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Theme

Inventory of Ectoparasites of a Waterbird within a Ramsar Site

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DEDICATION

In memory of my beloved grandfather, may God have mercy on his soul and grant him eternal peace in Paradise. His memory continues to inspire and guide me throughout my journey.

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ABSTRACT

This study was conducted at Lake Oubeira, located in El Kala National Park (north-eastern Algeria), and focused on cataloguing the ectoparasites of the Eurasian Wigeon (*Anas penelope*). The main objective was to characterise the diversity of ectoparasites associated with this species and to analyse their distribution in relation to various biological and ecological factors.

The study involved 30 Eurasian Wigeons, both male and female, examined during the period from October 2025 to April 2026. The analyses yielded a total of 2,617 ectoparasites belonging to five main groups: mites, ticks, diptera, louse-like mites and fleas. The prevalence observed reached 100%, with an average intensity of 87.23 parasites per individual.

The results showed that mites and ticks constitute the dominant groups within the ectoparasite community. Statistical analysis revealed that body region is the main factor influencing the distribution of ectoparasites, with the dorsal and caudal regions being the most heavily infested. However, no significant differences were observed based on the sex of the individuals, the wintering period or the month of sampling.

This study highlights the richness of the ectoparasite fauna associated with the Eurasian Wigeon and emphasises the importance of Lake Oubeira as a reservoir of biodiversity. It also contributes to improving our understanding of the parasitic ecology of waterbirds in Algeria and opens up avenues for future research into the influence of ectoparasites on the biology and conservation of avian species.

Keywords: Wigeon (*Anas penelope*), ectoparasites, mites, ticks, waterbirds, Lake Oubeira, parasitic biodiversity.

RESUME

La présente étude a été réalisée au niveau du lac Oubeira, situé dans le Parc National d'El Kala (Nord-Est de l'Algérie), et a porté sur l'inventaire des ectoparasites du Canard siffleur (*Anas penelope*). L'objectif principal était de caractériser la diversité des ectoparasites associés à cette espèce et d'analyser leur répartition en fonction de différents facteurs biologiques et écologiques.

L'étude a concerné 30 individus de Canard siffleur, mâles et femelles, examinés durant la période allant d'octobre 2025 à avril 2026. Les analyses ont permis de récolter un total de 2617 ectoparasites appartenant à cinq groupes principaux : les acariens, les tiques, les diptères, les poux broyeurs et les puces. La prévalence observée a atteint 100 %, avec une intensité moyenne de 87,23 parasites par individu.

Les résultats ont montré que les acariens et les tiques constituent les groupes dominants de la communauté ectoparasitaire. L'analyse statistique a révélé que la partie du corps représente le principal facteur influençant la répartition des ectoparasites, les régions dorsales et caudales étant les plus fortement infestées. En revanche, aucune différence significative n'a été observée en fonction du sexe des individus, de la période d'hivernage ou du mois d'échantillonnage.

Cette étude met en évidence la richesse de la faune ectoparasitaire associée au Canard siffleur et souligne l'importance du lac Oubeira en tant que réservoir de biodiversité. Elle contribue également à l'amélioration des connaissances sur l'écologie parasitaire des oiseaux d'eau en Algérie et ouvre des perspectives pour des recherches futures portant sur l'influence des ectoparasites sur la biologie et la conservation des espèces aviaires.

Mots-clés : Canard siffleur (*Anas penelope*), ectoparasites, acariens, tiques, oiseaux d'eau, lac Oubeira, biodiversité parasitaire.

ملخص

أُجريت هذه الدراسة في بحيرة أوبيرا، الواقعة في منتزه القالة الوطني (شمال شرق الجزائر)، وركزت على جرد الطفيليات الخارجية التي تصيب البط الصافر .(Anas penelope) كان الهدف الرئيسي هو تحديد تنوع الطفيليات الخارجية المرتبطة بهذا النوع وتحليل توزيعها وفقًا لعوامل بيولوجية وبيئية مختلفة.

شملت الدراسة 30 فردًا من البط الصافر، ذكورًا وإناثًا، تم فحصهم خلال الفترة الممتدة من أكتوبر 2025 إلى أبريل 2026. سمحت التحليلات بجمع ما مجموعه 2617 طفيليًا خارجيًا ينتمي إلى خمس مجموعات رئيسية: العث، والقراد، والذباب، والقمل المطحون، والبراغيث. وبلغ معدل الانتشار الملحوظ 100٪، بمتوسط كثافة قدره 87,23 طفيليًا لكل فرد.

وأظهرت النتائج أن العث والقراد يشكلان المجموعتين السائدتين في مجتمع الطفيليات الخارجية. وكشف التحليل الإحصائي أن جزء الجسم يمثل العامل الرئيسي المؤثر في توزيع الطفيليات الخارجية، حيث كانت المناطق الظهرية والذيلية هي الأكثر إصابة. في المقابل، لم يُلاحظ أي فرق ذي دلالة إحصائية حسب جنس الأفراد أو فترة الشتاء أو شهر أخذ العينات

. تسلط هذه الدراسة الضوء على ثراء الطفيليات الخارجية المرتبطة بالبطة الصافرة، وتؤكد على أهمية بحيرة أوبيرا باعتبارها مستودعاً للتنوع البيولوجي. كما تساهم في تحسين المعرفة حول بيئة الطفيليات لدى الطيور المائية في الجزائر، وتفتح آفاقاً لأبحاث مستقبلية تتناول تأثير الطفيليات الخارجية على بيولوجيا الطيور وحفظها.

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الكلمات المفتاحية: البط الصافر، الطفيليات الخارجية، العث، القراد، الطيور المائية، بحيرة أوبيرا، التنوع البيولوجي للطفيليات

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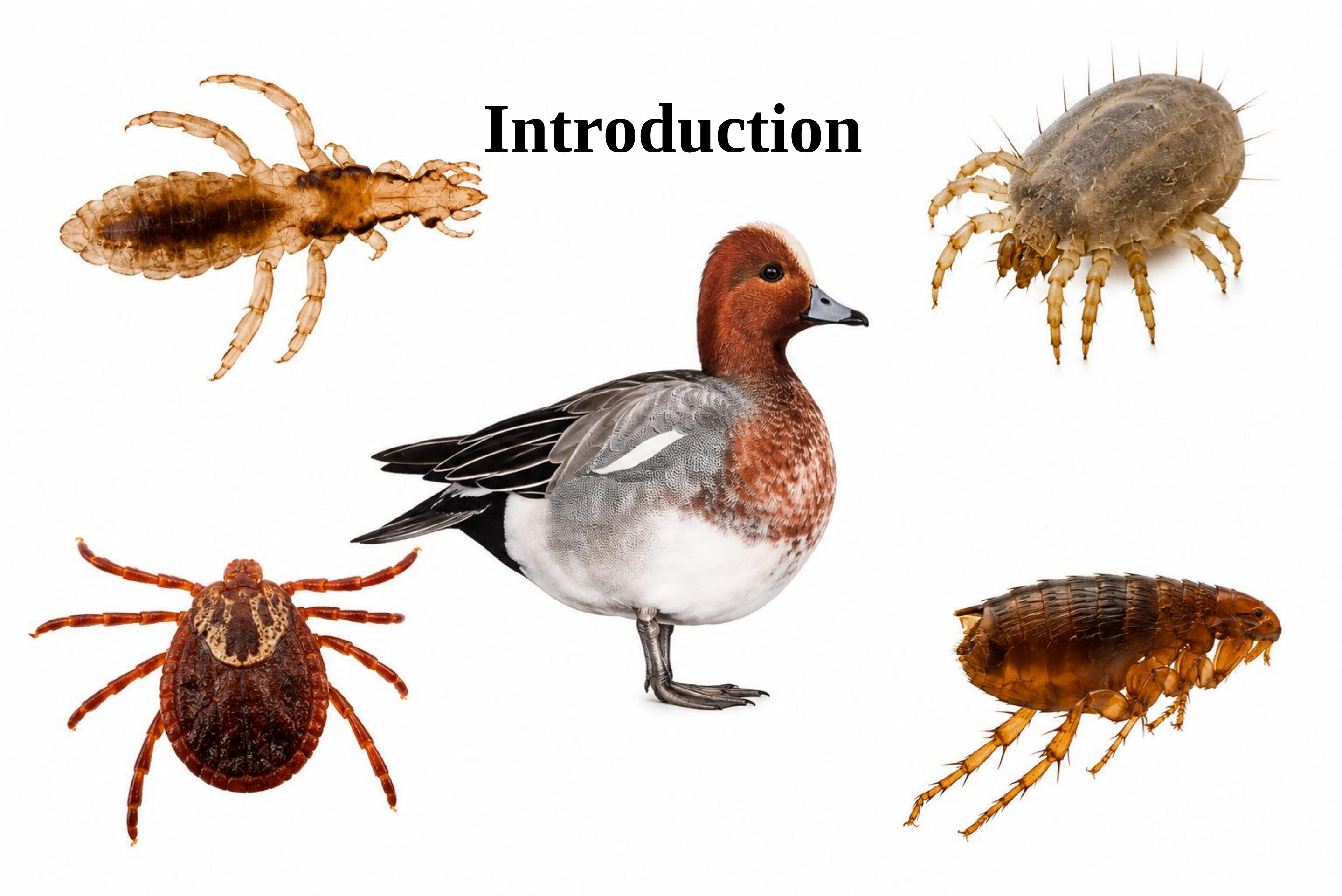


INTRODUCTION

Wild populations are controlled by various biotic and abiotic factors; among the biotic factors that can play a significant role in regulating wild populations are parasites **(Abdessamed, 2018).**

Over recent decades, research into the ecology and evolution of interactions between birds and their parasites has developed considerably. This research has demonstrated that parasites influence several biological traits of their hosts, with repercussions at the individual, population and community levels **(Rouag-Ziane et *al.*, 2007).**

Depending on whether one adopts the perspective of a parasitologist or an ecologist, parasites are often defined differently. For the former, a parasite is an organism that lives on or within another organism, known as a host, which it uses as its sole food source **(Bouslama, 2003 in Merabet Nouri, 2018)**. Ecologists give the same definition but with the stipulation that a parasite reduces the survival and/or reproductive success of its host **(Lanciani 1975 in Merabet Nouri, 2018).**

Parasites play a vital role in the functioning of ecosystems and actively contribute to the dynamics of the biosphere. Their impact is not limited to human health, but also affects the animals and plants involved in food chains. Birds, particularly those associated with aquatic environments, harbour a wide variety of internal and external parasites. These parasites include microparasites such as protozoa, viruses, bacteria and fungi, as well as macroparasites dominated by helminths, arthropods, acanthocephalans and certain annelids **(Tolba et *al.*, 2018).**

Another criterion for classifying parasites, independent of the first, is based on their location within their host **(Bush et *al.*, 2001 in Touati, 2014).** A distinction is thus made between ectoparasites, which are confined to the exterior of their host's body (integument, appendages); mesoparasites, which occupy cavities connected to the exterior (lung cavity, digestive system); and endoparasites, which develop within the internal environment (circulatory system, intercellular space, cells) **(Touati, 2014).**

Ectoparasites can be conveniently divided into three categories according to their ecological niches: Field ectoparasites include those that feed on their hosts only for a limited period and live freely for most of their life cycle (Lxodidae: Acarina), nest ectoparasites, which are most often found in or derived from the host's habitat rather than on the host itself (Argasidae: Acarina and Siphonaptera), and finally the permanent resident ectoparasites of the host's integument (Anoplura and Mallophaga). The term 'ectoparasite' is used in the strict sense of the word to refer to an arthropod associated with a vertebrate for all or a significant part of its life cycle **(Nelson, 1975 in Amoura, 2014).**

Ectoparasites include leeches and a variety of arthropods such as lice, fleas, ticks and mites. Most ectoparasites are associated with the skin and feathers, but some species infect subcutaneous sites (mites and flies) or internal sites such as the respiratory tract (leeches and mites) as well as the tongue pouches (lice). Leeches are included in the group of ectoparasites for convenience, although some may argue that they are not strictly speaking ectoparasites **(Tolba, 2014).**

Birds are highly nomadic and forage in a variety of locations and habitats, increasing the likelihood of exposure to a wide range of parasites. Birds therefore provide a good model for studying the effect of parasitism on the fitness of their hosts **(Amoura, 2014).**

Parasites mainly exploit their hosts by consuming tissue or blood, diverting resources, altering behaviour, and transmitting pathogens **(Chastel 1988, Atkinson & Van Riper 1991, Loye & Zuk 1991, Combes 1995, Clayton & Moore 1997 in Merabet Nouri, 2018),** They can also affect hosts at the individual, population or community level. At the individual level, they can cause illness and death in the host. The effects generally depend on the density of the parasite, and severe infections are often observed in dying or dead individuals. However, high levels of parasitism, involving hundreds or thousands of individuals, can also occur in birds that otherwise appear to be in good health **(Draidi, 2014).**

The physiological, morphological and behavioural effects on host individuals **(Poulin, 1998; Moore 2002; Comtois, 2004; Morley, 2006 in Touati, 2014)** are reflected at the population level in changes to their structure and dynamics **(Montaudouin et *al.*, 2003 in Touati,2014).** Community structure is affected by a cascade of effects on individuals and populations. **Poulin (1999)** identifies three types of disturbance to community structure caused by parasites: (1) the parasite, through its pathogenic effect, can alter the abundance of host species; (2) the parasite may have a severe effect on a host species that is important for the balance of the structure of the free-living organism population; (3) the parasite may affect the phenotype of host species that are functionally important for other free-living species in the community **(Touati, 2014).**

However, parasites have long been understudied in ecology and evolution. Today, parasitic ecology is a rapidly developing discipline, largely because ecologists are now recognising the potential role of parasites in regulating host populations, and their impact on the balance and functioning of ecosystems, The complex life cycle of parasites (often involving more than one host), the rapid succession of their generations compared to those of their hosts, and their rapid responses to environmental disturbances allow them to be used as indicators of biodiversity **(Hechinger et *al.*, 2007 in Touati, 2014)** and sources of stress **(Cross et *al.*, 2001)**, and as predictors of global changes related to global warming **(Lindgren et *al.*, 2000; Poulin & Mouritsen, 2006 in Touati, 2014).**

Identifying the specific parasite communities associated with different bird species remains, however, an essential step in addressing these issues. Such monitoring also helps to improve our understanding of the dynamics of pathogen communities linked to public health and/or veterinary issues **(Amoura, 2014).**

The Mediterranean basin is one of the planet’s 25 ‘hotspots’, classified as a high-biodiversity area due to its high levels of plant species—it is home to over 4.3% of the world’s plant species **(Myers et *al.*, 2000)** —within a relatively small area (10,000 km²), as well as reptiles, amphibians and freshwater fish. The mammal and bird fauna originate largely from Eurasian and African biogeographical regions and therefore exhibit relatively low levels of endemism. Furthermore, among the most significant aspects of biodiversity in the Mediterranean basin are ‘wetlands’ **(Merabet Nouri, 2018).**

Wetlands are becoming increasingly important across the globe. These habitats are exceptionally rich in biodiversity and extremely productive. Furthermore, wetlands worldwide represent a significant source of income for a growing population and are therefore of considerable socio-economic importance to local communities **(Raachi, 2007, in Boucherit, 2014).** Wetlands, among the threatened natural environments, are one of the most important resources for the world’s peoples. They play a vital role in the conservation and management of biodiversity **(Farinha and Trindade, 1994).** This idea was one of the key findings issued by the RAMSAR Scientific and Technical Assessment Panel (STAP) in 1971 **(Ben Azzouz, 2025).**

Algeria is considered to be the North African country with the most abundant inland water resources, given its highly varied topography and climate. These ecosystems provide a wide range of ecological habitats, fostering a high level of biodiversity. A survey of the wetland register was launched in 2009 and has enabled the updating of the inventory of 1,700 wetlands, of which 526 are georeferenced and mapped within a geographic information system; 280 naturally occurring wetlands and 246 anthropogenic wetlands; as of 2011, Algeria has 50 Ramsar sites of international importance, with a further 10 listed and scheduled for the next three-year period **(Zitouni, 2014 in Gherib, 2023).**

The El Kala region, situated in the far east of Algeria, is one of the country's wettest regions; it is home to the largest freshwater lakes, most of which are recognised as being of international importance **(Abdelmoumène, 2023).**

Lake Oubeira, the subject of this study, is a remarkable example of a natural Mediterranean wetland. It represents a rare and unique ecosystem within a vast complex of wetlands, classified as a natural reserve by UNESCO in 1990 **(Van Dijk and Ledant, 1983)**, who noted that the lake has long been used for fish farming as a breeding ground for cyprinids **(Meddour, 2001 in Abdelmoumène, 2023).**

Waterbirds find food, shelter or breeding grounds in wetlands. As a result, they are highly vulnerable to changes in ecological conditions. However, their presence also serves as an 'indicator'. The presence or abundance of their various species can indeed provide information on many aspects of the environment **(Touati, 2014).**

Among these waterbirds, Anatidae are considered good indicators of biodiversity. Indeed, ducks are closely linked to vegetation belts which serve as feeding grounds, areas for concealing nests and protection against predation **(Harbi, 2016 in Ounnas, 2023).**

The Anatidae family comprises more than 150 species found throughout the world **(Bullet Farrand, 1994 in Labbaci, 2017),** with El Kala National Park (north-eastern Algeria) hosting more than two-thirds of the Anatidae populations that winter in Algeria; these sites are home to breeding species, some of which are classified as vulnerable **(PNEK, 2011).** This family includes swans, geese and ducks. All species have webbed feet and most are aquatic birds.

The majority of species in this family exhibit marked sexual dimorphism, with the male having more colourful plumage than the female **(Choinière, 1995 in Labbaci, 2017).**

Migratory wild duck species, including the Eurasian Wigeon (Anas penelope), are exposed to various parasites that can affect their health and physical condition, particularly in the wetlands they frequent (**Bouchaala, 2017).**

In Algeria, the parasitic ecology of wild birds is largely overlooked, but today it is a fully-fledged discipline; ecologists are increasingly aware of the many ways in which parasites can significantly influence the processes regulating host populations and their impacts on the balance and functioning of the ecosystem **(Barroca, 2005 in Yakoubi and Selloum, 2022).**

The main objective of this study is to compile an inventory of the ectoparasites infesting the Eurasian Wigeon (*Anas penelope*) at Lake Oubeira, within El Kala National Park, in order to determine the species diversity and parasitic composition associated with this species in this wetland.

Our thesis is structured as follows:

•Introduction.

•The first chapter provides an overview of ectoparasites.

•The second chapter outlines the methodology.

•The third chapter is devoted to the results and their interpretation and a discussion comparing the obtained results with those reported in the literature.

•And finally, we conclude with a conclusion.

