (Figure.03) (Grine, 2021)

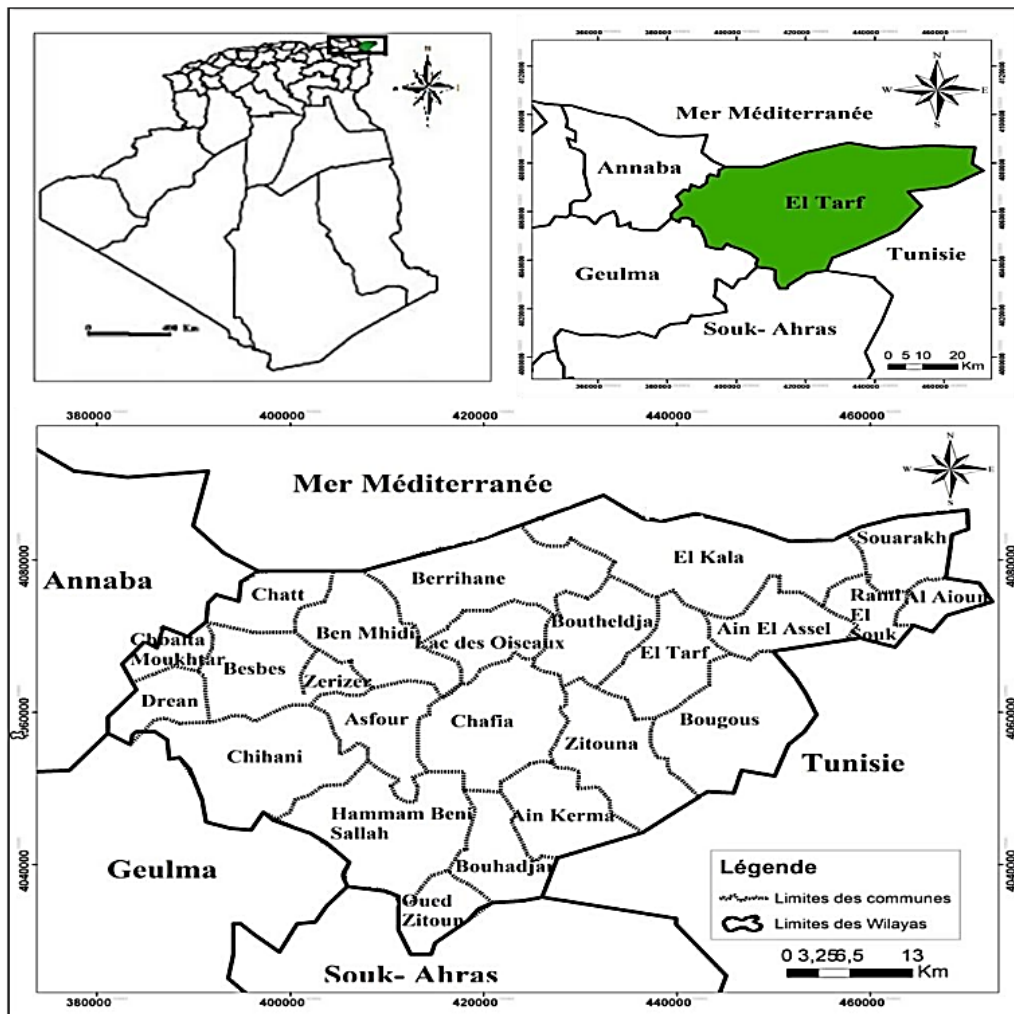


Figure 03: Geographical map of the study area (Chettibi, 2020).



I.2 Geomorphology

The region of El Tarf is characterized by different geomorphological units which are as follows: The Marais of the Mekhada which constitute a particular environment where during the winter a lake and during the summer pastures, the Grabbens which are represented by different plains, the Horests which are representing by the rocks and clay of the Numidian, the dunar massive and the rocky massives, the terraces and the different lakes, the mountains, hills, oads such as: El Kebir Est, Bounamoussa, Seybouse and finally the Plains mention those of Annaba; of El Tarf; of Bouteldja; El Asfour and of Oum Teboul. (Chettibi, 2020) (Fig.04)

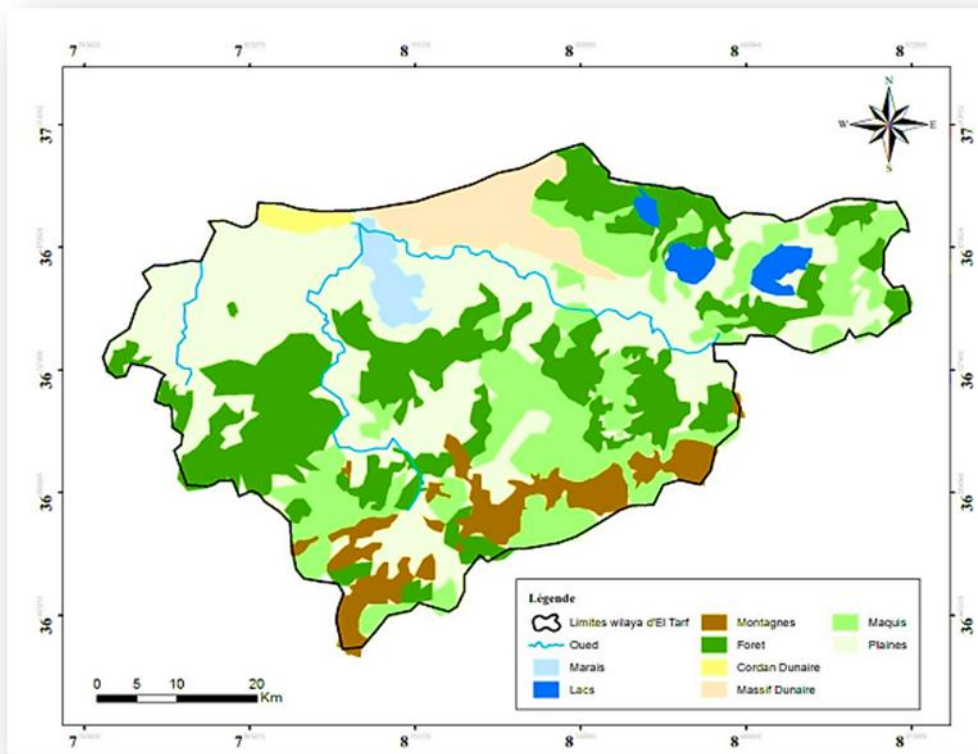


Figure 04: Map of the geomorphological units of El Tarf (Chettibi, 2020)



Material and Methods

I.3 Climatology

The climate is warm, temperate from El Tarf. In winter, there is much more precipitation than in summer. This climate is considered Csa "Mediterranean climate" according to the Köppen-Geiger climate classification (Grine, 2021). The average annual temperature in El Tarf is 18.3 °C. The average annual rainfall reached 694 mm.

I.4 The slope

The topography of the wilaya of El Tarf is integrated globally into the reliefs of the northeastern end of the Algerian Tellian chain. The de-levellations in the mountain range are generally greater than 300 m between the bottom of the oaks and the top of the reliefs. The slopes are very strong on the mountain level (>25%), medium on the low reliefs (12.5- 25%), weak on some hills and coastal Danube cordons (3-12,5%) and very weak (Chettibi, 2020). (Fig.05)

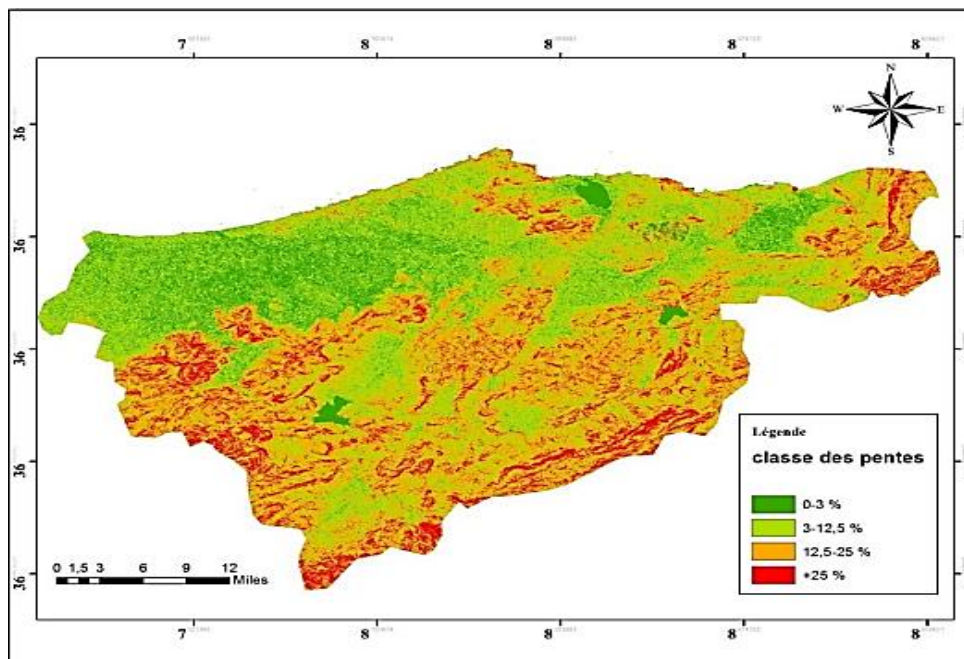


Figure 05: Slope map of the Willaya of El Tarf (Chettibi, 2020)



I.5 Hydrology

The region is drained by a very dense hydrographic network, the main oads of which are: oed El-Kebir, oed Bounamoussa and oed Seybousse. The region is also rich in groundwater (multiple springs), dams, lakes and hilly reservoirs.

I.6 Natural richness

I.6.1. Fauna

The heterogeneity of the natural habitats of the El Tarf region is home to a great diversity of wildlife and especially bird fauna. **Bouazouni, 2004** reports on endangered species such as the barbaric deer, the spotted hyena and the golden chacal, the strained hyena, the pig-eepic, the sweet fox, the laurel, the white cygnus, the ash goat and other water ducks.

I.6.2 Flora

Due to the diversification of the soil of the region, the flora of El Tarf is rich and diverse. The PNEK is home to a third of all Algeria's flora, approximately 850 species (**De Belair, 1990**), including: sea pine, oak oak, Aleppo pine and zen oak. Wild olive trees, freezers, province orchids and water chestnuts.

II. Description of study sites

II.1 Oubeira lake

Lake Oubeira is a freshwater pond of 2200 ha that lies on the coast 25 meters (**Joleaud, 1936**). It is the deepest freshwater lake in the PNEK. Its depth does not exceed 2 m and it is part of a quadrilateral of 5 x 4 km, developing about 19 km of shores. Its watercourse covers an area of 125 km², of which 40 km² are in flat terrain and 85 km² in hills. Functioning in an endogenous way, it is fed by about a dozen oads (Demnet El-Rihan, Boumerchen, Dey Elgraâ, oed Messida for the main ones...). In the winter, during heavy rainfall, the waters of the Oued El-Kebir reach the lake mainly through the Oud Messida which is born in the south. In summer, when the level of the ElKebir oak is at its lowest, the hydrological system operates in the opposite direction, the Messida having the peculiarity of sinking in both directions (**Bougessa, 1993 in Ammouchi et al., 1999**).



