People's Democratic Republic of Algeria

Ministry of Higher Education and Scientific Research

University Mohamed Khider, Biskra

Faculty of Exact Sciences, Nature and Life Sciences

Department of Nature and Life Sciences

Order number:……

Series:……..

Thesis Submitted in Fulfillment of the Requirements for the Degree of LMD Doctorate in Biotechnology

Option: Biotechnology and Health

Presented by: Djouhina CHABIRA

Entitled

Biodiversity of Parasites of the Ichthyofauna of Continental Freshwaters in the Northern Sahara (Algeria)

Defended on: 16/11/2025

Before the jury:

President	Ibrahim MERABTI	Prof. Mohamed Khider University, Biskra
Supervisor	Badreddine ATTIR	MCA Mohamed Khider University, Biskra
Co-supervisor	Adel MAMMERI	MCA Mohamed Boudiaf University, M'Sila
Examiner	Ayoub HADJEB	Prof. Mohamed Khider University, Biskra
Examiner	Rachid CHAIBI	Prof. Amar Telidji University, Laghouat

2025/2026

Abstract

Freshwater ecosystems harbor a rich diversity of life, yet the parasites of their fish inhabitants remain poorly understood, particularly in the Northern Sahara region of Algeria. This study investigated the parasite fauna of five fish species – *Oreochromis* sp. (14.53%), *Cyprinus carpio* (34.19%), *Barbus* sp. (17.09%), *Luciobarbus biscarensis* (16.67%) and *Carassius gibelio* (17.52%) – across three study regions of the northern Sahara (Biskra, Djelfa and Laghouat) over a seasonal period from October 2022 to June 2024. Parasites were identified using standard techniques, including the preparation of direct wet mounts for fresh examination, staining, and morphological examination. Stomach content analysis was performed on *C. carpio* to assess the dietary habits of this species. The analysis further investigated the relationship between host body shape/size and sex with overall host weight, documented the abundance, prevalence, and intensity of identified parasite species and assessed the impact of season, host size, and sex on their infection values, including those in the endemic *L. biscarensis*. Our findings revealed a diverse parasite community, with six parasite species and genera identified: *Ergasilus* sp., *Myxobolus* sp., *Trichodina* sp., *Dactylogyrus extensus*, *Dactylogyrus fimbriphallus* and *Bothriocephalus acheilognathi*. The *C. carpio* samples exhibited a consistent preference for zooplankton (Copepoda: %IRI = 38.92, Cladocera: %IRI = 33.59). Furthermore, a clear link was observed between the consumption of copepods and infection with *B. acheilognathi* (prevalence: 25.93%, mean intensity: 1.71 ± 1.01, abundance: 0.44 ± 0.91). The infection values for the identified parasite species varied significantly according to season, host size, and sex for several parasites. This research provides novel insights into the parasite ecology of freshwater fish in an understudied Saharan ecosystem, contributing valuable data on host-parasite interactions. Future research should prioritize molecular confirmation of parasite identities, implementing long-term monitoring against threats like climate change, and detailed study of *B. acheilognathi* prevalence in copepod intermediate hosts.

Keywords: Biodiversity, parasitofauna, *Dactylogyrus fimbriphallus*, ichtyology, Northern Sahara, Algeria.

ملخص

تحتضن النظم البيئية للمياه العذبة تنوعًا بيولوجيًا غنيًا، إلا أن الطفيليات التي تصيب أسماكها لا تزال غير مفهومة بشكل كافٍ، خصوصًا في منطقة الشمال الصحراوي من الجزائر. يهدف هذا البحث إلى دراسة الطفيليات المتواجدة لدى خمس أنواع من الأسماك: *Oreochromis* sp. (14.53%)، *Cyprinus carpio* (34.19%)، *Barbus* sp. (17.09%)، *Luciobarbus biscarensis* (16.67%) و *Carassius gibelio* (17.52%)، وذلك عبر ثلاث مناطق في الشمال الصحراوي (بسكرة، الجلفة والأغواط) خلال فترة موسمية من أكتوبر 2022 إلى يونيو 2024. تم تحديد الطفيليات باستخدام تقنيات معيارية، شملت إعداد الشرائح الرطبة للفحص المباشر، والتلوين، والدراسة المورفولوجية. كما تم تحليل محتويات المعدة لأسماك *C. carpio* بهدف تقييم نمطها الغذائي. بالإضافة إلى ذلك، تم فحص العلاقة بين شكل وحجم جسم العائل وجنسه مع الوزن الكلي، وتوثيق الوفرة، والانتشار، وشدة الإصابة للأنواع الطفيلية المعروفة، إلى جانب تقييم تأثير الموسم، وحجم العائل، والجنس على قيم العدوى، بما في ذلك لدى النوع المستوطن *L. biscarensis*. أظهرت النتائج وجود مجتمع طفيلي متنوع، حيث تم تحديد ستة أنواع وأجناس طفيلية: *Ergasilus* sp.، *Myxobolus* sp.، *Trichodina* sp.، *Dactylogyrus extensus*، *Dactylogyrus fimbriphallus* و *Bothriocephalus acheilognathi*. كما أظهرت عينات *C. carpio* تفضيلًا غذائيًا ثابتًا للعوالق الحيوانية (Copepoda:%IRI=38.92, Cladocera:%IRI = 33.59). وتم أيضًا تسجيل علاقة واضحة بين استهلاك القشريات المجدافية والإصابة بالطفيلي *B. acheilognathi* (الانتشار: 25.93%، شدة الإصابة: 1.71 ± 1.01، الوفرة: 0.44 ± 0.91). تبيّن أن قيم الإصابة بالأنواع الطفيلية تتغير بشكل واضح بحسب الموسم، وحجم العائل، والجنس لدى العديد من الطفيليات. وتقدم هذه الدراسة رؤى جديدة حول بيئة الطفيليات في أسماك المياه العذبة ضمن نظام بيئي صحراوي قليل الدراسة، كما تساهم في إثراء البيانات المتعلقة بتفاعلات العائل–الطفيلي. وتوصي الدراسة المستقبلية بإعطاء الأولوية للتأكيد الجزيئي لهويات الطفيليات، ووضع برامج مراقبة طويلة المدى لمواجهة تهديدات مثل التغير المناخي، ودراسة تفصيلية لمدى انتشار *B. acheilognathi* لدى القشريات المجدافية بوصفها عوائل وسيطة.

الكلمات المفتاحية: التنوع البيولوجي، الطفيليات، *Dactylogyrus fimbriphallus*، علم الأسماك، شمال الصحراء، الجزائر.

Résumé

Les écosystèmes d'eau douce abritent une riche diversité biologique, mais les parasites infectant leurs poissons restent encore peu étudiés, en particulier dans la région du Sahara septentrional en Algérie. Cette étude a examiné la faune parasitaire de cinq espèces de poissons — *Oreochromis* sp. (14,53 %), *Cyprinus carpio* (34,19 %), *Barbus* sp. (17,09 %), *Luciobarbus biscarensis* (16,67 %) et *Carassius gibelio* (17,52 %) — dans trois régions du nord Sahara (Biskra, Djelfa et Laghouat) sur une période saisonnière allant d'octobre 2022 à juin 2024. Les parasites ont été identifiés à l'aide de techniques standard, incluant la préparation de lames fraîches, la coloration, et l'examen morphologique. Une analyse du contenu stomacal a été réalisée chez *C. carpio* afin d'évaluer ses habitudes alimentaires. L'étude a également examiné la relation entre la morphologie corporelle, la taille, le sexe et le poids total du poisson, documenté l'abondance, la prévalence et l'intensité des parasites identifiés, et évalué l'effet de la saison, de la taille de l'hôte et du sexe sur leurs niveaux d'infection, y compris chez l'espèce endémique *L. biscarensis*. Nos résultats ont révélé une communauté parasitaire diversifiée composée de six espèces et genres: *Ergasilus* sp., *Myxobolus* sp., *Trichodina* sp., *Dactylogyrus extensus, Dactylogyrus fimbriphallus* et *Bothriocephalus acheilognathi*. Les individus de *C. carpio* ont montré une préférence alimentaire constante pour le zooplancton (Copepoda : %IRI = 38,92 ; Cladocera : %IRI = 33,59). De plus, une relation claire a été observée entre la consommation de copépodes et l'infection par *B. acheilognathi* (prévalence : 25,93 %, intensité moyenne : 1,71 ± 1,01, abondance : 0,44 ± 0,91). Les valeurs d'infection des parasites identifiés variaient significativement selon la saison, la taille de l'hôte et le sexe pour plusieurs d'entre eux. Cette recherche fournit des informations nouvelles sur l'écologie parasitaire des poissons d'eau douce dans un écosystème saharien peu exploré, et contribue à enrichir les connaissances sur les interactions hôte–parasite. Les travaux futurs devraient donner priorité à la confirmation moléculaire de l'identité des parasites, à la mise en place d'un suivi à long terme face aux menaces telles que le changement climatique, ainsi qu'à une étude approfondie de la prévalence de *B. acheilognathi* chez les copépodes, hôtes intermédiaires de ce parasite.

Mots-clés : Biodiversité, parasitofaune, *Dactylogyrus fimbriphallus*, ichtyologie, Sahara septentrional, Algérie.

Acknowledgements

It is with immense pleasure that I dedicate this space to acknowledge and express my deep appreciation to everyone who, directly or indirectly, played a role in the development and successful completion of this endeavor. Initially, I offer my heartfelt thanks to Allah, the Almighty, for His divine assistance, courage, and resilience He granted me throughout the demanding phases of my research activities.

Following this, I would like to express my deepest gratitude to my supervisor, Dr. Badreddine Attir, for his mentorship during my doctoral studies. His consistent availability and encouraging nature have been a significant source of support and motivation. I extend my sincere gratitude to my co-supervisor Dr. Adel Mammeri for his unwavering support, insightful guidance, and constructive feedback throughout this research project.

I am immensely grateful to Pr. Ali Aydogdu and his wonderful wife, Dr. Nurten Aydogdu, for dedicating their time and expertise to assist me during this research.

I would like to express my sincere gratitude to the esteemed members of my thesis defense jury for their time, insightful evaluation, and valuable feedback on this work.

I would also like to thank Pr. Ziane Laiadi, former director and Pr. Abdelhamid Moussi current director of the LGBVB laboratory at the University of Biskra, for their invaluable support. Also, Dr. Guendouz Abdelaziz, former Dean of the Faculty of Natural and Life Sciences at the University of Djelfa, for giving us access to the laboratory.

I am grateful to my Uncles Mr. Belkhier Chabira and Mr. Mohamed Harizi, along with Mr. Belkacem Chenoufi and Mr. Mohamed Sadki for kindly taking the time and effort to transport me to the various sampling locations. Their support was essential for the data collection phase of this study. And also Mr. Messaoud Abdellali and Mr. Guersis Mohamed for their help in catching and transporting the fish.

I extend my gratitude to Pr. Brahim Merabti, Head of the Doctoral Training at the University of Mohamed Khider Biskra, for his invaluable help and support throughout this research.

I am grateful to Pr. Rachid Chaibi, Head of the Department of Biology at the University of Amar Telidji Laghouat, Mr. Samir Herich, Director of the Fisheries and Aquaculture Station of Djelfa, Mr. Morad Bida, Director of the Fisheries and Aquaculture Station of Laghouat, and Mr. Nasreddin Chaiba, President of the Interstate Chamber of Fisheries and Aquaculture of Ouargla, for their crucial assistance in facilitating the acquisition of the fish samples necessary for this study.

I also thank Mr. Seddik Messaoudi, owner of the Messaoudi farm of Sidi Okba, and Mr. Farid Aroui, owner of the Model Farm of Dar Chioukh, for supplying fish samples used in this study.

Dedications

This work is dedicated to my incredible parents, my guiding stars and unwavering pillars of strength. Every step of this journey has been made possible by your boundless love, encouragement, and the countless ways you have supported me. I am eternally grateful for everything you have given me.

To my brother, Yasser, thank you for always being there.

To my wonderful sisters, Nihad and my youngest sister, Roufaida, your strength and love inspire me.

And to my dearest friend, Halima, thank you for your unwavering friendship and belief in me.

Djouhina CHABIRA

CONTENTS

List of abbreviations

%F	Frequency of occurrence
%N	Numerical Method
%IRI	Percentage of the index of relative importance
%VI	Vacuity index
A	Abundance
ANCOVA	Analysis of covariance
BD	Body depth
CL	Cephalic length
FAO	Food and Agriculture Organisation
h	The number of hosts examined
IAA	Integrated agriculture-aquaculture
IUCN	International Union for Conservation of Nature
MI	Mean intensity
IRI	Index of Relative Importance
min	Minimum
max	Maximum
n	The number of hosts infested by a given parasite species
P	Prevalence
P	The total number of individuals of a parasite species
SL	Standard length
SD	Standard deviation
SPSS	Statistical package for social science
TL	Total length

List of tables

List of figures

INTRODUCTION

Introduction

Freshwater ecosystems are indispensable resources, fundamentally intertwined with both human existence and the health of natural systems (Carpenter et al., 2011). These environments, encompassing rivers, lakes, and wetlands, serve as critical hubs within the landscape, integrating and organizing various aspects of the natural environment and human culture (Naiman and Turner, 2000). Their significance extends beyond providing tangible resources like fish and potable water, encompassing vital roles in transportation, energy generation, waste management, and recreation (Naiman and Turner, 2000). Moreover, freshwater ecosystems are renowned for their exceptional species diversity and endemism. While current estimates suggest approximately 44,000 of the world's described species inhabit these environments, a figure considered a substantial underestimation, the true biodiversity remains largely unexplored (Reaka-Kudla, 1997; Revenga et al., 2005).

The ongoing discovery of new freshwater species, exemplified by the description of approximately 200 new fish species annually (Lundberg et al., 2000), underscores the vast, still largely uncatalogued biodiversity. Furthermore, freshwater habitats exhibit unusually high levels of endemism, meaning that many species are found nowhere else on Earth (Revenga et al., 2005). Despite covering less than 1% of the Earth's surface, these ecosystems support a disproportionately large fraction of global biodiversity, notably in fish species (Dudgeon et al., 2006; Strayer and Dudgeon, 2010; Radinger et al., 2019). With around 13,000 known species, freshwater fish constitute 40-45% of global fish diversity (Lévêque et al., 2008). However, this remarkably diverse group faces significant threats, including some of the most severe levels of endangerment observed across all animal taxa (Cooke et al., 2012).

Within this global context of freshwater biodiversity, Algeria, with its diverse aquatic habitats ranging from ephemeral wadis to permanent lakes and rivers, harbors a unique assemblage of freshwater fish species. Although the freshwater fish fauna of Algeria has not been extensively documented, it comprises a diverse community of 48 species with 21 species identified as autochthonous and 27 as introduced, distributed across 15 families (Kara, 2012). A comprehensive analysis of these species, considering their systematic affinities, dietary habits, geographic distribution, and conservation status based on the IUCN Red List (IUCN, 2009), reveals patterns consistent with the broader Mediterranean basin. Notably, Cyprinidae, particularly species within the genus *Barbus*, dominate the Algerian freshwater fish community, representing 33.3% of the total species (Kraïem, 1983; Bianco, 1995; Elvira, 1995; Azeroual et al., 2000; Kara, 2012). This dominance is followed by Cichlidae, accounting for 16.6%, and Cyprinodontidae, at 8.3% (Kara, 2012). However, when considering only the native species, Cichlidae constitute the largest group, representing 23.8%, followed by Cyprinidae, at 19%, with a significant presence of *Barbus* species (Kara, 2012)

Freshwater fish species, integral components of aquatic ecosystems, are subject to a range of natural and anthropogenic pressures that threaten their populations. Natural factors can significantly influence fish survival, physiology, and population structure, such as, temperature fluctuation, seasonal water level fluctuations and predation pressure (Kennedy, 1975; Paperna, 1996). Anthropogenic impacts, notably habitat destruction, pollution, and climate change, are primary drivers of biodiversity loss, particularly in sensitive stream and river environments (Nicacio and Juen, 2015). Alongside these human-induced stressors, parasites represent a significant natural form of aggression affecting fish health and survival. In aquatic ecosystems, fish serve as hosts to a taxonomically diverse array of parasites, each with varied life cycle strategies (Barber et al., 2000). These parasites can exert a profound influence on fish biology, with effects ranging from nutrient depletion (Hassan et al., 2010) and behavioral alterations (Lafferty, 2008) to compromised immune function and, in severe cases, blindness (Echi et al., 2009a, 2009b). Furthermore, parasitic infections can lead to increased morbidity, mortality, and reductions in growth and fecundity (Nmor et al., 2003), as well as mechanical injuries, depending on the parasite species and load (Echi et al., 2009a, 2009b). Notably, in many aquatic ecosystems, fish act as intermediate hosts for larval parasites, resulting in some of the most dramatic biological impacts (Lafferty, 2008). Therefore, understanding the interplay between these anthropogenic and natural stressors, particularly the role of parasites, is crucial for effective conservation and management of freshwater fish populations.

While the parasitic fauna of freshwater fish in Algeria has garnered some attention, research efforts have been geographically skewed. The majority of studies have concentrated on the northern regions of the country (Meddour, 2009; Meddour et al., 2010; Boucenna et al., 2015; Brahmia, 2016; Berrouk et al., 2019; Berrouk et al., 2020a; Berrouk et al., 2020c), leaving the southern areas, particularly the northern Sahara, significantly understudied, with only a few conducted studies such as those of Attir et al. (2017) and Attir (2018). Research on fish parasites in Algeria is largely limited to the northern regions, leaving the northern Sahara poorly studied. Its unique habitats may host distinct and still undocumented parasite species. To fully understand Algeria's freshwater parasite diversity and host–parasite interactions, more studies are urgently needed, especially in the southern regions.

This study aims to document the diversity of the parasitic fauna in freshwater fish species collected from three regions of the northern Sahara. Our objectives include: 1) evaluating the effects of various morphometric measurements, sex, and their interactions on the weight of fish samples; 2) documenting parasite species richness, prevalence, and intensity; 3) analyzing the stomach content of *Cyprinus carpio* to determine their dietary composition; and 4) investigating the influence of seasonal variations, host sex, and host length on parasite infection values. By examining these factors, we aim to provide a comprehensive understanding of the ecological drivers shaping parasite-host interactions in this understudied ecosystem.

The present study is structured into two primary sections: the Bibliographic Part and the Experimental Part. The Bibliographic Part first establishes the necessary context in Chapter 1 by detailing the distribution and protection status of freshwater fish in Algeria, followed by a comprehensive synthesis of recent literature on fish parasitism in the country in Chapter 2. The Experimental Part then presents the core research, beginning with the materials and methods used across the Biskra, Djelfa, and Laghouat regions. The subsequent results section thoroughly describes the fish samples and the subsequent analysis of morphometric interactions, before presenting a region-by-region analysis of the parasite biodiversity found. Finally, the findings from the experimental work are analyzed and synthesized with existing knowledge and previous literature in the overarching Discussion, followed by the conclusion and perspectives for future research.