Chapter I:

Generalities on Ectoparasites

Generalities on Ectoparasites

I. General concepts of parasitism

I.1. Definition

I.1.1. Parasitology

It is the study of parasites, their hosts and their interactions with one another. As a biological discipline, the aim of parasitology is not determined by the organism or environment in question, but by their modes of life. This implies that it is a synthesis of other disciplines and draws on techniques from fields such as cell biology, bioinformatics, molecular biology, immunology, genetics and ecology **(Tolba, 2014).**

I.1.2. Parasitism

Parasitism is a relationship between two living organisms: one is the symbiont (the parasite) and the other is the host. In this relationship, one species (the symbiont) lives at the expense of another larger species (the host), which provides the symbiont with habitat and food.Parasites are metabolically dependent on their host, hence the necessity of this relationship for the parasite **(Combes, 2001in Abdessamed, 2018) (Fig.1).**

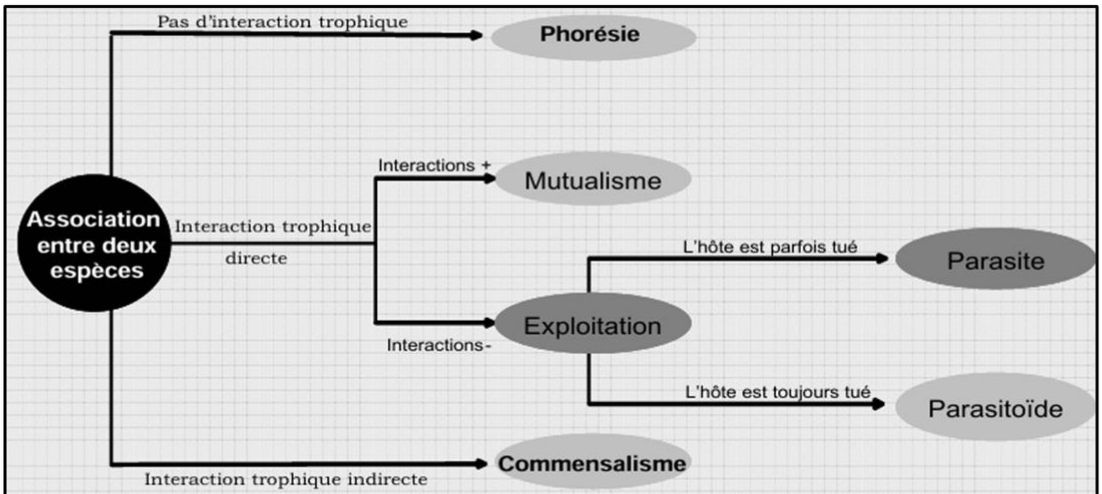


Figure 1 : Les différents types d'associations entre espèces (d'après Bush *et al.*, 2001). On distingue les associations sans échange trophique (phorésie) ou à échange trophique indirect (commensalisme) des relations à échange trophique direct. Parmi ces dernières, la situation où les deux partenaires tirent un bénéfice correspond à une situation dite de mutualisme alors que celle où l'un des deux partenaires « exploite » l'autre correspond à une situation dite d'exploitation.
Ces situations d'exploitation sont des situations où un organisme se développe sur ou dans un autre organisme -son hôte- et en tire sa subsistance. Si le résultat direct ou indirect de ce développement est la mort de l'hôte, alors on parle de parasitoïde (Eggleton & Gaston, 1990), sinon on parle de parasite.

Figure n°1: The different types of interspecific associations **(adapted from Bush et *al.*, 2001, in Barroca, 2005)**

I.1.3. Parasites

Parasites can be defined as organisms that spend a significant amount of time living within or on another living organism – the host – from which they obtain all or part of the nutrients they require and to which they have the potential to cause harm. The harm inflicted can affect both the individual and the population **(Combes, 1995 in Barroca, 2005)**. Finally, parasites differ from parasitoids in that they do not systematically kill their host **(Barroca, 2005).**

I.1.4. Parasitoidism

This is a specific form of parasitism that results in the death of the host; parasitoids are of considerable economic importance, as they contribute both naturally and experimentally (biological control) to reducing the number of crop and forest pests. Their effectiveness is sometimes enhanced by processes of polyembryony; a developing egg fragments and gives rise to multiple offspring, all of the same sex, of course **(Cassier et *al.*, 1998 in Tolba, 2014).**

I.1.5. Parasitoids

Consisting exclusively of insects, they deserve special attention. They lay their eggs on or inside the bodies of other insects, frequently the caterpillars of Lepidoptera. At the end of embryonic development, the parasitoid larva consumes the tissues of its host, often in a specific order, during pupation or emergence, causing the host's death. Parasitoids therefore combine the characteristics of a parasite (living entirely at the expense of a living organism) and a predator (tissue consumption and killing); to a certain extent, but on a different scale, they can be compared to bacteriophages **(Cassier et *al.*, 1998 in Tolba, 2014).**

I.1.6. Host

Defined as an organism that harbours the parasite, providing it with food and shelter. It is relatively larger than the parasite. **(Paniker, 2013 in Laidoudi and Rekibi, 2022)**. The host may belong to the following types:

- **Definitive host**: This is the living organism that harbours the adult or sexual form of the parasite **(Daou and Chaheb, 2021).**
- **Intermediate host**: This is the living organism that harbours the parasite in its larval or asexual form. The parasite must pass through this host in order to undergo transformations and become infective **(Anofel, 2014 in Daou and Chaheb, 2021).**

- **Paratenic or intermediate host**: Unlike the two previous hosts, this host is optional and is not essential to the life cycle of a parasite. Sometimes a pre-imago form of a parasite ends up in a host and does not find favourable conditions for development there. It then has the ability to encapsulate itself within the host's tissues and wait to move to another host where it will complete its life cycle **(Viatoux et *al.*, 2007 in Daou and Chaheb, 2021).**

I.2. Classification of parasites

Parasites belong to a wide variety of zoological groups **(Okba and Adjroud, 2020)**, including microparasites (viruses, bacteria and protozoa) and macroparasites (helminths and arthropods). Another criterion for classifying parasites, independent of the first, is based on their location within their host **(Bush et *al.*, 2001 in Barroca, 2005)**. A distinction is thus made between ectoparasites, which are confined to the exterior of their host's body (integument, appendages), mesoparasites, which occupy cavities connected to the exterior (lung cavity, digestive system) and endoparasites, which develop within the internal environment (circulatory system, intercellular space, cells) **(Barroca, 2005).**

I.2.1. Protozoa: (Single-celled organisms capable of movement): depending on the species, they move using pseudopods (rhizopodes), flagella, undulating membranes or cilia. They may be asexual or capable of reproduction, motile or encysted, and may be found inside or outside cells. **(Richard, 2019 in Daou and Chaheb, 2021)**

I.2.2. Helminths: Or worms (a subgroup of metazoans: multicellular organisms possessing differentiated tissues). They are recognised in adult forms of both sexes and in larval, embryonic or ovoid forms. **(Richard, 2019 in Daou and Chaheb, 2021)**

I.2.3. Fungi or micromycetes: These constitute a kingdom in their own right; they are microscopic fungi identified as isolated or clustered spores, or as free or tissue filaments **(Richard, 2019 in Daou and Chaheb, 2021).**

I.2.4. Arthropods: Molluscs, pararthropods (porocephals) and annelids are metazoans, multicellular organisms with differentiated tissues. Insects, arachnids molluscs and crustaceans, which may occur as adult (imago) males and females, eggs and larvae (nymphs). **(Anofel, 2014 in Daou and Chaheb, 2021)**

I.3. Types of parasites (Paniker, 2013 in Laidoudi and Rekibi, 2022)

I.3.1. Free-living parasite: This refers to non-parasitic stages that live independently of the host. E.g.: the cyst stage of *Naegleria fowleri*

I.3.2. Obligate parasite: A parasite that cannot exist without a host. E.g.: *Toxoplasma gondii* and *Plasmodium*.

I.3.3. Facultative parasite: An organism that can live either as a parasite or in a free-living form. Parasites that infect an unusual host are called accidental parasites. E.g.: *Echinococcus granulosus.*

I.4. Morphology

Parasites can take various forms: sexual (male and/or female) or asexual, eggs, larvae, resistant forms (cysts), but a single parasite may also assume distinct and markedly different forms corresponding to different stages of its development **(Candolfi et *al.*, 2008 in Okba and Adjroud, 2020**). Their size can exceed 10 metres (Taenia) and remain in the order of micrometres (microsporidia, Leishmania) **(Chabasse and Miegeville, 2007 in Okba and Adjroud, 2020).**

I.5. Locomotion

Some parasites are unable to move under their own power; they may be transported via the intestinal tract or bloodstream; some even have the ability to crawl or move forward using pseudopods (or rhizopodes), suction cups, cilia, flagella, or a undulating membrane **(Candolfi et *al.*, 2008 in Daou and Chaheb, 2021).**

I.6. Nutrition

The feeding mechanisms of parasites vary:

Parasites with a digestive tract (nematodes or roundworms) feed by capturing the products of digestion (intestinal chyme). Nutrients are absorbed thanks to enzymes secreted by the parasites. Some parasites lacking a digestive tract (flatworms: cestodes and trematodes) and fungi feed by osmosis. The diet of parasites is highly varied: some parasites are haematophagous (e.g. ticks, fleas, mosquitoes, the giant liver fluke...). Others are histophagous (e.g. small liver fluke, mites causing scabies, etc.) and feed on tissue or shed cells. Finally, others are chymivorous (e.g. roundworms) **(Bencheikh, 2010 in Daou et Chaheb, 2021).**

I.7. Parasitic cycles

The sequence of stages required for the development of a parasite from one generation to the next. The different cycles are defined by the number of hosts a parasite requires to ensure the transition to the next generation. We thus distinguish between single-host cycles (direct cycles) and cycles involving two or more hosts (indirect cycles) **(Daou and Chaheb, 2021)**

I.7.1. Direct life cycle (monoxenous): when a parasite requires only a single host to complete its development; this includes two types:

- **Short:** There is no mandatory passage into the external environment; the parasite is directly infective once the cycle is complete within the host. Example: Enterobius vermicularis (pinworm**). (Laidoudi and Rekibi, 2022)**

- **Long**: one of the parasitic stages must mature in the external environment to become infective. Example: Ascaris lumbricoides **(Menan, 2016 in Laidoudi and Rekibi, 2022) (Fig. 2).**

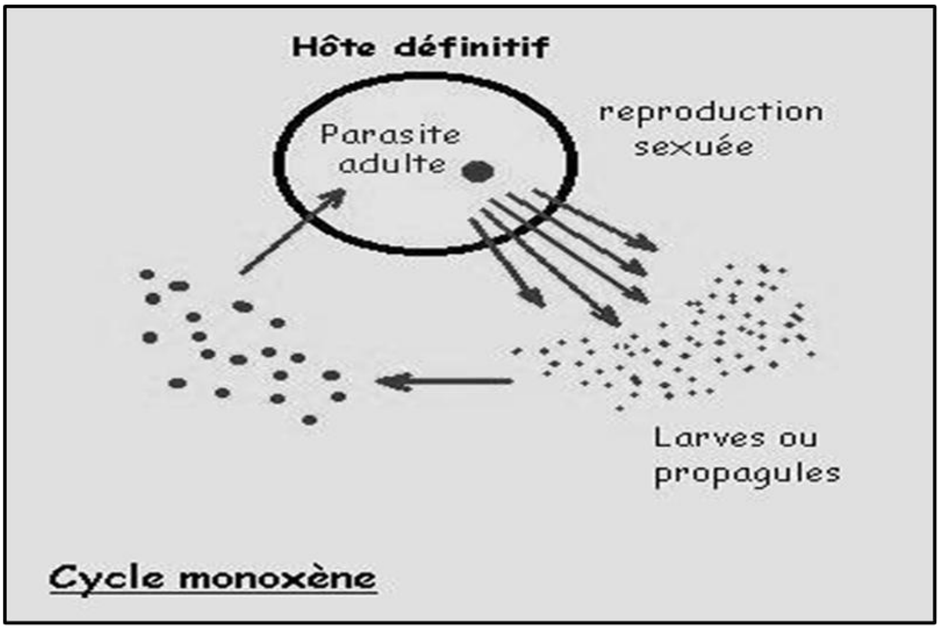


Figure n° 2: Diagram of the life cycle of a monoxenous parasite **(Tolba, 2014)**

I.7.2. Indirect (heteroxenous) life cycle: Where a parasite requires two or more hosts to complete its development **(Paniker, 2013 in Laidoudi and Rekibi, 2022) (Fig. 3).**

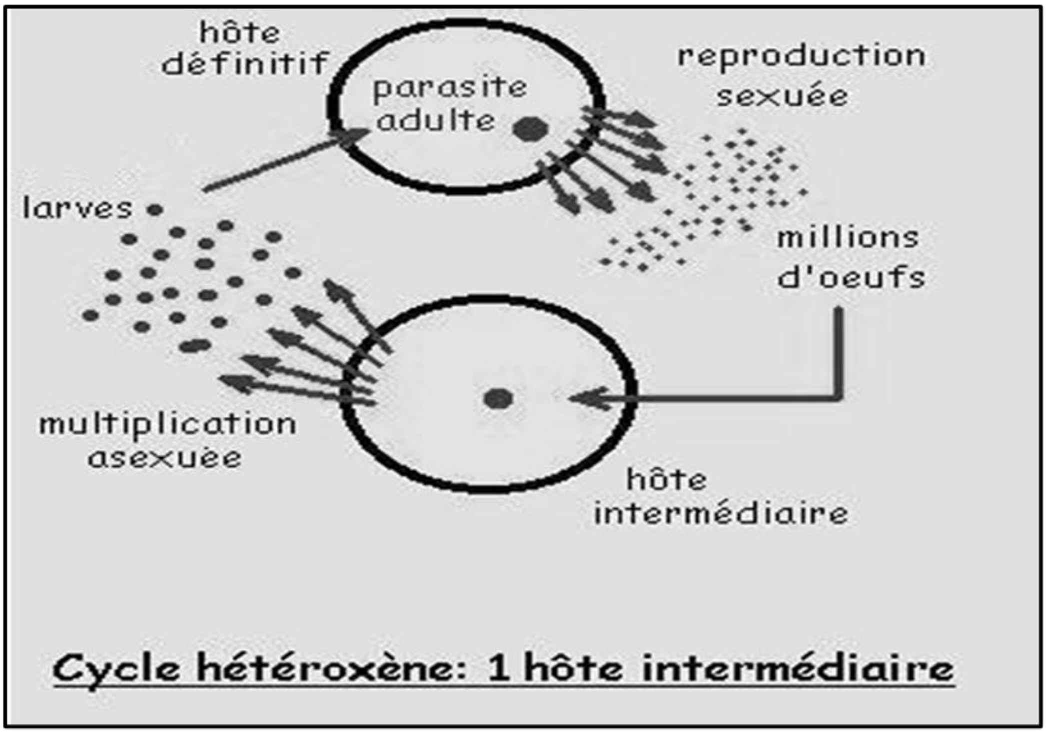


Figure n°3: Diagram of a heteroxenous cycle involving an intermediate host **(Tolba, 2014)**

I.8. Mode of life

I.8.1. Facultative parasitism: Organisms that normally lead a saprophytic life but may occasionally invade the host's body (e.g. so-called opportunistic fungi**). (Fred, 2002 in Okba and Adjroud, 2020)**

I.8.2. Accidental parasitism: Certain free-living animals, such as myriapods (centipedes) and insect larvae, are capable of entering a host and causing disturbances; these are referred to as accidental parasites. **(Viatoux et *al.*, 2007 in Daou and Chaheb, 2021)**

I.8.3. Obligate parasitism: These are organisms that are heavily dependent on their host for survival and are therefore unable to live independently outside the host (e.g. roundworms, tapeworms, fleas, lice**...). (Daou and Chaheb, 2021)**

I.8.4. Periodic parasitism: The parasite leaves the host once its nutritional needs have been met **(Lehman, 2016, in Okba and Adjroud, 2020).**

I.8.5. Temporary parasitism: Organisms that spend part of their life cycle as parasites but have free-living stages in the environment (e.g. flukes, eels**), (Fred, 2002 in Okba and Adjroud, 2020).**

I.8.6. Permanent parasitism: The parasite lives on the host for its entire life **(Lehman, 2016 in Okba and Adjroud, 2020).**

I.8.7. Accidental parasitism: Parasites that are found accidentally in an unusual host and survive there for a short time **(Lehman, 2016 in Daou and Chaheb, 2021).**

I.8.8. Opportunistic parasitism: Non-pathogenic organisms that can become parasitic and pathogenic if the host's susceptibility is increased **(Lehman, 2016 in Daou and Chaheb, 2021).**

I.9. Routes of entry and exit for parasites

I.9.1. Routes of entry for parasites into the host

Parasites can enter a host via several routes:

- Ingestion: The parasite is swallowed by the host. Generally, the parasitic form transmitted via this route is resistant to the action of various digestive secretions (e.g. amoebae, helminth eggs).
- Injection: The parasite is found in an invertebrate host (vector) and is injected when the host bites (e.g. trypanosomes, leishmania, etc.).
- Sexual contact: Direct transmission (e.g. Trichomonas vaginalis).
- Airborne transmission via inhalation: of cysts or spores.
- Transcutaneous transmission (through the skin): (e.g. hookworms).
- Blood transfusion: (e.g. malaria).
- Transplacental: Through the passage of parasites from the mother to the foetus during pregnancy (e.g. Toxoplasma gondii**) (Belkaid et *al.*, 1998 in Tolba, 2014).**

I.9.2. Routes of parasite excretion

The routes by which parasites are excreted or eliminated often determine the diagnosis of the conditions they cause. Indeed, these routes provide evidence of infestation following examination of the excreted specimen.