Figure 06: Oubeira Lake (Rezig, 2024)

II.2 Douar Brabtia

The Douar Brabtia, located at approximately $36^{\circ}51'10.678''$ N and $8^{\circ}19'58.693''$ E. This site is a small village located in the town of El Kala, in northeastern Algeria, in the wilaya of El Tarf. With its rich natural and cultural heritage, is a locality that embodies the diversity of the El Kala region

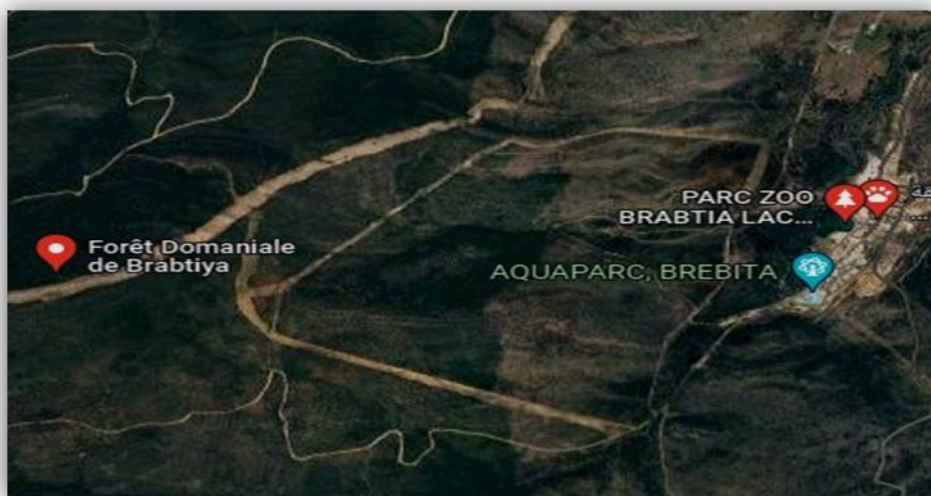


Figure 07 : Localisation géographique du Douar Brabtia



II.3 Ain Khiair's Sunderland

It is an extremely rare natural wetland of the Mediterranean region that can be considered a site of international importance. It is located 6 km north-east of the town of the commune of El Tarf with an elevation of 23 to 35 meters (average altitude) and area: 170 hectares in full water situation. Its geographical coordinates in the center are $36^{\circ} 48' 02,93''$ North – $8^{\circ} 19' 22,82''$ East, bordered by the agglomeration of Ain khiair at the eastern border and the western border of the Mechtat d'Ougbetcheir.



Figure 08: Geographical location of the Ain sub-area (Google earth, 2024)

II.4 Matrouha

The village of Matrouha ($36^{\circ} 43' 7''$ north- $8^{\circ} 16' 54''$ east), is a village in the commune of El Tarf with an area of 71160 m². Located near the village of Douar Guergour and the small town of El Tarf.



Figure 09: Geographical location of Matrouha (Google earth, 2024)

II .5 Zitouna

The municipality of Zitouna ($36^{\circ} 40' 05''$ north, $8^{\circ} 14' 5''$), with an area of 159.6 km². Located in northeastern Algeria to the southeast of the wiaya of El Tarf at 111 metres of maximum altitude. It is a municipality on the border with Tunisia.

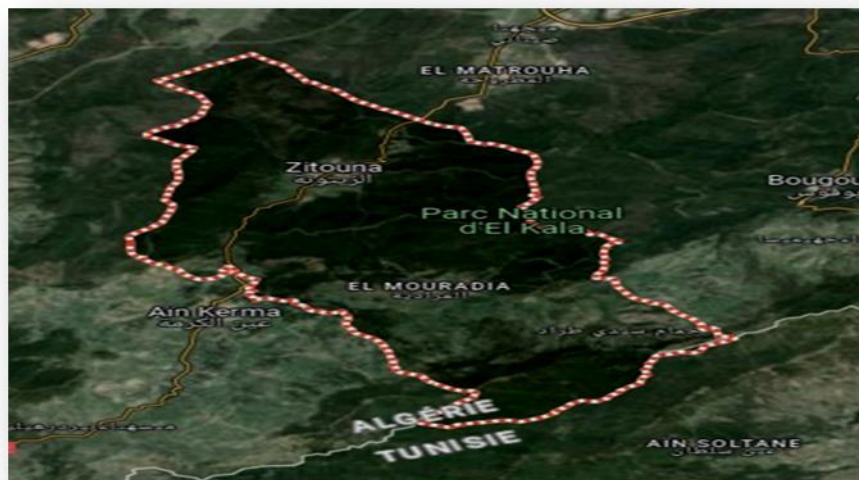


Figure 10: Geographical location of Zitouna (Google earth, 2024)



Material and Methods

II .6 Ain Karma

Ain Karma ($36^{\circ} 35' 38''$ north, $8^{\circ} 12' 04''$), with an area of 110,84 km². Located near the village of Mechtat Sidi Ahmed Bohli and M eradia and close to the town of Oum La bayene and the village Statir with a maximum altitude of 366 meters.



Figure 11: Geographical location of Ain Karma (Google earth, 2024)

II .6 Bouhadjar

Bouhadjar is a municipality in the province of El Tarf in northern Algeria. The municipality of Bouhadjar ($36^{\circ} 30' 11''$ north, $8^{\circ} 06' 19''$) has an altitude of 243 meters. It is bordered to the north by Cheffia, to the North-East by Ain Karma, south-east by Tunisia, southwest by Oued Zitoun and to the west by Hammam Beni Salah.

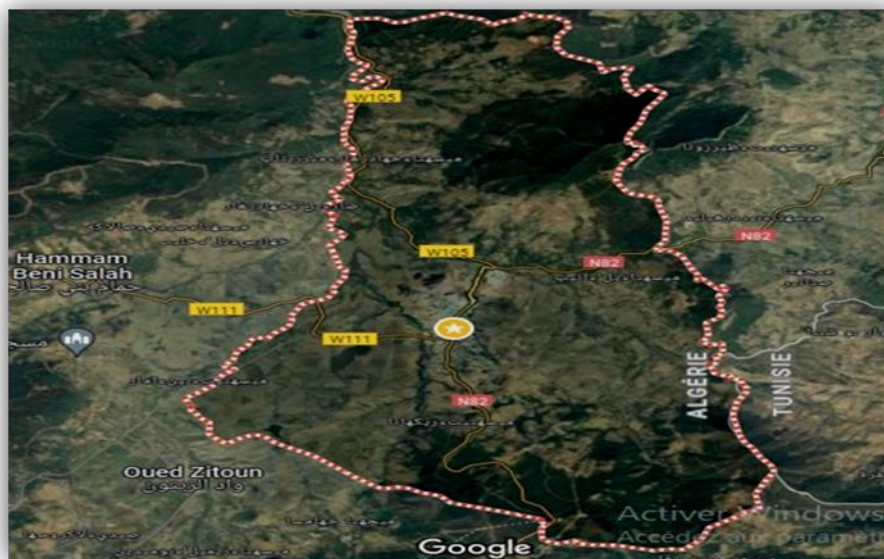


Figure 12: Geographical location of Bouhadjar (Google earth, 2024)

III. The Biological Model: Soil Fauna

The soil fauna is extremely numerous, although very variable from season to season or from soil to soil, it can be estimated that its weight per hectare is on average 2.5 tons. In some soils, whether naturally rich in organic matter, or enriched with debris, compost or crop residues, this weight reaches 5 tonnes per hectare and even more (**Annonyme 2024**).

The soil fauna is very varied, most of its representatives are microscopic animals (a few tenths of a millimeter): protozoa (nude amibes, theke amibs, flagellates, ciliates), tardigrades, rotiferos, nematodes, molluscs. Others are animals that will be attributed to the microfauna (less than one centimeter): various insects, especially their larval ecophases (collemboles, diptères, coléoptères, lepidoptères, etc.), myriapods, isopods, enchytraeided worms, pseudo-scorpions, etc. Finally, a number of species will be part of the macrofauna (imago of insects, lombricidal earthworms, molluscs, arachnids, reptiles, micromammifères rodents and insectivores, etc.) (**Annonyme 2024**).



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Tableau 1 : Classification de la pédafaune en fonction de la taille (Freyssinel, 2007)

| « classe » | taille (mm) | exemples |
|------------|-------------|---|
| Microfaune | < 0,2 | protozoaires, nématodes, rotifères, tardigrades |
| Mésofaune | 0,2 à 4 | Enchytréides |
| | | microarthropodes insectes aptérygotes (protooures, diploures, collemboles) acariens, myriapodes (pauropodes, symphytes) |
| Macrofaune | 4 à 100 | lumbricidés, mollusques |
| | | macroarthropodes insectes ptérygotes, myriapodes (diplopedes, chilopodes) crustacés isopodes |
| mégafaune | >100 | vertébrés (rongeurs et insectivores terricoles) |

IV. Sampling methods

As part of our study, the sampling was done in a random manner and was done using a metal square measuring 20 cm to 20 cm and 10 cm in height to be sampled over a period of three seasons of the year (autumn, winter and spring) between 2023-2024 During each season we make many exits for the sampling of the slate and the horizon.



Figure 13: Place the metal square



- We make a square above the surface of the ground



Figure 14: a square above the surface of the ground.

- With the help of a pile, we collect samples from the soil, we remove the first layer of soil that is humus and put it in a sachet. We dig 10 cm deep and put the ground in another sachet. Each sample is placed in its own label bag, site.



Figure 15: Sampling of horizon and litter



Material and Methods

V. Fauna soil extraction: Berlese device

Berlese-Tullgren It is a selective (dynamic) method by which microarthropods (Acaridae, collamboles and other pterygot insects) are harvested without the intervention of an operator. (Amri, 2006).

The technique is to modify the living conditions of microorganisms through the use of thermodynamic agents: the illumination, the increase in temperature and the drying of the animal to leave the sample, thanks to their tactic. The principle of this technique is to place a volume of soil on a wide mesh tile placed on a tap. The latter's bottle is immersed in a bottle containing a liquid from the conservation of the wildlife "75° ethyl alcohol". In order to accelerate the leakage of microarthropods, we placed a lamp with a power of 70 watts, located at a distance of 25 cm above the threshold for 5 days.



Figure 16 : Berlése device (Rezig, 2024)



VI. Statistical analysis

For the analysis of our results, we used certain parameters and ecological indices.

Soil fauna data grouped by families were analyzed over different seasons with:

Levene test was used to compare variation in soil fauna abundance over the 03 seasons (autumn, winter and spring).

The results obtained were subjected to a multivariate analysis of the type Factor Analysis of Correspondence (AFC), in order to obtain a segregation of the main families observed during the three seasons (autumn, winter and spring).

- The Factorial Analysis of Correspondences is to represent a maximum total inertia on the first factor axis, a maximum of residual on the second axis.
- All these statistical analyses were performed by the software Xlstat.

We also calculated the Frequency of occurrence or constant :

The consistency is expressed by the number of records containing the species studied relative to the total number of reports (Dajoz, 1982). The constant is calculated using the following formula:

$$F_i (\%) = (P_i / P) * 100$$

P_i= number of surveys containing the species studied.

P = total number of surveyed species.

If :

F_i = 100% → the species is ubiquitous; - If $75\% \leq F_i < 100\%$ → is a constant species; - if $50\% \leq F_i < 75\%$ → is regular species. - If $25\% \leq F_i < 50\%$ → is an accessory species, - If $5\% \leq F_i < 25\%$ → is accidental species and - If $F_i < 5\%$ → is rare.

VI.1. Richness

This is the total number of species recorded in a population during a series of (n) surveys carried out in an environment (**Blondel, 1975, in Nebili 2013**).



VI.2. Abundance

Specific abundance of a species is the number of individuals of that species in a given Environment. The relative abundance of a species (fi) is the ratio of its Specific abundance to total abundance (relative frequency).

VI.3. Shannon Weaver Diversity Index

The specific diversity of a population expresses the degree of complexity of that population. It is expressed by the shannon-winner index (H'), which incorporates both the wealth of the population and the specific abundance.

The formula for the Shannon-winner index is as follows:

$$H' = -\sum p_i \log_2 p_i$$

H'= Shannon-wieaver biodiversity index

i = one species in the study environment,

Pi= the proportion of a species i to the total number of species (S) in the research environment (or specific wealth of the environment), which is calculated as follows:

$$P(i) = n_i / N$$

Or **ni** is the number of individuals for species i and N is the total population (the individuals of all species)

N: total population

H': Expressed in bits (Binary digit)

H' Max: the maximum theoretical diversity

The Shannon Diversity Index (H') measures the degree and level of complexity of a population. The higher it is, the more it corresponds to an enlarged population of many species with a low representativity. On the contrary, a low value represents a population



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dominated by a species or a population with a small number of species with a high representativity (Blondel, 1995).