BIBLIOGRAPHIC PART

CHAPTER 1

AQUACULTURE, DISTRIBUTION AND PROTECTION STATUS OF INLAND FRESH-WATER ICHTHYOFAUNA IN ALGERIA

Chapter 1. Aquaculture, distribution and protection status of inland fresh water ichthyofauna in Algeria

1. Distribution of natural and artificial aquatic surfaces in Algeria

Inland water surfaces are represented mainly by water bodies and rivers which are abundant in Algeria. They are most common in the northern part of the country as shown in Figure 1.

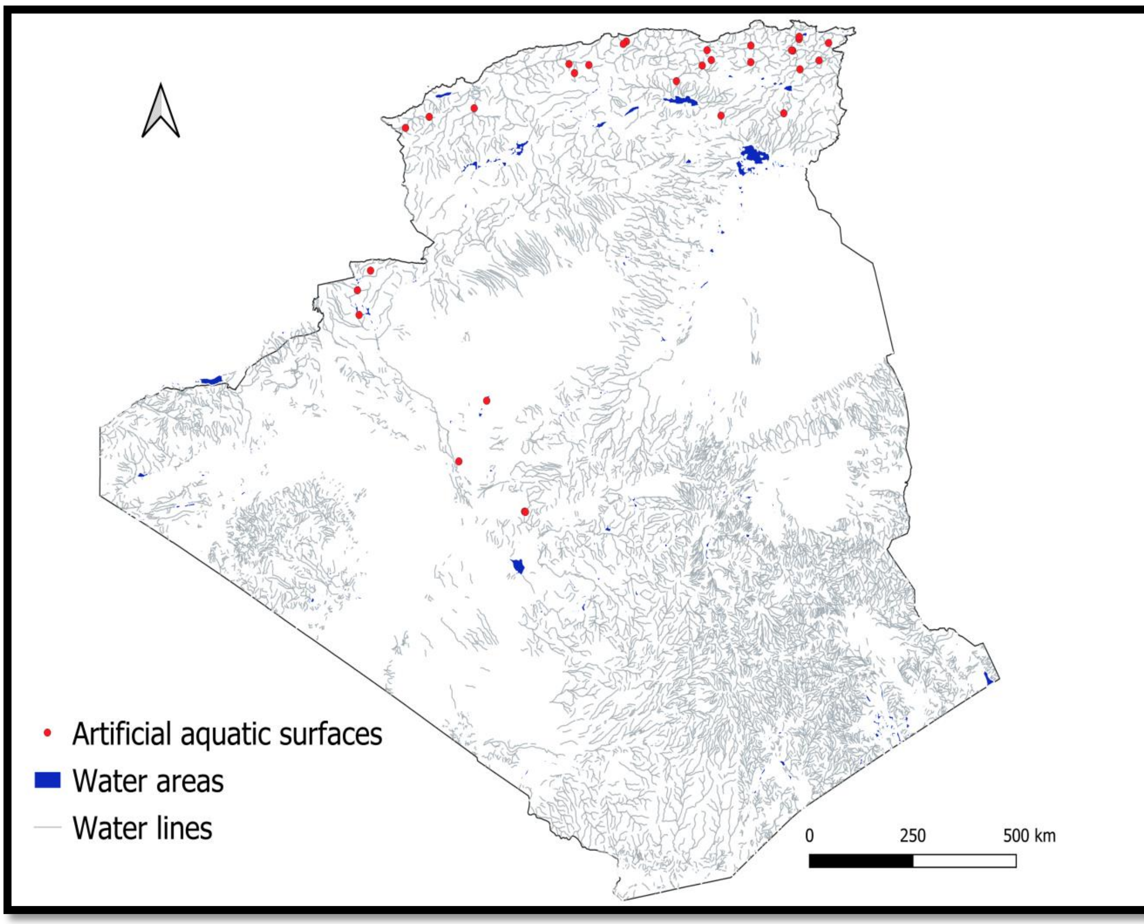


Figure 1. Distribution of natural and artificial aquatic surfaces in Algeria (original figure).

Data used in the figure are extracted from: (Aissaoui et al., 2017; Allalgua et al., 2021; Attou & Arab, 2013, 2019; Benali et al., 2021; Benayache et al., 2022; Berrouk et al., 2020b; Bouamra et al., 2017; Boucenna et al., 2015; Brahimi et al., 2016, 2018; Derrag & Youcef, 2014; Djezzar et al., 2021; Mimeche et al., 2013, 2018; Mimeche & Oliva-Paterna, 2018; Guettaf et al., 2019; Habila et al., 2017; Hadou-Sanoun et al., 2012; Khelifi et al., 2017; Menasria et al., 2020; Mouaissia et al., 2017; Reghaissia et al., 2022; Rouis et al., 2016; Sadouni & Iguer-Ouada, 2019; Sahli et al., 2020; Sahtout et al., 2017; Saoudi et al., 2017; Sellaoui & Bounaceur, 2020; Touil et al., 2019).

Algeria is one of the Mediterranean countries characterized by a dry semi-arid climate, therefore it has constructed reservoirs and dams to retain and store freshwater, particularly in the north (Figure 1) since it has a higher precipitation rate by comparison to the southern part of the country. As examples of natural and artificial water areas, respectively; Lake Oubeira is the largest freshwater lake in Algeria, located in El Kala National Park (El Taref Governorate), its surface area is of approximately 2,200 ha and its highest depth is of 4 m, exploited for fishing and irrigation (Amrani et al., 2014), and the Béni-Haroun reservoir situated in the northeastern area of Algeria (Mila Governorate), it is the largest freshwater dam in the country with a capacity of around a billion cubic meters, used as a drinking water source, for irrigation, for fishing and fish farming (Benayache et al., 2022).

2. Aquaculture practice in Algeria

The Algerian economy has shown growth in recent years. Algerian authorities are working to expand fish production via aquaculture. Regarding the status of aquaculture in the national economy, the overall value of aquaculture production from the Near East and North Africa (NENA) region was estimated at 2.3 billion USD in 2018, of which 16 million USD came from Algeria. Algerian aquaculture production increased from 1 416 tonnes in 2017 to 5 100 tonnes in 2018, among these productions; 3 016 tonnes were obtained in freshwater, while 2 084 tonnes in brackish water. In Algeria, priority has been given to inland aquaculture of species such as *Tilapia* sp. in irrigation systems and carps in ponds, lakes and reservoirs (Dickson, 2022).

Among the advantages of inland aquaculture in Algeria; is that the majority of sites are still poorly valued; the proximity to the European markets and higher temperatures and cheaper labour than on the northern shore of the Mediterranean (Kara et al., 2016). Furthermore, in Algeria, the practice of aquaponics and the use of biofloc technologies, are viewed as the more highly technical and advanced technology being used within IAA systems (Corner et al., 2020).

On the other hand, there are some constraints that hinder inland aquaculture progress, as; the fact that freshwater fish are little appreciated by consumers and face strong competition from marine fish; high cost of feed; modern technologies (hatchery and grow-out) little known; lack of qualified staff; limitations due to fresh water shortage (quantity and quality); weak health surveillance systems and biosecurity (Kara et al., 2016). However, the Algerian authorities have introduced a financial support system for the development of aquaculture activity, including credit facilities subsidized or zero-rate credit granted by the Bank for Agricultural and Rural Development (*RFIG* credit: Companion credit ; *ETTAHADI* credit : Challenge credit), underpinned by the Ministry of Agriculture, Rural Development and Fisheries. Also, Algeria is suffering from unpredictable natural disasters and they are trying to figure out a method to calculate and harvest the water from these events (Corner et al., 2020).

On the field, integrated agriculture-aquaculture (IAA) systems have been adopted in Algeria where a FAO pilot project developed integrated *Tilapia sp.* farming in palm groves at Ouargla Governorate, based on water used for irrigation of palms and accompanying crops. This project demonstrated that farmers could increase their revenue by adding fish farming to their activities and that integrated systems could be included in the national agriculture investment programme (Corner et al., 2020 ; Dickson, 2022).

The FAO pilot project report on IAA in desert and arid lands from Algeria showed that approximately 600 farmers are operating IAA systems in Algeria, producing around 5 000 tonnes of carps, catfish and tilapia with date palm, cereals and market gardens. Integration was reported to produce more benefits than conventional agriculture, reducing or eliminating the need for fertilization of crops and increasing the productivity of water (Dickson, 2022). According to Corner et al., (2020), the main freshwater fish produced in the irrigation basins in arid areas of Algeria, are : tilapia (with dominance of Red Tilapia) ; Catfish ; African sharptooth catfish ; Common carp ; Crucian carp ; Silver carp and Bighead carp.

Artificial and natural water areas scattered throughout the country's territory are estimated at 100,000 ha and valued by aquaculture, therefore they contain a great biomass reserve of fish species so-called highly migratory species (Reghaissia et al., 2022).

The expansion of aquaculture in Algeria could have major socio-economic implications. Increasing fish production can improve the country's food security, create new jobs and therefore contribute to rural development. In addition, Algeria can further develop its own aquaculture production to fulfil the needs of the local market and potentially explore export opportunities to other high consumption potential countries. However, it is important to consider the potential challenges that need to be addressed, such as the contradiction in the targets and evaluation of aquaculture programmes, management instability in aquaculture institutions, insufficient aquaculture research and training, shortage of trained staff, lack of an effective extension service, underdeveloped aquafeed industry. Finally, there are also challenges to desert aquaculture and consumer perception, the attempt to develop aquaculture in Algeria's desert regions poses challenges linked to climate change, such as the reduction in rainfall and the increase in temperatures. In addition, consumer preferences for marine fish constitute an obstacle to market demand for products from aquaculture (Taguemount et al., 2023).

3. Distribution of wild fish species in Algeria

According to the data collected and reported in Table 1, the population of the ichthyofauna existing in Algeria in the last ten years is represented by 50 species belonging to 15 families, with two unspecified species and a predominance of Cyprinidae with 23 species and Mugilidae with five species, followed by Cichlidae with four species and both Clupeidae and Poeciliidae having three species each.

As for Clariidae and Moronidae, including two species each, and the remaining families integrated only one species for each one. The results obtained are similar to the findings of Kara (2012), yet there are quite some differences regarding a few families not mentioned by the author such as : Atherinidae, Mugilidae, Moronidae and Carangidae, and others not found in this current study as well as the following families; Esocidae, Gasterosteidae, Salmonidae and Siluridae.

Table 1. Freshwater fish species found in Algeria during the last decade (2011-2023).

Family	Species	Reference	Red List Status (2022-10-09)	Red List Status (2009-12-16) (Kara, 2012)
Cyprinidae	*Abramis brama*	(Guettaf et al., 2019; Houda et al., 2021; Djezzar et al., 2021; Reghaissia et al., 2022; Mounia et al., 2022)	LC	LC
	Alburnus alburnus	(Attou & Arab, 2013, 2019; Amalou and Moulaï, 2020; Reghaissia et al., 2022)	LC	LC
	Barbus sp.	(Nazarizadeh et al., 2023)	NE	NE
	Carassius auratus	(Baikeche et al., 2021)	LC	NE
	Carassius carassius	(Khelifi et al., 2017; Reghaissia et al., 2022)	LC	LC
	Ctenopharyngodon idella	(Baikeche et al., 2021)	LC	NE
	Cyprinus carpio	(Mimeche et al., 2013; Derrag & Youcef, 2014; Amrani et al., 2014; Boucenna et al., 2015; Aissaoui et al., 2017; Sahtout et al., 2017; Saoudi et al., 2017; Bouamra et al., 2017; Mimeche & Oliva-Paterna, 2018; Karim et al., 2019; Amalou and Moulaï, 2020; Baikeche et al., 2021; Djezzar et al., 2021; Benayache et al., 2022)	VU	VU
	Hypophthalmichthys molitrix	(Mimeche et al., 2013; Mimeche & Oliva-Paterna, 2018; Baikeche et al., 2021).	NT	NE
	Hypophthalmichthys Nobilis	(Mimeche et al., 2013; Mimeche & Oliva-Paterna, 2018; Baikeche et al., 2021).	DD	NE
	Luciobarbus biscarensis	(Touil et al., 2019)	LC	-
	Luciobarbus callensis	(Djoudad-Kadji et al., 2012; Mimeche et al., 2013; Morsi et al., 2015; Rouis et al., 2016; Habila et al., 2017; Bouamra et al., 2017; Mouaissia et al., 2017; Mimeche et al.,	LC	LC

		2018; Mimeche & Oliva-Paterna, 2018; Aberkane et al., 2018; Touil et al., 2019; Berrouk et al., 2020b; Menasria et al., 2020; Amalou and Moulaï, 2020; Allalgua et al., 2021; Abbaci et al., 2023)		
	Luciobarbus leptopogon	(Touil et al., 2019)	EN	-
	Luciobarbus chelifensis	(Brahimi et al., 2017; Touil et al., 2019)	LC	-
	Luciobarbus lanigarensis	(Benali et al., 2021)	VU	-
	Luciobarbus mascarensis	(Brahimi et al., 2017; Touil et al., 2019; Benali et al., 2021)	EN	-
	Luciobarbus numidiensis	(Brahimi et al., 2018)	EN	-
	Luciobarbus pallaryi	(Brahimi et al., 2016; Touil et al., 2019)	LC	-
	Luciobarbus setivimensis	(Hadou-Sanoun et al., 2012; Attou & Arab, 2013; Aissaoui et al., 2017; Fergani and Arab, 2017; Touil et al., 2019; Baikeche et al., 2021)	LC	-
	Pseudophoxinus callensis	(Amalou and Moulaï, 2020; Baikeche et al., 2021; Morsi et al., 2021)	LC	DD
	Pseudophoxinus sp.	(Salhi et al., 2021)	-	-
	Pseudorasbora parva	(Baikeche et al., 2021)	LC	NE
	Rutilus rutilus	(Amalou and Moulaï, 2020; Baikeche et al., 2021; Arab et al., 2021; Reghaissia et al., 2022)	LC	-
	Squalius cephalus	(Mimeche et al., 2013; Mimeche & Oliva-Paterna, 2018)	LC	-
Clupeidae	*Alosa algeriensis*	(Baikeche et al., 2021)	EN	-
	Alosa alosa	(Amalou and Moulaï, 2020)	RE	LC
	Alosa fallax	(Amalou and Moulaï, 2020)	RE	LC
Anguillidae	*Anguilla anguilla*	(Amrani et al., 2014; Bakaria et al., 2018; Amalou and Moulaï, 2020; Baikeche et al., 2021; Derbal et al., 2022; Tahri & Bensouilah, 2023)	EN	CR

Cyprinodonati-dae	*Aphanius fasciatus*	(Guezi et al., 2017; Ghazi et al., 2018, 2019; Labbaci et al., 2021)	LC	LC
Atherinidae	*Atherina boyeri*	(Amalou and Moulaï, 2020 ; Baikeche et al., 2021)	LC	-
Mugilidae	*Chelon auratus*	(Amalou and Moulaï, 2020)	LC	-
	Chelon labrosus	(Amalou and Moulaï, 2020)	LC	-
	Chelon ramada	(Amalou and Moulaï, 2020)	LC	-
	Chelon saliens	(Amalou and Moulaï, 2020)	LC	-
	Mugil cephalus	(Amalou and Moulaï, 2020; Baikeche et al., 2021)	LC	-
Clariidae	*Clarias anguillaris*	(Behmene et al., 2022)	DD	NE
	Clarias gariepinus	(Behmene et al., 2022)	LC	NE
Moronidae	*Dicentrarchus labrax*	(Amalou and Moulaï, 2020)	NT	-
	Dicentrarchus punctatus	(Amalou and Moulaï, 2020)	LC	-
Poeciliidae	*Gambusia affinis*	(Zaidi & Soltani, 2011; Chenchouni, 2012; Ghazi et al., 2019; Sellaoui & Bounaceur, 2020; Cheghib et al., 2020; Djezzar et al., 2021; Denna et al., 2022)	LC	NE
	Gambusia holbrooki	(Mimeche et al., 2013; Mimeche & Oliva-Paterna, 2018; Benslimane et al., 2019; Baikeche et al., 2021)	LC	NE
	Molly Poecilia sphenops	(Ghazi et al., 2019)	LC	-
Cichlidae	*Hemichromis bimaculatus*	(Guezi & Kara, 2015; Ghazi et al., 2019; Ghazi & Bachir, 2021)	LC	NE
	Oreochromis niloticus	(Mimeche et al., 2013; Mimeche & Oliva-Paterna, 2018; Sahli et al., 2020)	LC	NE
	Tilapia sp.	(Chenchouni, 2012)	-	-
	Tilapia zillii	(Chebaani et al., 2014; Zouakh et al., 2016; Ghazi et al., 2019; Ghazi & Bachir, 2021; Rabie et al., 2021)	LC	NE
Centrarchidae	*Micropterus salmoides*	(Baikeche et al., 2021)	LC	NE

Petromyzontid-ae	*Petromyzon marinus*	(Amalou and Moulaï, 2020; Baikeche et al., 2021)	LC	LC
Blenniidae	*Salaria fluviatilis*	(Laporte et al., 2015; Amalou and Moulaï, 2020; Amalou et al., 2020; Baikeche et al., 2021;Wagner et al., 2021)	LC	LC
Percidae	*Sander lucioperca*	(Bouamra et al., 2017; Baikeche et al., 2021; Djezzar et al., 2021)	LC	LC
	Gymnocephalus cernuus	(Arab et al., 2020)	LC	-
Carangidae	*Trachinotus ovatus*	(Amalou and Moulaï, 2020)	LC	-

LC: Least Concern; DD: Data Deficient; VU: Vulnerable; CR: Critically Endangered; EN: Endangered; NT: Near Threatened; NE: Not Evaluated; RE: Regionally Extinct.

The map presented in Figure 2, indicates the presence of few freshwater fish species in the southern part of Algeria. This fact may be due to the lack of inland water surfaces in these regions, in opposition to the northern part of the country (Table 2) where 44 species were counted out of the whole 50 freshwater fish species. Moreover, 40 % of the Algerian inland water fish fauna is located in the Governorate of Bejaia, including a dense hydrographic network made of several streams and rivers such as the Soummam river, regarded as one of the largest rivers in the country (Amalou and Moulaï, 2020), due to its importance and richness, this river was used as a sampling site in several studies where 18 species were recorded; 16 species mentioned by Amalou and Moulaï (2020) and four species by Djoudad-Kadji et al. (2012). The concentration of the freshwater fish species in the northern part of the country is also due to the fact that introduced species represent more than 50% of the total ichthyologic diversity in the country, and all the three main waves of introductions described by Kara (2012) took place in the freshwater bodies located north of Algeria, leaving the southern part with less species. Fish distributions and assemblages could also be particularly affected by salinization, with fragmentation or complete disappearance of freshwater fish populations (Beatty et al., 2011), the salinity levels in the Sahara region are high in many water bodies as a result to the evaporation and the accumulation of soluble salts in the surrounding soil or water surfaces (Medjani et al., 2017), leading to less concentration of fish species.