The main routes of excretion are:

- **Excretion:**
  - Larvae, eggs, adult worms or worm segments, cysts and vegetative forms of protozoa are detected in the stools (faeces).
  - In urine, eggs of Schistosoma haematobium (the causative agent of urinary *schistosomiasis*) are diagnosed.
- **Secretions:** Bronchial secretions, for example, may contain eggs of the lung fluke *(Paragonimus westermani*).
- **Skin wounds:** Fly larvae (maggots) may emerge through skin wounds, or via the intervention of a blood-feeding vector (Anopheles for malaria, sand fly for leishmaniasis).
- **Death of the host:** Sometimes, the parasite can only be released and continue its life cycle after the death of its host (e.g. hydatid cyst). (**Tolba, 2014)**

II. Classification of parasites by location

II.1. Endoparasites

Endoparasites are parasites that live inside the host organism. They may be found either within cells and tissues, in extracellular spaces such as body fluids, or in the digestive tract. **(Gassem-hafirassou, 2014 in Bendif et *al.*, 2025)**

II.2. Mesoparasites

These occupy the natural cavities of their hosts that are connected to the external environment: the pulmonary passages and cavities, the digestive tract and its associated structures, the urinary bladder and the genital tract. They consume the contents and secretions of these cavities (phagotrophy, microphagy, osmotrophy) or, as previously mentioned, suck blood after breaching the walls. The force required to overcome the resistance to detachment created by the movement of surrounding fluids is obviously less than in the previous case. **(Cassier et *al.*, 1998 in Tolba, 2014)**

II.3. Ectoparasite

An external parasite that lives on the body surface of a living being. Its life cycle can cause a disease in the host, known for this reason as ectoparasitosis **(Heather et *al.*, 2013 in Okba and Adjroud, 2020) (Fig. 4).**

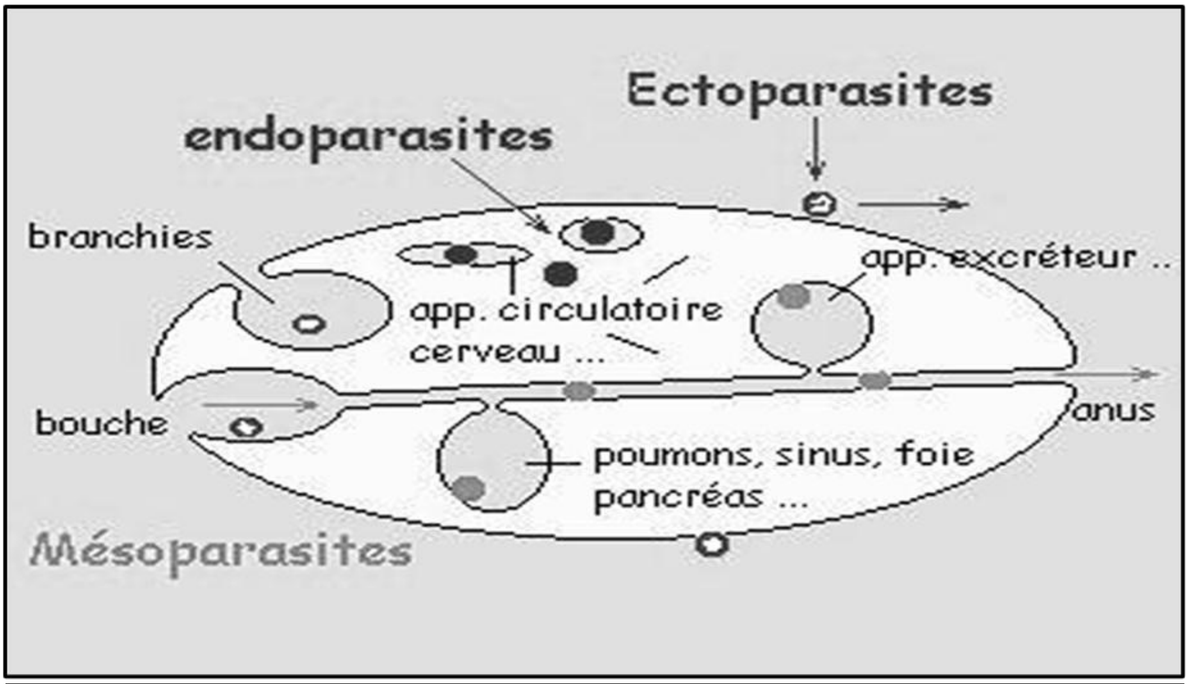


Figure n° 4: General location of parasites within the host organism **(Tolba, 2014).**

III. Avian ectoparasites

III.1. Definition

Ectoparasites are small organisms that primarily affect the skin. They feed either by consuming dead skin and feather cells, or by piercing the integument and sucking blood or tissue secretions (including lymph) **(Touati, 2014).**

These include:

- Fleas
- Ticks
- Biting or chewing lice (mallophages)

- Certain pupiparous dipterans that do not lay eggs but expel a pupa or larva that has developed within the uterus: Hippoboscidae, Nycteribiidae and Stroblidae.

- Certain non-pupating Diptera such as *Neothtiophilus* sp., *Protocalliphorus* sp., and the Carnidae, which are known to parasitise birds.

- Migrating larvae laid by non-parasitic adult Diptera and responsible for myiasis.

- Blood-feeding Diptera such as Culicidae or Simulidae. They remain on the animal only for the duration of a bite but are potential vectors of viruses and pathogens, particularly in the warmer months when they are abundant. Birds are no exception to this rule, and many Culicidae feed specifically on them.

- Burrowing mites (causes of scabies) that dig tunnels in the epidermis and the Demodex genus, which live beneath the skin **(Baudhuin, 2006 in Touati, 2014) (Fig. 5).**

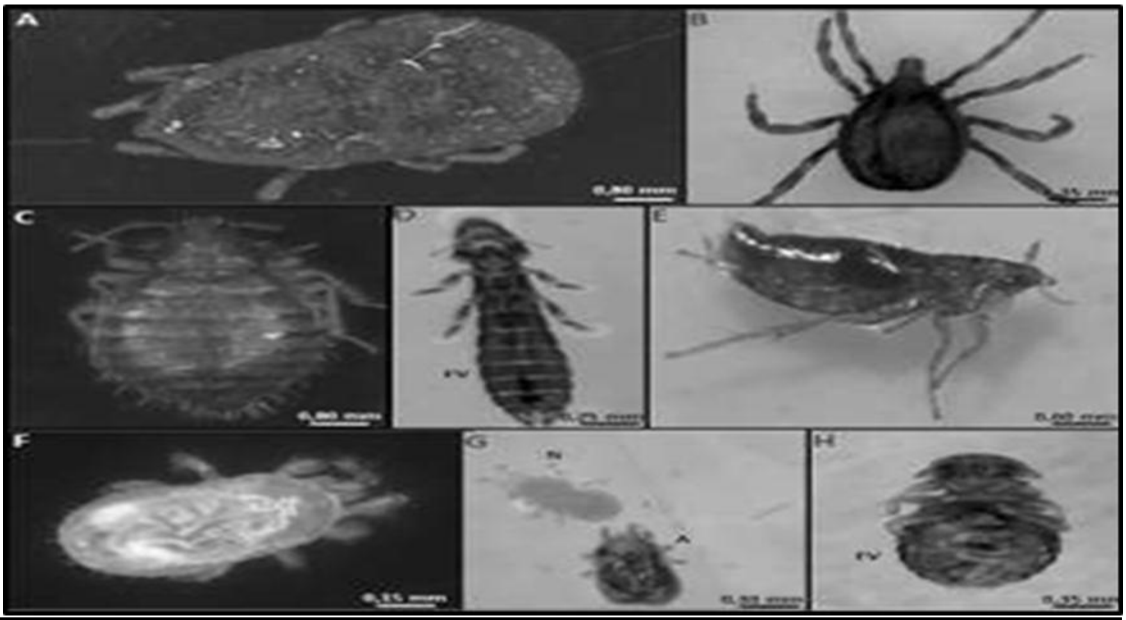


Figure n°5: Ectoparasites collected from birds in Algeria **(Bazizneffah et *al.*, 2015)**

III.2. Fleas

Fleas belong to the phylum Arthropoda, class Insecta. The suborder Siphonaptera (formerly Aphaniptera) comprises around 2,500 species and subspecies and over 200 genera, which most authors group into 17 families and 2 superfamilies: the Pulicoidea (two families: Tungidae and Pulicidae) and the Ceratophylloidea (15 families**) (Touati, 2014).**

The specificity of the 2,500 different species is not as strict as that of lice (Anoplura). Thus, a flea species that normally parasitises a specific host may occasionally feed on other hosts. Most are parasites of mammals, whilst around 100 species are found on birds. *Ceratophyllus* *gallinae* parasitises a wide variety of birds **(Hopla et *al.*, 1994; Franc, 2004; Beaucournu et *al.*, 2005; Duchemin et *al.*, 2006; Simon, 2009 in Touati, 2014) (Fig. 6).**

Kingdom: Animalia

Phylum: Arthropoda

Subphylum: Mandibulata (Antennata)

Class: Insecta

Subclass: Pterygota

Superorder: Oligoneoptera

Order: Aphanipteroidea

Suborder: Siphonaptera

Figure n° 6: The flea **(Barnes, 2007, in Touati, 2014).**

Fleas are wingless insects, yellow or dark brown in colour, measuring 1 to 8 mm in length. Their bodies are flattened laterally, which helps them move through fur. Their legs are adapted for jumping. They parasitise mammals and birds; their medical significance lies not only in the damage caused by their bites but also in their ability to transmit pathogens.

Fleas can be responsible for transmitting numerous parasitic or microbial agents that cause diseases of varying severity, such as murine typhus caused by Rickettsia *mooseri = Rickettsia typhi*, intestinal helminthiasis caused by *Hymenolepis fraterna*, tularemia caused by the bacillus *Francisella tularensis*, or bacillary angiomatosis caused by the bacterium *Bartonella henselae*, and the best known of these is the plague **(Hopla et *al.*, 1994; Franc, 1996; Beaty & Marquardt, 2005; Simon, 2009 in Touati, 2014) (Fig. 7).**

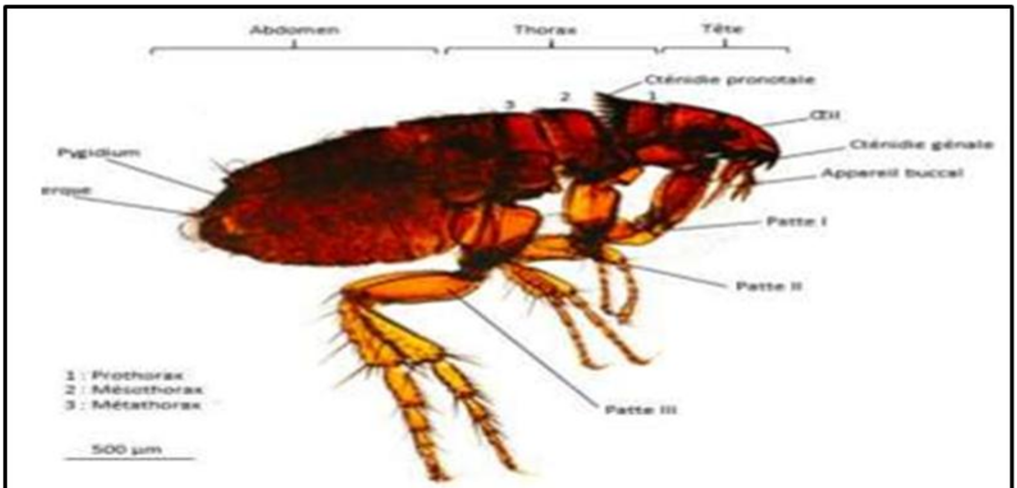


Figure n°7: General morphology of an adult flea (**Lafon and Serceau, 2019, in Yakoubi and Selloum, 2022).**

III.3. Ticks

Ticks, which are obligate blood-feeding parasites, are found throughout the world, from warm to cold regions. They are divided into two main groups: hard ticks (Ixodidae) and soft ticks (Argasidae). **(Bendif et *al.*, 2025)**

Ticks are an order of arachnid mites. This order comprises 896 species classified into three families **(Guglielmone, 2010 in Amoura, 2014).** They spend part of their life cycle on the ground (hatching, metamorphosis and searching for a host), and another part (two or three stages) attached to the skin of mammals (wild and farmed), birds or reptiles, feeding on their blood via a rostrum **(Amoura, 2014)**. Their bites can cause various adverse effects, such as anaemia, allergic reactions, or the injection of toxins leading to paralysis and tropical dyshidrosis. They also transmit numerous infectious agents (bacteria, viruses, parasites), many of which play a major role in human and veterinary health. The increase in tick-associated diseases and changes in their distribution have intensified research into these arthropods in recent years. **(Gérard et *al.*, 2017 in Bendif et *al.*, 2025) (Fig. 8).**

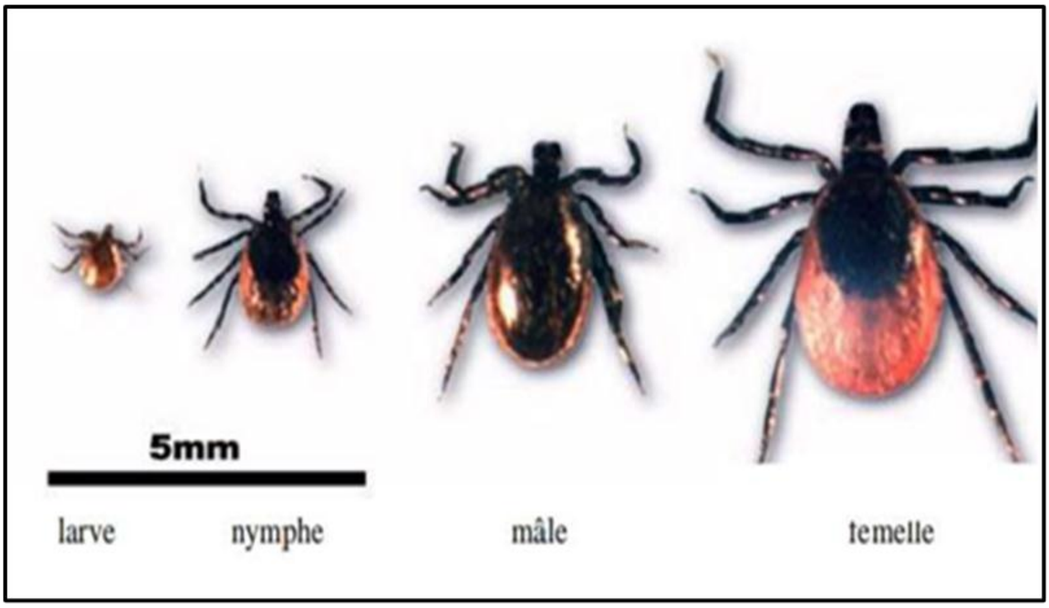


Figure n° 8: The different life stages of ticks **(Francois, 2008, in Yakoubi and Selloum, 2022)**

III.3.1. Different families of ticks

a) The Ixodiadae or 'hard ticks'

Ticks, or Ixoda (from the Greek Ixos = glue, referring to their tenacious attachment to the host), are arachnid arthropods belonging to the subclass Acari and the order Ixodida

(Krantz & Walker, 2009). The Ixodidae family (hard ticks) is characterised by the presence of a well-developed dorsal shield (scutum), a terminal rostrum present at all life stages, excavated palps, and finally, very pronounced sexual dimorphism. Birds are generally the preferred hosts of certain hard ticks (particularly those belonging to the genera Ixodes, *Hyalomma* and *Amblyomma*) **(Touati, 2014) (Fig. 9).**

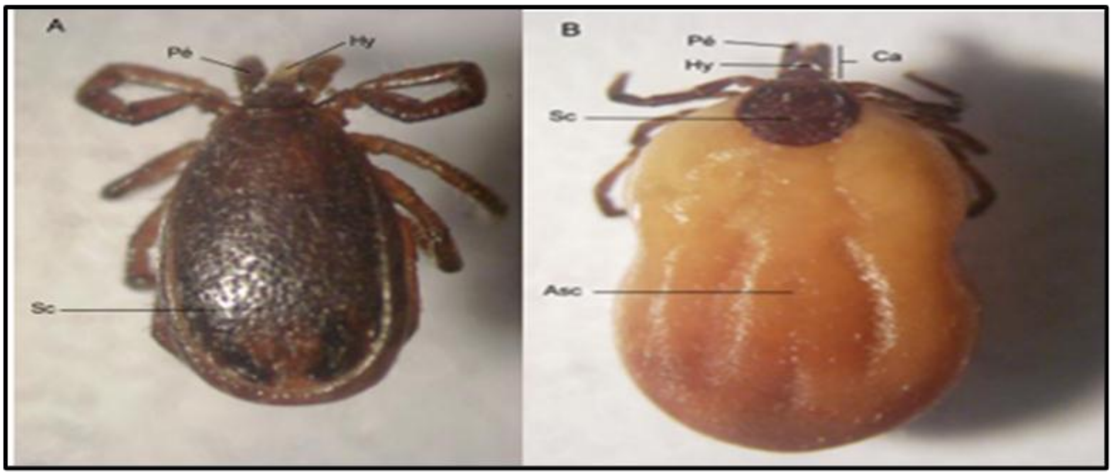


Figure n°9: Ixodes ricinus (A) male (B) female, dorsal view. Ca: capitulum; Pé: pedipalps; Hy: hypostome; Sc: scutum; Asc: alloscutum **(Laamri et *al.*, 2012 in Touati, 2014)**

b) The Argasidae ('soft ticks')

The Argasidae are very different from the *Ixodidae*. Morphologically, the Argasidae family (soft ticks) is characterised by the absence of a chitinous scutellum, the presence of an inferior rostrum (except in larvae, where it is terminal), as well as cylindrical palpi and low sexual dimorphism. Argasidae, *Argas and Ornithodoros,* live in burrows, nests, caves, crevices, in woodwork and walls, under bark, etc., often close to their host. If the host disappears, they can survive without food for several years. After each meal, the female lays around 200 eggs, which reach adulthood within a few months **(Mouchet et *al.*, 1978; Mouchet et *al.*, 1995; Moreno, 2004 in Touati, 2014) (Fig. 10).**

Figure n°10: Soft tick (Argasidae) **(Yakoubi and Selloum, 2022)**

c) The Nuttalliellidae

The family Nuttalliellidae is represented by the monotypic genus Nuttalliella **(Horak et *al.*, 2003).** It comprises a single species, *Nuttalliella namaqua*, which shares characteristics similar to those of the Argasidae and Ixodidae. The larvae and nymphs of N. namaqua have a morphology similar to that of the females **(Latif et *al.*, 2012 in Yakoubi and Selloum, 2022) (Fig. 11).**

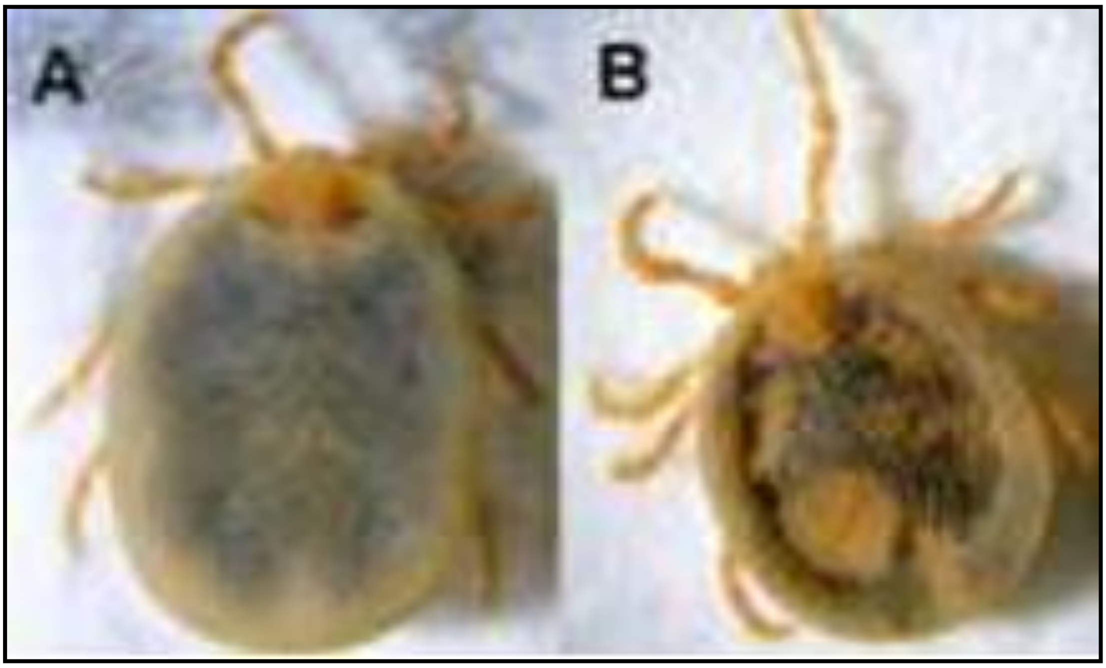


Figure n°11 : Nuttalliella namaqua (A) female (B) male **(Latif et *al.*, 2012 in Yakoubi and Selloum, 2022)**

III.4. Mites

Mites are spherical arachnids formed by the fusion of the cephalothorax and abdomen. Adults have four pairs of legs and are wingless. They include chiggers, ticks and the Sarcoptiformes group (scabies mites) **(Wangrawa, 2010 in Yakoubi and Selloum, 2022).**

According to **Touati. (2014)**, the order of mites comprises five suborders, which are classified according to the presence or absence of stigmata and epimeres.