VI.4. Equitability Index

Populations with very different physiology can thus have the same diversity, so it is necessary to calculate parallel to the diversity index H' the equitable (E) by relating the observed diversity to the maximum theoretical diversity ($H' \text{ Max}$).

$$E = H' / H' \text{ Max}$$

$$H' \text{ Max} = \log_2 S$$

Equalitability ranges from 0 to 1, it tends to 0 when almost all of the staff is concentrated on one species, it tend to 1 when all species are the same Abundance, a theoretical situation to the extent that there are still rare spaces in a population.

Chapter III: Results and Interpretations



Results and Interpretations

Chapter III: Results and Interpretations

I. Qualitative and quantitative analysis of soil fauna

I.1. Systematics of soil fauna at the study sites

The taxonomic determination made it possible to create a faunistic list of soil fauna. Based on the results obtained, 22 families belonging to 8 classes were identified. (Tab 02.)

Table 02: Soil fauna composition within the study sites

| Reign | Branch | Class | Order | Family |
|----------|------------|--------------|-------------------|-----------------|
| Animalia | Arthropoda | Insecta | Coleoptera | Staphyllinidae |
| | | | | Carabidae |
| | | | | Tenebrionidae |
| | | | | Lampyridae |
| | | | | Phalacridae |
| | | | | Scarabaidae |
| | | | Hymenoptera | Scoliidae |
| | | | Diptera | Cecidomyiidae |
| | | | Orthoptera | Gryllidae |
| | | | Embioptera | Oligotomyiides |
| | | Malacostraca | Isopoda | Oniscidae |
| | | | | Armadillidiidae |
| | | Chilopoda | Scolopendromoepha | Scolopendra |
| | | | Geophilomorpha | Geophilides |
| | | Arachnida | Trombidiformes | Tetranychidae |
| | Aranea | | | Dysderidae |
| | Diplopoda | Julida | Julidae | |
| | Mollusca | Gastropoda | Stylommatophora | Hygromiidae |
| | | | | Helicidae |
| | | | Mesogastropoda | Diplommatinidae |
| | Nematoda | Secernentea | Ascaridida | Ascarididae |
| | Annelida | Clitellata | Haplotaxida | Lumbricidae |



Results and Interpretations

I.2. Relative abundance of different classes at study sites

The harvested fauna consists mainly of the Gasteropoda class with 55% and that of Clitellata with a percentage of 25.

The insect class accounted for 12% of the total wildlife collected. The soil fauna obtained shows that 2% of the Secrentea class is identified. The classes of Malacostraca, Diplopoda and Arachnida are present with a small percentage of 1%. The Chilopoda class is present by 0.1%. (Fig 17)

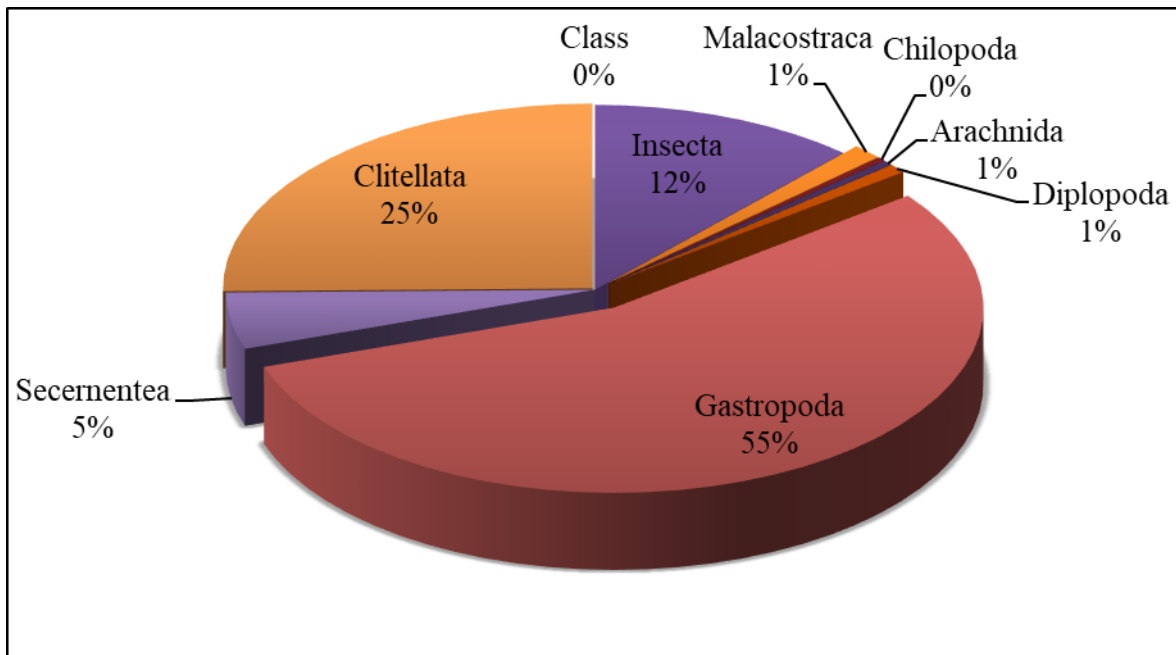


Figure 17: Relative abundance of different classes between October 2023 and April 2024



Results and Interpretations

I.3. Frequency of occurrence of different soil fauna families

The frequency of occurrence calculated from all the samples taken at the different stations and throughout the study period provides us with the following data:

- Ten accidental families: Helicidae, Lampyridae, Pholacridae, Dysderidae, Geophilidae, Oligotomidae, Tetranychidae, Armadillidiidae, Gryllidae and Carabidae.
- The population consists of eight accessory families: Dipommatinidae, Scoliidae, Carabidae, Scolopandridae, Cecidomyiidae, Julidae, Ténébrionidés and Staphylinidae.
- The regular families are Hygromiidae, Ascarididae, Scarabaeidae and Oniscidae.
- A single omnipresent family is the Lumbricidae family. (**Tab 03**)

Tableau 03: Frequency of occurrence of different soil fauna families within the study sites.

| Family | Accidentelle 0-25 | Accessoire 25≤F<50 | Regular 50≤F<75 | Constant 75≤F<100 | Omnipresent 100% |
|-----------------|----------------------|-----------------------|--------------------|----------------------|---------------------|
| Lumricidae | | | | | X |
| Hygromiidae | | | X | | |
| Dipommatinidae | | X | | | |
| Helicidae | X | | | | |
| Ascarididae | | | X | | |
| Scoliidae | | X | | | |
| Scarabaeidae | | | X | | |
| Carabidae | | X | | | |
| Scolopandridae | | X | | | |
| Oniscidae | | | X | | |
| Lampyridae | X | | | | |
| Pholacridae | X | | | | |
| Dysderidae | X | | | | |
| Geophilidae | X | | | | |
| Oligotomidae | X | | | | |
| Cecidomyiidae | | X | | | |
| Julidae | | X | | | |
| Tetranychidae | X | | | | |
| Armadillidiidae | X | | | | |
| Gryllidae | X | | | | |
| Ténébrionidés | | X | | | |
| Staphylinidae | | X | | | |
| Carabidae | X | | | | |



Results and Interpretations

II. Composition of soil fauna populations at the level of the various study sites

II.1. Oubeira lake

The relative abundance of each family at Lake Oubeira level allowed us to record the higher value for the Lumricidae family with a percentage of 80, followed by Ascarididae with a percent of 11. Julidae and Oniscidae were represented with 4% and 2% respectively. The families Staphylinidae, Oligotomidae and Cecidomyiidae were represented with a low abundance with a percentage of one. (Fig 18)

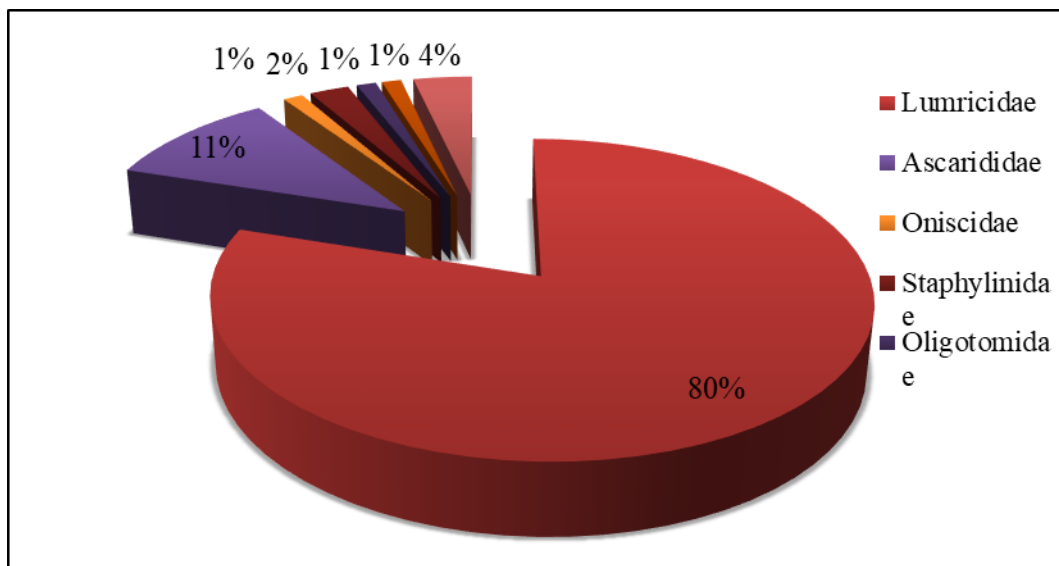


Figure 18: Relative abundance of each family of soil fauna at Lake Oubeira.

II.2. Brabtia

Our results show that the Dipommatinidae family was the most abundant with 30%, followed by the Hygromiidae family with 29%. The family Oligotomidae was registered with 16%, followed by the family Ascarididae with a percentage of 9%, and the family Lumricidae with 8%. The families Scoliidae, Scarabaeidae and Scolopendrida were registered with low percentages with 5, 2 and 1 respectively. (Fig 19)



Results and Interpretations

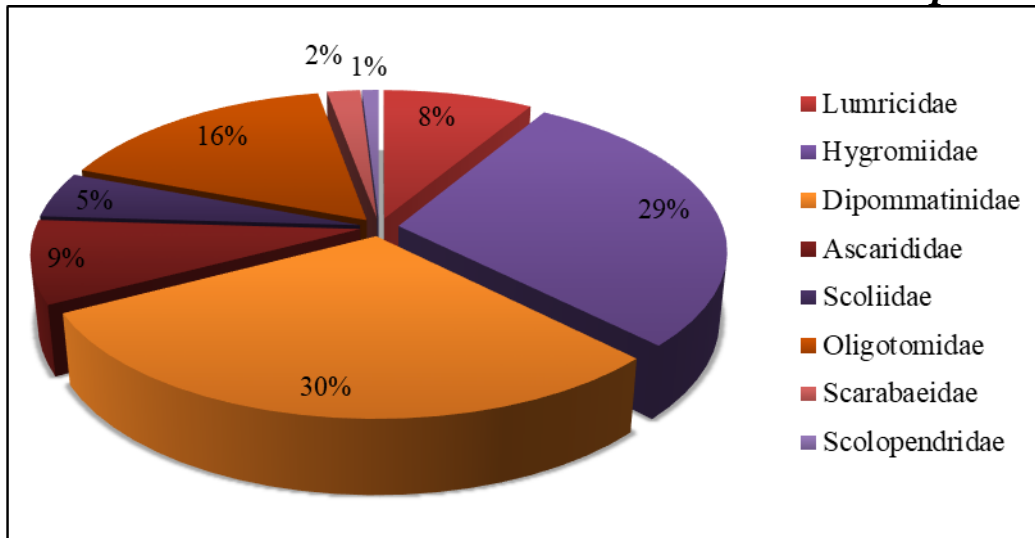


Figure 19: Relative abundance of each family of soil fauna at Brabtia.