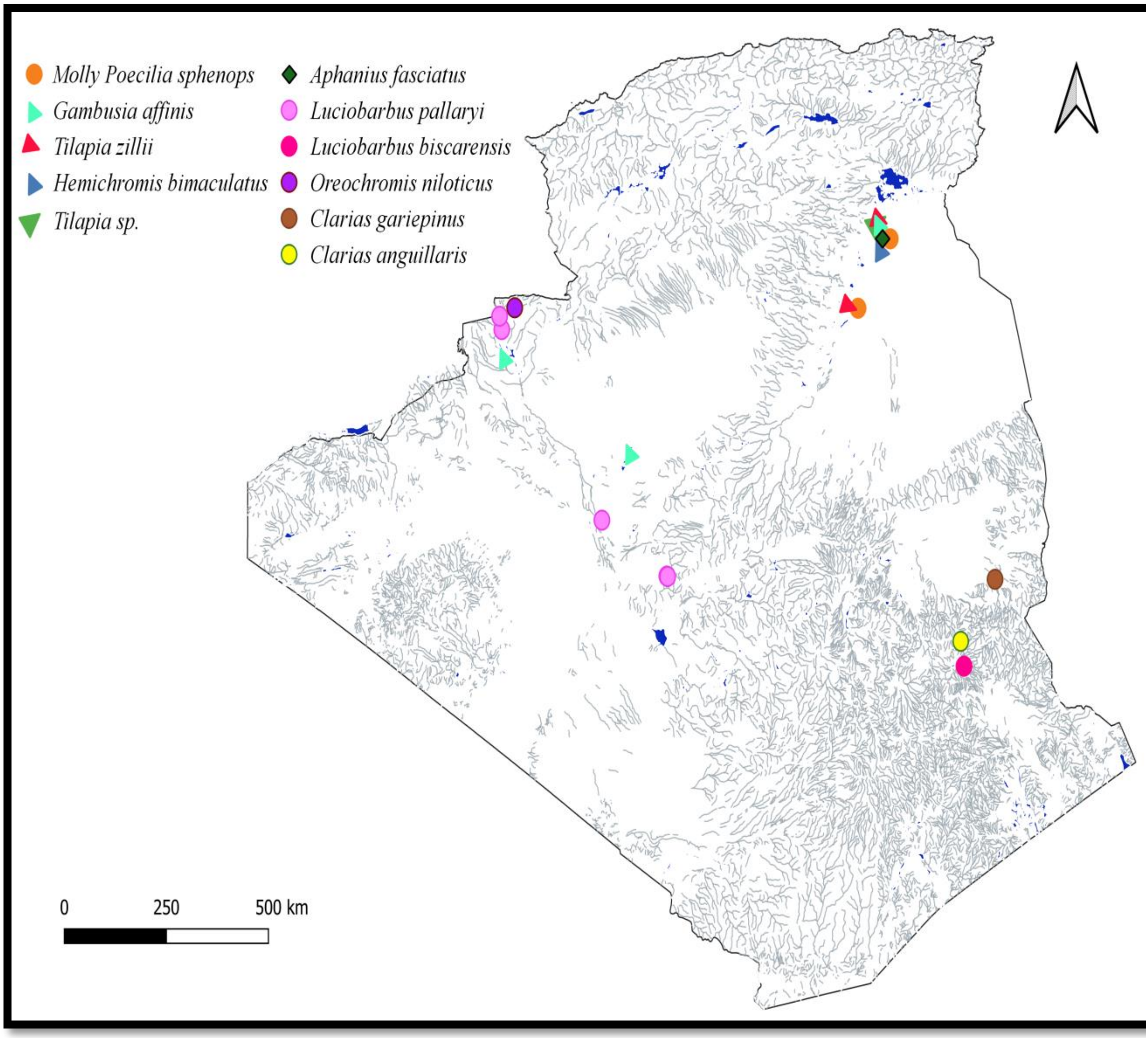


Figure 2. Distribution of freshwater fish species in the southern part of Algeria (original figure).

Data used in the figure are extracted from: (Behmene et al., 2022; Brahimi et al., 2016; Chebaani et al., 2014; Chenchouni, 2012; Ghazi et al., 2019; Ghazi & Bachir, 2021; Sahli et al., 2020; Sellaoui & Bounaceur, 2020; Touil et al., 2019; Zouakh et al., 2016).

According to the Table 2, the most reported freshwater wild fish species by literature in the northern part of Algeria were*: L. callensis; C. carpio; R. rutilus; A. alburnus; A. brama; L. setivimensis* and *C. carassius.* While the less reported freshwater wild fish species were*: S. cephalus; T. ovatus; M. salmoides; Pseudophoxinus sp.; O. niloticus; D. punctatus; D. labrax; C. idella; C. saliens; C. aurata; C. labrosus; A. fasciatus; A. fallax* and *A. alosa.*

Table 2. Freshwater wild fish species distribution in the northern part of Algeria

Fish species	**Governorates**																							
	Chlef	**Batna**	**Béjaia**	**Biskra**	**Blida**	**Tlemcen**	**Tiaret**	**Tizi Ouzou**	**Algiers**	**Sétif**	**Skikda**	**Annaba**	**Guelm**	**M'Sila**	**Mascara**	**BBA**	**Boumerdès**	**El Taref**	**Khenchela**	**Mila**	**Ain Defla**	**Souk**	**Relizane**	**El M'Ghair**
Abramis Brama										* 2			* 1,2					* 2	* 2	* 2,4, 50	* 3	* 2		
Alburnus Alburnus			* 7							* 2			* 2				* 5,6	* 2	* 2	* 2		* 2		
Alosa Algeriensis								* 8									* 8							
Alosa alosa			* 7																					
Alosa fallax			* 7																					
Anguilla Anguilla			* 7					* 8			* 51						* 8	* 9,10, 52						
Aphanius Fasciatus																								* 11, 12, 53
Atherina Boyeri			* 7					* 8																
Barbus sp.																	* 54							
Carassius Auratus								* 8									* 8							
Carassius Carassius										* 2			* 2					* 2	* 2	* 13,2		* 2		

Chelon Aurata			* 7																					
Chelon Labrosus			* 7																					
Chelon Ramada			* 7																					
Chelon Saliens			* 7																					
Ctenopharyngodon idella								* 8																
Cyprinus Carpio			* 7			* 20		* 8						* 14, 17		* 16		* 9, 23		* 15, 19	* 3, 22	* 18, 21		
Dicentrarchus Labrax			* 7																					
Dicentrarchus Punctatus			* 7																					
Gambusia Affinis				* 26								* 24, 27						* 25, 27			* 3			
Gambusia Holbrooki								* 8						* 14, 17				* 28						
Gymnocephalus Cernuus		* 55																						
Hypophthalmichthys Molitrix			* 29					* 8						* 14, 17										
Hypophthalmichthys Nobilis								* 8						* 14, 17										
Luciobarbus biscarensis		* 30		* 30										* 30										
Luciobarbus Callensis			* 7, 33, 35		* 37						* 30	* 32	* 30	* 14, 17, 38			* 34	* 30, 56		* 31, 32, 36, 40	* 22, 31	* 39		
Luciobarbus Leptopogon					* 30				* 30															

Luciobarbus Chelifensis	* 30, 41																				* 30		* 30	
Luciobarbus Lanigarensis						* 42									* 42									
Luciobarbus Mascarensis						* 42									* 30, 41, 42									
Luciobarbus Numidiensis																				* 43				
Luciobarbus Setivimensis			* 30		* 44			* 8								* 30	* 6, 30, 45			* 19				
Micropterus Salmoides								* 8																
Mugil Cephalus			* 7					* 8									* 8							
Oreochromis Niloticus														* 14, 17										
Petromyzon Marinus			* 7					* 8																
Pseudophoxinus Callensis			* 7					* 8			* 46													
Pseudophoxinus sp.														* 47										
Pseudorasbora Parva								* 8									* 8							
Rutilus Rutilus			* 7			* 57		* 8		* 2	* 57		* 2					* 2	* 2	* 2	* 57	* 2		
Salaria Fluviatilis			* 7, 48, 49, 58					* 8																
Sander Lucioperca								* 8													* 3, 22			

Squalius Cephalus														* 14, 17										
Trachinotus Ovatus			* 7																					

* : Presence; BBA: Bordj-Bouarreridj; Data used in the table are extracted from: 1) Guettaf et al.(2019); 2) Reghaissia et al.(2022); 3) Djezzar et al.(2021); 4) Houda et al., (2021); 5) Attou & Arab, (2019); 6) Attou & Arab, (2013); 7) Amalou and Moulaï, (2020); 8) Baikeche et al., (2021); 9) Amrani et al.(2014); 10) Bakaria et al.(2018); 11) Guezi et al.(2017); 12) Ghazi et al.(2018); 13) Khelifi et al.(2017); 14) Mimeche & Oliva-Paterna, (2018); 15) Benayache et al.(2022); 16) Saoudi et al.(2017); 17) Mimeche et al.(2013); 18) Sahtout et al.(2017); 19) Aissaoui et al.(2017); 20) Derrag & Youcef, (2014); 21) Boucenna et al.(2015); 22) Bouamra et al.(2017); 23) Karim et al. (2019); 24) Zaidi & Soltani, (2011); 25) Cheghib et al., 2020); 26) Sellaoui & Bounaceur, (2020); 27) Denna et al. (2022); 28) Benslimane et al. (2019); 29) Sadouni & Iguer-Ouada, (2019); 30) Touil et al. (2019); 31) Habila et al. (2017); 32) Menasria et al. (2020); 33) Aberkane et al. (2018); 34) Rouis et al. (2016); 35) Djoudad-Kadji et al.(2012); 36) Mouaissia et al.(2017); 37) Morsi et al.(2015); 38) Mimeche et al.(2018); 39) Allalgua et al. (2021); 40) Berrouk et al.(2020b); 41) Brahimi et al.(2017); 42) Benali et al. (2021); 43) Brahimi et al. (2018); 44) Fergani and Arab, (2017); 45) Hadou-Sanoun et al. (2012); 46) Morsi et al. (2021); 47) Salhi et al. (2021); 48) Laporte et al. 2015; 49) Amalou et al. (2020) ; 50) Mounia et al. (2022); 51) Derbal et al. (2022); 52) Tahri & Bensouilah, (2023); 53) Labbaci et al. (2021); 54) 6) Nazarizadeh et al. (2023); 55) Arab et al. (2020); 56) Abbaci et al. (2023); 57) Arab et al. (2021); 58) Wagner et al. (2021).

As regards the Septentrional Sahara, Attir et al. (2017) reported the presence of *T. zillii* in Lake Temacine (Northern Algerian Sahara). Also, the presence of *T. nilotica* was notified in several natural and artificial sites of the septentrional Sahara of Algeria (Attir et al. 2011a, 2011b, 2012).Furthermore, Attir (2018) and Attir and Yekhlef (2018) reported the existence of several freshwater fish species in the Governorates of Biskra, Batna, Ouargla, Msila, Djelfa and Laghouat, where ichthyofauna was dominated by: *A. fasciatus*, *B. biscarensis*, *Barbus* sp., *P. parva*, *Pseudophoxinus* sp., *C. carpio*, *C. gibelio*, *C. carassius*, *T. zillii*, *T. nilotica* and *H. bimaculatus*.

4. Freshwater fish protection status

Based on the IUCN Red List database reviewed on October 9th 2022, the status of the most species mentioned in Table 1, are of least concern as they do not qualify as threatened or near threatened such as *A. brama*, *A. alburnus*, *A. fasciatus* and *L.*

callensis. However some species are regionally extinct yet, though they were of least concern in 2009 (Kara, 2012), among which *A. alosa* and *A. fallax*. Many other fish species go from not evaluated to least concern, including: *H. bimaculatus*, *M. salmoides* and *T. zillii* (Table 1). *L. leptopogon*, *L. mascarensis, L. numidiensis* and *A. algeriensis* are endangered and their previous status is unknown, therefore it remains unknown whether their populations has increased or decreased and the same goes for *D. labrax* and *H. molitrix* which are near threatened. On the other hand the population of *A.anguilla* increased in the last decade and is now endangered after being critically endangered in 2009 according to Kara (2012).

The introduction of fish species can affect local ecosystems in a variety of ways; they can hybridize with, prey on or out-compete native species, they can also transmit parasites and pathogens and provoke changes in communities (Kara, 2012). An impressive number of fish invasions in inland waters have contributed to the disappearance of many autochthonous species worldwide, and have had an adverse impact on environmental quality, the endemic fish species are among the most vulnerable species to introductions (Kara, 2012), which might explain the extinction of autochthonous fish populations such as *A. alosa* and *A. fallax*. Therefore, further introductions should not be contemplated without rigorous research and risk assessment.

The comparison between the red list status of fish species in 2009 and in the present, only indicates the fragile state of the Algerian ichthyofauna, therefore, in order to protect the fish diversity and to avoid the extinction of the frail species, it is extremely necessary to take appropriate measures, for instance, strengthening of fisheries management including the implementation of strict regulations on fishing, creation of protected areas to allow fish populations to recover, deterrence of illegal fishing activities, implementation of reintroduction projects for fragile species, conducting research to improve the understanding of the biology and ecology of endangered and vulnerable fish species.

CHAPTER 2

REVIEW OF FRESHWATER FISH PARASITISM IN ALGERIA: A SYNTHESIS OF THE MAIN PUBLICATIONS FROM 2013 TO 2023

This chapter is based on the authors' article, "Review of freshwater fish parasitism in Algeria: a synthesis of the main publications from 2013 to 2023", published in Brazilian Journal of Animal and Environmental Research, 7(4), e75764, 2024.

Chapter 2. Review of freshwater fish parasitism in Algeria: a synthesis of the main publications from 2013 to 2023

1. Introduction

Global biodiversity is declining at a rapid rate (Olson et al., 2002) and for many types of taxonomic group and in a wide range of environments, extinction levels are 100 to 1000 times higher than in prehistoric times (Pimm et al., 1995). The world's ecosystems of freshwater are a vital human life resource, providing food, clean water, recreation, subsistence and other ecosystem services. They are worth approximately more than $ 4 trillion per year (Costanza et al., 2014; Youn et al., 2014; Béné et al., 2016; Lynch et al., 2016). These ecosystems, consisting of lakes, rivers and wetlands, cover less than 1% of the total surface of the planet (Mittermeier et al., 2010), yet they host more than 10% of all the species recorded (Mittermeier et al., 2010; Dijkstra et al., 2014), of which 30% are vertebrates.

Although freshwater is a significant contributor to the global biodiversity and the well-being of humans, there is a global crisis in freshwater biodiversity due to high and increasing global pressures and threats on freshwater ecosystems compared to neighbouring terrestrial ecosystems (Nel et al., 2007; Hermoso and Clavero, 2011; Darwall et al., 2018). Over the past 50 years, the populations of freshwater vertebrates have decreased by more than 80%, a decline rate twice that of marine or terrestrial systems (Beaufort et al., 2016).

Freshwater fish represent more than 25% of the total vertebrate fauna on Earth and are among the most threatened taxa in a global context (Duncan and Lockwood, 2001; Darwall et al., 2008). Mediterranean freshwater ichthyofauna is particularly threatened due to endemism (Olson and Dinerstein, 2002; Abell et al., 2008). According to Smith and Darwall (2006), more than 70% of the 228 endemic fish species for which suitable data are currently available are already extinct, vulnerable, endangered or critically endangered. These estimated numbers are three times greater than for other animal groups of the Mediterranean (Hermoso and Clavero, 2011). As regards Mediterranean endemic freshwater ichthyofauna, the percentage of threatened species is one of the highest on the IUCN Regional Assessment of the Conservation Status of Freshwater Fish (Darwall et al., 2008).

Additionally, species of freshwater fish are subject to multiple stresses, both natural and anthropogenic; parasitism is one of the natural aggressions (Ben Hebireche and Gaamour, 2010) and is one of the major factors influencing the sustainability of natural communities and populations (Combes, 1995; Morand and Arias Gonzalez, 1997). For example, Gyrodactylus salaris Malmberg, 1957, which is a monogenean parasite, is considered amongst the most serious threats to the Atlantic salmon in Norway, having nearly wiped out the populations of salmon in the Signaldalen and Skibotn rivers in the northern Norway (Adolfsen et al., 2021). Moreover, Ichthyophthirius multifiliis Fouquet, 1876, is a ciliated protozoan parasite which causes disease and ultimately mortality in a broad freshwater fish species range, resulting in significant economic losses in aquaculture (Teixeira Alves and Taylor, 2020).

The aim of this review is to assess and study the biodiversity of freshwater fish parasites in Algeria, both in wild and cultured fish, and to contribute to the understanding of the distribution and bioecology of the parasites of freshwater fish, as there is a great lack of such studies, as no previous research has been conducted in this field in Algeria, previous studies only indicated the presence of parasite species, such as the studies conducted by Attir et al. (2017), Reghaissia et al. (2022) and Abbaci et al. (2023).

2. Material and methods

During March 2023, the literature was searched using the following five databases: Science Direct, PubMed, Springer, Scopus and Google Scholar, using the following keywords: "freshwater", "fish", "parasite", "Algeria", "Copepoda", "Nematoda", "Acanthocephala", "Digenea", "Cestoda", "Protozoa", "Helminth", "Monogenea", "Trematoda", "Cichlidae", "Cyprinidae". The keywords were used individually or in different combinations to collect all publications indicating parasitism of freshwater fis h in Algeria between 2013 and 2023, all duplicate records were omitted, the titles and abstracts of the remaining research studies were reviewed. Articles were excluded on the basis of the following eligibility criteria: the host fish are only freshwater fish (wild or farmed), the sampling was done in Algeria, research article, access to full text in English or French, articles published in the years mentioned above. A set of 25 references were retained concerning freshwater fish distribution in Algeria (Figure 3), data regarding: the host fish species, the recorded parasite species and the geographical sampling site location, were extracted from each article.

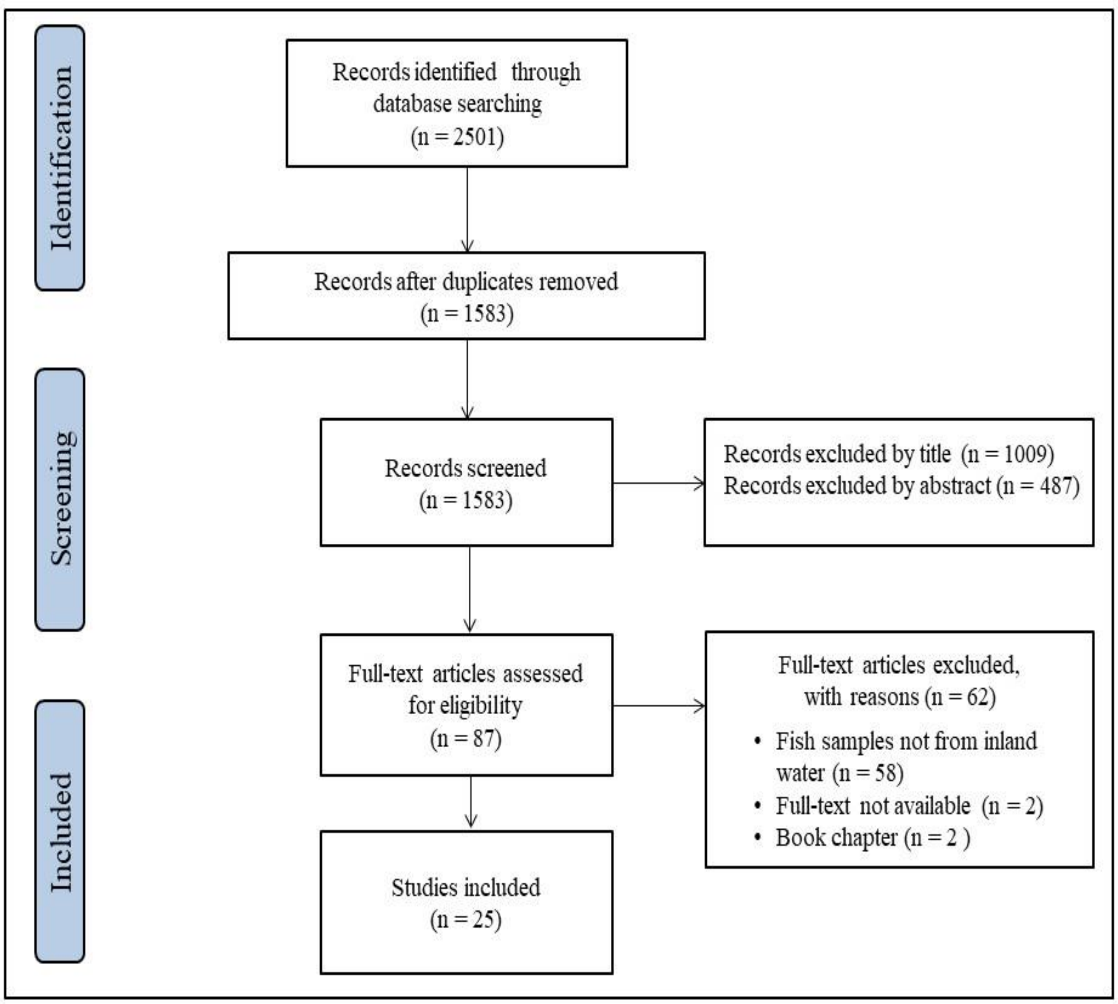


Figure 3. Study flow chart (original figure)..