- Absence of stigmata behind the hips, legs attached to epimeres - Acaridae: no visible stigmata (astigmatic type). -Cryptostigmata (or Oribatae): very small and numerous stigmata (cryptostigmatic type). - Trombidiformes: stigmata on the gnathosoma (prostigmatic type).

- Presence of stigmata behind the hips, no epimeres - Mesostigmata: stigmata near the third hips (mesostigmatic type). - Ixodidae: stigmata behind the fourth hips (metastigmatic type)

(Fig. 12).

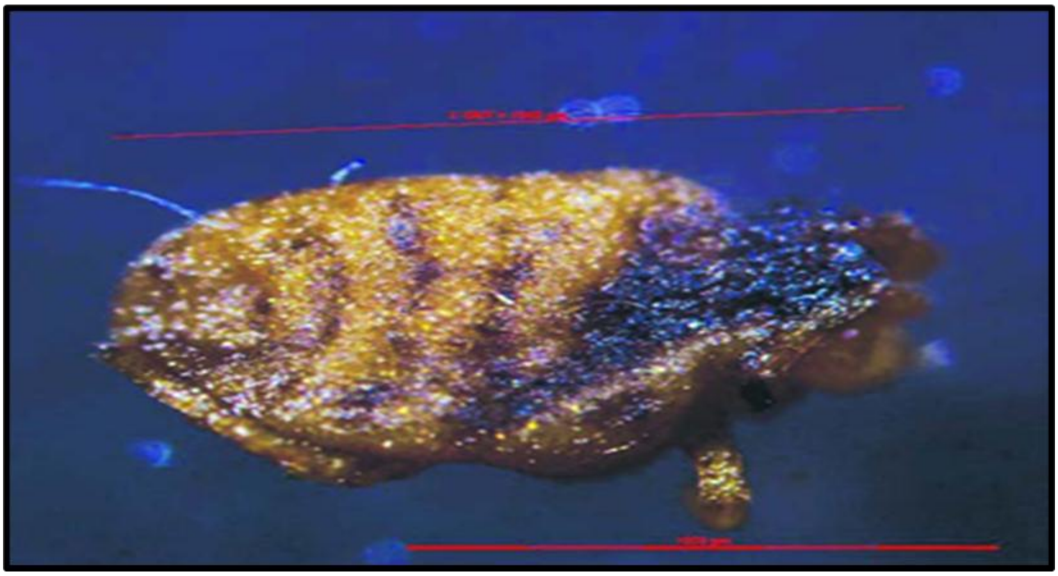


Figure n° 12: Mite under an optical microscope (x100), taken from a Common Coot's nest. MARBEC. Mite under optical microscope (x100**).** **(Mammeria et *al.*, 2021**)

III.4.1. Bird mites

The genus Dermanyssus is characterised by a soft, finely striated integument, with the exception of two small plastrons. The mandibles are modified into a long, thread-like stylet in the female, and into a lanceolate, articulated proboscis in the male. Bird mites inhabit the hollow reeds used as perches in small bird cages and spread over the birds during the night. The two species, *Dermanyssus gallinae* and *Ornithonyssus sylviarum*, are the most commonly encountered in birds **(Andre, 1998 in Yakoubi and Selloum, 2022).**

III.4.1.1. *Dermanyssus gallinae*

Dermanyssus gallinae, also known as the ‘false louse’ or ‘red poultry louse’, is a blood-feeding avian parasite; at rest it is yellowish-brown in colour and blackish-red when engorged with blood; its primary hosts are the nests of pigeons, various birds and poultry houses **(Magdoud et *al.*, 2019 in Bendif et *al.*, 2025)**. This mite is oval in shape, slightly flattened, wider at the rear than at the front, and edged with short, spaced bristles. The dorsal shield is elongated **(Wangrawa, 2010)**. The male measures 600 µm in length and 320 µm in width. Its mandibles are didactylous, with one of the fingers elongated into a thin, wavy blade. The female, which is larger, measures 750 µm in length and 400 µm in width, and has mandibles shaped like long, slender stilettos. **(Wangrawa, 2010 in Bendif et *al.*, 2025)**

Their pathogenic effect is caused by the bites from their rostrum, which draw a relatively large amount of blood from the host. This can lead to significant anaemia in young animals. Itching from the bites, the young animals are deprived of sleep and may eventually die, exhausted and drained of blood, after ten to fifteen days. In adults, insomnia and anaemia lead to weight loss coupled with a reduction in brooding among females. Usually, birds examined during the day show no dermanysses or even any trace of bites. Indeed, these intermittent parasites attack at night in most cases. However, they are sometimes found to be permanently present, moving day and night across the bird’s surface, sometimes in countless numbers **(Andre, 1998 in Touati, 2014) (Fig. 13).**

Figure n°13: Male *Dermanyssus gallinae* **(Akdemir et *al.*, 2009 in Bendif et *al.*, 2025)**

III.4.1.2. *Ornithonyssus sylviarum*

Ornithonyssus sylviarum has been reported on chickens, pigeons and other birds, but may also temporarily parasitise rodents and humans **(Baker, 2007 in Yakoubi and Selloum, 2022)**. Superficially, O. sylviarum resembles D. gallinae; both are active bloodsuckers and can cause significant damage **(Weisbroth, 1960 in Yakoubi and Selloum, 2022).** The two species are easily distinguished by several characteristics; for instance, the adult O. sylviarum is generally smaller (0.6 mm) than the adult D. gallinae (1.5 mm). In O. sylviarum, females have a distinct sternal plate, whereas males have a fused genito-ventral plate. The anal shields of adult females are distinctly different in the two species: O. sylviarum has a teardrop-shaped anal plate, whilst D. gallinae has a square or keystone-shaped anal plate; they also differ in their chelicerae, which are claw-shaped in O. sylviarum and whip-shaped in D. gallinae**. (Murilo et *al.*, 2017 in Yakoubi and Selloum, 2022) (Fig. 14).**

Figure n°14: Dorsal view of *Ornithonyssus sylviarum* **(Blaine, 2012 in Yakoubi and Selloum, 2022)**

III.4.1.3. Knemidocoptic Mange

The parasite responsible for knemidocoptic mange in pigeons is the mite *Knemidokoptes mutans*, which affects the birds' feet, causing irritation, inflammation and hyperkeratinisation. This leads to thickening of the skin, lifting of the scales and sometimes deformation of the feet, making movement difficult. Crusty lesions may extend as far as the base of the beak, whilst feathers in the affected areas fall out or break off. **(Gérard et *al.*, 2017 in Bendif et *al.*, 2025).**

III.5. Lice

Lice belong to the order Phtiraptera (wingless) and are ectoparasites specific to birds and mammals; they spend their entire life cycle on the host, their eggs are attached to the feathers with a glandular cement, and their spread depends heavily on direct contact between different hosts **(Amoura, 2014).**

Lice are traditionally divided into two orders: Mallophaga (chewing lice) and Anoplura (sucking lice). Mallophaga lice, also known as Phthiraptera, are ectoparasites of wild and domestic birds and certain species of mammals. They feed on skin and feather debris, and sometimes cause wounds, feeding on the resulting blood **(Seguy, 1944 in Yakoubi and Selloum, 2022).** Most of these species have a prominent jaw on the underside of the head; the head is rounder and wider than the thorax, and the prothorax is separated from the other two thoracic segments **(Clayton et *al.*, 1992 in Yakoubi and Selloum, 2022) (Fig. 15).**

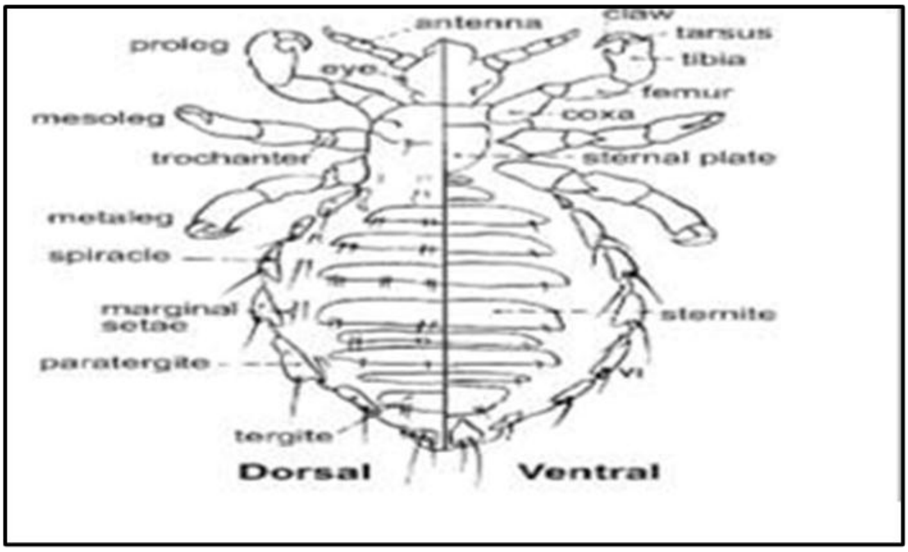


Figure n°15: General morphology of lice **(Ignoffo, 1959, in Yakoubi and Selloum, 2022).**

III.5.1. Chewing lice (Mallophaga)

These are phthiraptera with chewing mouthparts, commonly known as chewing lice. Their head is wider than their thorax. It is worth noting that lice belong to the insect group because their body is segmented and divided into three parts: a head, a thorax and an abdomen. They have three pairs of legs and a single pair of small antennae. All lice are flattened from back to front. Their sensory organs are poorly developed. They are found on birds and mammals **(Touati, 2014).**

A heavy infestation of feather mites causes extreme discomfort and itching, which disrupts feeding. Severe irritation may be observed, leading to damage to the plumage. The symptoms that develop therefore include disturbed rest in the animals, stunted growth in juveniles, and weight loss in adults. However, these are linked to the severity of the bird’s infestation; wild birds are rarely heavily infested. There are differences in pathogenicity between species of mallophages. In small numbers, *Goniodes dissimilis* has little effect on its host. The pathogenic effects of *Lipeurus caponis* are also very mild in healthy animals, although young birds are sometimes subject to massive infestations. In contrast, *Cuclotogaster heterographus* can cause serious disorders, or even death, particularly in young birds. Furthermore, the eggs of this species have a crinkled appearance, which allows them to clump together at the base of the feathers. These compact clusters are responsible for a parasitic crust that severely damages the plumage **(Baud'huin, 2003 in Touati, 2014) (Fig. 16)**

Figure n°16: Crushing lice **(Sánchez, 2011 in Touati, 2014)**

III.6. Moth

Mites are small organisms (0.1–10 mm) that feed on blood and are parasites of insects and vertebrates. Their abdomen is unsegmented and lacks silk-producing filaments. Adults have four pairs of short legs. Mites differ from other arachnids in that the front part of their body is mobile, resembling a head. Meanwhile, the mouthparts are attached to the rest of the body. **(Evert et *al.*, 2007 in Yakoubi and Selloum, 2022)**.

There are nearly 45,000 known species; their life cycle begins with eggs, followed by larvae, nymphs and finally the mature adult. They can complete this cycle in approximately seven days, depending on the environment. Their spread depends heavily on direct contact between adults or, during the breeding season, between adults and chicks. Mites feed on skin scales or feather particles, oily secretions **(Krantz 1978, Gaud & Atyeo 1996, Proctor 2003 in Amoura, 2014),** and fungal spores and diatoms may also form part of their diet **(Dubinin, 1951 in Amoura, 2014) (Fig. 17).**

Figure n°17: Bird mite **(Anonymous, 2009 in Yakoubi and Selloum, 2022)**

III.7. Leeches

Leeches belong to the Animal Kingdom, the group of triploblastic coelomate metazoans, the phylum Annelida, and the class Acheta, which is classified within the family Hirudinidae. There are over 300 species of leeches, divided into 4 orders and subdivided into 127 genera **(Jardin, 2005 in Touati, 2014)**

Leeches are hermaphroditic invertebrates shaped like flattened worms, usually of a rather dark colour. They protect their eggs until hatching, and the young cling to their bellies until they are ready to live independently. They possess suction cups, located at the ends of their bodies, which aid their movement. Leeches are blood-feeding; blood is the main component of their diet. They attach themselves to their prey, make a small bite and inject saliva that prevents clotting, allowing them to feed on the blood for longer and gorge themselves **(Amoura, 2014).**

II.8. Bedbugs

The bedbug is an oval-shaped blood-sucking insect belonging to the Heteroptera family. It parasitises all animals, but humans are its preferred host. The females lay eggs that hatch within a week. The complete life cycle lasts eleven weeks. The painful bite, which appears as a papule, can transmit infectious diseases.

The characteristics that distinguish bedbugs from many other insects are as follows

- Incomplete or gradual metamorphosis (hemimetabolous insects) - Possess two pairs of wings, except in a few specific cases
- The mouthparts are arranged as a highly evolved piercing organ, enabling the injection of saliva and the ingestion of fluids produced by the digestion of the same.
- The presence of scent glands in the abdomen secretes a volatile liquid with a more or less unpleasant odour, which acts as a repellent against predator**s (Pericart, 1992 in Yakoubiet Selloum and 2022) (Fig. 18).**

Figure n° 18: Swallow bug: *Oeciacus hirundinis*, *Cimex lectularius* **(Delaunay et *al.*, 2015 in Yakoubi and Selloum, 2022),** *Cimex colombarius* **(Bockba, 2010 in Yakoubi and Salloum, 2022)**

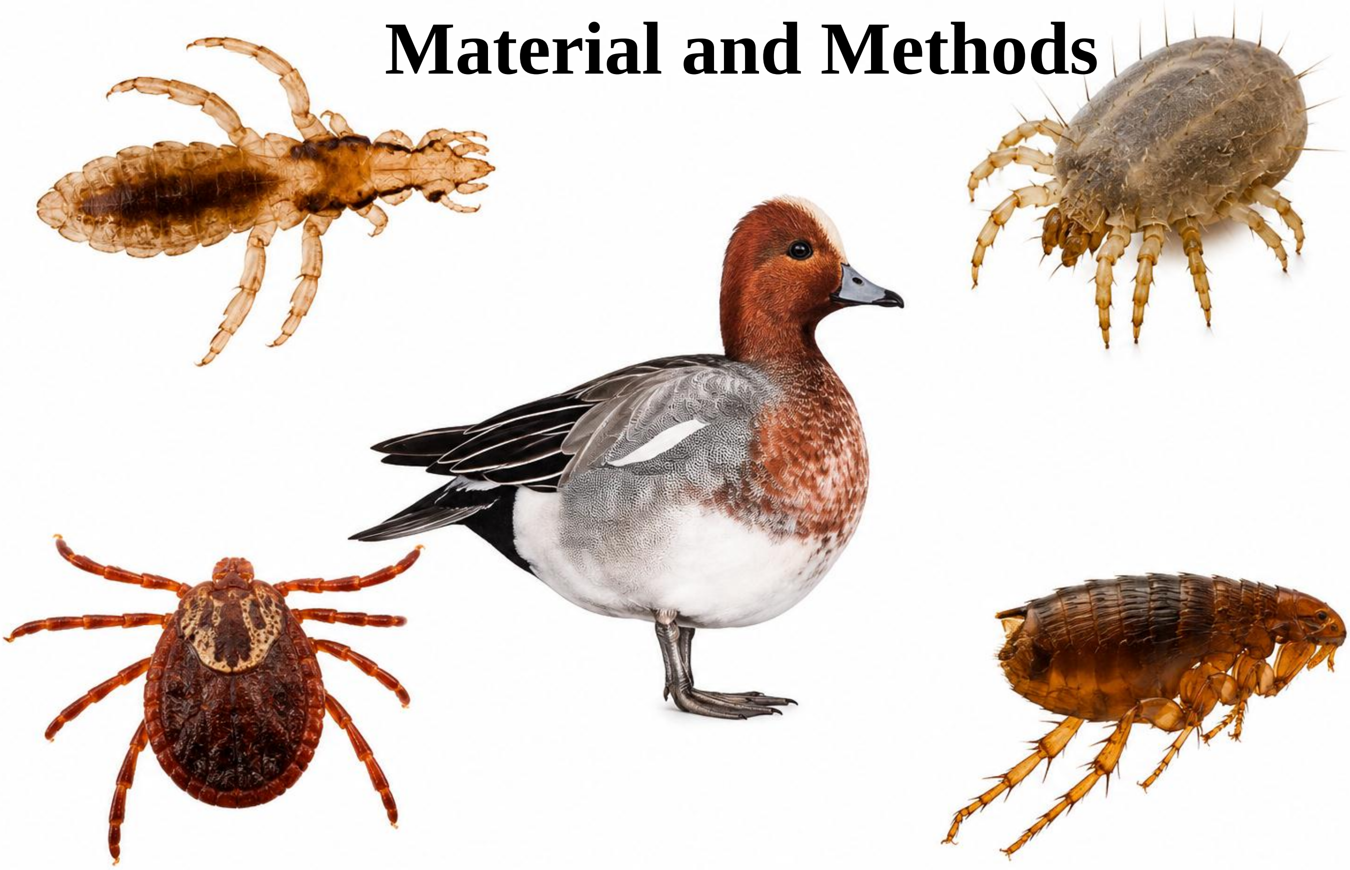
III.9. Myiasis

Myiasis is an infestation of the tissues of living, necrotic or dead vertebrates caused by fly larvae **(James, 1982 in Touati, 2014)**. The fly larvae causing myiasis occupy swollen, conspicuous cavities located just beneath the skin, which open outwards through a pore. They eventually emerge from the host through a port and fall to the ground, where they pupate. The larvae can be removed through the pores using forceps from living or dead hosts, or by dissection if the host is dead **(Losson, 1997; Philips, 2006 in Touati, 2014).**

After eggs are laid by a primary species, the larva hatches and penetrates the skin, which it tears open using its mouth hooks; it then secretes enzymes that digest and liquefy the tissues. Secondary species, attracted by the smell of decomposing tissue, then exacerbate the lesion. Bacterial complications are very common. The irritation and pain cause rapid weight loss, which is often the first symptom noticed (the larvae are buried in the wool). Deaths often result from the resulting septicaemia. A distinction is made between myiasis of the body, the genital region, the tail and the sheath **(Touati, 2014).**

Chapter II:

Material and Methods



Material and Methods

I. Description of the Study Area: El Kala National Park

El-Kala National Park was established on 23 July 1983 by Presidential Decree No. 83-462,and on 17 December 1990 it was designated by UNESCO as a Biosphere Reserve under the 'Man and the Biosphere' (MAB) programme. It is one of Algeria's first legally protected areas and one of the largest protected areas in the north **(Garti and Tafticht, 2018).**