II.3. Ain Khia Suberland

The Lumricidae family is the most abundant with 42%, followed by the Armadillidiidae family with 20%. The families Scarabaeidae and Tetranychidae are represented with an identical percentage of 8%. The Scoliiidae family was represented with 7%. The families Oniscidae, Gryllidae and Julidae were represented with a low 5% abundance. (Fig 20)

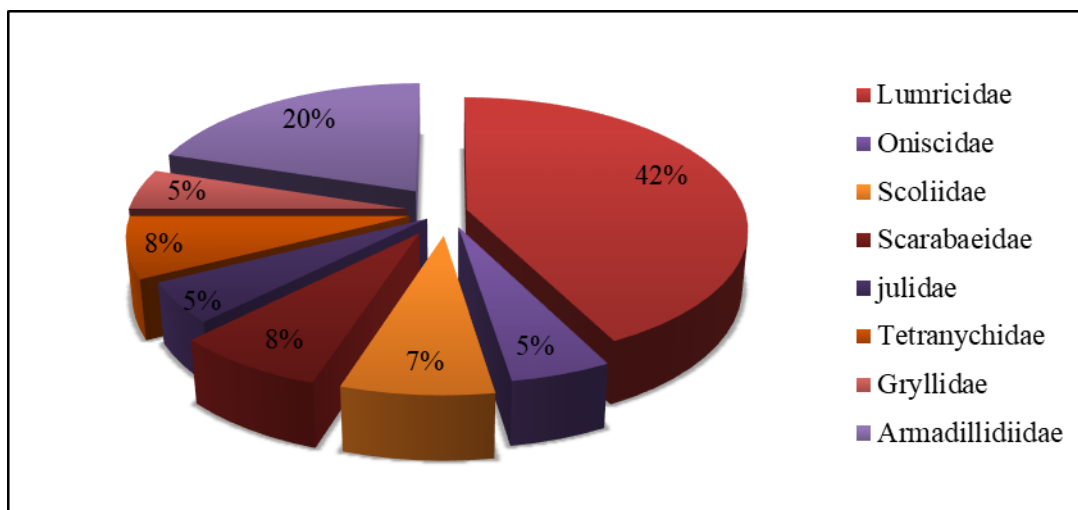


Figure 20: The relative abundance of each family of soil fauna at the level of the Ain Khia



Results and Interpretations

II.4. Matrouha

From the figure below, it was observed that the higher abundance values were recorded for the families Hygromiidae and Dipommatinidae with 65% and 34% respectively. Followed by the Oniscidae family with a percentage of one.

The lowest values were observed for the Lumricidae, Staphylinidae, Ténébrionidés and Carabidae families with 0.1%. (**Fig 21**)

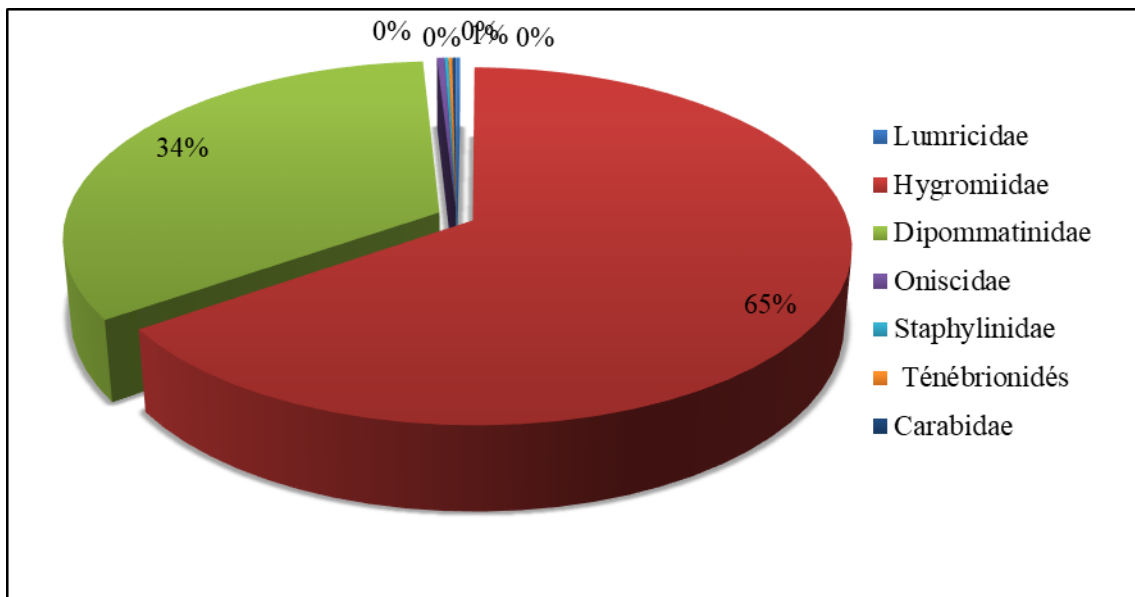


Figure 21: Relative abundance of each family of soil fauna at Matrouha

II.5. Zitouna

The Lumbricidae family has a fairly high abundance and frequency throughout the study period at Zitouna level with 64%. Followed by the families Ténébrionidés and Ascarididae with 27% and 5% respectively.

The families Hygromiidae, Oniscidae, Scoliidae and Scarabidae are less numerous and less common with 1%. (**Fig 22**)



Results and Interpretations

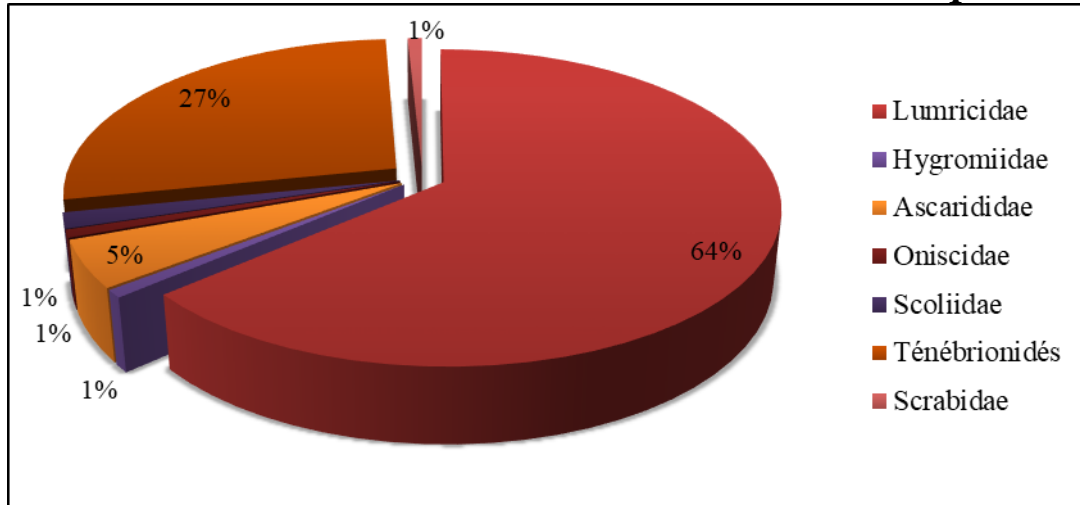


Figure 22: Relative abundance of each family of soil fauna at Zitouna .

II.6. Ain Karma

At Ain Karma, the Lumbricidae family is abundant and relatively common, with 48% of the soil wildlife harvested. The families Ascarididae, Scarabaeidae, and Carabidae are represented by 14%, 12% and 7%. Followed by the families Hygromiidae and Dipommatinidae with 5%.

The presence of the Oniscidae and Scoliidae families is limited to 4% and 2% respectively. The families Lampyridae, Pholacridae and Dysderidae are not abundant by 1%. The families of Helicidae and Scolopandridae are the least represented in the soil fauna harvested at Ain Karma level by 0.1%. (**Fig 23**)



Results and Interpretations

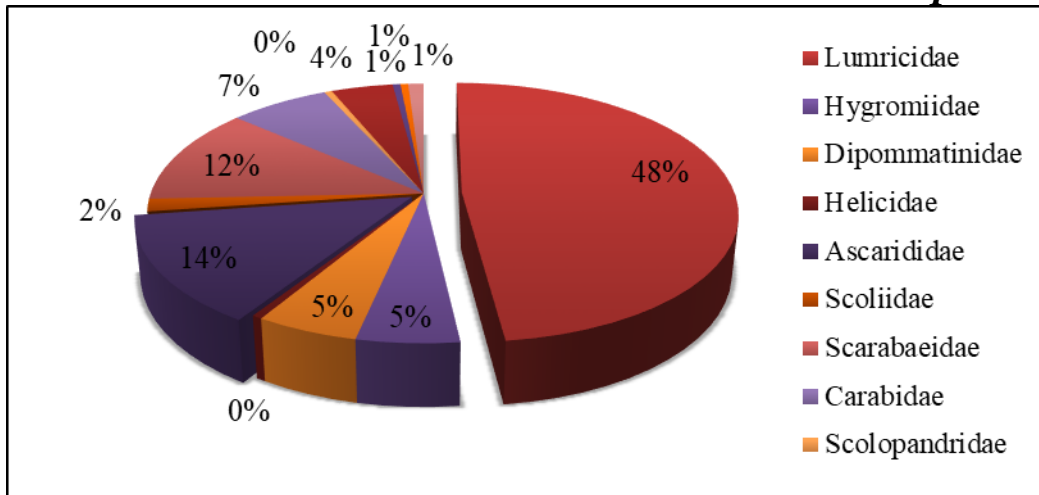


Figure 23: Relative abundance of each family of soil fauna at Ain Karma

II.7. Bouhadjar

The relative abundance of each family at the Bouhadjar during the study period allowed us to record the highest value of relative abundance for the Lumricidae family, with a percentage of 41, followed by the Scarabaeidae family with a percent of 25.

The families Ascarididae, Julidae, are represented by 12% and 8% respectively. The families Scoliidae, Oligotomidae and Geophilidae are less numerous with 4%. The family Cecidomyiidae was registered with the lowest value of 2% (**Fig 24**)

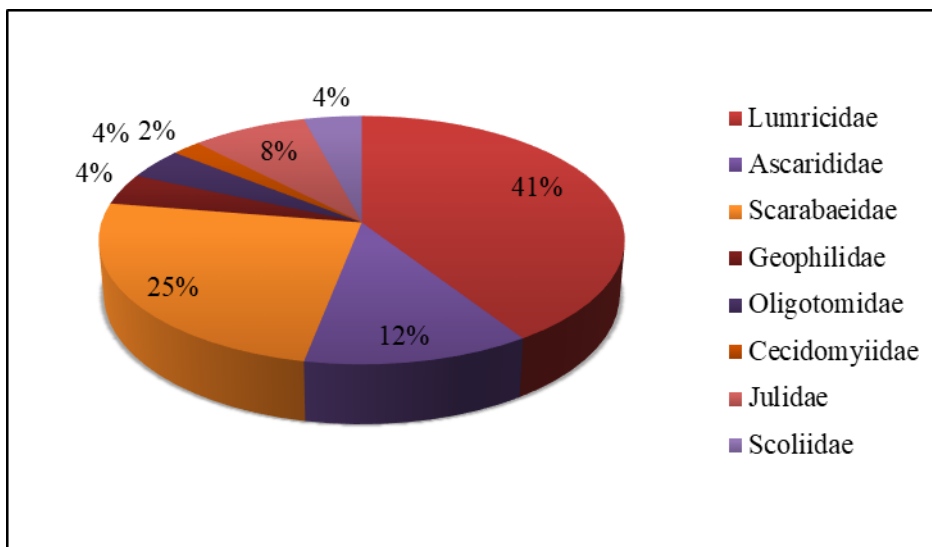


Figure 24: Abondance relative de chaque famille de la faune du sol au niveau de Bouhadjar.