3. Results and discussion

Table (3) describes the distribution of freshwater fish parasites in different governorates of Algeria during the last 10 years. The data shows that 36 species of parasites have been reported in 11 fish species, belonging to the following 11 classes: Conoidasida, Copepoda, Secernentea, Monogenea, Maxillopoda, Cestoda, Eoacanthocephala, Oligohymenophorea, Cyrtophoria, Myxosporea and Trematoda.

Based on the results, *Anguilla anguilla* Linnaeus, 1758, *Luciobarbus callensis* Valenciennes, 1842, *Aphanius fasciatus* Valenciennes, 1821 and *Cyprinus carpio* Linnaeus, 1758 are the species of fish most frequently infected, while each of them hosts 5 classes of parasites and at least six species, the first three fish species are autochthonous in association with 18 other fish species they represent 43.75% of the fauna of freshwater fish of Algeria (Kara, 2012), which has prompted studies to focus on these species, in addition to the fact that *Anguilla anguilla* is considered an endangered species based on the IUCN Red List, which was established by the IUCN to identify threats driving species toward extinction and to track changes in biodiversity conservation status (Ferreira et al., 2023), the database was reviewed on 1 August 2023.

Ergasilus sieboldi Von Nordmann, 1832 and *Ergasilus briani* Markevich, 1933, are among the most cited parasites, they belong to the families Ergasilidae (Mahmoud *et* al., 2021), which have a wide range of distribution in marine, brackish and freshwater environments (Míč et al., 2023), these ectoparasites attach themselves to the body, the gills and the fins of fish hosts (Iyaji and Eyo, 2008), they are considered as one of the most important primary parasites, represented by the class of crustaceans, which contains highly diversified parasites and, in addition to a wide range of morphologies, also belongs to several major groups whose most common crustacean parasites have been assigned to the order Isopoda and the super-order Copepoda (Berrouk et al., 2018). *Ergasilus* spp. are often found incidentally on farmed or wild fish, when present in small quantities they cause fewer problems, but in heavy infestations their feeding activity can be debilitating (Iyaji and Eyo, 2008).

E. sieboldi and other species of Ergasilus have been reported to cause problems in captive freshwater fish (including eels) in North America (Kabata, 1981; Hogans, 1989) and Europe (Grabda, 1991; Tuuha et al., 1992). In Africa, sever infestations of *Ergasilus* sp. cause acute inflammation and haemorrhage in the gills of host fish associated with parasite attachment and feeding (Paperna, 1975). The chronic infections lead to the production of excessive gill mucus and the clogging of the lamellar blood vessels (Paperna and Zwerner, 1974), resulting in osmoregulatory and respiratory failure (Hogans, 1989; Barker and Cone, 2000).

Anguillicola crassus (Nematoda, Dracunculoidea, Kuwahara, Niimi and Hagaki, 1974) also known as the eel swim bladder nematode, is reported by five authors according to Table (1), the parasite is found in several eel species (Kuwahara et al., 1974). It is originally from Asia, where it parasitises *Anguilla japonica* Temminck and Schlegel, 1846, or the Japanese eel (Kuwahara et al., 1974), but it also considered as an invasive parasite for a further five species of anguillid eel worldwide (Moravec, 2006; Sasal et al., 2008; Lefebvre et al., 2012; Myrenås et al., 2023). *A. crassus* has little or no impact on the overall health of its native host species *A. japonica,* while it is both potential and actual pathogen in *A. anguilla*, which is an immunologically naive host with no evolutionary history with this parasite (Taraschewski, 2006). *A. crassus* leads to functional and structural lesions in the swim bladder, particularly at high densities, reducing its capacity to operate as a hydrostatic organ and thus reducing migratory capacity and swimming performance in eels (Kennedy, 2007; Palstra et al., 2007). *A. crassus* is a potential contributor to eel mortality when present in large numbers and in association with certain other environmental stressors (Giari et al., 2021), as observed in Hungary in the Balaton Lake, in the summers of 1991 and 1992 (Molnar et al., 1991, 1994).

Ligula intestinalis Linnaeus, 1758 is also one of the most commonly reported parasites, infecting *Rutilus rutilus* Linnaeus, 1758, *L. callensis*, *Barbus* sp. and *C. carpio.* It is a widespread and abundant parasite, mostly infecting cyprinids as intermediate hosts (Dubinina, 1980; Hoole et al., 2010). The parasite is known to have a complicated life cycle with a piscivorous bird as the final host and two intermediate aquatic hosts (Dubinina, 1980). Its life cycle is initiated in the fish-eating bird or final host's intestinal tract, where the parasite achieves sexual maturity and releases its eggs (Gabagambi et al., 2019). The eggs are transferred through the bird faeces into the aquatic ecosystem and hatch eventually into free-swimming larvae, fed on by a planktonic copepod, which is the first intermediate host, where they develop into little larva. Their cycle continues when the infected copepods are consumed by the next intermediate host, which is usually a cyprinid fish. The parasite transforms into a larger larva inside the body cavity of the fish, and the cycle ends when the host fish is ingested by birds (Gabagambi et al., 2019).

A. fasciatus, is an endemic fish species in the Mediterranean region, it was reported by Ghazi et al. (2018) to be infected with *Myxobolus*, which belongs to the Myxosporangium, a common metazoan parasite (Liu et al., 2022), which is widely distributed worldwide and mainly parasitises fish, there are currently more than 2,500 species of myxospores worldwide (Gómez et al., 2014), many myxozoans are highly pathogenic to their hosts (Lisnerová et al., 2020), affecting host growth and development and causing physiological abnormalities (Liu et al., 2022), as well as causing numerous fish diseases. Myxospore infection may directly lead to the death of the host, resulting in severe ecological pollution and economic losses (Zhang et al., 2010). *Myxobolus* is the most common species of myxospores, it is also one of the most harmful groups of myxospores to fish hosts (Zhang et al., 2010).

Carp species are commonly infected by different species of *Dactylogyrus* (Tancredo et al., 2019), as shown in Table (3), which indicates that *C. carpio* species in Algeria are infected by four species of *Dactylogyrus* (D); *D. extensus* Mueller and Van Cleave, 1932, *D. cyclocirus* Paperna, 1973, *D. arcuatus* Yamguti, 1942, *D. anchoratus* Dujardin, 1845. Some of the *Dactylogyrus* species are highly pathogenic, in particular to fingerlings, resulting in major liabilities for producers and massive mortality rates (Buchmann et al., 1993; Bretzinger et al., 1999; Kritsky and Heckmann, 2002; Jalali and Barzegar, 2005). Numerous studies have investigated the infestation mechanisms and the biology of these parasite species (Ergens and Dulmaa, 1969; Mhaisen et al., 2013), identifying the following species as the most widespread : *D. vastator* Nybelin, 1924, *D. minutus* Kulwiec, 1927, *D. anchoratus*, *D. achmerowi* Gussev 1955, *D. formosus* Kulwiec, 1927, *D. arcuatus, D. difformis* Wegener, 1857, *D. intermedius* Wegener, 1910, and *D. extensus* (Gibson et al., 1996; Jarkovský et al., 2004; Stojanovski et al., 2008; Molnár, 2012).Three of these species are reported from Algeria (Boucenna et al., 2015; Brahmia et al., 2016). Outbreaks of monogenean parasites occur as a result of their life cycle in a a specific host, temperature and culture densities (Turgut and Akin, 2003), with host fish sites of infection usually being the gills, fins and/or skin (Bagge et al., 2005; Kasembele et al., 2023), but very occasionally also the stomach, eyes, urinary bladder, oral or nasal cavity, intestine and heart (Llewellyn, 1960; Euzet and Combes 1998).

The present review is constrained by the limited number of studies currently available on freshwater fish parasites of Algeria. This limitation may restrict the depth and the generalizability of the drawn conclusions, given that the results are based on a limited range of research. Therefore, further studies should aim to fill this gap by conducting more in-depth research, focusing in particular on the under-represented regions or species. An increase in the contributions to the literature will enable a fuller insight and support more robust reviews.

Table 3. Parasitism of freshwater fish (wild or farmed) in Algeria during the last decade.

Host species	Parasites		Localities	References
	Classes	Species		
Carassius carassius	Conoidasida	*Cryptosporidium* spp.	Algiers Mila Khenchela Souk-Ahras Guelma Tebessa Setif	(Reghaissia et al.; 2022)
	Copepoda	*Ergasilus briani* *Ergasilus megaceros* *Ergasilus sieboldi* *Paraergasilus brevigiditus* *Neoergasilus japonicus* *Lernea cyprinacea*	Mila	(Berrouk et al., 2018, 2019, 2020a, 2022)
Anguilla anguilla	Secernentea (Nematoda)	*Anguillicola crassus*	El'Taref	(Tahri et al., 2016, 2017; Djouahra and Arab, 2017; Bakaria et al., 2018; Tahri and Bensouilah, 2023)
		Cucullanus sp.	El'Taref	(Bakaria et al., 2018)
		Hysterothylacium sp.	El'Taref	(Tahri et al., 2017)
	Monogenea	*Pseudodactylogyrus* sp.	El'Taref	(Tahri et al., 2017, 2018; Bakaria et al., 2018)

	Copepoda	*Ergasilus* sp.	El'Taref	(Bakaria et al., 2018)
		Ergasilus gibbus	El'Taref	(Tahri et al., 2017, 2018)
	Maxillopoda	*Argulus foliaceus*	El'Taref	(Tahri et al., 2017, 2018; Bakaria et al., 2018)
	Cestoda	*Bothriocephalus claviceps*	El'Taref	(Tahri et al., 2017; Bakaria et al., 2018)
Coptodon zillii	Monogenea	*Cichlidogyrus cubitus*	Touggourt	(Attir et al., 2017)
Abramis brama	Conoidasida	*Cryptosporidium* sp.	Algiers Mila Khenchela Souk-Ahras Guelma Tebessa Setif	(Reghaissia et al., 2022)
Rutilus rutilus	Conoidasida	*Cryptosporidium* sp.	Algiers Mila Khenchela Souk-Ahras Guelma Tebessa Setif	(Reghaissia et al., 2022)
	Cestoda	*Ligula intestinalis*	Tlemcen Ain Defla Skikda	(Arab et al., 2021)
Albernus albernus	Conoidasida	*Cryptosporidium* sp.	Algiers Mila Khenchela Souk-Ahras Guelma Tebessa Setif	(Reghaissia et al., 2022)
Luciobarbus	Monogenea	*Dactylogyrus*	Souk-Ahras	(Allalgua et

callensis		*heteromorphus*		al., 2021; Amel et al., 2022)
	Cestoda	*Ligula intestinalis*	Algiers	(Rouis et al., 2016)
	Eoacanthocephala (Acanthocephala)	*Acanthogyrus maroccanus*	Souk-Ahras Skikda Mila	(Menasria et al., 2020)
	Secernentea (Nematoda)	*Anisakis* sp.	El'Taref	(Abbaci et al., 2023)
	Copepoda	*Ergasilus briani* *Ergasilus megaceros* *Ergasilus peregrinus* *Ergasilus sieboldi* *Paraergasilus brevigiditus* *Neoergasilus longispinosis* *Neoergasilus japonicas* *Lernea cyprinacea*	Mila	(Berrouk et al., 2018, 2020a, 2019)
Barbus sp.	Cestoda	*Ligula intestinalis*	Algers	(Nazarizadeh et al., 2023)
Aphanius fasciatus	Oligohymenophorea (Protozoa)	*Trichodina*	El M'Ghair	(Ghazi et al., 2018)
	Cyrtophoria (Protozoa)	*Chilodonella*		
	Myxosporea	*Myxobolus*		
	Monogenea	*Dactylogyrus* *Onchobdella*		
	Trematoda	*Posthodiplostomum*		
Abramis brama	Copepoda	*Ergasilus sieboldi* *Ergasilus briani*	Mila	(Berrouk et al., 2019, 2020a, 2020c; Houda et al., 2021)

Cyprinus carpio	Monogenea	*Dactylogyrus extensus* *Dactylogyrus cyclocirus* *Dactylogyrus arcuatus* *Pseudacolpenteron pavlovskii*	Souk-Ahras	(Allalgua et al., 2015)
		Dactylogyrus anchoratus	Souk-Ahras El'Taref	(Allalgua et al., 2015; Brahmia et al., 2016)
	Maxillopoda	*Argulus foliaceus*	El'Taref	(Brahmia et al., 2016)
	Cestoda	*Bothriocephalus acheilognathi* *Ligula intestinalis*		
	Secernentea (Nematoda)	*Contracaecum* sp.		
	Copepoda	*Ergasilus peregrinus*	Souk-Ahras Mila	(Boucenna et al., 2015; Berrouk et al., 2020c)
		Ergasilus sieboldi *Lernaea cyprinacae*	Souk-Ahras Mila	(Boucenna et al., 2015; Berrouk et al., 2019, 2020a, 2020c)
		Ergasilus briani *Neoergasilus japonicas,* *Neoergasilus Longispinosis*	Mila	(Berrouk et al., 2019, 2020a, 2020c)

4. Conclusion

The study on the freshwater fishes parasites distribution in Algeria during the last decade showed that the authors reported the presence of 36 parasite species belonging to 11 classes and infecting 11 fish species, among them, parasites that can cause high mortality such as *Dactylogyrus* species and *Myxobolus*, others have less impact on the fish host, for example *Ergasilus* species. Out of all freshwater fish species in Algeria, only 11 species have been studied for parasitic infections. The lack of currently available data on the bioecology and the distribution of freshwater fish parasites in Algeria highlights the need for further studies.

EXPERIMENTAL PART

MATERIALS AND METHODS

1. Materials and methods

1.1 Description of research regions

1.1.1 Biskra region

The province of Biskra is located in the north-east of the Algerian Sahara, about 400 km away from the capital. It covers an estimated area of 10500 km², comprising 27 communes and 10 daïras. Its altitude is 125 m above sea level and is bordered by the following provinces: Batna, to the north, Khenchela to the east, Ouled Djellal to the south and El Oued in the south-east, It has an arid climate, with hot dry summers and cold, dry winters (Farhi, 2001; Mammeri, 2016; DSA, Biskra, 2022).

The relief is divided into 4 main zones: Mountainous zone, located in the north (El Kantara, Djamoura, M'chounche) and whose highest point is Djebel Taktiout (1942 m), plateaux, which are located in the west and extending from north to south, encompassing a part of Tolga, plains area, extends along the El-Outaya (Fontaine des Gazelles dam) - Sidi Okba - Zeribet El Oued and depression zone, located in the south-eastern part of the Biskra region (Chatt-Melghigh) (Sellaoui, 2021).

The present study was conducted in three artificial sites, Foum El Kherza dam, a fish farm in the commune of Sidi Okba and a fish farm in the commune of El Outaya (Figure 4).

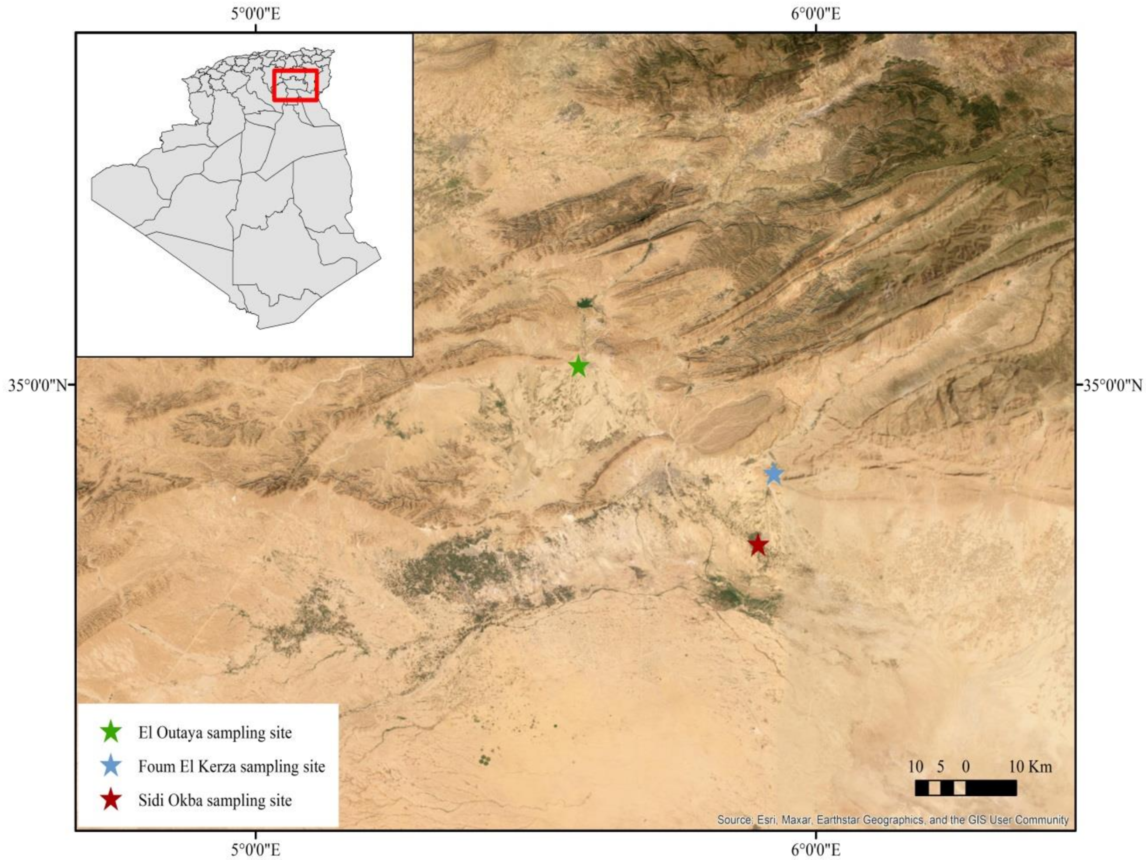


Figure 4. Sampling sites in the region of Biskra (original figure)..