This site covers an area of 76,438 hectares and serves as a refuge for Mediterranean biodiversity. It is home to 1,264 plant species and 878 animal species, including rare species. Forests cover more than 69% of the park's area, whilst over 120,000 people live in the region, placing increasing pressure on biodiversity. Studies highlight the importance of protecting these natural resources to ensure their sustainability, making the park an important model for environmental conservation and ecological awareness **(Ben Azouz, 2025).**

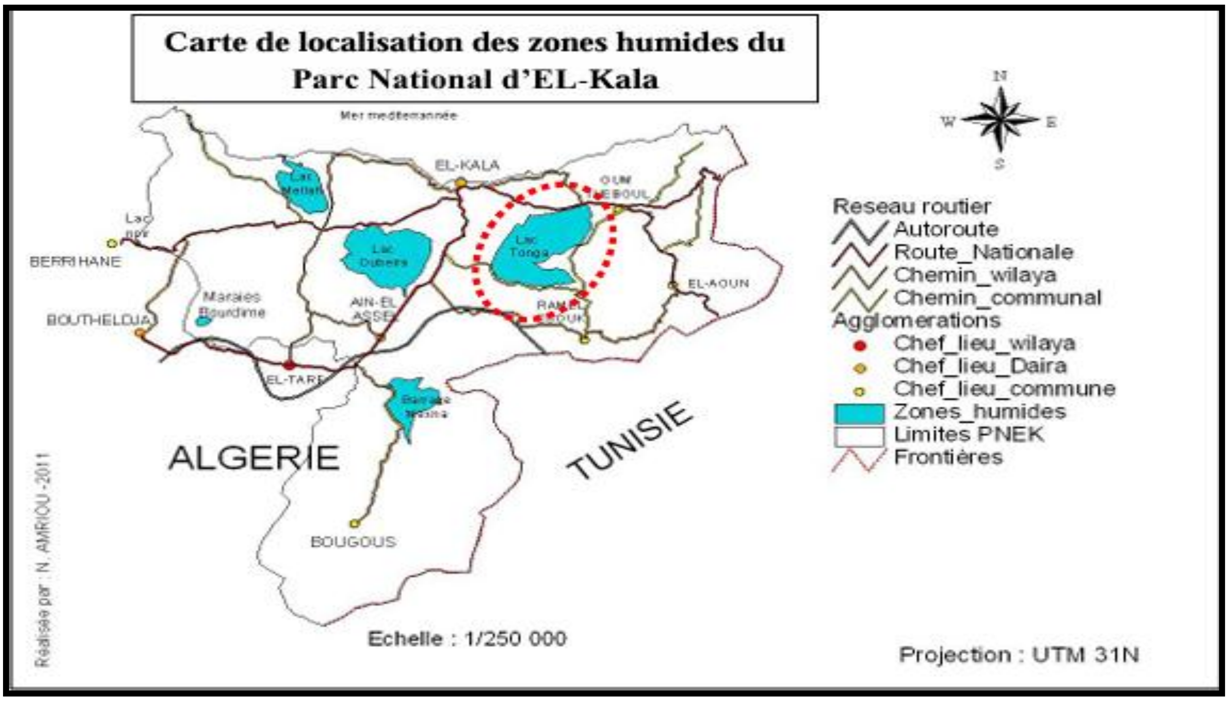


Figure n° 19: Map showing the geographical location of the PNEK wetlands **(Amriou, 2011 in Labbaci, 2017).**

II. Descreption of the study site: Lake Oubeira

II.1. Description and location

The Lake Oubeira catchment area is situated 5 km south-west of El Kala and 54 km east of Annaba. It is located within El Kala National Park, which lies in the far north-east of the country on the border with Tunisia. Lake Oubeira is situated at the centre of a 9,800-hectare catchment area. With a depth of 4 m, it is the deepest freshwater body in the region, covering an average surface area of 2,200 hectares and with a perimeter of approximately 32 km. It forms a subcircular shape within a rectangle measuring 7 km at its longest and 3.5 km at its widest, with a diameter of 5 to 6 km. It is classified as the second largest body of water in the P.N.E.K. Lake Oubeira is an almost circular basin with no outflow to the sea (it is an endorheic system); the land within the catchment area is divided between forest land, where private plots are rare, and agricultural land, most of which is privately owned and used primarily for groundnut cultivation, market gardening and grazing **(Messerer, 1999 in Boumaraf, 2010).**

This lake is very important for the wintering of waterbirds and is also home to some rare species. It features a diversity of aquatic vegetation, including water chestnut (*Trapa natans*) and white-water lily (*Nymphaea alba*), and is the only known site for the yellow water lily (*Nuphar luteum*) **(Kahli, 1996 in Ben Azzouz, 2025).**

Lake Oubeira regularly hosts around 20,000 waterbirds, with a population peak at the start of the migratory season in November and December, prior to the official census **(Belhadj, 1996 in Ben Azzouz, 2025) (Figs. 20 and 21).**

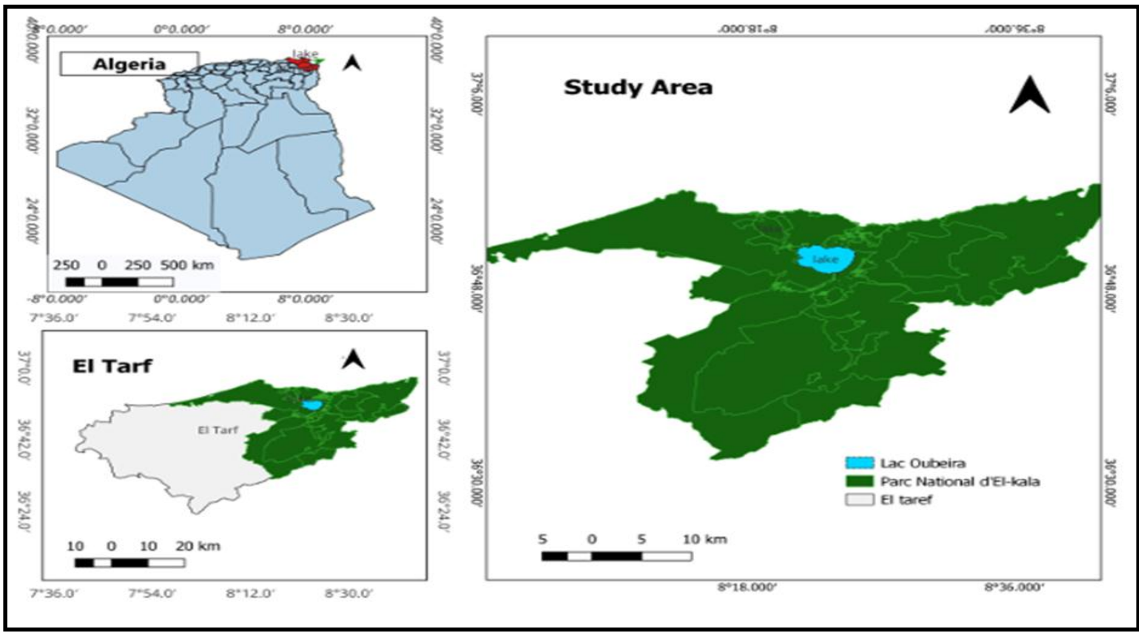


Figure n° 20: Geographical location of Lake Oubeira **(Rizi, 2023)**

Figure n° 21: Lake Oubeira **(© Faci, 2026)**

II.2. Physical environment

II.2.1. Geomorphology

Lake Oubeïra is surrounded by clay-sandstone hillsides covered in forest. It is bordered over a width of 1 to 2 km by recent Quaternary deposits that form the continental plain

L'extension de ces formations retrace une variation très importante du niveau du lac, celui-ci disparaît sur la bordure Nord pour laisser apparaitre le niveau actuel, représenté essentiellement par les marécages. Le pourtour du lac laisse apparaître des sables et des limons récents correspondant à un milieu lacustre Néo pléistocène **(Brahmia, 2002).**

II.2.2. Geology

According to geological studies conducted by **(Joleaud Deleau, 1998 in Ben Azzouz, 2025)**, the Lake Oubeira basin is characterised by the following formations:

- Clayey sediments that are submerged in winter.
- Silty sediments present at the bottom of Pleistocene valleys, composed of sand and silt
- Distinct sandy rocks formed by aggregation, leading to the formation of dunes.
- Pontian formations containing two types of sandy clays, grey, yellow or red in colour, as well as conglomerates and red or yellow sands.
- Neogene sandy sediments, often white and friable, covering 33% of the catchment area.
- Clay-shale marls of various colours, with intercalations of small beds of quartzite sandstone, developed mainly on valley slopes.
- Clay, sandstone and black nummulite-bearing limestones from the Middle Eocene.

II.2.3. Climate

Lake Oubeïra, along with the El Kala region, lies within the sub-humid zone with warm winters, characterised by prevailing north-westerly winds. Average annual rainfall ranges between 700 and 800 mm and occurs mainly from early October to the end of March. The region is characterised by two seasons: a dry season from May to September and a wet season from September to April. The water temperature ranges from 8.8 to 15.2°C in January. The average air temperature, calculated over a 28-year period from 1968/69 to 1995/96, is

17.50°C, with 11.65°C in January (the coldest month) and an average of 25°C in August (the hottest month). Average evaporation is 74.15 mm, with a maximum of 152.08 mm and a minimum of 22.47 mm. The lake waters are very turbid, especially in winter, with a pH ranging between 8 and 10.65. **(Abdelmoumène, 2023).**

II.2.4. Hydrogeology and hydrography

From a hydrogeological perspective, two types of formation are found in the region: permeable formations and low-permeability formations. Sandstones, Numidian clays, as well as clays and silts belong to the low-permeability formations. Their permeability is low, ranging from 10^{-6} m/s in clays and sandstones, to 10^{-5} to 10^{-4} m/s in silts and alluvial clays.

Lake Oubeïra is fed by major watercourses: Oued Demt Rihan to the north, Oued Bou Merchène to the north-east, Oued Dey El Garaa to the east and Oued Messida to the south. In winter, during periods of heavy rainfall, the waters of Oued El Kébir reach the lake mainly via Oued Messida.

In summer, when the water level of Oued El Kébir is at its lowest, the hydrological system operates in the opposite direction, as Oued Messida has the unique characteristic of flowing in both directions depending on whether the water level is high or low **(Boumaraf, 2010).**

II.3. Ecological characteristics

This is the only major site within the region’s wetland complex that exhibits a typical spatial arrangement of vegetation belts (helophytes), with a large area colonised by floating hydrophyte beds. In summer, the vegetation belts are clearly visible and virtually unbroken all around the lake, varying in width and density depending on the shoreline; the widest belts (around 400 m) consist mainly of helophytes, *Phragmites australis*, *Typha angustifolia* and *Scirpus scirpus* sp.). The floating beds consist of hydrophytes, water chestnut (Trapa natans), milfoil (*Myriophyllum* sp.), pondweed (*Potamogeton* sp.), etc.

These formations cover the large expanse of open water. Although considered a prime wintering site, this lake, despite its vegetation being limited to the edges, is a nesting site for several species of waterbirds such as the Moorhen (*Gallinula chloropus*), the Little Bittern (*Ixobrychus minutus*), the Spotted Crake *(Moraena morzana*), the Water Rail (Rallus aquaticus), etc. It is also a feeding ground for species that nest in other wetlands in the region, such as ducks, the whiskered tern (*Chlidonia hybrid*), the purple heron (*Ardea purpurea*) and the squacco heron (Ardea ralloides), the little egret (*Egretta garzetta*) and the cattle egret (*Bubulcus ibis*), as well as waders. This site has been affected by the introduction of Chinese carp, which has caused disruption to the environment, notably through the disappearance of the aquatic vegetation.

III. Biological model

Our biological model is the Whistling Duck (*Anas penelope*), which belongs to the Anatidae family.

III.1. Taxonomy

- **Kingdom:** Animalia

- **Phylum:** Chordata.

- Subphylum: Vertebrata.

- Class: Aves.

- Order: Anseriformes.

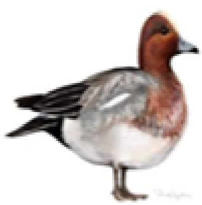
- Family : Anatidae

- Genus : Anas.

- Species: Anas penelope (Linnaeus 1758).

Figure n°22 : Eurasian Wigeon (Site 1)

III.2. Description



The Wigeon is a gregarious bird during the non-breeding season. It is stocky and not particularly slender, unlike most other species of surface-feeding ducks. Up close, in good light, it reveals its splendour. The upper parts (back, small coverts and scapulars) and the flanks are grey, with fine mottling. Between these, there is very often an elongated white patch corresponding to the white on the wing. The lower neck and breast are a wine-red colour. The head and upper neck are chestnut, except for a pale-yellow forehead stripe. The eye is dark. The bill is steel-blue with a black tip. At the rear, the rump and undertail coverts are black. The tail itself is grey. The underparts are white. Behind the grey scapulars, the long black tertial feathers with grey edges are visible. In flight, the bird's striking black-and-white contrast on the forewing is unmistakable (black secondary feathers and greater coverts, and white (small and medium-sized coverts). In the Hooded Merganser, the contrasting patch is restricted to the inner half of the forearm and is reversed, with the white square at the rear, on the flight feathers.

The male in eclipse plumage is distinctly different, with his reddish-brown plumage, vivid on the flanks. He resembles the female, but with a warmer tone. The yellow forehead stripe has disappeared. The white wing coverts, highly visible in flight, appear as a white lateral line when perched.

The female is easy to recognise when she is paired. When she is alone, it is more difficult. Her silhouette is already that of the male, with a rounded forehead. The beak is also practically the same. However, in terms of plumage, she is very different. Perched on the water, she appears entirely brown with a warmer shade on the head and flanks. The deep brown feathers on the upper parts are edged with reddish-beige. When standing, she displays a white lower breast and belly. A white stripe is sometimes visible on the side.

The juvenile resembles a female, perhaps with a less distinct beak. The young male develops its characteristic features during its first winter.

The male's powerful whistle is, moreover, an excellent means of identifying the species, whilst the female utters only a brief song. Total body length: 45 to 51 cm. Weight: 415 to 970 g. **(site 1)**

III.3. Habitat

In winter, the Wigeon overwinters along the coast and on large lakes, in estuaries and bays. It must spend between 12 and 16 hours a day feeding on plants of low nutritional value. In grassy areas, the Wigeon shows a preference for sites where biomass ranges from 80 to 120 g of dry matter per m²; the minimum required to avoid mortality or emigration for the species is 8 g/m².

In the Camargue, the Wigeon is found in areas of low to moderate salinity, covering areas ranging from several tens to several hundred hectares, rich in submerged aquatic plants that provide their food and which are generally undisturbed by human activity **(Site 2).**

III.4. Reproduction

New pairs form in the autumn, as soon as they arrive at their wintering grounds. By the end of winter, reproductive readiness is primarily governed by the photoperiod—that is, by the increase in light levels and the lengthening of the days, which determine the quality of the habitat and the abundance of resources

Figure n°23: A female Eurasian wigeon with her ducklings **(site 1)**

Once on site, between April and June, the female chooses the nest site, which is always well concealed in tall grass, on dry land some distance from the water. It is built from grass and other plant material. Incubation begins after the last of the 6 to 12 eggs in the clutch has been laid and lasts an average of three and a half weeks. The female spends most of her time on the nest, whilst the male keeps watch from the water. The chicks are precocial and leave the nest together, approximately 24 hours after hatching. They become independent after 37 to 48 days of development, a period that varies depending on the habitat's suitability **(Site 1).**

III.5 Distribution

The Wigeon is very widely distributed, breeding in most Nordic countries and extending as far as subarctic and boreal zones. The distribution of breeders wintering on the coasts of the English Channel and the Atlantic generally lies between 55° and 70° north latitude, with a sporadic distribution in the southern part of its range. Birds recorded along the Mediterranean coast originate from central Siberia and constitute a population geographically isolated from the former.

Western populations winter mainly along the coast from Europe to North Africa, with only a few birds reaching sub-Saharan Africa each year.

Generally speaking, adult males tend to remain in the northern part of the wintering area, whilst females and immature males move to more southerly regions, likely due to the aggressiveness of the males, who establish a hierarchical social structure, a process further facilitated by their numerical dominance within the populations **(site 2) (Fig.24).**

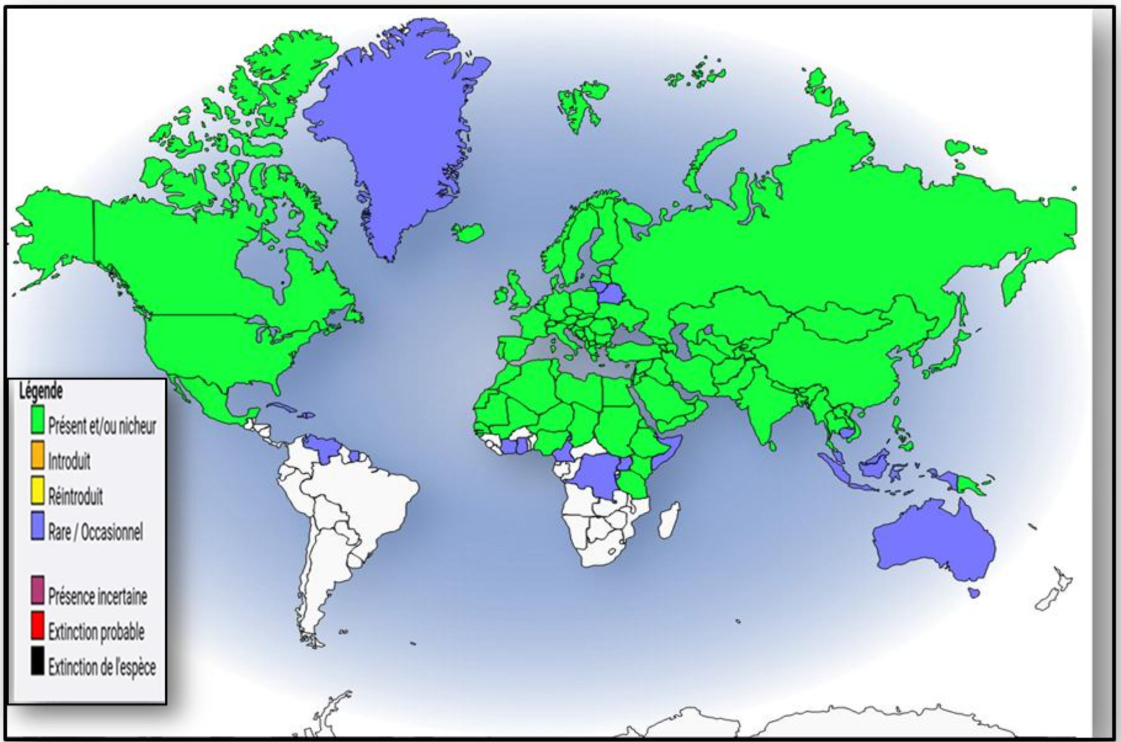


Figure n° 24: Distribution map of the Whistling Duck worldwide **(Site 1)**

The main threats to the Eurasian Wigeon include the high concentration of the population in a limited number of sites, which reduces the possibility of moving to alternative habitats in the event of habitat degradation. The species is also vulnerable to hunting pressure, particularly during periods of severe cold and night-time hunting. Disturbances linked to human activities, such as fishing, hunting and water sports, disrupt its behaviour and reduce the carrying capacity of suitable wetlands. Added to this is the ongoing degradation of wetland habitats, which leads to a reduction in areas suitable for wintering and foraging, thereby contributing to population declines in several regions **(Site 2).**

IV. Methodology

IV.1. Sampling

Parasitological sampling is a crucial step that requires particular attention, as the reliability of the results depends directly on the quality of the sample collected.