Results and Interpretations

III. Variance of soil fauna at the level of the different study sites

The calculated p-value is less than the $\alpha=0,05$ significance level, the zero hypothesis H_0 should be rejected and the alternative hypotheses H_a retained. At least one of the variations is different from the other. (Tab.04)

Table 04: Descriptive statistics of the various study sites

| Variable | Observations | Minimum | Maximum | Average | Ecart-type |
|------------------------|--------------|---------|---------|---------|------------|
| Ain Karma | 23 | 0,000 | 92,000 | 8,304 | 19,694 |
| Bouhadjar | 23 | 0,000 | 20,000 | 2,130 | 4,789 |
| Brabtia | 23 | 0,000 | 31,000 | 4,522 | 9,224 |
| La Subérai d'Ain khiar | 23 | 0,000 | 27,000 | 2,957 | 6,951 |
| Lac Oubeira | 23 | 0,000 | 27,000 | 2,783 | 7,000 |
| Matrouha | 23 | 0,000 | 357,000 | 23,870 | 82,180 |
| Zitouna | 23 | 0,000 | 79,000 | 5,391 | 17,544 |

Table 05: Levene Test / Bilateral Test

| | |
|----------------------|---------|
| F (Valeur observée) | 5,958 |
| F (Valeur critique) | 2,158 |
| DDL1 | 6 |
| DDL2 | 154 |
| p-value (bilatérale) | <0,0001 |
| alpha | 0,05 |



Results and Interpretations

IV. Factor Correspondence Analysis (CFA)

The factorial analysis of the correspondence of the data collected throughout the study period is expressed on the factor level (F1xF2) of the AFC with a rate of inertia around 100%. **(Fig.25).**

The factorial map displays information on the abundance of the different families of soil fauna in the different sites of study (Lake Oubeira, Brabtia, Suberaie d'Ain Khiair, Matrouha, Zitouna, Ain Karma and Bouhadjar).

The graphs from the factor analysis clearly show that the F1 axis expresses 46.45% and the F2 axis 20,36%.

Axis 1 opposes two groups, the first in positive position, it corresponds to the species infested in Matrouha with three families with very high abundance it is: Hygromiidae, Carabidae and Diplommatinidae.

The second group characterized by less frequent and less abundant species infested in Brabtia, Lake Oubeira, Bouhadjar and Ain Karma on the negative side are the families of: Staphyllinidae, Carabidae, Scoliidae, Oligotomyiides, Geophilides and Julidae.

Axis 2 is characterized by a group, which is in a positive position, it includes 06 families listed in the sub-area of Ain Khiair and Zitouna with very strong abundance: Armadillidiidae, Gryllidae, Tetranychidae, Tenebrionidae, Cecidomyiidae and Lumbricidae

.



Results and Interpretations

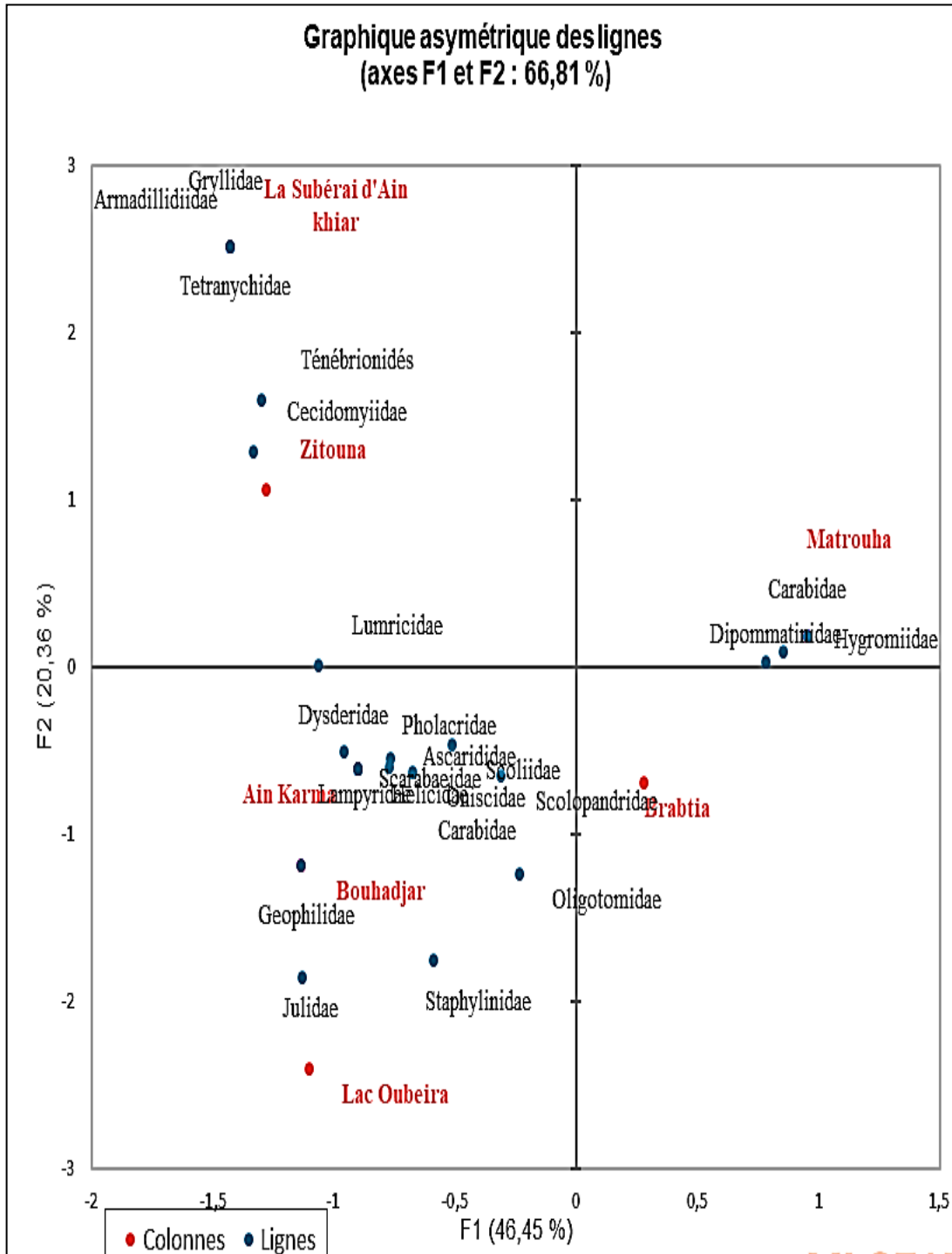


Figure 25: Factorial correspondence analysis (CFA) carried out on the 7 study sites and 22 families of soil fauna.



Results and Interpretations

V. Ecological parameters in the study sites for the different horizon of the soil

V.1. Composition Parameter

V.1.1 Richness

It is noted that Ain Karma is the most represented with 13 families, followed by Brabtia, Suberaie d'Ain Khiair and Bouhadjar by 8 families while Lake Oubeira, Matrouha and Zitouna are represented by 7 families. (Fig.26)

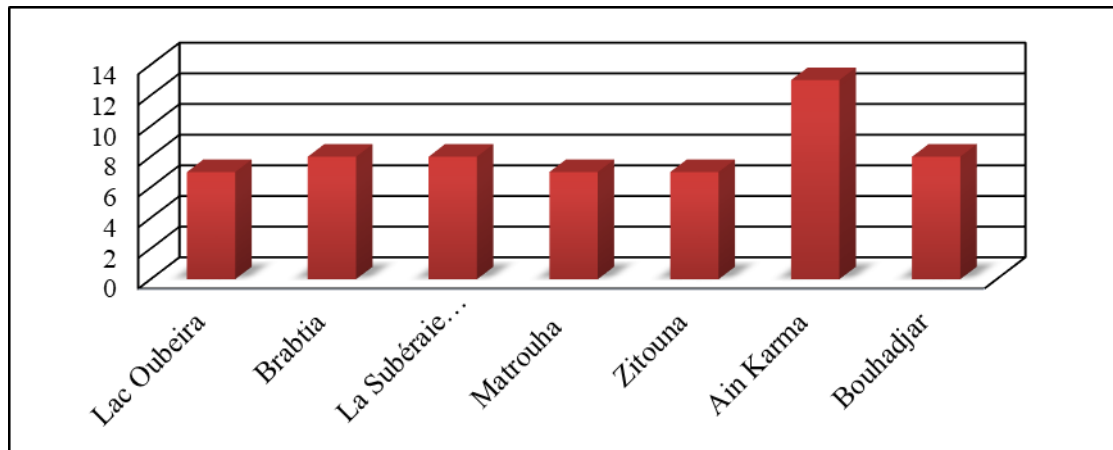


Figure 26: Richness of soil fauna families at the different study sites.

V.1.2 Abundance

The results collected show us that Matrouha are the most abundant p 548 individuals. Followed by Ain Karma, Zitouna, Brabtia, Lake Oubeira with 191, 124 and 85 individuals respectively. On the other hand, Bouhadjar and Ain Khiair are the least abundant with 49 and 40 individuals respectively. (Fig.27)

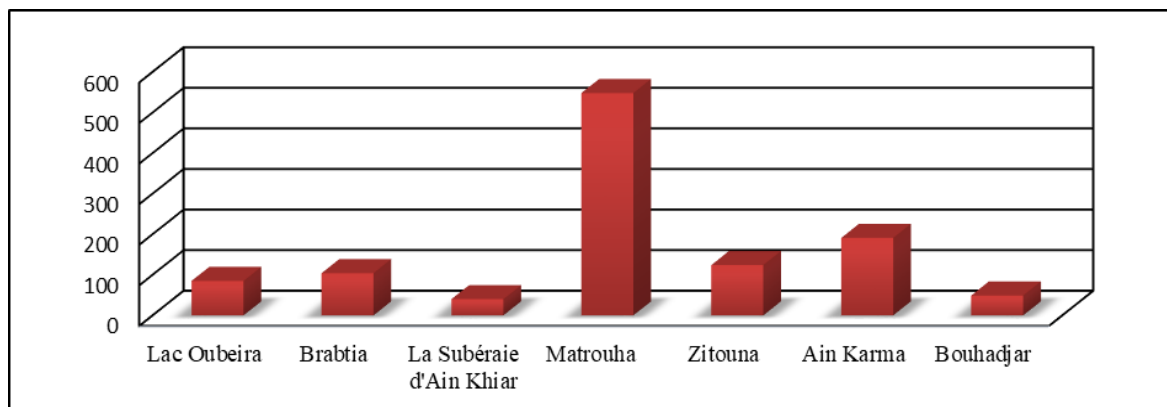


Figure 27: Total abundance of families in the different study sites.



Results and Interpretations

V.2. Structural parameter

V.2.1 Shannon Weaver's diversity index H' and equitability E

According to our study, the highest values in the Shannon Weaver Diversity Index were recorded for Ain Karma, Brabtia and Bouhadjar with 1.72 bits, 1.70 bits and 1.63 bits respectively. It is followed by the Ain Khiair subserie with 1.56 bits and Lake Oubeira with 1.38 bits. However, Zitouna and Matrouha were the least diversified with 0.97 bits and 0.72 bits respectively.

While Brabtia, Bouhadjar and Lake Oubeira were the most balanced with 0.82, 0.79 and 0.77 respectively. Come after Ain Khiair's subserie with 0.75 and Ain Karma with 0.67. On the other hand, Zitouna and Matrouha are the least balanced with 0.49 and 0.34 respectively.