1.1.2 Djelfa region

Djelfa is a province situated in central Algeria, in the high plains. To the north the province is surrounded by the Tellian Atlas Mountains, featuring a mountainous ground with lush forests and green valleys. To the south the landscape progressively transforms into the arid Sahara Desert plains. This varied topography has moulded the region's distinct cultural and ecological identity. The province lies approximately between between longitude of 2° and 5° East and latitude of 33° and 36° North. It is situated 300 km south of the capital and bordered to the north by the provinces of Tissemsilt and Médéa, to the south by the provinces of Ouargla, El Oued and Ghardaïa, to the west by the provinces of Tiaret and Laghouat and to the east by the provinces of Biskra and M'sila. In spite of its arid climate, Djelfa has a rich biodiversity, with a wide variety of animal and plant species well adapted to its challenging conditions (Koussa, 2017).

The present study was conducted in three different sites belonging to the Djelfa province, two artificial sites, which are the Chbika artificial lake and a fish farm in the commune of Dar Chioukh. Wadi Tadmit was the third site, a natural water stream located in the commune of Tadmit (Oued Tadmit River) (Figure 5).

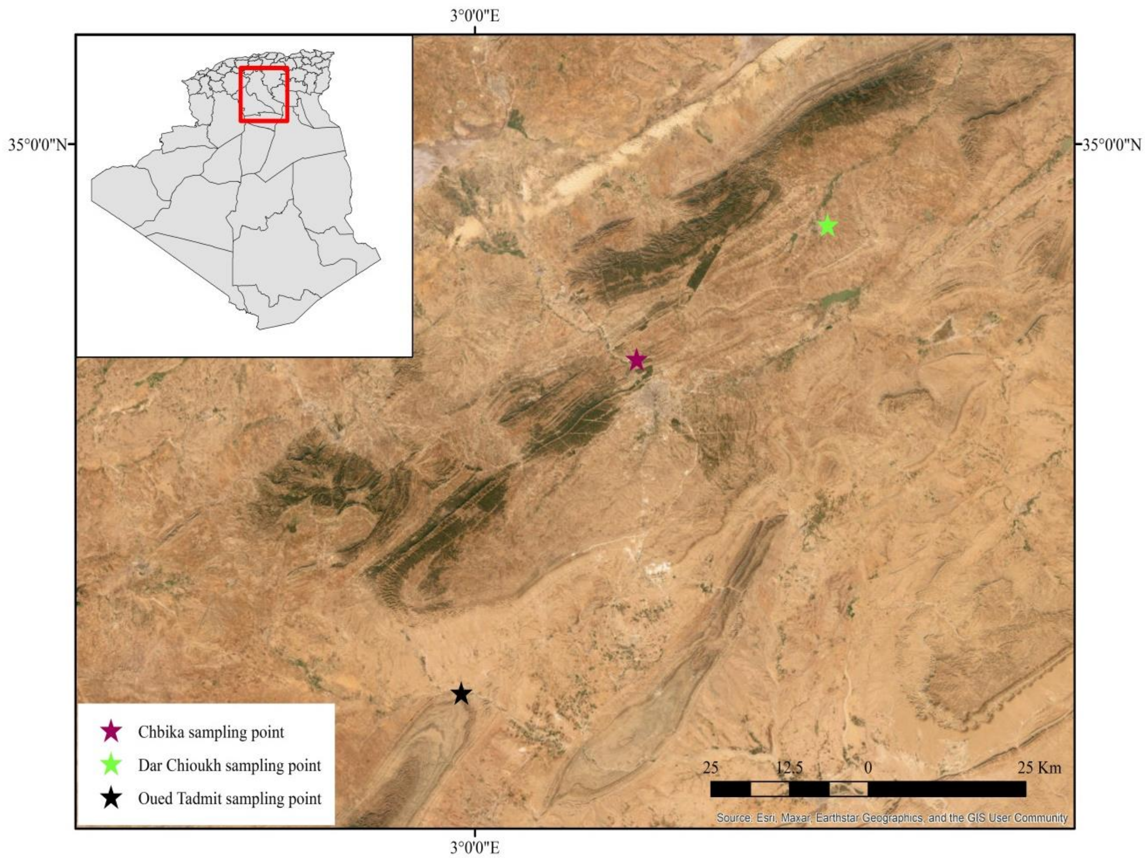


Figure 5. Sampling sites in the region of Djelfa (original figure).

1.1.3 Laghouat region

The province of Laghouat is located at 400 km south of Algier on the road from Algiers to Ghardaïa at an altitude of 751 m on the southern slopes of the Saharan Atlas, at a longitude of: 2°52'60‘’ E and latitude of 33°47'50 N. It is founded on the banks of the Oued Mzi, the biggest wadi in the southern part of the Saharan Atlas, and is surrounded to the south by a large pastoral area extending as far as the Bordj de Tilghemt, which covers an area of 400 km^2. The province is bounded to the north-east by the province of Djelfa, to the north-west by the provinces of Tiaret and El Bayadh and to the South by the province of Ghardaïa. Laghouat is strategically located as a staging post between the north and south of the country. It is the meeting point of the Saharan tracks, giving it the status of one of the gateways to the Sahara (Benkouider, 2019).

In terms of nature, the Laghouat region is comprised of two distinct zones: The Saharan Atlas zone, characterised by altitudes ranging from 1,000 to 1,700 m with slopes of 12.5 to 25%. This area lies to the north-west of the Wilaya (Aflou and Brida regions), comprising 47,095 hectares of old-growth forest, 315,125 hectares of alfa grassland and 1,531,766 hectares of grazing land. And the High Plateaux and Saharan Plateaux zone, with altitudes ranging from 700 to 1000 m and slopes of 0 to 3%, is characterised by vast expanses of steppe covering 1,900,000 ha, much of which has been degraded by prolonged drought (Kaddouri, 2021).

The present study was conducted in an artificial lake located in the commune of Tadjerouna (Figure 6).

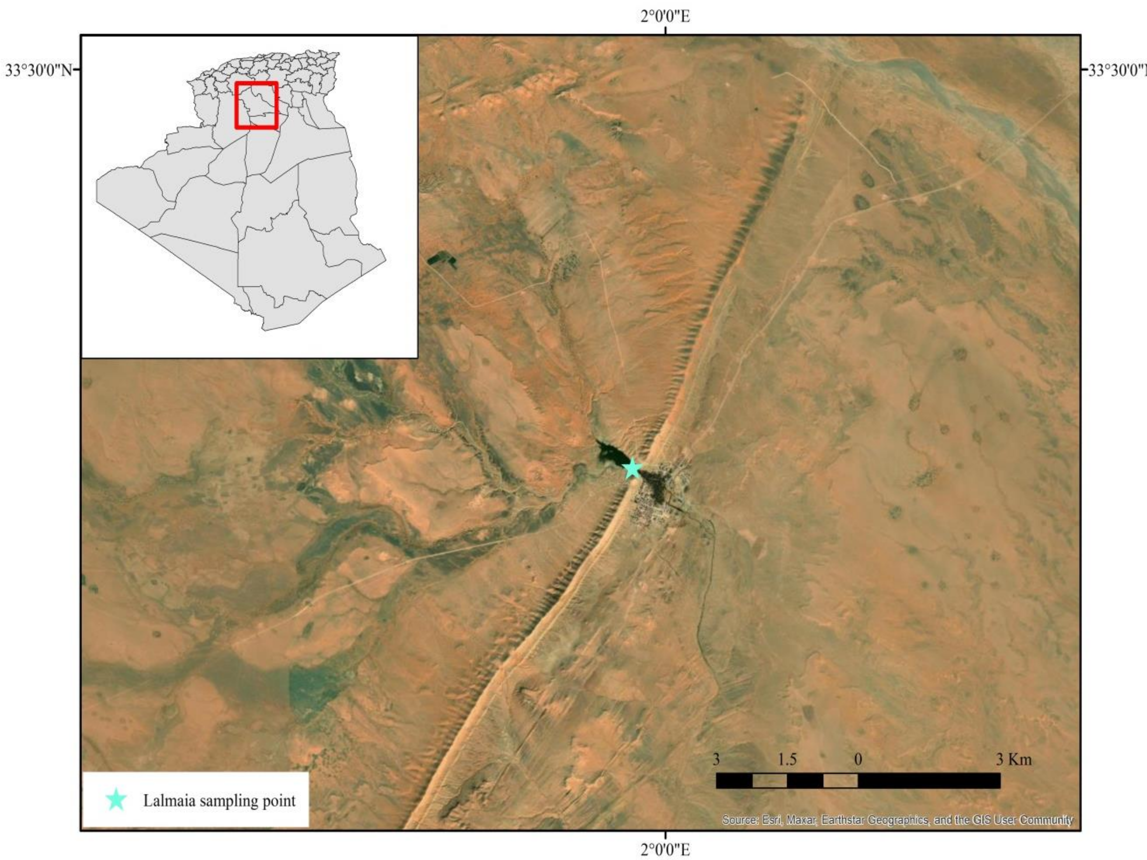


Figure 6. Sampling site in the region of Laghouat (original figure).

1.2. Collection of Samples

Fish sampling efforts were undertaken to collect specimens between 2022 and 2024 to ensure a representative collection of the ichthyofauna within the three study regions. These sampling activities employed the following methodologies:

1.2.1. Traps and pots

Traps or creels consist of a stiff frame covered with wire mesh or netting. These cages or baskets can vary in shape, size, construction design and material, but all feature a funnel-shaped entrance, which facilitates the entry of aquatic animals but makes it more difficult for them to escape. These cages or baskets can vary in size, shape, construction design and material, but all feature a funnel-shaped entrance, which facilitates the entry of aquatic animals but makes it more difficult for them to escape. They fall into the category of passive fishing gear. Placed on the bottom, usually in strings, baited generally to catch crustaceans, they may also be used to capture molluscs or certain species of fish. The pots (with solid sides instead of grids) provide an attractive hiding place for certain molluscs (particularly octopus), which hide in them while the pots are removed from the water (European Parliament, 2015).

Fyke nets (possibly baited) or fishing nets (staked nets) are also forms of easily detachable or semi-permanent fixed funnel trap systems, built with visible net panels, in which the fish are easily led to the entrance or entrances, yet are unable to escape. Trap, creel or pot fishing can be a very selective method. The animals are caught alive, making it easy to release any undersized or unwanted specimens, generally without harming them, the animals caught could be further stored alive in tanks (European Parliament, 2015).

1.2.2. Lines and hooks

Fishing lines are fairly simple devices equipped with baited hooks or artificial lures. The lines can be hand-held or tied to a leader or other type of support (e.g. a fishing rod). The characteristics of the lines and hooks (size, shape, and thickness), the type of bait, along with the duration of immersion and the time of setting, depend on the fishery and the target species. Selectivity can vary and can be adjusted accordingly, using different hook shapes and sizes, but also bait size and nature (European Parliament, 2015).

Fish captured using hook and line are generally of good or even very good quality particularly in the case of active line fishing methods (European Parliament, 2015) (Figure 7).

- The samples were transported immediately after capture to the laboratory frozen in cooler or alive in plastic tanks.

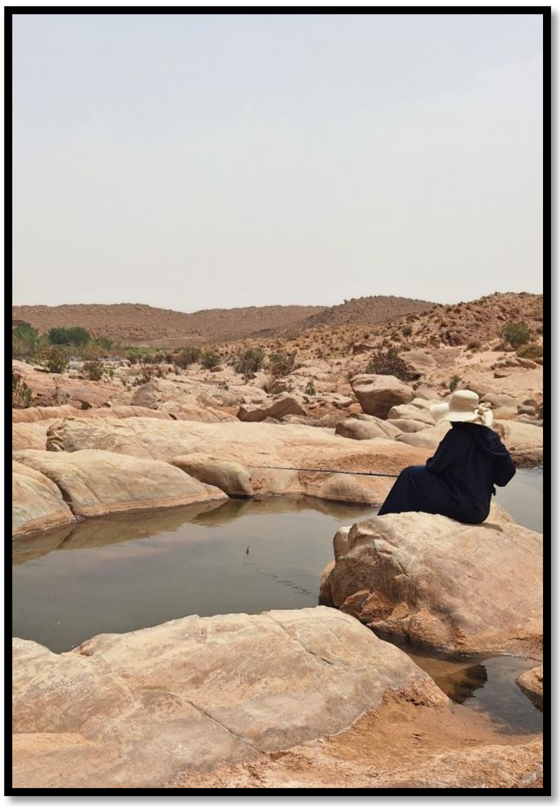


Figure 7. Fish sampling using a fishing rod (original photo).

1.3. Fish samples identification

In this study, the identification of fish samples collected from various sampling locations was conducted with meticulous attention to taxonomic accuracy. To ensure reliable species determination, the following established identification keys were employed, each utilized for specific genera or species:

- **Kottelat and Freyhof (2007):**
    - "Handbook of European Freshwater Fishes" by Kottelat and Freyhof (2007) was specifically utilized for the identification of *Carassius gibelio* and *Cyprinus carpio*. This comprehensive European freshwater fish guide provided the necessary detailed morphological descriptions and comparative analyses to accurately distinguish these species, which are known to be present in the studied region.
- **Mbega and Teugels (2003):**
    - "Guide de Détermination des Poissons du Bassin Inférieur de l'Ogooué" by Mbega and Teugels (2003) was used for the identification of fish belonging to the *Barbus* genus. Although this guide pertains to the fishes of the lower Ogooué basin, it contained information that, when combined with other resources, was helpful in the identification of the *Barbus* specimens that were collected. This was very important, due to the difficulty of the *Barbus* Genus.
- **Brahimi et al. (2017):**
    - The article "*Luciobarbus chelifensis* and *L. mascarensis*, two new species from Algeria (Teleostei: Cyprinidae)" by Brahimi et al. (2017) containing a Key to species of *Luciobarbus* in the African Mediterranean and Sahara basins in Central Algeria and Tunisia, was specifically used for the identification of *Luciobarbus biscarensis*. This article, focused on the *Luciobarbus* species of Algeria and Tunisia, provided the regional expertise and species-specific key necessary for the accurate classification of this species.

- ***Oreochromis* sp.:**

  - *Oreochromis* sp. samples were obtained directly from established fish farms. As these specimens had been previously identified by the aquaculture facilities, further taxonomic identification was deemed unnecessary. Their identification was accepted as provided by the fish farms.

By applying these targeted identification resources and acknowledging the pre-identification of the *Oreochromis* sp. samples, the identification of each species or genus was done using the most appropriate and relevant taxonomic information. This approach allowed for a more precise and accurate species identification, enhancing the reliability of our research findings.

1.4. Gender and age determination

1.4.1 Gender

The gender of samples was determined by the examination of the gonads using the stereomicroscope or with naked eye. For the fish species mentioned in the following study, gonads appear in the form of two elongated lobes hanging against the abdominal wall, the ovaries are, fusiform, cylindrical and paired, their color gets orange-yellow during the breeding season, and they are generally larger than the testes which are generally flattened and milky white in color (Chaibi, 2013).

1.4.2 Age

The correct determination of age in fish is essential for a proper understanding of the species population's dynamics and its life cycle (Ombredane and Baglinière, 1992). Age could be determined by two methods; directly by reading anatomical parts such as scales, opercules, otoliths, vertebrae and fin rays, or indirectly using statistical method by studying the distribution of any measurable character (metric character), and the repartition of this distribution in age classes (Do-Chi, 1977). As for the scales, the increase in their age takes the form of circular striations that are spaced more or less closely together, depending on the rate of growth. The striae which appear during the winter will be close together (annulus), unlike the ones appearing during summer which are far apart (circulis), and that is due to the fact that winter growth is about 3 to 4 times slower than summer growth. On the basis of the number of alternations (closely spaced striae/spaced striae), the number of years the fish has lived can be estimated (Poulet, 2004; Ould Bilal, 2005).

The scales used to establish age were taken from the latero-dorsal area. This is the area where the scales appear earliest, and they show up very clearly (Boet and Le Louarn, 1985). The scales were collected and cleaned thoroughly under running water and checked using stereomicroscope to remove any mucus or tissue fragments and to eliminate newly-formed scales and old ones whose central part was in the process of being reshaped (Meunier, 1988). The scales were then dry-mounted between the slide and the cover slip, with adhesive tape connecting the ends, with four scales per individual.

To determine the age, the scales are observed under stereomicroscope at 4X magnification, their reading is most effective if the sample is taken just before, or during the growth arrest phase, yet some difficulties may occur especially due to the presence of "false rings", the tracing of which is often incomplete and may be linked to changes in metabolism, reproduction, stress or injury, fish diseases. Likewise, in older fish, the peripheral circulae may be compressed. Therefore, to obtain a better interpretation, it is essential to examine the scale as a whole (Bouhbouh, 2002).

1.5 Morphometric measurements

The length of each fish specimen was measured in centimeters (cm) with a graduated ruler, encompassing: Total length or (TL) (the straight-line distance from the most anterior point of the snout to the posterior extremity of the caudal fin), standard length (SL) (the distance from the snout tip to the point where the caudal fin connects to the body),cephalic length or head length (CL) (measured from the snout tip to the posterior edge of the operculum), and body depth (BD) (the vertical distance between the insertions of the anterior dorsal fin spines and the pelvic fins) (Attir, 2018) (Figure 8).

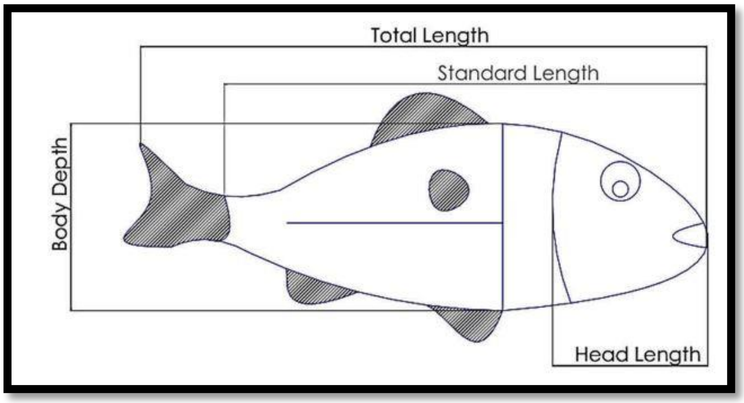


Figure 8. Fish morphometric measurements. Adapted from Jayraj et al., 2019, p. 3.

1.6 Searching for parasites

1.6.1 Searching for haemoparasites

1.6.1.1 Smears preparation

To detect haemoparasites, live fish are required. The test is performed by sampling a small quantity of blood from the gill vein using disposable subcutaneous syringes. While holding the animal steady, each syringe is inserted at an angle of 30° to 60° (Knotková et al., 2002; López-Olvera et al., 2003).

Once removal of the needle is complete, a fresh drop of blood is placed on the edge of a degreased slide and smeared over the entire surface with a second slide set at a 45° angle. After taking the smear, the slide is left to air dry under an aerated cover to protect it from dust and thereby prevent its alteration. Finally, the smears obtained are labeled with the code of the corresponding specimen (Knotková et al., 2002; López-Olvera et al., 2003).