The main objective is to obtain a specimen that is representative of the parasite being sought, whilst avoiding any alteration or contamination that might influence the analysis. To ensure the validity of the tests, several factors must be controlled, including the choice of equipment used, the sampling techniques applied, and the conditions for transport, storage and identification of the samples. These various precautions ensure a correct and reliable interpretation of the results obtained.

IV.2. Collection of individuals

The Wigeon individuals studied were collected between October 2025 and April 2026. After being collected in the field, each bird was placed individually in a sealed bag to prevent the spread or loss of any ectoparasites present on the plumage. The specimens were then weighed using an electronic scale before the various observations and procedures required for the study were carried out.

IV.3. Morphometric measurements

A series of morphometric measurements was taken on each individual to assess certain biological characteristics in relation to the observed parasite load. The parameters measured were as follows:

- Weight
- Beak length
- Wing length (folded)
- Wing length (spread)
- Wingspan
- Tarsus length.

IV.4. Equipment used

- The equipment used in this study includes:

A binocular magnifying glass (stereomicroscope); Petri dishes; microscope slides and cover slips; fine-tipped forceps and dissection equipment; sample collection and storage bags; a tape measure; an electronic balance (digital balance); as well as rating sheets and data logbooks **(Fig. 25).**




Figure n° 25: Some photographs of the equipment used during the study period **(© Faci, 2026)**

IV.5. Collection and quantification of ectoparasites

The search for ectoparasites was carried out by means of a thorough visual inspection of the birds' entire bodies. The plumage was then examined in several areas of the body, including the head, neck, back, belly, wings and tail. Feathers collected from each region were stored separately in bags to facilitate the identification of the different parasitic microhabitats.

IV.6. Collection of ectoparasites

The feathers collected were examined under a binocular magnifying glass to detect the presence of parasites. The collection was carried out with care to avoid damaging the specimens. Particular attention was also paid to examining the storage bags, as some parasites may leave the host after its death. Parasites visible to the naked eye were collected directly, whilst smaller forms required the use of a suitable magnifying glass to facilitate their observation and isolation.

IV 7. Taxonomic characterisation of ectoparasites

Following collection, the various groups of ectoparasites were sorted and then identified on the basis of their morphological characteristics. The count carried out made it possible to determine the taxonomic richness and abundance of the parasitic species associated with the Wigeon. The data obtained were then used to assess the diversity of the ectoparasite communities observed in the individuals studied.

IV 8. Parasite indices

As part of this study, several parasite indices were calculated to assess the level of ectoparasite infestation in the Wigeon. The parameters selected were prevalence, abundance and average parasite intensity. These indices provide a better characterisation of the relationship between the parasites and their hosts.

IV 8.1. Prevalence (P)

Prevalence represents the percentage of hosts infested by a given species of parasite out of the total number of individuals examined. It is calculated using the following formula:

$$\boxed{P\,(\%) = N/H \times 100}$$

Where:

- N: number of infested hosts;

- H: total number of individuals examined.

IV 8.2. Abundance (A)

Abundance is defined as the ratio of the total number of parasites collected to the total number of hosts examined. It is expressed by the following formula:

$$\boxed{A = n/H}$$

Where:

n: total number of parasites collected;

H: total number of individuals examined.

IV 8.3. Average parasite intensity (I)

Average parasite intensity refers to the average number of parasites observed in infested hosts. It is calculated using the following formula:

$$\boxed{I = n/N}$$

Where:

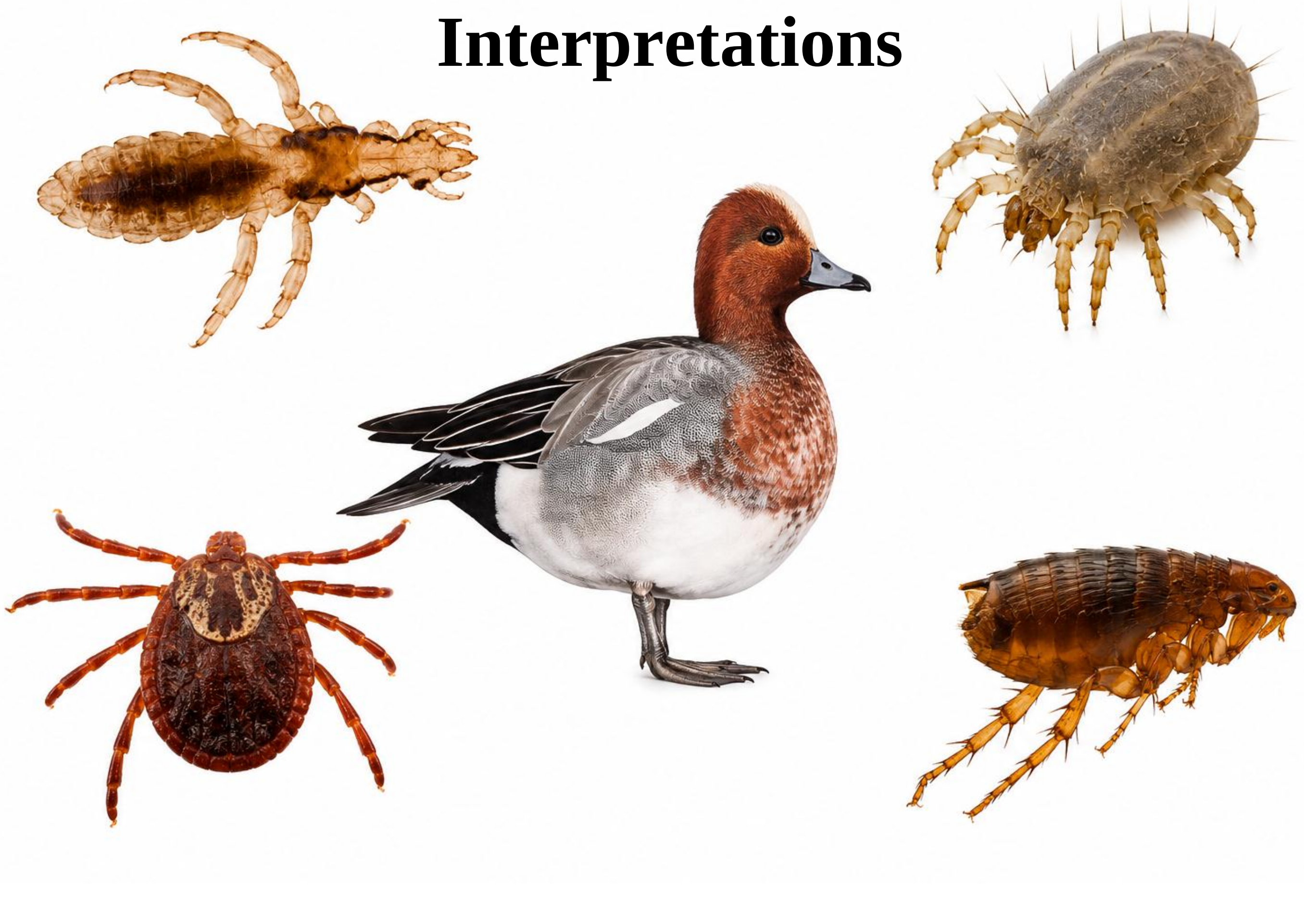
n: total number of parasites collected;

N: number of infested hosts.

IV 9. Statistical analyses

Statistical analyses were performed using R software version 4.5.1 (R Core Team, 2023). The data were checked for normality and homogeneity of variances prior to the application of parametric tests.

Chapter III: Results and Interpretations



RESULTS AND INTERPRETATIONS

The figures presented illustrate the results of the study on ectoparasite infestation in wigeons at Lake Oubeira between October 2025 and April 2026, covering 30 individuals over a seven month period during the wintering season.

The graphs provide an overview of the data collected on the Wigeon at Lake Oubeira during the wintering season.

I. Prevalence (P)

$$\boxed{P\ (\%) = N/H \times 100}$$

- N: number of infested hosts
- H: total number of individuals examined

We have: 30 individuals examined, all of whom are infested, so:

- N = 30 (number of infested hosts)
- H = 30 (total number of hosts examined)

P (%) = 30/30 × 100

therefore:

Prevalence = 100%

A prevalence of 100% indicates that all individuals examined were carrying at least one ectoparasite. No individual was free from infestation, which indicates widespread infestation within the sample studied.

II. Abundance (A)

$$\boxed{A = n/H}$$

Where:

n: total number of parasites collected;

H: total number of individuals examined

We have: 2617 parasites collected, therefore A = 2617/30

A = 87.23

The average abundance of 87.23 indicates that there were, on average, 87.23 ectoparasites per wigeon examined. This value reflects a relatively high parasite load within the sample studied.

III. Average parasite intensity (I)

$$\boxed{I = n/N}$$

n: total number of parasites collected;

N: number of infested hosts.

We have: 2,617 parasites collected, therefore I = 2,617/30

I=87.23

The average intensity of 87.23 indicates that each infested wigeon hosted an average of 87.23 ectoparasites. This value represents the average number of parasites observed in the infested hosts in the sample studied.

IV. Distribution of ectoparasite counts per observation

The histogram shows that the majority of counts fall within the range of 1 to 3 parasites per observation, with an average of 1.94. The distribution is slightly right-skewed, which is typical of count data in parasitology. **(Fig. 26).**

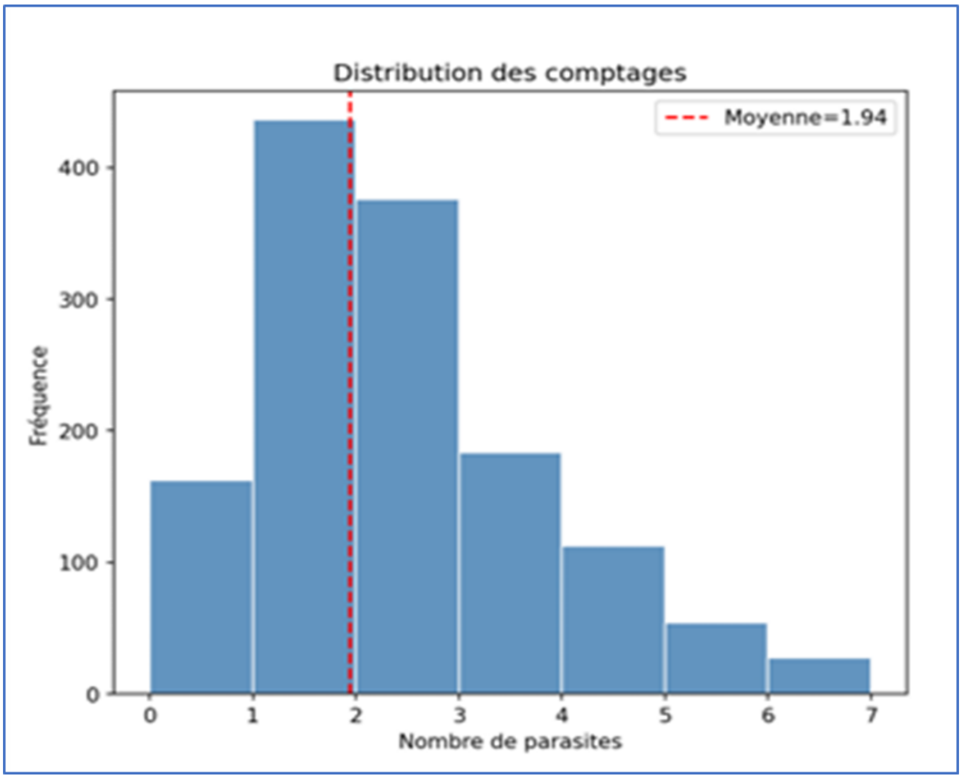


Figure n°26: Distribution of the number of ectoparasites observed in Eurasian wigeons at Lake Oubeira

V. Distribution of parasite load across body regions in the Wigeon

The graph highlights a clear hierarchy among the different body regions: the tail has the highest parasite loads, with a median of around 2 and values reaching as high as 6, followed by the breast, belly and back. Conversely, the legs, whether left or right, as well as the head, show much lower loads, with a median close to 1. This distribution suggests that ectoparasites preferentially colonise the dorsal and caudal regions of the Wigeon **(Fig. 27).**

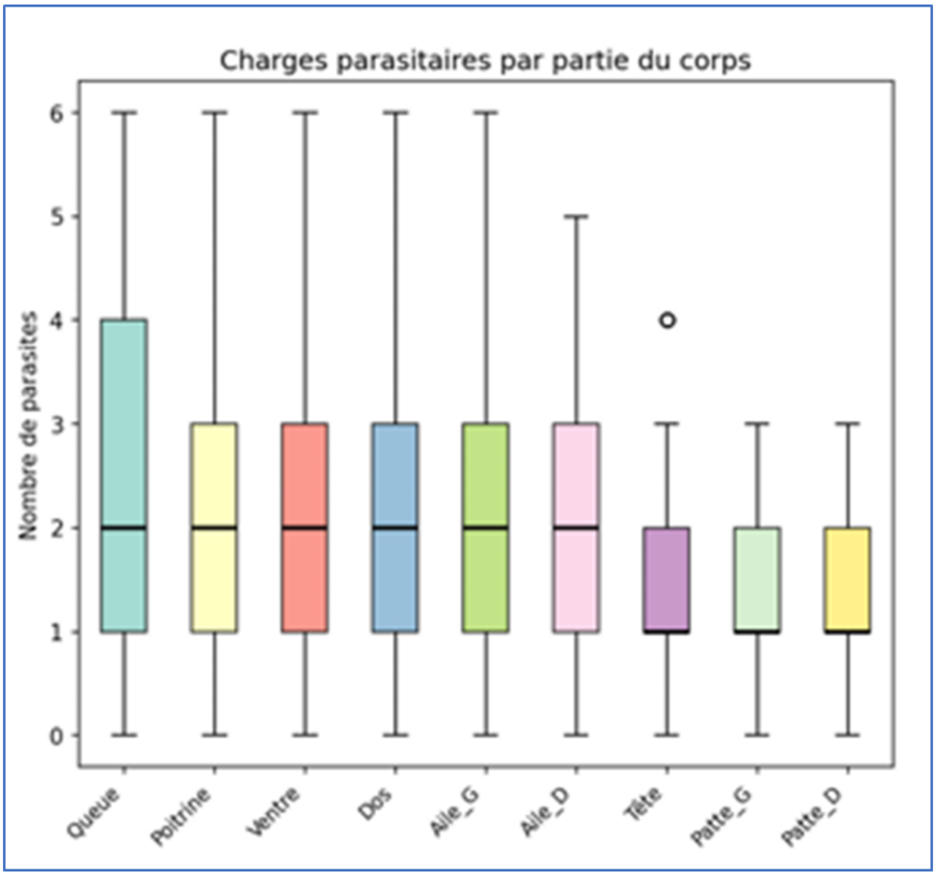


Figure n°27 : Distribution of Parasite Load by Body Region in the Eurasian Wigeon (Boxplot)

V.1. Effect of the sex of the Eurasian Wigeon on parasite load

The graph reveals no significant difference between males and females (Mann-Whitney, p = 0.557). The distributions appear to overlap significantly, suggesting that the sex of the Wigeon is not a factor explaining the variability in parasite load at Lake Oubeira during the period under consideration **(Fig. 28).**

Figure n°28: Comparison of Parasite Load Between Male and Female Eurasian Wigeons

V.2. Monthly trends in parasite load in the Wigeon

The bar chart shows relatively stable average parasite load values between October 2025 and April 2026, ranging from 1.81 in October to 2.11 in November. The error bars overlap considerably from one month to the next, indicating that no significant monthly differences are detectable. These results suggest that the parasite load in Wigeons at Lake Oubeira remains stable throughout the wintering period, with no marked seasonal peak **(Fig. 29).**

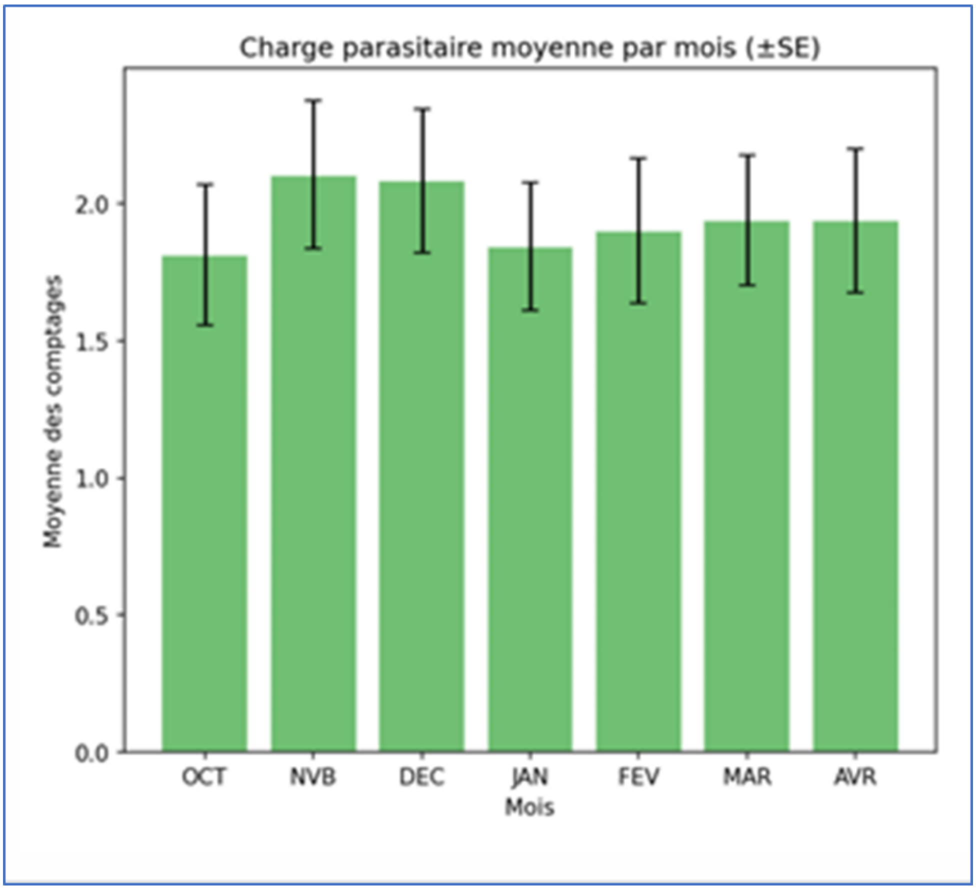


Figure n°29: Average monthly parasitic load in the Eurasian wigeon at Lake Oubeira

V.3. Composition of the parasite community and average parasite load by parasite type in the Wigeon