(Fig.28)

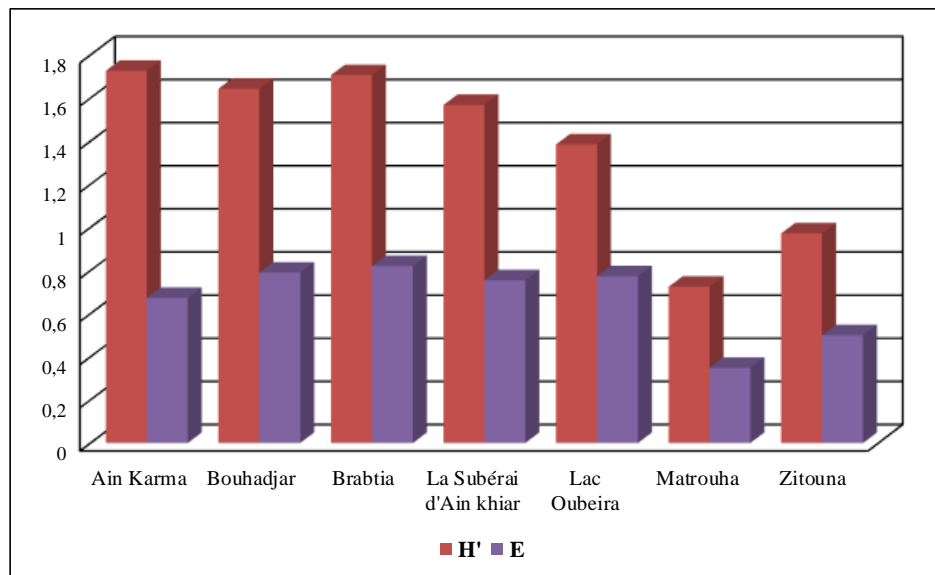


Figure 28: Diversity of Shannon Weaver H' and Equitability index E at the different study sites.



Results and Interpretations

VI. Seasonal variation of soil fauna at different study sites

VI.1. Composition ecological parameter

VI.1.1. richness

Litter

Ain Khiair and Bouhadjar's litiere recorded a high wealth representing 10 and 6 families respectively during the winter.

It is also observed that the suburbs of Ain Khiair, Matrouha, Lake Oubeira and Zitouna recorded the highest wealth values during the spring, while Brabtia and Bouhadjar recorded lowest values in the spring with only 2 families.

During the autumn, average values were recorded in all study sites compared to other seasons.

The lowest value in all study sites and during all seasons was observed at the level of Lake Oubeira during the winter with a single family. (Fig.29)

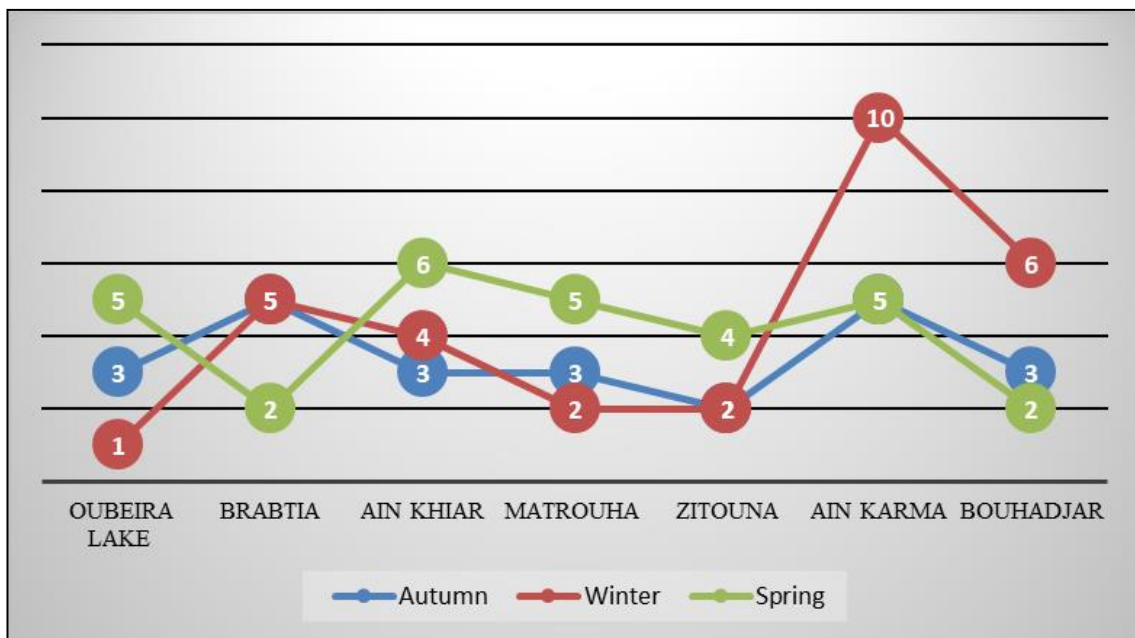


Figure 29: Seasonal variation in litter richness at the study sites.



Results and Interpretations

Horizon

On the horizon, Ain Karma and Bouhadjar recorded the highest values of wealth with 7 families during the winter.

Ain Khiar, Zitouna, Matrouha and Lake Oubeira submarines marked higher values of wealth during the spring with 5, 4 and 3 families respectively. On the other hand, Brabtia recorded a higher value of wealth during the autumn with 5 families.

The value of the least wealth was observed at the level of the Ain Khiar subsea during the winter with a single family. (Fig.30)

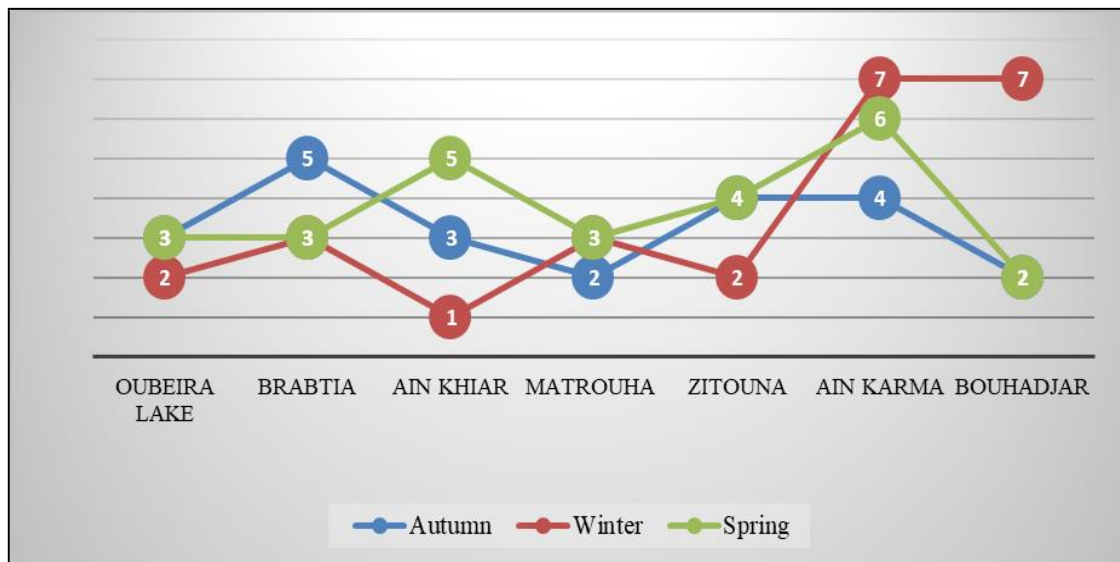


Figure 30: Seasonal variation in the richness of the horizon at the study sites.

VI.1.2. Abundance

Litter

In autumn, Matrouha shows a very high density with 168 individuals, while Brabtia notes a notable number of individuals, much less than that of Matouha with 52 individuals. Come after Ain Karma and Lake Ubeira with 36 and 25 individuals respectively. Bouhadjar and Zitouna recorded almost identical values with 12 and 14 individuals for each of them. The lowest value for this season was recorded at the level of Ain Khiar subsea with 3 individuals.



Results and Interpretations

In winter, Ain Karma and Matrouha recorded the highest abundance with 27 and 21 individuals respectively, followed by Zitouna and Bouhadjar with moderate values of 10 individuals. Brabtia has a low abundance with 6 individuals. The lowest abundance values were recorded at Ain Khiair and Lake Oubeira with 3 individuals and 1 individual.

In the spring, the highest abundance was recorded at the Matrouha level with 94 individuals, followed by the Suberai of Ain Khiair and Zitouna with 49 and 41 individuals respectively. The lowest abundance was recorded at Bouhadjar level with 3 individuals. (Fig.31)

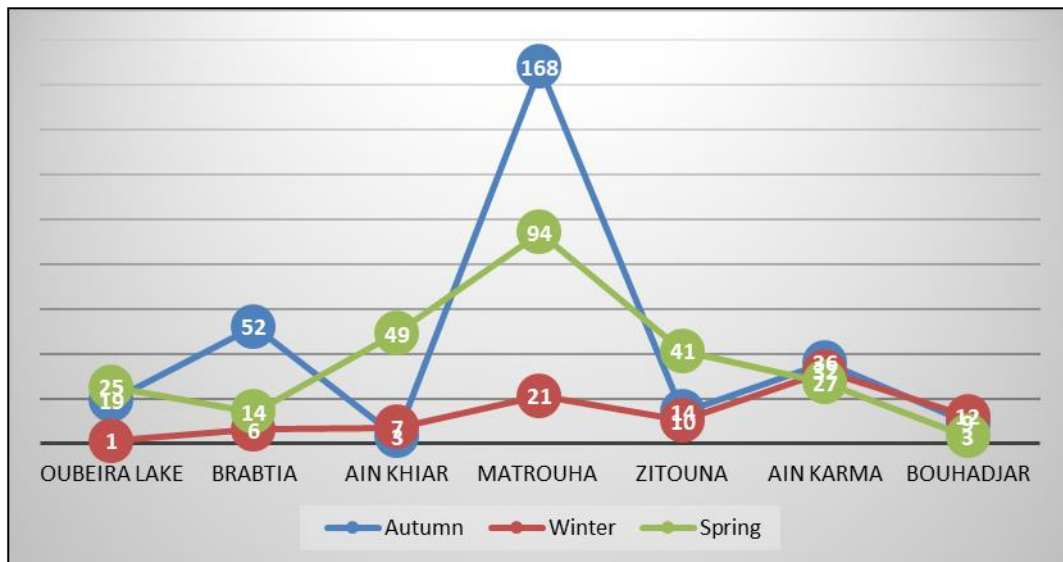


Figure 31: Seasonal variation in litter abundance at the study sites.

Horizon

In the autumn, Matrouha recorded the highest abundance compared to other sites and seasons with 211 individuals, followed by Zitouna, Ain Karma with 44 individuals. Bouhadjar and Ain Khiair presented the lowest values with 6 and 5 individuals.



Results and Interpretations

In winter, Ain Karma recorded the highest abundance with 42 individuals. Followed by Bouhadjar with 16 individuals, the lowest value was recorded at the level of Brabtia and Lake Oubeira with 6 individuals.

In the spring, an increase in abundance was observed in Zitouna with 67 individuals. Subsequently, Matrouha and Lake Oubeira are followed by 34 and 20 individuals. The lowest abundance was observed in Brabtia and Bouhadjar, with 5 and 3 individuals respectively. (Fig.32)

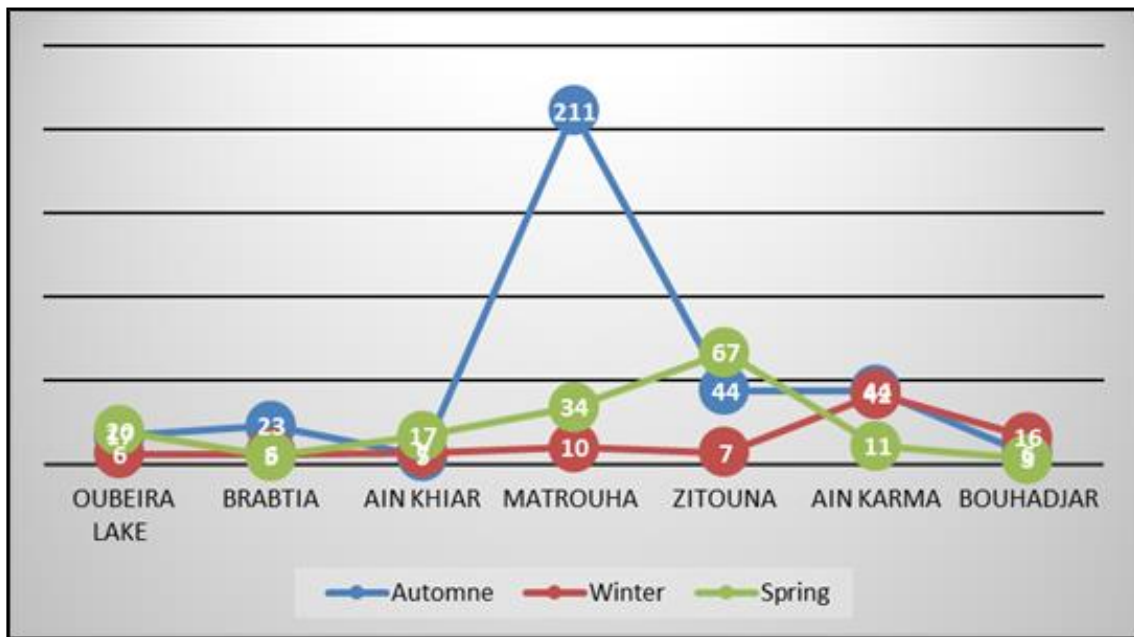


Figure 32: Seasonal variation of the abundance of the horizon at the study sites.