1.6.1.2 Smears staining

The smears are stained using May-Grunwald and Giemsa Romanowski (MGG). The staining is used specifically to characterise blood cells and detect haemoparasites (Giemsa, 1904; Knotková et al., 2002; Petithory et al, 2005). The smears were stained as follows:

- A 10% solution of Giemsa was prepared by diluting 100 ml of pure Giemsa in 900 ml of distilled water (Petithory et al, 2005).
- A sufficient quantity of pure May Grunwald was then gently poured using a syringe onto the entire surface of the smear, and it was applied for 3 minutes without the dye drying out.
- The smears were rinsed quickly with distilled water without scraping the smear during rinsing.
- Sufficient drops of diluted Giemsa were applied onto the smears for 18 to 20 minutes without allowing the smears to dry out.
- The smears were rinsed with distilled water and left to air dry.
- The slides were examined microscopically with the (×10), (×40) and (×100) objectives (Beghora, 2014).

1.6.2 Searching for ectoparasites

1.6.2.1 Gill Monogenea

The gills were removed and examined separately, they were dissected and each one was placed in a separate Petri dish containing saline water. The gills were then examined under stereomicroscope to search for Monogenea parasites, the parasites found were detached and extracted in situ using a fine needle, they were then collected and counted, Microscopic observation of the morpho-anatomical characteristics of the parasites was used to for their identification (Djebbari et al., 2009).

Figure 9. Gill extraction from *Cyprinus carpio* for parasite examination (original photo).

1.6.2.2 Other ectoparasites

Other ectoparasites were collected by rinsing thoroughly the gills with distilled water, this action allowed them to detach, especially protozoa and copepod parasites, the rinsing water was the collected in a Petri dish and examined under a stereomicroscope, the parasites were further examined after being placed on slides and counted under a microscope (4X10). The skin and the fins were also examined under the stereomicroscope for the search for other ectoparasites.

1.6.3 Searching for internal parasites

For the search for internal parasites, the following the steps were carried out:

- The abdominal cavity is opened, starting from the anus and moving to the anterior part of the fish sample (Figure 10).
- The digestive tract was cut at the anus and the oesophagus and extracted.
- The digestive tract was placed in a Petri dish containing physiological water and was opened using scissors and needles.
- All the internal organs (liver, kidneys, etc.) were extracted and placed in a Petri dish containing physiological water (Figure 11).

- The internal parasites were searched in the Petri dishes with the help of a stereomicroscope and the parasites found were collected, counted and preserved.

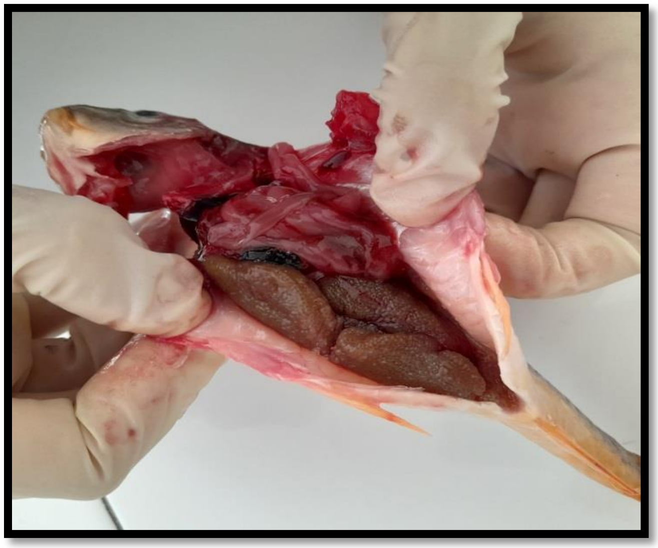


Figure 10. Fish abdominal cavity exposed for organ extraction (original photo).

Figure 11. Extracted fish organs for parasite screening including gills, intestines and swim bladder (original photo).

1.6.4 Staining and fixation of parasites

The Monogenea parasites were fixed using ammonium picrate solution (Malmberg, 1957) or glycerol - picric acid mixture, which allowed them to be made into permanent preparations. Other helminth parasites including Digenea, Cestoda and Acanthocephala were fixed in 4% formalin or in physiological water, iron-acetocarmine and alum hematoxylin were used for the staining of these parasite species, they were then transferred to alcohol series and mounted in Canada balsam. As for parasite specimens belonging to Nematoda species, they were preserved in a medium of glycerol-water for one month, and then they were prepared in pure glycerol (Fernando et al., 1972).

1.6.5 Identification of parasites

The identification of the collected parasite samples was done using the following keys of identification: Markevic, 1951; Yamaguti, 1958, 1959, 1961, 1963; Bychovskaya and Pavlovskaya, 1962; Gussev, 1985; Gussev et al. 1987; Moravec, 1994; Hoffman, 1999; Pugachev et al. 2010.

1.7. Data analysis

The infection values of the detected parasites were determined according to Bush et al. 1997. The mean intensity, prevalence and abundance of infection were calculated using the following formulae:

Prevalence = Ratio of the number of hosts infested by a given parasite species (n) divided by the number of hosts examined (h) x 100.

The ratio is expressed as a percentage: P = n/h.

Abundance = Ratio of the total number of individuals of a parasite species (p) in a host sample over the total number of hosts (infested + non-infested) in the sample (h).

This is the average number of individuals of a parasite species per host examined: A = p/h.

Mean intensity = Ratio of the total number of individuals of a parasite species in a host sample (p) to the number of infested hosts in a sample (n).

It is the average number of parasite individuals per parasitized host in the sample: MI = p/n.

Kolmogorov-Smirnov test was employed to test whether the continuous data were normal, the test of Kruskal-Wallis (more than two groups) was applied to evaluate if the mean density of parasite species between seasons varied significantly, and to compare two groups, the Mann-Whitney U test was used. To determine the interactions between total length, standard length, body depth, cephalic length, weight and sex, the ANCOVA analyses (Analysis of Covariance) was used. IBM SPSS Statistics v.28 was used to perform statistical analyses and the significance level of $\alpha \leq 0.05$ was determined.

1.8. Stomach content analysis

Stomach analyses were conducted seasonally to determine the feeding characteristics of *C. carpio* individuals collected from the Chbika Artificial Lake, and to detect possible seasonal differences in feeding. Therefore the analyses of the stomach weights and contents of 78 *C. carpio* samples were conducted. As *C. carpio* has no well-defined stomach, the fullness of the whole gut was assessed (Hyslop, 1980), the guts of the collected *C. carpio* were separated from the fish and each gut was preserved separately in 5% formalin. Each gut was carefully stretched, using a pair of blunt forceps, all attached tissues, such as viscera and adherent fat were removed. Particular attention was paid to the removal of attached tissue to avoid injury or pressure on the gut to ensure that the gut contents were not lost (Shafi et al., 2012). The gut was then weighed carefully on a precision balance and the gut contents were extracted and the food items were observed using a microscope and grouped into different categories and identified to the lowest possible taxonomic categories using identification keys (Edmondson, 1959; Pennak, 1978).

The following methods were used to evaluate stomach content data and understand the feeding ecology of *C. carpio* (Hynes 1950; Hureau 1970; Pinkas et al., 1971; Hyslop 1980; Hacunda, 1981; Hashim et al 2017).

The Vacuity Index (%VI) represented the percentage of empty stomachs out of the total number of stomachs examined. The Frequency of Occurrence (%F) method determined the percentage of stomachs in which each food group was present. The Numerical Method (%N) quantified the relative abundance of each food group, indicating its numerical importance. The Index of Relative Importance (IRI) was established to determine the nutritional characteristics of the species and to facilitate the interpretation of the results. The IRI value was calculated as follows:

$$IRI = \%N * \%F$$

In order to provide a clear indication of the relative importance of each food item in the fish's diet, the %IRI (percentage Index of Relative Importance) was calculated using the calculated IRI value. The %IRI was calculated as follows:

$$\%IRI = (IRI * 100) / \sum IRI$$

RESULTS

2. Results

2.1. Characteristics of the fish examined

Over the course of this study, several fish species were identified across the three study regions. Table 4 provides a consolidated view of the identified fish species and their overall relative abundance. *Cyprinus carpio* represents the most dominant species of the examined fish population with 34.19%, followed by *Carassius gibelio* (17.52%) and *Barbus* sp. (17.09%).

Table 4. List of fish species investigated across all study sites.

Fish species	Percentage (%)	Family
Oreochromis sp.	14.53	Cichlidae
Cyprinus carpio	34.19	Cyprinidae
Barbus sp.	17.09	Cyprinidae
Luciobarbus biscarensis	16.67	Cyprinidae
Carassius gibelio	17.52	Cyprinidae

2.1.1 *Oreochromis*

Oreochromis or red tilapia is a farmed fish species resulting from the hybridization of two species (*Oreochromis niloticus* x *Oreochromis mossambicus*), recognised by its pinkish colour (tending towards orange-red) with black spots; a more or less compressed body of various shapes but never very elongated, and covered with cycloid scales. The red tilapia, *O. niloticus* (Linnaeus, 1758) x *O. mossambicus* (Peters, 1852) is a fertile hybrid used in semi-intensive culture systems, which demonstrates an antagonistic relationship between its body growth and its reproductive process (Oulhiz, 2018) (Figure 12).

Figure 12. *Oreochromis* sp. (original photo).

Table 4 summarizes the morphometric characteristics and sex ratio of the sampled *Oreochromis* sp. population. The weight of the fish ranged from 21 g to 225 g, with an average weight of 108.69 ± 60.76 g. Total length varied between 10.5 cm and 23.2 cm, averaging 17.01 ± 3.66 cm, while the standard length ranged from 8.5 cm to 18.6 cm, with a mean of 13.91 ± 2.92 cm. The cephalic length (CL) showed a minimum of 3 cm and a maximum of 8 cm, with an average of 4.74 ± 1.08 cm. The body depth (BD) ranged from 2.8 cm to 7.1 cm, with a mean of 5.16 ± 1.26 cm.

The sex ratio was observed as 52.94 % were males and 47.06 % were females suggesting a slightly higher proportion of males in the sampled population.

Table 5. Characteristics of the sampled *Oreochromis* sp. population: morphometrics and sex ratio.

Parameters	**Minimum**	**Maximum**	**Mean ± SD**
Weight (W) (g)	21	225	108.69 ± 60.76
Total Length (TL) (cm)	10.5	23.2	17.01 ± 3.66
Standard Length (SL) (cm)	8.5	18.6	13.91 ± 2.92

Cephalic Length (CL) (cm)	3	8	4.74 ± 1.08
Body Depth (BD) (cm)	2.8	7.1	5.16 ± 1.26
Sex Ratio	52.94 % Males, 47.06 % Females		

2.1.2 *Cyprinus carpio*

The common carp is distinguished by its full covering of scales, numbering 33 to 40 along its lateral line (Terofal, 1987), in stark contrast to the mirror carp which has only a few scales along this line (Keith and Allardi, 2001). The common carp's body is robust and slightly elongated, with a dark back that ranges in color from gray-green to gray-brown, depending on its environment (Terofal, 1987; Keith and Allardi, 2001). Its flanks display golden-hued scales, while its belly is a creamy white or yellowish (Spillmann, 1961; Keith and Allardi, 2001). The carp's mouth is positioned at the end of its snout and can extend outwards, featuring four barbels on its upper lip (Terofal, 1987). It lacks teeth in its mouth, instead possessing pharyngeal teeth. Its long, truncated dorsal fin and forked caudal fin are notable features. This species is highly adaptable, exhibiting significant variations in size, scaling, and color across different habitats, including flowing, still, and brackish waters. Significant differences separate wild carp from domestic farmed carp; the former typically have a more streamlined, cylindrical body, whereas the latter are bred for a deeper, more robust build (Truslé and Quignard, 2001) (Figure 13).

Figure 13. *Cyprinus carpio* (original photo).

The morphometric features and sex ratio of the collected fish specimens are summarized in Table 5. Total weight varied considerably, spanning from 18 g to 322 g, with a mean of 126.97 ± 64.57 g. The sampled fish exhibited a range in total length (10.8 – 28.5 cm, mean ± SD: 19.92 ± 3.59 cm) and standard length (8.7 – 23.1 cm, mean ± SD: 16.12 ± 2.94 cm). Cephalic length (CL) showed a minimum of 2.4 cm and a maximum of 7.1 cm, with an average of 4.89 ± 0.96 cm. Body depth (BD) ranged from 3 cm to 7.8 cm, averaging 5.61 ± 0.95 cm. The sex ratio shows an imbalance in favour of males, with males comprising 56.88 % of the sample and females 43.12 %.

Table 6. Characteristics of the sampled *Cyprinus carpio* population: morphometrics and sex ratio.

Parameters	Minimum	Maximum	Mean ± SD
Weight (W) (g)	18	322	126.97 ± 64.57
Total Length (TL) (cm)	10.8	28.5	19.92 ± 3.59
Standard Length (SL) (cm)	8.7	23.1	16.12 ± 2.94
Cephalic Length (CL) (cm)	2.4	7.1	4.89 ± 0.96
Body Depth (BD) (cm)	3	7.8	5.61 ± 0.95
Sex Ratio	56.88 % Males, 43.12 % Females		

2.1.3 *Barbus*

Fishes within the *Barbus* genus exhibit a suite of distinct morphological characteristics that aid in their systematic classification. Their bodies are typically fusiform, showing varying degrees of lateral compression, and are enveloped in cycloid scales. The precise count and radial striation patterns of these scales are vital taxonomic indicators. Notably, they possess relatively small eyes and mouths framed by fleshy, mobile lips. A defining feature is the presence of two pairs of barbels, sensory appendages that give rise to their common name. A complete lateral line extends along their body. Their dorsal fin presents a robust, simple, and often denticulated final ray, the morphology of which is diagnostically significant. Furthermore, they have well-developed pharyngeal bones equipped with teeth, contributing to their feeding adaptations (Kraïem, 1983) (Figure 14).

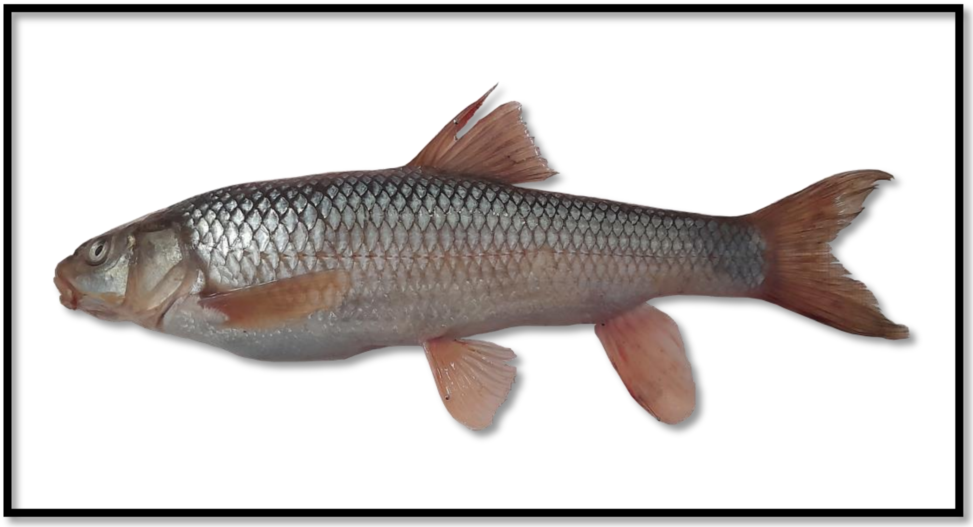


Figure 14. *Barbus* sp. (original photo).

Table 6 presents the morphometric characteristics and sex ratio of the *Barbus* sp. fish population. Fish weight ranged from 81 g to 215 g (mean ± SD: 152.5 ± 38.76 g). Total length and standard length averaged 22.95 ± 1.96 cm (range: 18.6 – 25.6 cm) and 19.31 ± 1.70 cm (range: 15.7 – 21.6 cm), respectively. Cephalic length (CL) ranged from 3.7 to 5.5 cm (mean ± SD: 4.79 ± 0.46 cm), and body depth (BD) averaged 4.94 ± 0.42 cm (range: 4 – 5.7 cm). The sex ratio indicated female bias, with 41.25% males and 58.75% females.

Table 7. Characteristics of the sampled *Barbus* sp. population: morphometrics and sex ratio.

Parameters	**Minimum**	**Maximum**	**Mean ± SD**
Weight (W) (g)	81	215	152.5 ± 38.76
Total Length (TL) (cm)	18.6	25.6	22.95 ± 1.96
Standard Length (SL) (cm)	15.7	21.6	19.31 ± 1.70
Cephalic Length (CL) (cm)	3.7	5.5	4.79 ± 0.46

Body Depth (BD) (cm)	4	5.7	4.94 ± 0.42
Sex Ratio	41.25 % Males, 58.75 % Females		

2.1.4 *Luciobarbus biscarensis*

L. biscarensis is defined by a unique set of physical traits within the larger *Luciobarbus* group. This genus encompasses cyprinid fish capable of reaching substantial sizes, characterized by a dorsal fin with a final, unbranched, ossified, and serrated ray, alongside 7 to 9 branched rays. The anal fin contains 5 branched rays, and the lateral line features between 41 and 51 scales. The pharyngeal bone structure includes three rows of teeth, arranged in a 2+3+5 pattern. Within *Luciobarbus*, species are categorized based on the placement of barbels on the snout. *L. biscarensis* belongs to the group with anterior barbels situated on the sides of the snout. This species is notably distinguished by a high count of lateral line scales, ranging from 49 to 51, plus an additional 1 or 2. It also exhibits 8½ to 9½ rows of upper transverse scales and 7½ to 8½ rows of lower transverse scales. The dorsal fin has 5 hard, unbranched rays, and its origin is located posterior to the pelvic fin (Brahimi, 2018) (Figure 15).

Figure 15. *Luciobarbus biscarensis* (original photo).

Table 7 details the morphometric characteristics and sex ratio of the *L. biscarensis* fish population. Fish weight ranged from 4 and 15 g, with mean ± SD of 6.44 ± 2.09 g. Similarly, total length (mean ± SD: 8.01 ± 1.22 cm, range: 5.3 - 11.6 cm), standard length (mean ± SD: 6.48 ± 1.06 cm, range: 4.2 – 9.7 cm), cephalic length (CL) (mean ± SD: 1.74 ± 0.27 cm, range: 1.1 – 2.3 cm), and body depth (BD) (mean ± SD: 1.33 ± 0.25 cm, range: 0.8 – 2 cm) displayed varying degrees of dispersion. The sex ratio revealed an imbalance, with a higher percentage of males (57.69%) compared to females (42.31%).

Table 8. Characteristics of the sampled *Luciobarbus biscarensis* population: morphometrics and sex ratio.