The bar chart shows that mites (μ = 3.11) and ticks (μ = 2.49) clearly dominate the parasite community, together accounting for the bulk of the parasite load on the Wigeon. Fleas constitute the least common group, with an average load of 0.85. This distribution indicates a strong dominance of mites and ticks in the infestation of Wigeons at Lake Oubeira during the wintering period studied **(Fig. 30).**

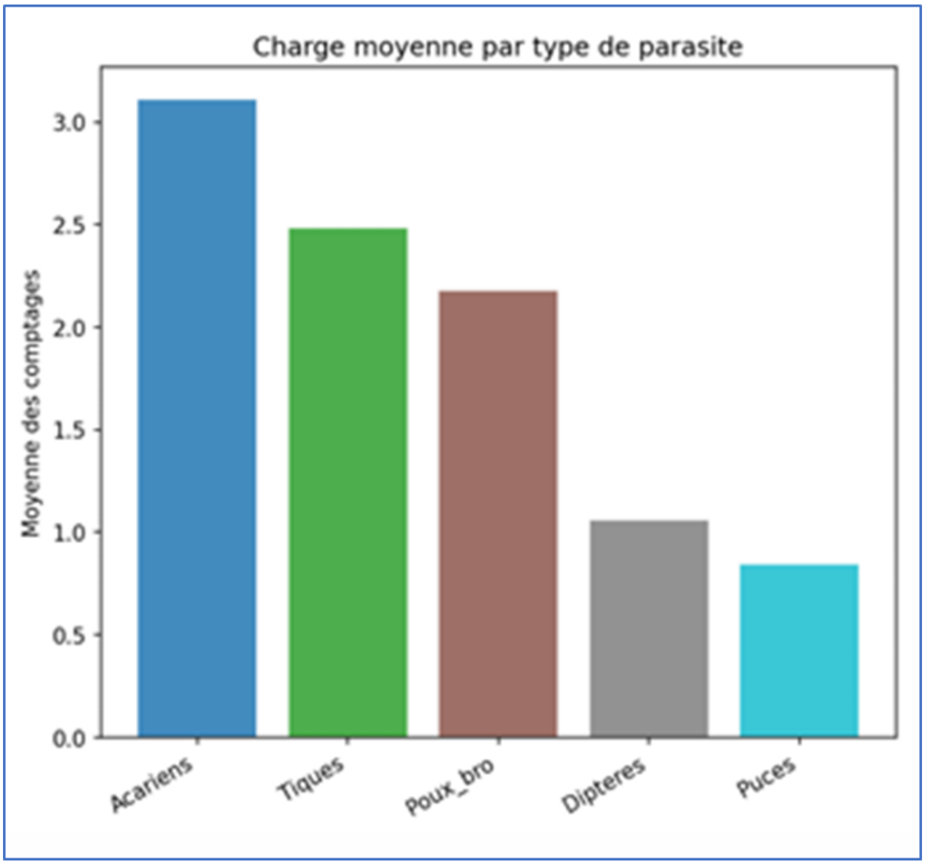


Figure n°30: Average parasite load by parasite type in the Eurasian wigeon at Lake Oubeira

V. 4. Average parasite load by sex and body part in the Wigeon

The heat map reveals that infestation patterns by body part are very similar between male and female Wigeons. In both sexes, average loads range from 1.1 (right leg) to 2.6 (tail), confirming that the anatomical area is the main factor determining the distribution of ectoparasites, regardless of sex **(Fig. 31).**

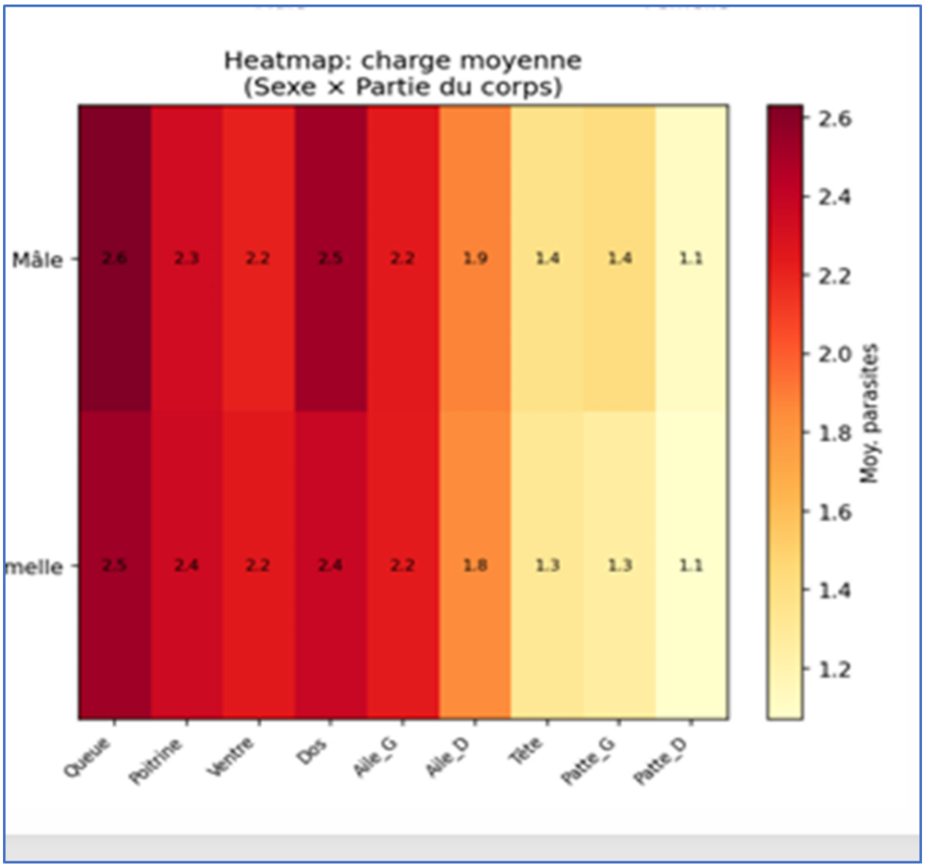


Figure n°31 : Average parasite load by sex and by body region in the Eurasian Wigeon at Lake Oubeira

V.5. Temporal trends in parasite load by sex at the start and end of the wintering period in the Wigeon

The graph shows contrasting patterns between male and female Wigeons during the wintering period. At the start of the wintering period (October 2025), females have a lower load ($\mu \approx 1.67$), then reach a marked peak in December 2025 ($\mu \approx 2.55$), whilst males display a more stable profile (1.85 to 2.17). From January to March 2026, the trends partially reverse: females begin a gradual increase until March 2026, whilst males remain stable at around 1.87. These cross-correlated fluctuations should be interpreted with caution, as each month corresponds to different individuals: approximately 4 to 5 Wigeons are examined for ectoparasite counts, without longitudinal monitoring of the same birds **(Fig. 32).**

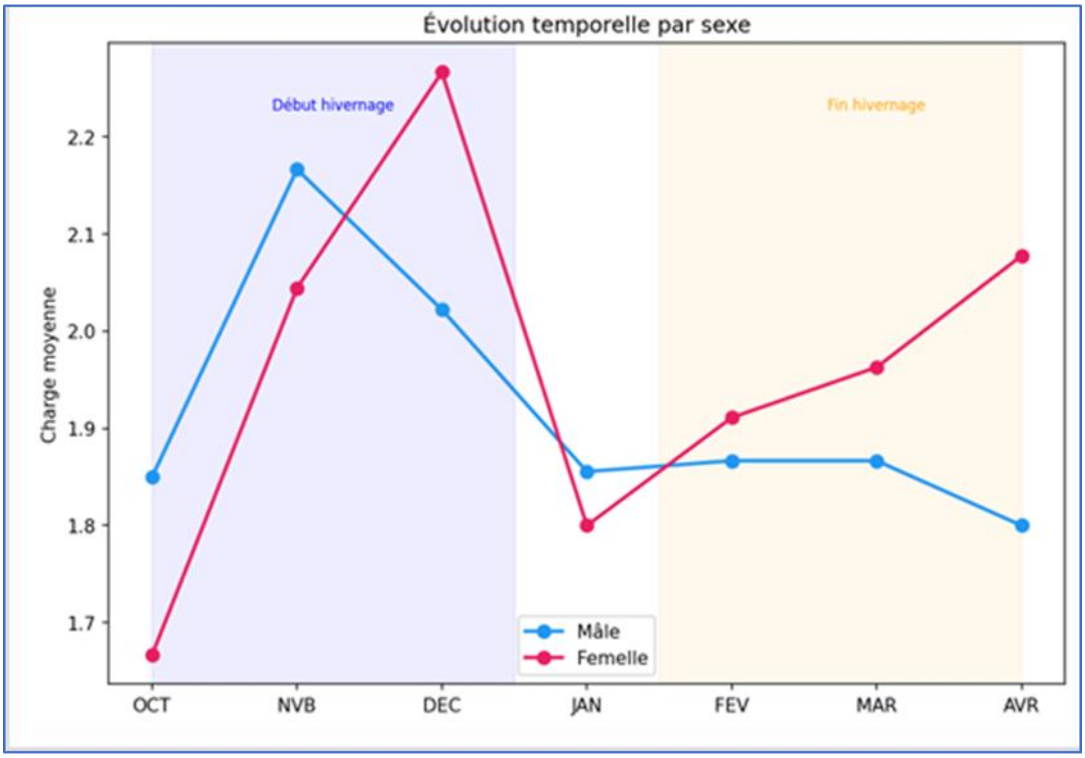


Figure n°32: Temporal variation in parasite load by sex between the beginning and end of the overwintering period in the Eurasian wigeon

V.6. Ectoparasite infestation profile in the Whistling Duck

Principal component analysis (PCA) reveals that the first two axes explain 57.6% of the total variance (PC1 = 33.3%, PC2 = 24.3%). The five types of parasites show positive correlations with one another, as indicated by the vectors pointing in a common direction on the biplot. Male and female Wigeons are distributed in an intermixed pattern on the factor plot, with no distinct segregation. This lack of grouping by sex confirms that there is no significant difference in parasite profile associated with the host's sex within this population **(Fig. 33).**

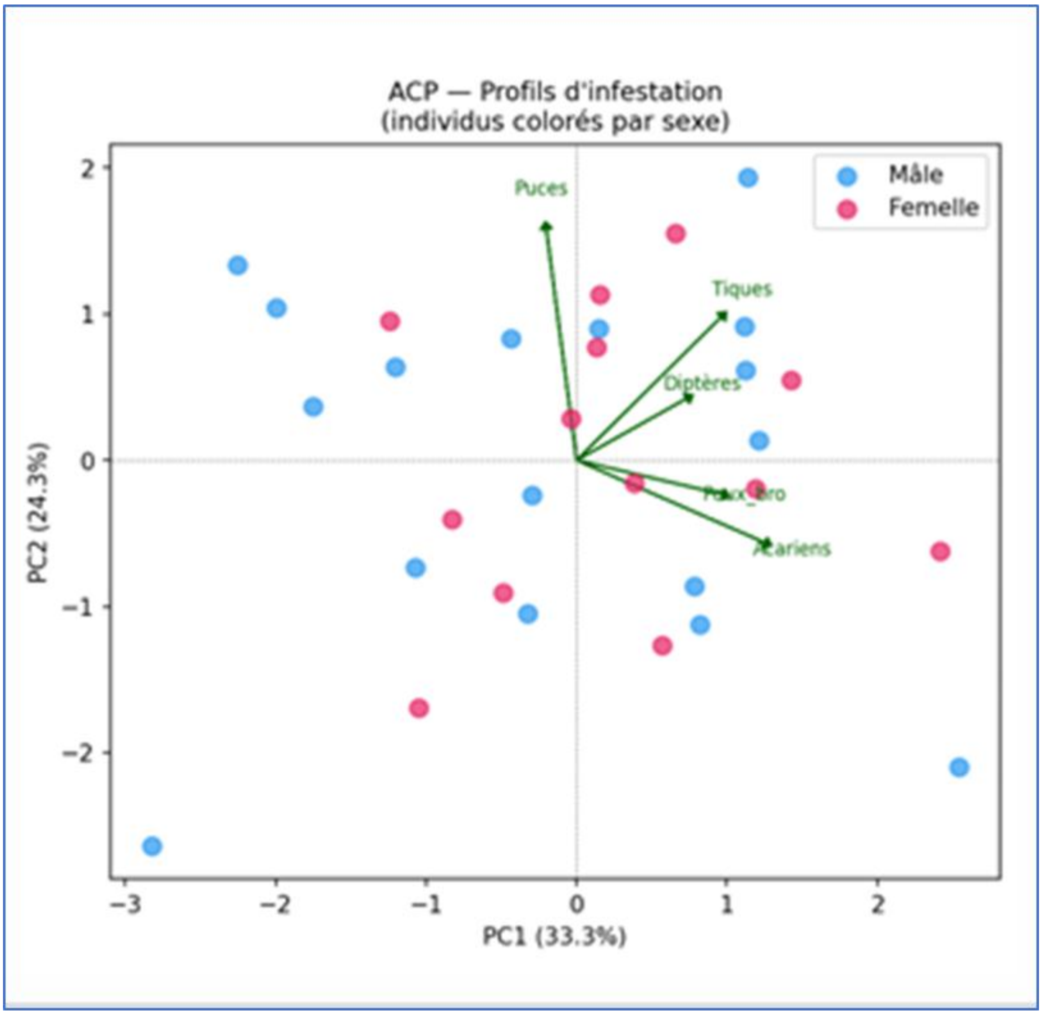


Figure n°33: Ectoparasite infestation profiles in the Eurasian wigeon

V.7. Infestation profile by body part according to the wintering period in the Wigeon

The line graph shows that the distribution pattern of ectoparasites remains stable between the start and end of the wintering period in the Wigeon. The tail and back have the highest parasite loads (≈ 2.4–2.7), followed by the breast, belly and wings, whilst the legs and head remain the least infested areas (≈ 1.1–1.4). The two curves are almost superimposed, indicating that parasite distribution is determined by anatomical rather than seasonal factors **(Fig. 34).**

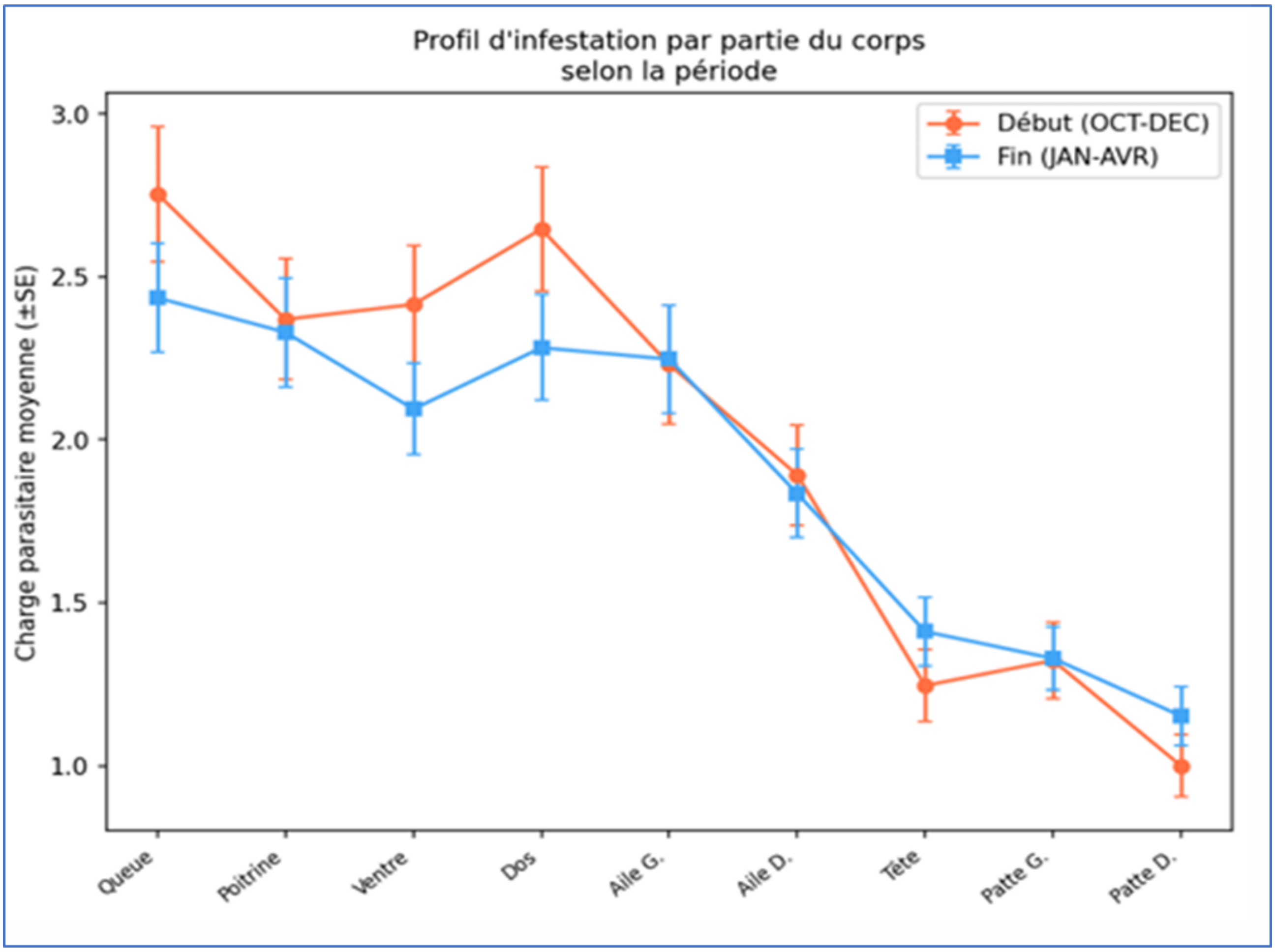


Figure n°34: Body-site infestation profiles according to overwintering period in the Eurasian wigeon

DISCUSSION

Lake Oubeira, located in north-eastern Algeria, is home to an enormous diversity of birdlife despite the pressures of rural human activity to which it is subjected. Although its surface area is relatively small (2,200 hectares), the lake retains immense biological and ecological value, particularly due to the quality of the bird populations it hosts during the wintering and breeding seasons.