Results and Interpretations

VI.2. The ecological parameters of structure

VI.2.1. Shannon Weaver's Diversity Index H

Litter

During the autumn, we noticed that Brabtia was the most diversified with 1.2 bits, followed by Ain Khiar, Ain Karma, Bouhadjar and Lake Oubeira with 1.09 bits; 1.08 bit; 1.06 bit and 0.8 bit respectively. Zitouna and Matrouha were the least diversified with 0.7 bits and 0.6 bits each.

During the winter, our results showed that Ain Karma and Bouhadjar were the most diversified with 1.8 bits and 1.5 bits respectively. It is followed by Ain Khiar, Matrouha and Zitouna with 1.1 bits; 0.6 bits and 0.3 bits respectively. The lake of Oubeira, on the other hand, has zero diversity.

During the spring, the highest diversity was recorded at the level of the Ain Khiar and Ain Karma Submarine with 1.35 bits and 1.34 bits respectively. Followed by Matrouha's litera with 0.9 bits, Lake Oubeira 0.7 bits and Bouhadjar; and 0.6 bits. Zitouna and Brabtia were the least diversified with 0.5 and 0.4 respectively. (Fig.33)

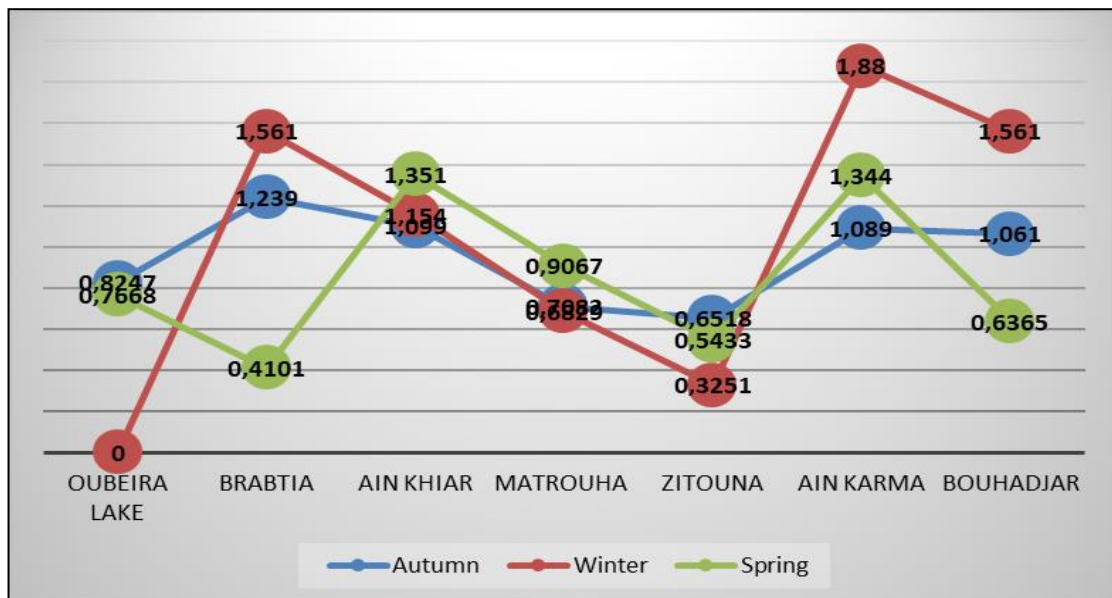


Figure 33: Seasonal variation of Shannon Weaver H' diversity index of litter in the study sites.



Results and Interpretations

Horizon

During the autumn, the horizon of Brabtia was the most diverse with 1.25 bits. Followed by the horizon of the Suberaie of Ain Khiair and Ain Karma with 1.05 bits. The horizon of Zitouna, Bouhadjar, Lake Oubeira and Matrouha are the least diversified with 0.9 bits; 0.6 bit; 0.57 bits and 0.55 bits respectively.

During the winter, the highest value of the H' diversity index was recorded at the level of Bouhadjar and Ain Karma with 1.66 bits and 1.37 bits respectively. Followed by the horizon of Matrouha, Brabtia, Lake Oubeira and Zitouna with mean values of 0.9 bits; 0.8 bit; 0.6 bits and 0.4 bits each. 'On the other hand, the horizon of the Subéraie of Ain Khiair has zero diversity.

During the spring, the highest diversity is observed at the level of Ain Karma, the Ain Khiair Suberaie and Brabtia with 1.7 bits; 1.4 bits and 1.05 bits respectively. Followed by Matrouha with 0.9 bits and Zitouna with 0.8 bits. However, Bouhadjar and Lake Oubeira recorded the lowest values of diversity with 0.63 bits and 0.61 bits each (**Fig.34**)

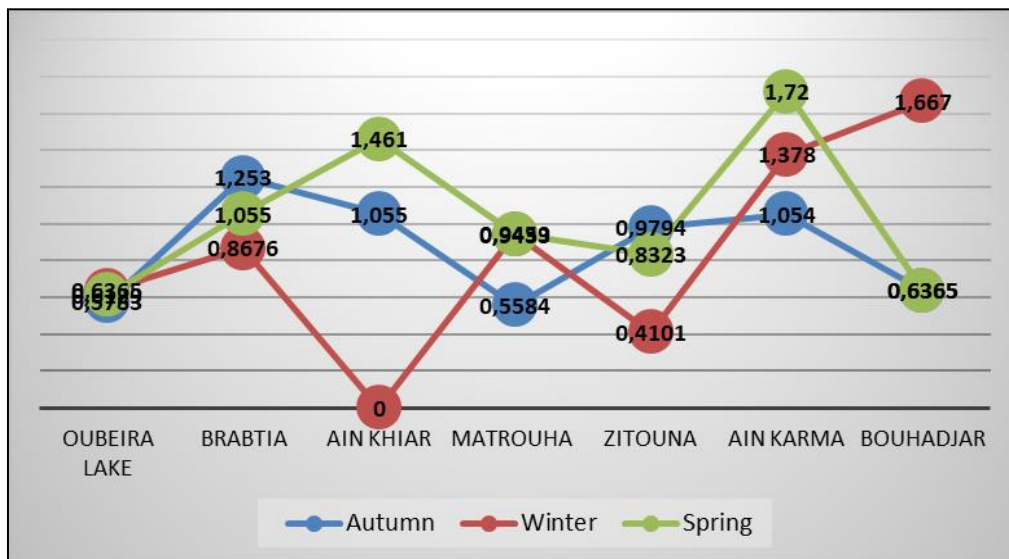


Figure 34: Seasonal variation of Horizon's Shannon Weaver H' diversity index in the study sites.



Results and Interpretations

VI.2.2. Equitability

Litter

During the autumn, it is noted that the Suberia of Ain Khiair is the most balanced with 1. Followed by Bouhadjar, Zitouna, Brabtia and Lake Oubeira with 0.96; 0.94; 0.76 and 0.75 respectively. On the other hand, the least balanced sites are Ain Karma with 0.67 and Matrouha with 0.64.

During the winter, we observed that Matrouha and Brabtia were the most balanced with 0.98 and 0.96 respectively. Followed by the sub-area of Ain Khiair, Ain karma and Zitouna with 0.83; 0.81 and 0.4 each of them. On the other hand, Lake Oubeira is unbalanced and has a zero value.

During the spring, we recorded the highest equality values for Bouhadjar, Ain karma and Ain Khiair Suberaie with 0.9; 0.8 and 0.7 respectively. Followed by Brabtia of 0.59 and Matrouha 0.56 which have almost similar proportions. On the other hand, Lake Oubeira with 0.4 and Zitouna with 0.3 are the least balanced. (Fig.35)

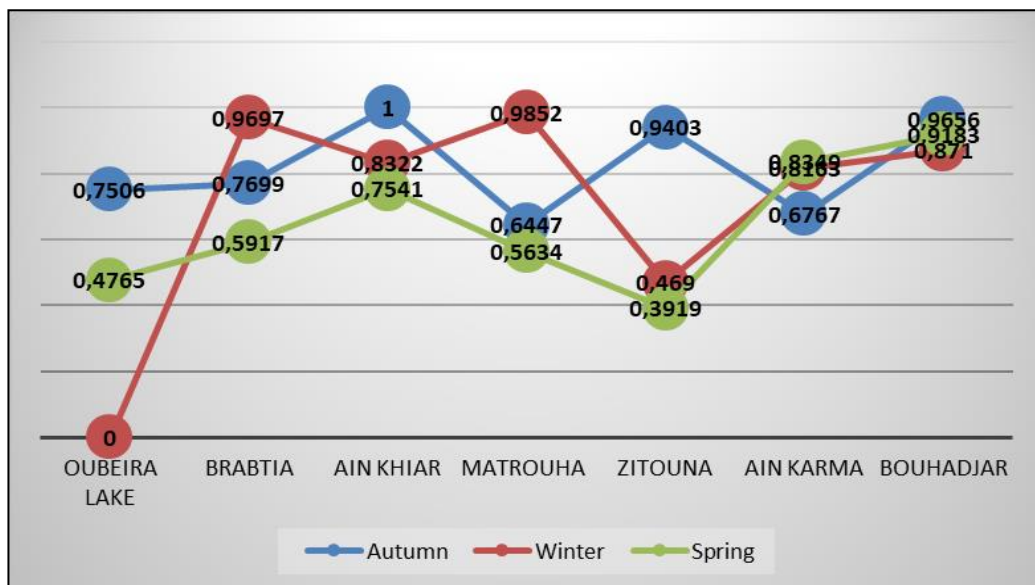


Figure 35: Seasonal variation for litter equitability index (E) in the study sites.



Results and Interpretations

Horizon

During the autumn, we recorded the highest equality values in the sub-area of Ain Khiair, Matrouha and Bouhadjar with 0.96; 0.91 and 0.8 respectively. Followed by Brabtia with 0.77, Ain Karma with 0.76 and Zitouna with 0.70. Lake Oubeira recorded the lowest value with 0.5.

During the winter, it is noted that Lake Oubeira, Matrouha and Bouhadjar were the most balanced with 0.9; 0.85 and 0.85 respectively. Followed by Brabtia, Ain Karma and Zitouna with 0.78 and 0.7 and 0.5 each. On the other hand, the fairness of the Subéraie of Ain Khiair is null.