Parameters	Minimum	Maximum	Mean ± SD
Weight (W) (g)	4	15	6.44 ± 2.09
Total Length (TL) (cm)	5.3	11.6	8.01 ± 1.22
Standard Length (SL) (cm)	4.2	9.7	6.48 ± 1.06
Cephalic Length (CL) (cm)	1.1	2.3	1.74 ± 0.27
Body Depth (BD) (cm)	0.8	2	1.33 ± 0.25
Sex Ratio	57.69% Males, 42.31% Females		

2.1.5 *Carassius gibelio*

C. gibelio is a fish species belonging to the genus *Carassius*, commonly referred to as carassins, and represents a group of freshwater bony fishes belonging to the vast and diverse family Cyprinidae and to the order Cypriniformes. It is characterized with its silvery-brown body, the heavily serrated last simple anal and dorsal rays, its lateral line with 29-33 scales, its 37-52 gill rakers, its anal fin with 5½ branched rays, the free edge of dorsal concave or straight and having a black peritoneum (Kottelat and Freyhof, 2007) (Figure 16).

Figure 16. *Carassius gibelio* (original photo).

The *C. gibelio* population's morphometry and sex structure are presented in Table 8. Weight ranged from 66 g to 242 g (mean 145.26 ± 53.13 g). Length measurements included total length (19.43 ± 2.54 cm, range 15.5 – 24.1 cm), standard length (15.98 ± 2.08 cm, range 12.6 – 19.9 cm), and cephalic length (CL) (4.33 ± 0.53 cm, range 3.5 – 5.4 cm). Body depth (BD) averaged 6.47 ± 0.84 cm, with a range of 5.1 - 8 cm. The sex ratio showed female dominance, with 60.98% females and 39.02% males.

Table 9. Characteristics of the sampled *Carassius gibelio* population: morphometrics and sex ratio.

Parameters	**Minimum**	**Maximum**	**Mean ± SD**
Weight (W) (g)	66	242	145.26 ± 53.13
Total Length (TL) (cm)	15.5	24.1	19.43 ± 2.54
Standard Length (SL) (cm)	12.6	19.9	15.98 ± 2.08
Cephalic Length (CL) (cm)	3.5	5.4	4.33 ± 0.53
Body Depth (BD) (cm)	5.1	8	6.47 ± 0.84
Sex Ratio	39.02% Males, 60.98% Females		

2.2. Interactions of morphometrics, sex, and weight in fish

An analysis of covariance (ANCOVA) was conducted to examine the effects of total length, standard length, body depth, cephalic length, and sex on the weight of the fish samples of all fish species examined during this study, including potential two-way interactions with sex.

2.2.1 *Oreochromis* sp.

The results of the ANCOVA for *Oreochromis* sp. samples are presented in Table 9. The overall model was significant ($F(9, 58) = 181.841$, $p < 0.001$), accounting for a substantial proportion of the variance in weight ($R^2 = 0.966$). Significant main effects were observed for total length ($F(1, 58) = 9.818$, $p = 0.003$) and sex ($F(1, 58) = 5.831$, $p = 0.019$). Furthermore, a significant interaction was found between sex and body depth ($F(1, 58) = 5.113$, $p = 0.028$). The main effects of standard length ($p = 0.846$) and cephalic length ($p = 0.275$), as well as the interactions between sex and total length ($p = 0.458$), sex and standard length ($p = 0.867$), and sex and cephalic length ($p = 0.172$), were not statistically significant.

Table 10. Results of analysis of covariance examining the effects of morphometric variables (total length, standard length, body depth, cephalic length) and sex on *Oreochromis* sp. samples weight.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	238896.037[a]	9	26544.004	181.841	< 0.001
Intercept	52682.896	1	52682.896	360.907	< 0.001
TL	1433.205	1	1433.205	9.818	0.003
SL	5.582	1	5.582	0.038	0.846
BD	59.690	1	59.690	0.409	0.525
CL	177.531	1	177.531	1.216	0.275
Sex	851.238	1	851.238	5.831	0.019
Sex * TL	81.419	1	81.419	0.558	0.458

Sex * SL	4.151	1	4.151	0.028	0.867
Sex * BD	746.378	1	746.378	5.113	0.028
Sex * CL	278.884	1	278.884	1.911	0.172
Error	8466.478	58	145.974		
Total	1050699.000	68			
Corrected Total	247362.515	67			

Dependent Variable: Weight / a. R Squared = 0.966 (Adjusted R Squared = 0.960)

2.2.2 *Cyprinus carpio*

A high proportion of the variance in *C. carpio* weight (Weight) was explained by the ANCOVA model ($R^2 = 0.953$, $F(9, 150) = 336.824$, $p < 0.001$), which examined the effects of sex, total length (TL), standard length (SL), body depth (BD), and cephalic length (CL), and their interactions with sex as shown in Table 10. The analysis revealed significant main effects for standard length ($p = 0.027$) and body depth ($p = 0.002$). Notably, significant interactions with sex were observed for total length ($p = 0.002$) and standard length ($p = 0.042$), suggesting sex-specific relationships with weight for these variables. In contrast, the main effects of sex and cephalic length, and the interactions of sex with body depth and cephalic length, were not statistically significant.

Table 11. Results of analysis of covariance examining the effects of morphometric variables (total length, standard length, body depth, cephalic length) and sex on *Cyprinus carpio* samples weight.

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	631741.132[a]	9	70193.459	336.824	< 0.001
Intercept	204601.633	1	204601.633	981.783	< 0.001
Sex	593.499	1	593.499	2.848	0.094
TL	585.562	1	585.562	2.810	0.096
SL	1042.029	1	1042.029	5.000	0.027
BD	2132.301	1	2132.301	10.232	0.002

CL	487.072	1	487.072	2.337	0.128
Sex * TL	2053.356	1	2053.356	9.853	0.002
Sex * SL	876.674	1	876.674	4.207	0.042
Sex * BD	217.813	1	217.813	1.045	0.308
Sex * CL	367.332	1	367.332	1.763	0.186
Error	31259.712	150	208.398		
Total	3242371.000	160			
Corrected Total	663000.844	159			

Dependent Variable: Weight / a. R Squared = 0.953 (Adjusted R Squared = 0.950)

2.2.3 *Barbus* sp.

The Analysis of Covariance revealed a significant model ($F(9, 70) = 269.223$, $p < .001$), explaining a large portion of the variance in fish weight ($R^2 = 0.972$). Total length ($p < 0.001$) and body depth ($p = 0.032$) had significant main effects on weight. However, the main effects of sex, standard length, and cephalic length were not significant. Similarly, none of the interaction terms between sex and the morphometric variables reached statistical significance in predicting fish weight (Table 11).

Table 12. Results of analysis of covariance examining the effects of morphometric variables (total length, standard length, body depth, cephalic length) and sex on *Barbus* sp. samples weight.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	115332.087[a]	9	12814.676	269.223	< 0.001
Intercept	41769.132	1	41769.132	877.526	< 0.001
Sex	9.722	1	9.722	0.204	0.653
TL	947.460	1	947.460	19.905	< 0.001
SL	10.851	1	10.851	0.228	0.635
BD	226.612	1	226.612	4.761	0.032
CL	0.387	1	0.387	0.008	0.928
Sex * TL	8.693	1	8.693	0.183	0.670

Sex * SL	29.911	1	29.911	0.628	0.431
Sex * BD	147.941	1	147.941	3.108	0.082
Sex * CL	68.206	1	68.206	1.433	0.235
Error	3331.913	70	47.599		
Total	1979164.000	80			
Corrected Total	118664.000	79			

Dependent Variable: Weight / a. R Squared = 0.972 (Adjusted R Squared = 0.968)

2.2.4 *Luciobarbus biscarensis*

The ANCOVA analysis revealed a significant model ($F(9, 68) = 3.529$, $p = 0.001$), explaining approximately 31.8% of the variance in fish weight ($R^2 = 0.318$). Among the main effects, only cephalic length ($p = 0.013$) showed a significant relationship with the weight of *L. biscarensis*. While the main effects of sex, total length, standard length, and body depth were not significant, there was a significant interaction between sex and cephalic length ($p = 0.010$). The remaining interaction terms were not statistically significant (Table 12).

Table 13. Results of analysis of covariance examining the effects of morphometric variables (total length, standard length, body depth, cephalic length) and sex on *Luciobarbus biscarensis* samples weight.

Source	**Type III Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
Corrected Model	2572.355[a]	9	285.817	3.529	0.001
Intercept	235.278	1	235.278	2.905	0.093
Sex	97.070	1	97.070	1.199	0.277
TL	3.780	1	3.780	0.047	0.830
SL	16.978	1	16.978	0.210	0.649
BD	258.097	1	258.097	3.187	0.079
CL	531.425	1	531.425	6.562	0.013
Sex * TL	24.307	1	24.307	0.300	0.586
Sex * SL	6.868	1	6.868	0.085	0.772

Sex * BD	262.284	1	262.284	3.239	0.076
Sex * CL	566.345	1	566.345	6.993	0.010
Error	5506.940	68	80.984		
Total	12527.000	78			
Corrected Total	8079.295	77			

Dependent Variable: Weight / a. R Squared = 0.318 (Adjusted R Squared = 0.228)

2.2.5 *Carassius gibelio*

The weight of the *C. gibelio* samples was strongly predicted by the ANCOVA model ($p < 0.001$, $R^2 = .991$). Total length emerged as a significant main predictor ($p = .002$). While sex, standard length, body depth, and cephalic length did not independently influence weight significantly, there was a near-significant indication that the relationship between cephalic length and weight might differ by sex ($p = .058$). No other interactions between sex and the morphometric variables were significant (Table 13).

Table 14. Results of analysis of covariance examining the effects of morphometric variables (total length, standard length, body depth, cephalic length) and sex on *Carassius gibelio* samples weight.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	228174.138[a]	9	25352.682	888.060	< 0.001
Intercept	65744.700	1	65744.700	2302.921	< 0.001
Sex	80.415	1	80.415	2.817	0.098
TL	303.173	1	303.173	10.620	0.002
SL	5.858	1	5.858	0.205	0.652
BD	2.312	1	2.312	0.081	0.777
CL	10.055	1	10.055	0.352	0.555
Sex * TL	2.265	1	2.265	0.079	0.779
Sex * SL	0.000	1	0.000	0.000	0.997
Sex * BD	1.431	1	1.431	0.050	0.823

Sex * CL	105.871	1	105.871	3.708	0.058
Error	2055.484	72	28.548		
Total	1960375.000	82			
Corrected Total	230229.622	81			

Dependent Variable: Weight / a. R Squared = 0.991 (Adjusted R Squared = 0.990)

2.3. Study of the biodiversity of parasites in the freshwater ichthyofauna of the Djelfa region

2.3.1 Identification of parasites detected in host fish in the study region

Seasonal determination was conducted of the parasitic fauna of *Cyprinus carpio* from the artificial Lake of Chbika, *Luciobarbus biscaransis* from Oued Tadmit River. Fish samples of *Oreochromis* sp. from a fish farm in the commune of Dar Chioukh were also examined. The parasite species collected have been identified using the above mentioned keys of identification.

As a result of the studies carried out in this context, the following parasite species have been identified: two Monogenea species; *Dactylogyrus fimbriphallus* and *Dactylogyrus extensus*, one species of Cestoda (*Bothriocephalus acheilognathi*), one species of Myxozoa (*Myxobolus sp*) and one species of Oligohymenophorea (*Trichodina* sp.). No parasites were observed in fish samples collected from the fish farm of Dar Chioukh (Table 14).

Table 15. The parasite species detected in the fish species examined in Djelfa region and their distribution in hosts

Fish species	Monogenea		Cestoda	Myxozoa	Oligohymenophorea
	Dactylogyrus fimbriphallus	*Dactylogyrus extensus*	*Bothriocephalus acheilognathi*	*Myxobolus* sp.	*Trichodina* sp.
C. carpio	_	171	36	_	16
L. biscaransis	306	_	50	103	_

2.3.2 Parasite description

2.3.2.1 Myxozoa

- ***Myxobolus* sp.**

Phylum: Cnidaria

Subphylum: Endocnidozoa

Class: Myxozoa

Subclass: Myxosporea

Order: Bivalvulida

Suborder: Platysporina

Family: Myxobolidae

Genus: *Myxobolus* (Figure 17)

- **Host**: *L. biscarensis* and *C. carpio*
- **Location**: Gills

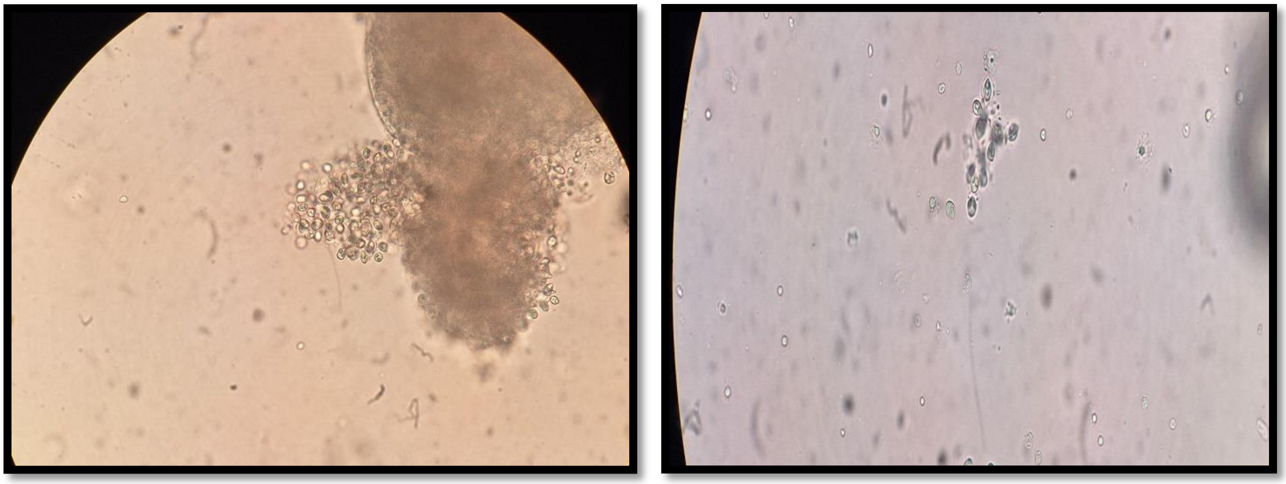


Figure 17. Spores of *Myxobolus* sp. from *Luciobarbus biscarensis* and *Cyprinus carpio* (original photo).

2.3.2.2 Cestoda

- ***Bothriocephalus acheilognathi***

Phylum: Platyhelminthes

Subphylum: Rhabditophora

Superclass: Neodermata

Class: Cestoda

Subclass: Eucestoda

Order: Bothriocephalidea

Family: Bothriocephalidae

Genus: *Bothriocephalus*

Species: *Bothriocephalus acheilognathi* (Figure 18, 19, 20, 21)

- **Host**: *C. carpio* and *L. biscaransis*
- **Location**: intestines

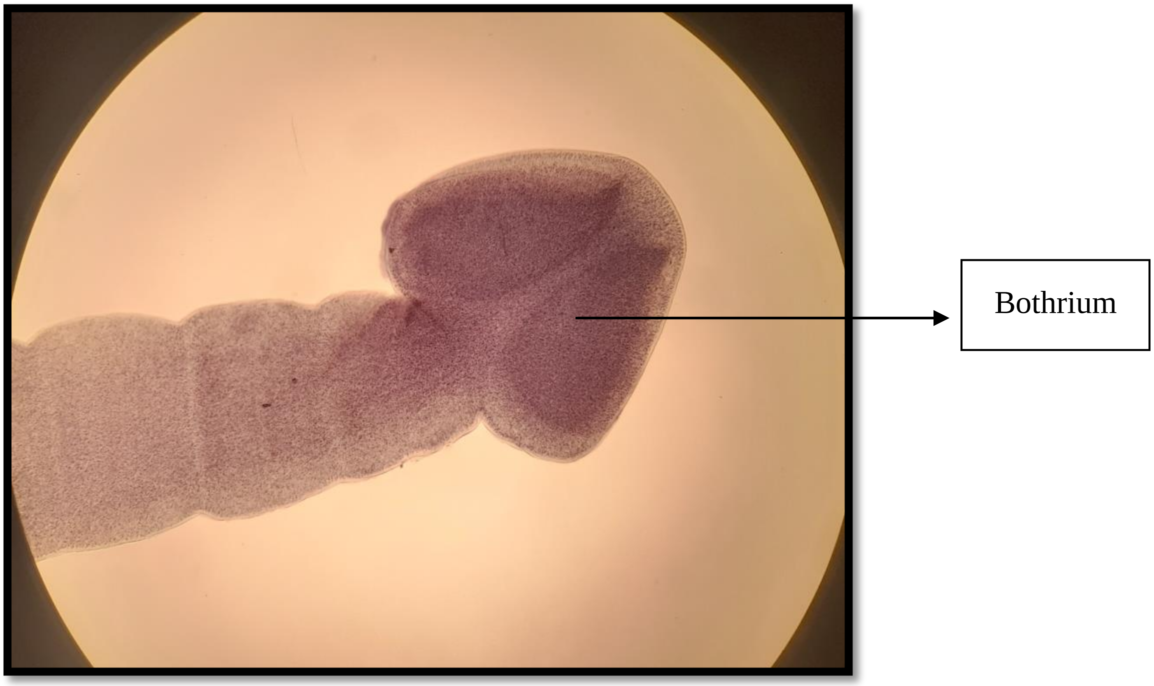


Figure 18. The scolex of *Bothriocephalus acheilognathi* collected from *Cyprinus carpio* and *Luciobarbus biscarensis* (original photo).

Figure 19. Detailed View of the reproductive structures of *Bothriocephalus acheilognathi* collected from *Cyprinus carpio* and *Luciobarbus biscarensis*

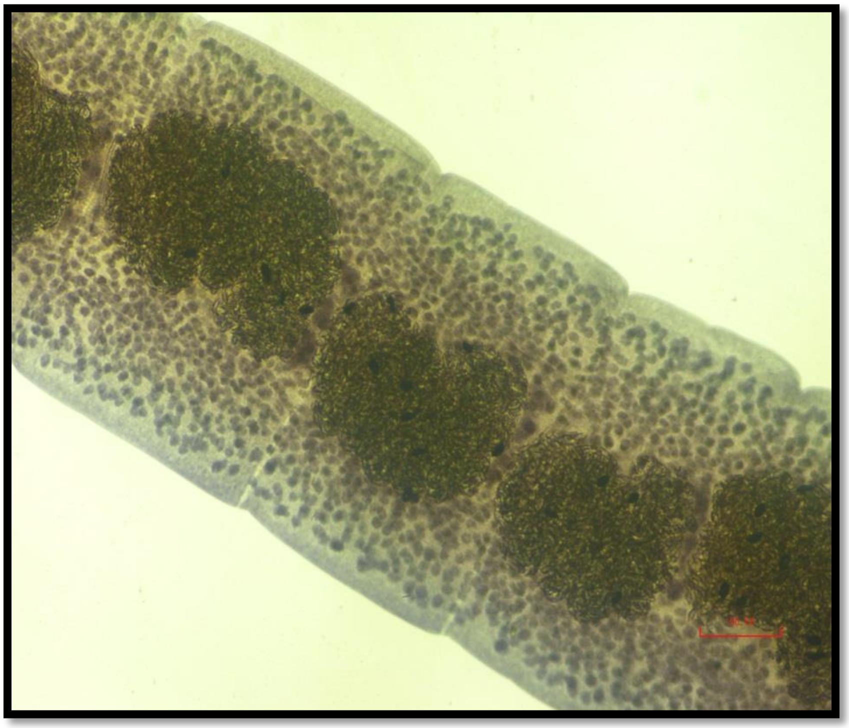


Figure 20. Mature segments of *Bothriocephalus acheilognathi* showing egg masses, collected from *Cyprinus carpio* and *Luciobarbus biscarensis* (original photo).