In accordance with the protocol used throughout the wintering period during the 2025–2026 season to meet our study objectives, the survey of ectoparasites on the Eurasian Wigeon has led to the following findings:

- **stability of parasite load**

The absence of any significant difference between the start and end of the wintering period suggests a constant parasite pressure at Lake Oubeira, in contrast to European studies showing winter peaks in Anatidae and Rallidae **(Baziz & Neffah, 2016; Touati, 2019).** This temporal stability could be explained by the region's Mediterranean climate, where variations in temperature and rainfall remain moderate compared to continental temperate zones **(Shifaw et *al.*, 2021).** The systematic collection of approximately 4 to 5 individuals per month limits intra-monthly variability and allows for a robust estimate of the average population size **(Hudson et *al.*, 2021).** The similarity between the early and late wintering periods also indicates that the Whistling Duck at Lake Oubeira does not experience major physiological stress related to winter conditions, unlike what is observed in colder areas **(Moyer et *al.*, 2020).**

- **Preferential anatomical distribution of ectoparasites**

The clear hierarchy among body regions (Tail > Breast > Belly > Back >> Legs > Head) confirms the hypothesis that ectoparasites preferentially colonise areas that are less accessible for preening **(Peironny et *al.*, 2022; Moyer et *al.*, 2020)**. This pattern corresponds to observations in the Mallard, where louse mites and other mites concentrate on the dorsal and caudal feathers **(Clayton & Dabert, 2021).** In the Wigeon, the caudal region constitutes a preferred microhabitat for ectoparasites, likely due to a lower density of uropygial glands and limited access for pre-ingestion **(Fine et *al.*, 2023).** The tail, being the most heavily infested area, may also play a role in the vertical transmission of parasites between individuals during social interactions **(Ballweber, 2020).** The legs and head, which are less infested, are likely better protected by active grooming behaviours and by an anatomical structure less conducive to the attachment of ectoparasites **(Clayton & Dabert, 2021).**

Absence of sexual dimorphism

The absence of differences in parasite load between males and females contrasts with certain studies in which males exhibit higher parasite loads due to their more active behaviour and testosterone-related immunosuppression **(Møller & Iglesias, 2020; Poulin, 2022).** In the Whistling Duck, this lack of parasite dimorphism could reflect similar preening behaviours between the sexes, parasite pressure strong enough to mask physiological differences, or an insufficient sample size to detect subtle differences **(Ghoul & Gagui, 2018).** The absence of sex segregation in the PCA also confirms that males and females share the same ecological niches within Lake Oubeira, with no notable differences in habitat use or foraging behaviour **(Robinson et *al.*, 2023).**

Parasite composition: dominance of mites and ticks

The dominance of mites and ticks over fleas corresponds to the patterns observed in Algerian waterbirds, where mites and louse mites account for over 70% of the total prevalence **(Bacir & Bouslimo, 2006; Touati, 2019).** This functional dominance may be linked to the ability of mites to survive in humid environments and to reproduce rapidly on the host **(Ballweber, 2020).** Mites, in particular, are well adapted to aquatic and semi-aquatic environments, where they can survive off the host for long periods **(Ngor et *al.*, 2020).** Fleas, on the other hand, require drier conditions to thrive and are therefore less common in waterbirds **(Peironny et *al.*, 2022).**

Ecological implications and outlook

The absence of sexual segregation in the ACP and the stability of the infestation pattern suggest that the spatial distribution of ectoparasites in the Whistling Duck is determined primarily by stable anatomical factors rather than by seasonal or sexual factors **(Robinson et *al.*, 2023).** These findings have important implications for the management of Algerian wetlands; the Wigeon of Lake Oubeira constitutes a stable reservoir of ectoparasites, parasite control interventions should prioritise the dorsal and caudal regions, and longitudinal monitoring over several years would enable the detection of long-term trends linked to climate change **(Ngor et *al.*, 2020; Robinson et *al.*, 2023).** The Eurasian Wigeon, as an abundant and widely distributed species in Mediterranean wetlands, could also serve as an indicator species for monitoring the health of aquatic ecosystems **(Touati, 2019).**

Implications for bird health and conservation

A high parasite burden could affect the physical condition of the Whistling Duck, notably by impairing plumage quality, increasing physiological stress and reducing flight capacity **(Møller & Iglesias, 2020)**. However, the absence of sexual dimorphism and the stability over time suggest that the Wigeon population at Lake Oubeira is well adapted to this parasite pressure and that it does not reach a critical threshold affecting its fitness **(Poulin, 2022).** Future studies should measure the birds' body condition, body mass and immune resistance to better understand the actual impacts of parasite infestation on population health **(Hudson et *al.*, 2021).**

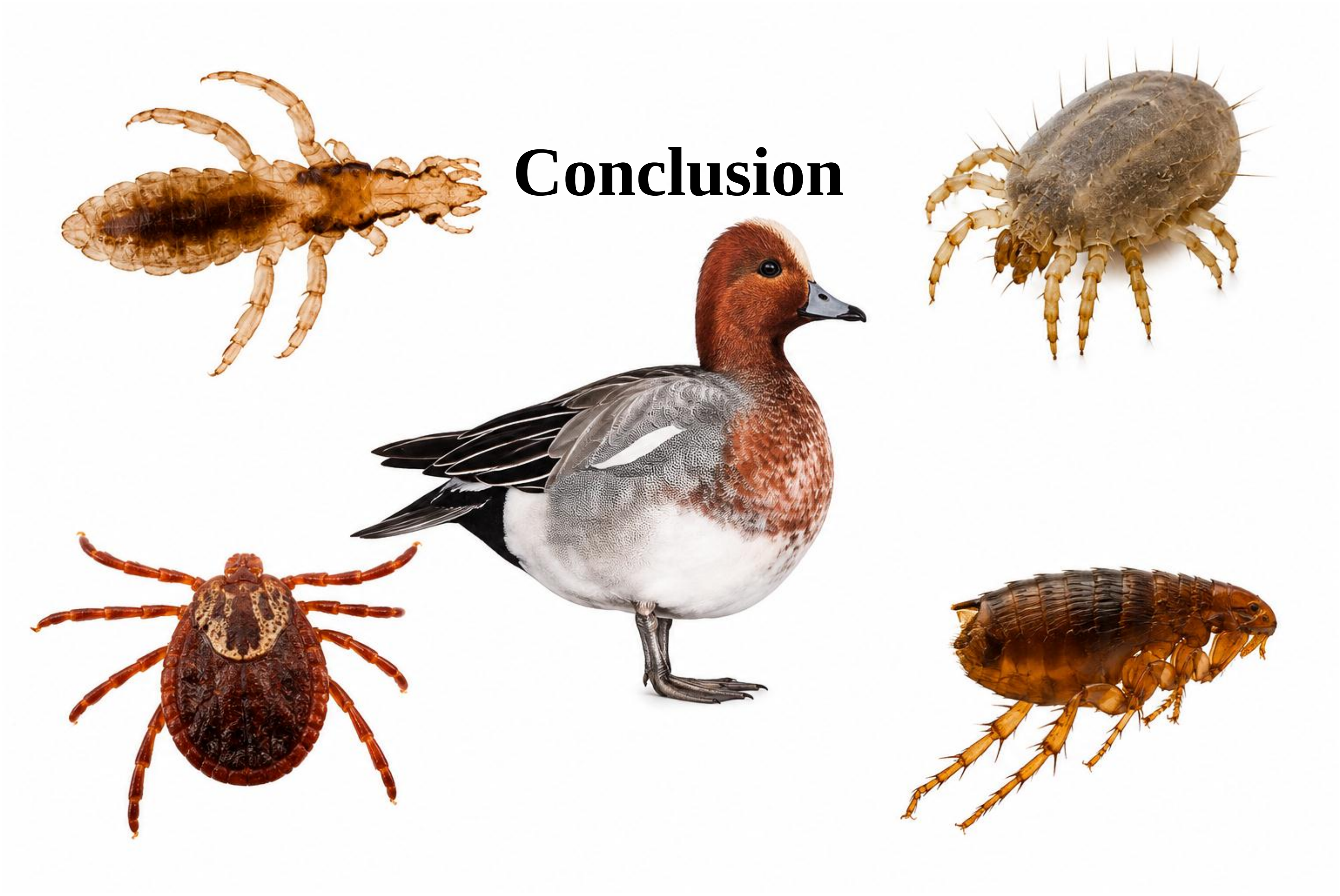
Limitations of the study

Several limitations should be taken into account: the lack of individual longitudinal monitoring, the relatively small sample size, and the lack of data on the birds' general health status (body mass, general condition) **(Hudson et *al.*, 2021).** The lack of follow-up on the same individuals from one month to the next prevents the detection of individual changes in parasite load and the distinction between the effects of age, experience and initial condition **(Shifaw et *al.*, 2021).** The sample size of 30 individuals over 7 months also limits the statistical power to detect subtle differences between groups **(Hudson et *al.*, 2021).** Future studies should incorporate these parameters and increase the sample size to better understand the impacts of parasite infestation on the fitness of the Wigeon **(Robinson et *al.*, 2023).**

Research prospects

Future studies should explore the relationships between parasite load and reproduction, feeding and social behaviour in the Whistling Duck **(Ngor et *al.*, 2020).** The inclusion of additional environmental variables (temperature, humidity, water level, habitat quality) would provide a better understanding of the factors determining parasite pressure in this Mediterranean wetland **(Robinson et *al.*, 2023).** Comparative research across several wetland sites in Algeria would also help determine whether the patterns observed at Lake Oubeira are specific to this site or represent regional trends **(Touati, 2019).**

Conclusion



CONCLUSION

Wetlands are ecosystems of major ecological importance due to their biological richness and the vital role they play in sustaining numerous animal and plant species. Among the organisms that contribute to the complexity of these ecosystems are parasites, which have long been overlooked despite their involvement in the functioning of natural communities and in the regulation of host populations. In waterbirds, ectoparasites represent a significant component of biodiversity and can influence various aspects of their hosts' biology, behaviour and ecology.

In this context, the present study was conducted at Lake Oubeira, one of the most important wetlands in El Kala National Park, in north-eastern Algeria. Its main objective was to compile an inventory of ectoparasites associated with the Eurasian Wigeon (Anas penelope) and to study the structure of their parasite community during the wintering period.

An examination of 30 individuals revealed widespread infestation within the study population, with a prevalence of 100%. A total of 2,617 ectoparasites were collected, corresponding to an average intensity of 87.23 parasites per host. The parasites identified belong to five main groups: mites, ticks, diptera, chewing lice and fleas. This diversity confirms that the Eurasian Wigeon is a suitable host for numerous species of ectoparasites within Mediterranean wetlands.

Analysis of the composition of the parasite community revealed a clear dominance of mites and ticks throughout the study period. This dominance is consistent with observations reported for several species of waterbirds studied in Algeria and other regions of the world. The high prevalence of these groups may be linked to their ability to adapt to wet environmental conditions, as well as their capacity to efficiently exploit the resources provided by their host. Conversely, fleas and certain dipterans were observed in lower numbers, probably due to ecological requirements that are less compatible with the conditions of the studied environment.

The results also show that body location is the main factor influencing the distribution of ectoparasites. The dorsal and caudal regions appear to be the most common sites of infestation, likely reflecting the existence of conditions favourable to the establishment and development of parasites in these areas.

However, no significant differences were observed based on the sex of the individuals, the wintering period or monthly variations. These observations suggest a relative homogeneity in parasite pressure within the studied population during the period under consideration.

Beyond its parasitological significance, this study contributes to a better understanding of the biodiversity associated with waterbirds in Algerian wetlands. It highlights the role of the Eurasian Wigeon (Anas penelope) as a host to a diverse community of ectoparasites and emphasises the importance of Lake Oubeira as a reservoir of biodiversity, both for birdlife and for the organisms associated with it.

Finally, the results obtained open up new avenues of research into the relationships between ectoparasites and the biology of the Eurasian Wigeon, particularly their potential effects on physical condition, reproductive success, behaviour and population dynamics. The integration of environmental parameters such as temperature, humidity, water level and habitat quality would also provide a better understanding of the mechanisms governing the distribution and abundance of ectoparasites in Mediterranean wetland ecosystems. Comparative studies carried out in other Algerian wetlands would also help to better identify spatial variations in parasite diversity and assess the influence of the ecological characteristics specific to each site.

This study therefore contributes to our understanding of host-parasite relationships in the Whistling Duck in the wetlands of north-eastern Algeria and highlights the importance of continuing research into parasitic biodiversity, a field that remains under-documented in Algeria.

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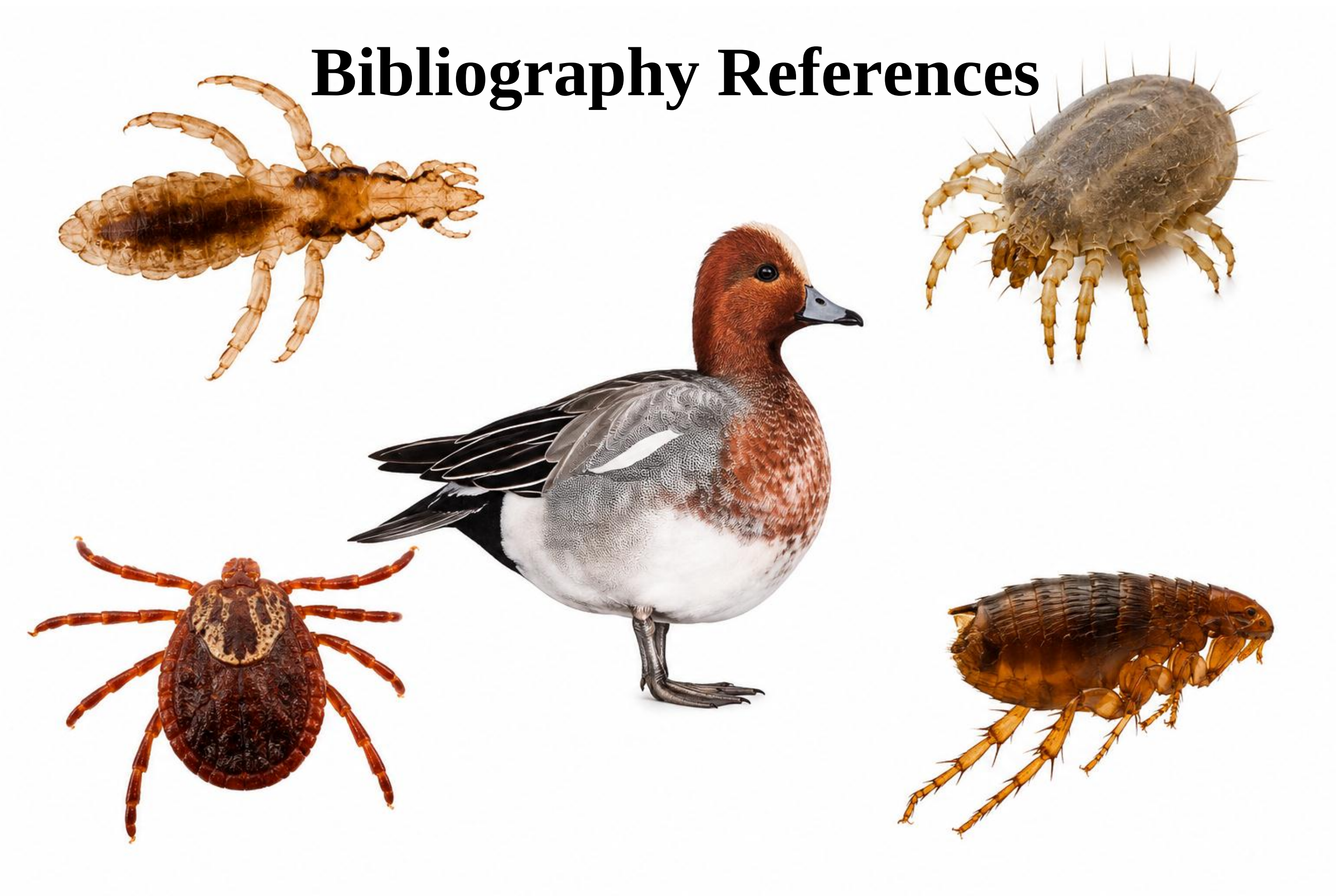

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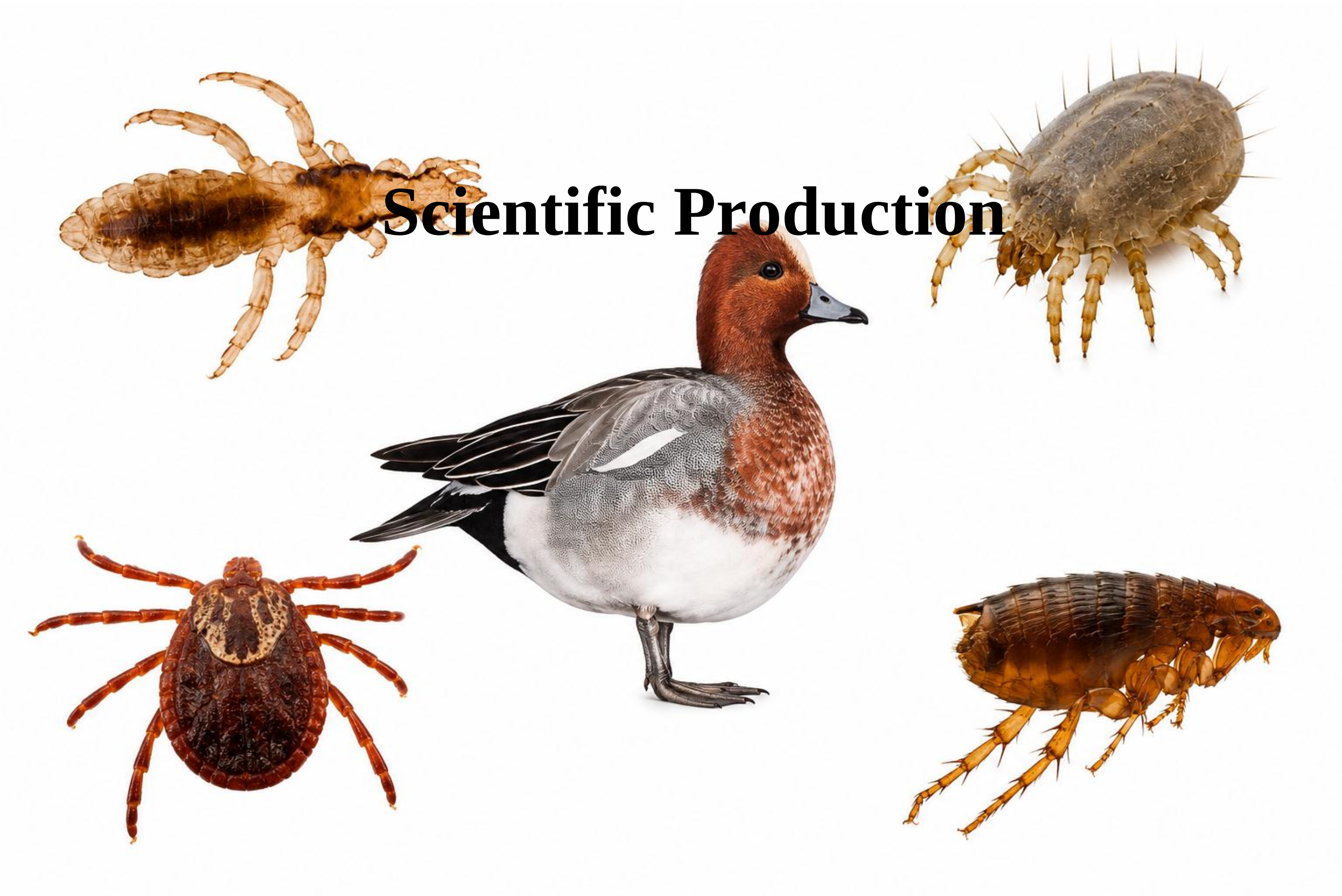

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ATTESTATION DE PARTICIPATION

Cette attestation est fièrement décernée à :

FACI Aya El Rahmane

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Co-auteurs: RIZI Hadia, CHETTIBI Ahlam, BOUKSIBA Chahrazed

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