During the spring, we observed that Brabtia and Ain Karma were the most balanced with 0.96. Followed by Bouhadjar, the Subéraie d'Ain Khiair with 0.9 and Matrouha with 0.8. Lake Oubeira was the least balanced with 0.5. (Fig.36)

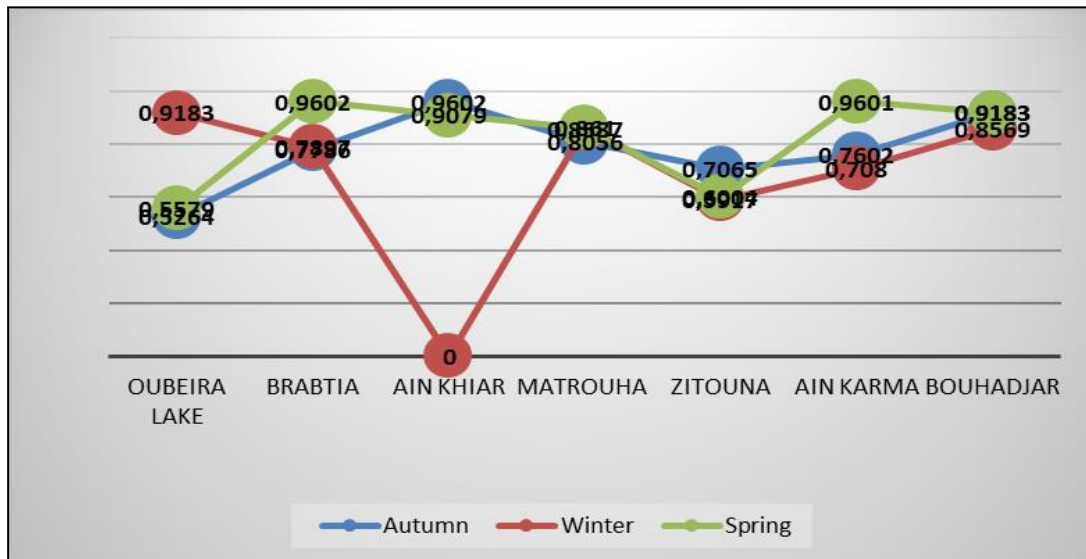


Figure 36: Seasonal variation of Horizon Equitability Index (E) in study sites.

DISCUSSION



DISCUSSION

Chapter IV: Discussion

The present study deals with the study of soil fauna according to an altitudinal gradient at the level of the wilaya of El Tarf. The purpose of choosing this topic was to find out the effect of altitude change on soil fauna diversity and whether this factor is considered to contribute to a major role in soil biodiversity.

The duration of these works was spread over 3 seasons of the year (autumn, winter and spring) between 2023-2024 in 7 different regions of the wilaya of El Tarf (Oubeira lake , Brabtia, Ain Khia Suberland , Matrouha, Zitouna, Ain Karma and Bouhadjar). Each season, we performed several field trips at random locations in the areas mentioned above. The soil fauna was extracted with the help of the Berlése apparatus. Our study reveals a taxonomic diversity of 22 families belonging to 15 orders, 8 classes and 4 branches. These families are collected from seven sampling sites in the wilaya of El Tarf. The present results are comparable to those mentioned by (**Fekkoun *et al.*, 2011**) who did the same type of sampling at a citrus garden at Baba Ali in Mitidja where he found 3 families, 3 orders and 2 branches. (**Torche and Ben Nacer, 2009**), at the level of the Oued El Garahe near Ain Mlila, noted 34 families, 12 orders and 6 branches. Also (**Hachemi and Hazem, 2009**) at the levels of Ain Fekroun, they found 28 families, 10 orders, and 5 branches.

In fact, the horizon is home to a similar number of 572 individuals at the litiere level and 576 at the horizon. It is possible to associate soil fauna species with particular Horizons and consequently with gradients of temperature, organic matter and soil texture. The heterogeneous distribution of the observed paedophane controlled by physical and chemical parameters such as salinity, temperature and edaphics (substrate nature), not to mention other external factors such as climate change (**Lavelle, 1983**). According to **Blondel *et al.*, (1973)**, the Shannon-Weaver Diversity Index is the best index that can be adopted. It serves the quantitative study of specific diversity (Ramade, 1984). The Shannon-Weaver Diversity Index provides information on the diversity of species in each environment. The value of H' has two probability, H' minimum and H' maximum. H' equals zero (minimum value) when the sample contains only one species. diversity h' increases as the number of species increases (**legendre et Legendre, 1984**).



DISCUSSION

The Equality Index, also called the Regularity Index, compares two populations with different specific wealth (Dajoz, 1985). Therefore, this index is defined as the ratio of entropies corresponding to the numbers of the diversities H' and H'_{max} . (**Legendre et Legendre, 1984**).

The results observed in the El Tarf wilaya are consistent with other similar studies, such as those conducted by **Smith and Jones (2020)** and **Brown et al., (2018)**, which also found gradients of altitude diversity in comparable ecosystems. These studies reinforce the idea that Shannon-Weaver diversity is a sensitive indicator of environmental and human variations. While Brabtia, Bouhadjar and Lake Oubeira were the most balanced with 0.82, 0.79 and 0.77 respectively. Followed by Ain Khiar with 0.75 and Ain Karma with 0.67. The least balanced are Zitouna with 0.49 and Matrouha with 0.34. These values of E all tend towards 1 which allows us to confirm that the effectiveness of the different extracted species is in balance with each other. The same is true for (**Hachemi and Hazem, 2009**) at Ain Fekroun level where they a fairness value of 0.80.

The variations observed in the number of families of soil fauna across the different sites of the El Tarf wilaya highlight significant differences in local ecological diversity. Ain Karma stands out with 13 families, indicating an exceptional biological wealth. This high diversity can be attributed to favourable environmental conditions and effective management of habitats that support a variety of species. (**Magurran, 2004**).

In comparison, Brabtia, the sub-area of Ain Khiar and Bouhadjar, with 8 families each, show a moderate diversity. These sites, although important for biodiversity, may be subject to environmental or anthropological pressures that limit the number of families present (**Whittaker, 1972**). Adjustments to management practices in these areas could improve environmental conditions and thus increase diversity. Lake Oubeira, Matrouha and Zitouna, with 7 families each, present the lowest wealth among the sites studied. This low diversity can be the result of greater environmental disturbances such as pollution, deforestation or intensive agricultural practices that adversely affect biodiversity (**Tilman, 1996**). These sites may require conservation interventions and



DISCUSSION

ecological restoration efforts to improve biodiversity and support a wider variety of soil fauna families.

The results observed in the El Tarf wilaya are consistent with other similar studies, such as that of **Smith and Jones (2020)**, which also found significant variations in family diversity in response to different environmental conditions and management practice. **Brown et al., (2018)** also showed that ecosystems with a greater variety of habitats tend to support greater family diversity, thus highlighting the importance of sustainable management of natural resources.

Observations of the distribution of soil fauna families across different sites in the El Tarf wilaya reveal varied diversity and distribution depending on species and seasons. The Lumbricidae family is the most widespread on all sites and for almost all seasons, illustrates their ability to adapt to various environments and their crucial role in soil health. (**Edwards & Bohlen, 1996**). Their significant presence could indicate good soil quality and favourable conditions for the decomposition of organic matter and the formation of humus.

Species present in a single site, such as Geophilidae in Bouhadjar and Armadillidiidae, Gryllidae and Tetranychidae in the Ain Khia subarea, show very strong ecological specialization. This could be due to unique microhabitats or strictly local environmental conditions that are not reproduced in other sites (**Jones and al., 2009**).

Ascarididae and Oniscidae are present on all five sites, showing a notable but slightly less ubiquitous distribution than Lumbricidae. This distribution may be related to specific ecological factors such as the availability of organic matter and soil moisture, which are essential for their survival and propagation. (**Lavelle and al., 2006**).

Soil organisms show high seasonal variation in taxons, resulting in significant vertical movements in response to climatic conditions. During the wet season and spring, an increase in soil humidity promotes the migration of organisms to the upper layers, especially the lithera, where the decomposition of organic matter is active and food resources are abundant. This migration is observed in Annélides, such as earthworms, arthropods, collemboles and



DISCUSSION

mollusks, which benefit from favorable surface conditions (**Hopkin & Read, 1992**). On the other hand, during the dry summer season and autumn, surface conditions become less hospitable due to decreased humidity and rising temperatures. Soil organisms then tend to move to deeper horizons to find more stable conditions and residual humidity.

This behavior is an adaptation mechanism to avoid water and thermal stress, thus enabling the species to survive in variable climatic conditions (**Decaëns and al., 2006**). Altitude also influences the distribution and abundance of soil organisms, as it affects temperature and humidity gradients. At higher altitudes, temperatures are generally lower and relative humidity is higher, creating specific microclimates that promote distinct biological diversity. Studies have shown that the species wealth and abundance of soil fauna communities can increase with altitude up to a certain point, after which too extreme conditions can lead to species decrease (**Löffler and al., 2011**).

Conclusion



Conclusion

During this study, we conducted an inventory of soil fauna in seven sites at different altitudes of the Wilaya of El Tarf, namely: Lake Oubeira, Douar Brabtia, the subarea of Ain Khiair, Matrouha, Zitouna, Ain Karma and Bouhadjar. This study was conducted for three seasons from October 2023 to April 2024.

The results show that 22 soil fauna families are harvested in the study area. Each family has its own characteristics, including sizes, shapes and distribution areas that are different and depend on various conditions including variation in altitude and seasons. We noted the presence of families widely distributed in these sites, including the Lumricidae, this family was present in all the sites studied, for almost all seasons and in the two layers resulting from soil extraction. It is followed by the Ascarididae, Oniscidae and Scoliidae. Other families are then distributed into four sites: the Hygromiidae and the Scarabaeidae.

These families include Julidae, Oligotomyiidae, and Diplommatinidae. Some of these families are divided into only two study sites: Cecidomyiidae, Staphylinidae, Carabidae, Ténébrionidés and Scolopendridae. After many species appeared in a single site including: Geophilidae, Armadillidiidae, Gryllidae, Tetranychidae, Helicidae, Lampyridae, Pholacridae and Dysderidae.

Ain Karma site was the most diverse site with 13 families, followed by douar Brabtia, the subarea of Ain Khiair and Bouhadjar with 8 families, then Lake Oubeira, Matrouha and Zitouna with 7 families.

The landslide and the horizons of the soil are home to distinct wildlife communities in terms of diversity and abundance. The litière is characterized by a very diverse and abundant fauna due to its richness in organic matter and its favourable conditions. On the other hand, wildlife diversity and abundance generally diminish with the depth of soil horizons, where conditions become less favourable for many organisms (Brady, 2008).



Studies of soil fauna according to an altitudinal gradient in the Wilaya of El Tarf

Conclusion

Altitude and seasonal variations profoundly influence the dynamics of soil fauna communities. The vertical migration of organisms, responding to seasonal changes, is essential for their survival and ecological function.

These seasonal displacements and altitude distribution highlight the importance of understanding and preserving the environmental conditions specific to each area in order to maintain the diversity and health of soil ecosystems. Sustainable management of these habitats is crucial to supporting biodiversity and the ecosystem services they provide.

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ANNEXE



Family: Scarabaeidae



Family: Staphylinidae



Family: Cecidomyiidae



Family: Oniscidae



Family: Scoliidae



Family: Lampyridae



Family: Oligotomidae



Family: Diplommatinidae



Family: Carabidae



Family: Pholacridae



Family: Geophilidae



Family: Hygromiidae



Family: Dysderidae



Family : Scolopendra



Family: Ascarididae



Family: Lumbricidae

Scientifique production

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FACULTE DES SCIENCES DE LA NATURE ET DE LA VIE



ATTESTATION DE PARTICIPATION

Le Comité Scientifique de la Journée d'Etude sur les Zones Humides
(JEZH, 24 – webinaire) qui s'est déroulé le **21 Février 2024**

Certifie que : **Mme. Rezig Djihene**

Co-auteurs : RIZI Hadia et CHETTIBI Ahlem

A présenté une **communication affichée** dont l'intitulé: **L'IMPACT DE L'ALTITUDES SUR LA DIVERSITE DE LA FAUNE DU SOL AU NIVEAU DU PNEK : CAS LAC OUBEIRA ET LA SUBERAIE DE AIN KHIAR.**



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