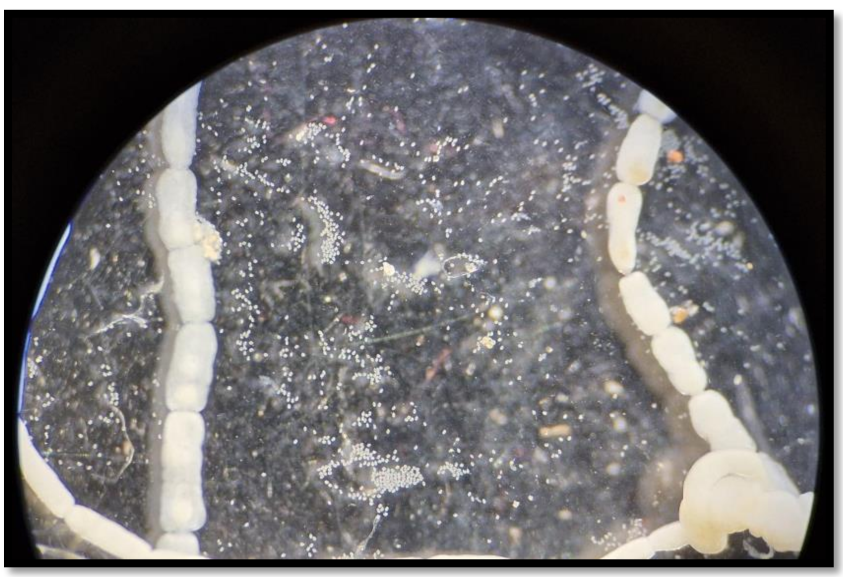


Figure 21. *Bothriocephalus acheilognathi* with released eggs in Petri dish (original photo).

2.3.2.3 Monogenea

2.3.2.3.1 *Dactylogyrus fimbriphallus*

Phylum: Platyhelminthes

Subphylum: Rhabditophora

Superclass: Neodermata

Class: Monogenea

Subclass: Monopisthocotylea

Order: Dactylogyridea

Family: Dactylogyridae

Genus: *Dactylogyrus*

Species: *Dactylogyrus fimbriphallus* (Figure 22)

- **Host**: *L. biscaransis*
- **Location**: Gills

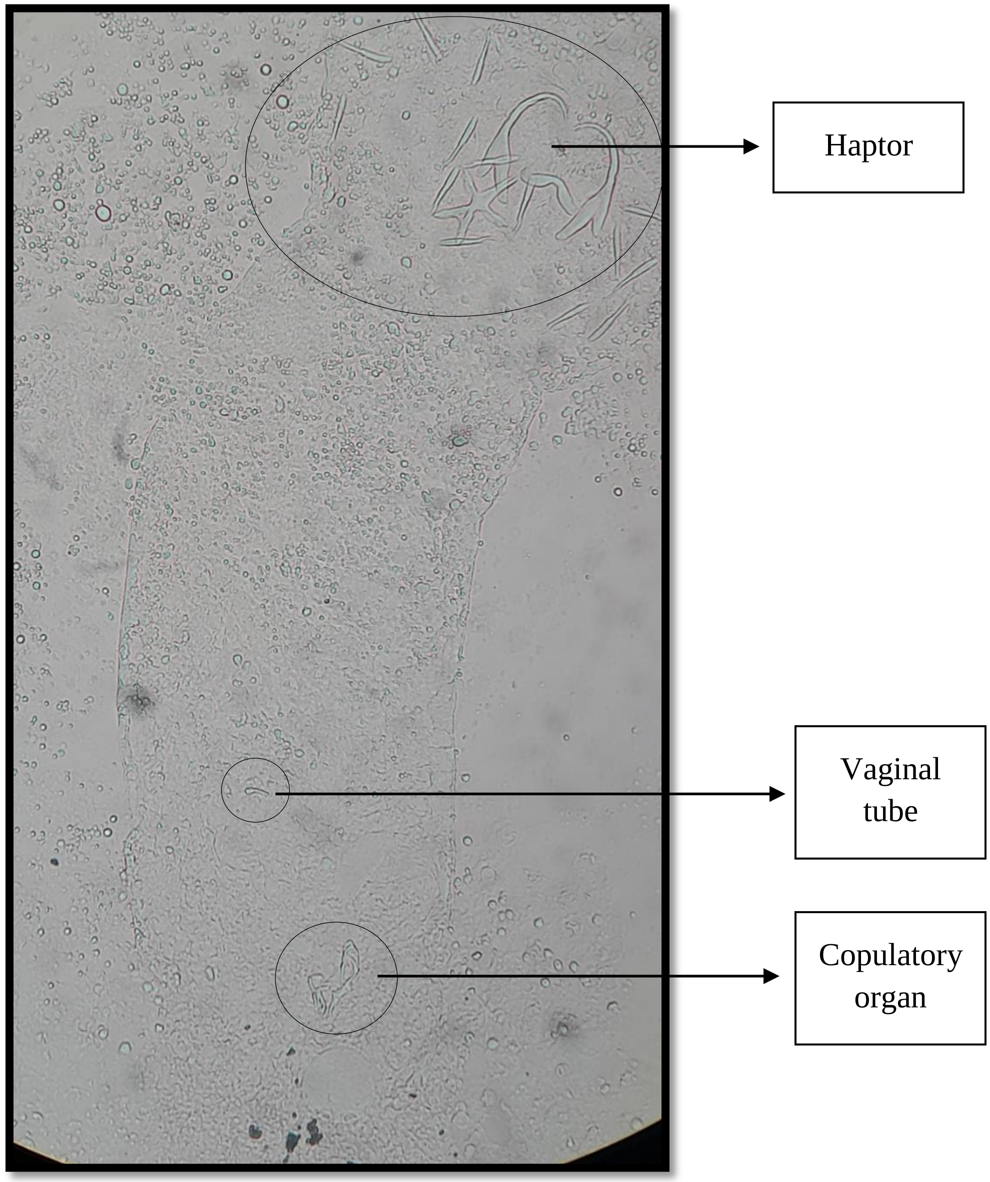


Figure 22. *Dactylogyrus fimbriphallus* collected from *Luciobarbus biscarensis* (original photo).

2.3.2.3.2 *Dactylogyrus extensus*

Phylum: Platyhelminthes

Subphylum: Rhabditophora

Superclass: Neodermata

Class: Monogenea

Subclass: Monopisthocotylea

Order: Dactylogyridea

Family: Dactylogyridae

Genus: *Dactylogyrus*

Species: *Dactylogyrus extensus* (Figure 23, 24)

- **Host**: *C. carpio*
- **Location**: Gills

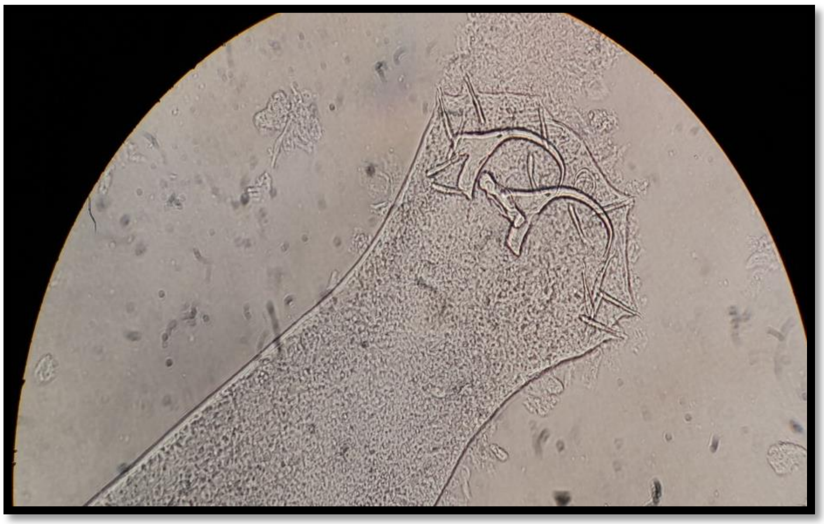


Figure 23. The haptor of *Dactylogyrus extensus* collected from *Cyprinus carpio* (original photo).

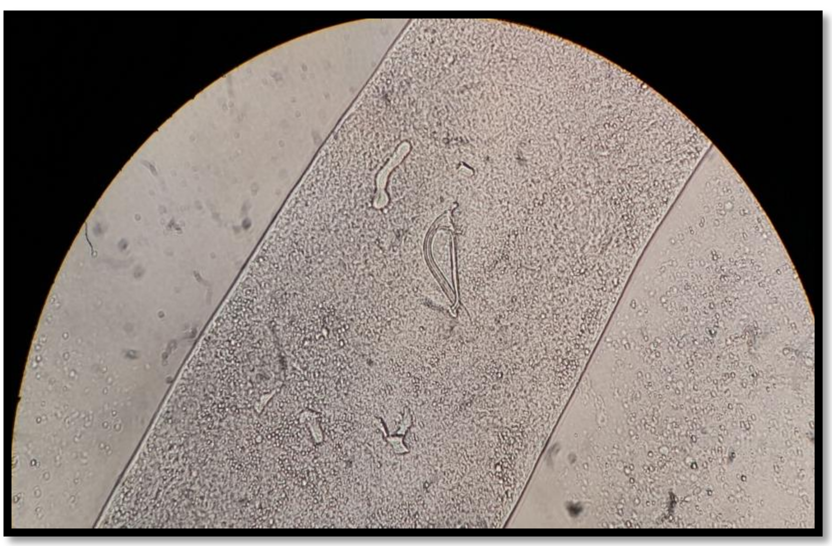


Figure 24. Reproductive organs of *Dactylogyrus extensus* collected from *Cyprinus carpio* (original photo).

2.3.2.4 Oligohymenophorea

Phylum: Ciliophora

Subphylum: Intramacronucleata

Infraphylum: Ventrata

Class: Oligohymenophorea

Subclass: Peritrichia

Order: Mobilida

Family: Trichodinidae

Genus: *Trichodina* (Figure 25)

- **Host**: *C. carpio*
- **Location**: Gills

Figure 25. *Trichodina* sp. collected from the gills of *Cyprinus Carpio* (original photo).

2.3.3 Parasitism of studied fish species

In the scope of this study and in the sites of the Djelfa region, the following results were found: *L. biscaransis* was infected with three parasite species, *D. fimbriphallus* and *Myxobolus* sp. in the gills and *B. acheilognathi* found in the intestines of fish samples collected from the Tadmit River, *D. extensus* and *Trichodina* sp. were found in the gills and *B. acheilognathi* in the and intestines of *C. carpio* collected from the Chbika Lake.

2.3.3.1 *Luciobarbus biscaransis*

Seasonal sampling results indicate that the Monogenea parasite *D. fimbriphallus* is the dominant parasite species in *L. biscaransis.* The parasite was recorded during all sampling seasons with a total of 306 parasites found in 33 of the total 78 host fish sample, while the levels of the mean intensity and the abundance were 9.27 ± 12.50 parasites per fish and 3.92 ± 9.28, respectively, and its prevalence was 42.31%. The season in which this parasite species was most abundant is autumn with a total of 237 parasites found in 14 out of the 20 fish studied, with a maximum of 53 parasites identified in one fish sample. The infection values during this season were 16.93 ± 16.24, 11.85 ± 15.61 and 70% for the mean intensity, abundance and prevalence, respectively. The second recorded parasite species is *Myxobolus* sp. with a total of 103 individuals, which was found in 22 fish host, with a mean intensity of 4.9 ± 4.99 parasites per fish, an abundance of 1.32 ± 3.36 and a prevalence level of 26.92%, which was also found during all seasons, with a highest level of infection recorded during autumn as 11 out of the 20 samples were infected with 78 parasites, giving abundance of 3.9 ± 5.77, mean intensity of 7.09 ± 6.19 and a prevalence of 55%. During the same season, a maximum of 23 parasites were identified in one host fish. The parasite with the lowest infection values is *B. acheilognathi*, found in 14 fish individuals out of the total 78 examined samples with a total of 14 parasites. The infection parameters of this parasite species were 19.23% for the prevalence, 3.33 ± 2.02 for the mean intensity and 0.64 ± 1.58 for the abundance. Seasonal sampling revealed the presence of *B. acheilognathi* in fish hosts across all seasons, the maximum number of parasites recorded in one fish was seven, and was recorded during summer sampling, spring and summer recorded the highest infection values giving prevalence, mean intensity and abundance of 20%, 4.5 ± 2.52 and 0.90 ± 2.10, respectively, for summer season, and prevalence, mean intensity and abundance of 30%, 3.33 ± 2.07 and 1 ± 1.89, respectively (Table 15).

Differences in the number of parasites detected in each season were calculated using the Kruskal-Wallis test, there was a significant correlation between the seasons and the numbers of *D. fimbriphallus* ($p < 0.001$), a significant correlation was also recorded for *Myxobolus* sp. ($p = 0.003$). No significant correlation was found for *B. acheilognathi* ($p = 0.437$).

Table 16. Distribution of infection values of parasites recorded in *Luciobarbus biscarensis* from Djelfa region according to seasons.

	Autumn	Winter	Spring	Summer
Number of examined fish	20	18	20	20
Number of infected fish	17	6	13	14
D. fimbriphallus				
Number of infected Fish	14	3	5	11
Infection Prevalence (%)	70	16.67	25	55
Mean intensity ±SD	16.93 ± 16.24	2.67 ± 0.58	3 ± 2.35	4.18 ± 3.40
Abundance ±SD	11.85 ± 15.61	0.44 ± 1.04	0.75 ± 1.71	2.30 ± 3.26
Min – Max. Parasite Numbers	6–53	2–3	1–5	2–13
Total Number of Parasites	237	8	22	46
***Myxobolus* sp.**				
Number of infected Fish	11	2	4	5
Infection Prevalence (%)	55	11.11	20	25
Mean intensity ±SD	7.09 ± 6.19	2 ± 0	2 ± 0.82	2.6 ± 1.52
Abundance ±SD	3.9 ± 5.77	0.22 ± 0.65	0.40 ± 0.88	0.65 ± 1.35
Min – Max. Parasite Numbers	1–23	2–2	1–2	1–5
Total Number of Parasites	78	4	8	13

B. acheilognathi				
Number of infected Fish	3	2	6	4
Infection Prevalence (%)	15	11.11	30	20
Mean intensity ±SD	2.67 ± 1.53	2 ± 1.41	3.33 ± 2.07	4.5 ± 2.52
Abundance ±SD	0.4 ± 1.10	0.22 ± 0.73	1 ± 1.89	0.90 ± 2.10
Min – Max. Parasite Numbers	1–4	1–3	1–6	1–7
Total Number of Parasites	8	4	20	18

The Mann–Whitney U-test was used to calculate the significance of the difference per season (Table 16), in the case of *D. fimbriphallus*, it showed that there was a significant difference between infection in spring and summer (p = 0.039, U = 132.500), between summer and winter (p = 0.014, U = 107.500) and when comparing spring and autumn (p< 0.001, U = 76.000). As for *Myxobolus* sp. there was no significant difference between infection in summer and winter (p = 0.26, U = 154.000) and between spring and summer (p = 0.657, U = 188.000), yet there was a significant difference when comparing spring and autumn (p= 0.008, U = 114.500). *B. acheilognathi* showed no significant difference when comparing spring and summer (p = 0.569, U = 184.000), summer and winter (p = 0.394, U = 161.500) and when comparing spring and autumn (p = 0.236, U = 168.000).

Table 17. Results of Mann-Whitney U-test comparing seasonal parasite infection values in *Luciobarbus biscarensis*.

	Spring and summer	**Summer and winter**	**Spring and autumn**
D. fimbriphallus			
P value	0.039	0.014	< 0.001
Mann–Whitney U value	132.500	107.500	76.000

***Myxobolus* sp.**			
P value	0.657	0.26	0.008
Mann–Whitney U value	188.000	154.000	114.500
B. acheilognathi			
P value	0.569	0.394	0.236
Mann–Whitney U value	184.000	161.500	168.000

The maximum number of dactylogyrid parasites was recorded in the fish host with a total length of 11 cm with 53 parasite individuals during autumn. The host fish with the total length of 8.2 cm contained the maximum number of *Myxobolus* sp. (23 parasite), which were also recorded in autumn. There was a positive correlation between the parasite burden of *D. fimbriphallus* and the fork length (Figure 26) with a significant but weak correlation ($r = 0.287$, $p = 0.011$).

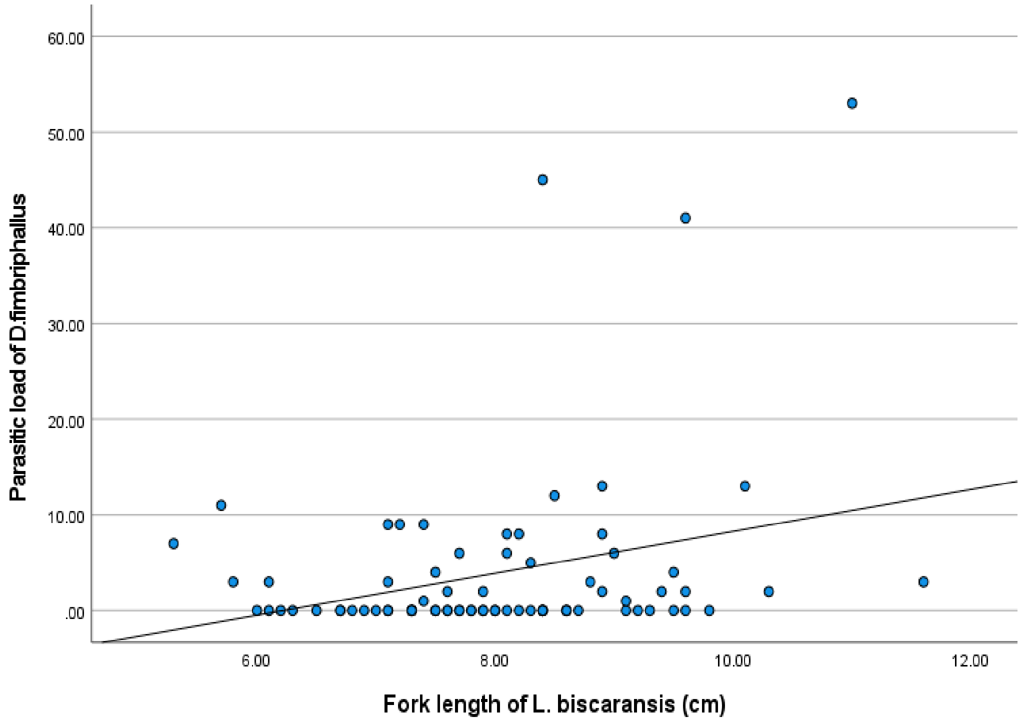


Figure 26. Relationship between the fork length of *Luciobarbus biscarensis* and *Dactylogyrus fimbriphallus.*

As for *Myxobolus* sp., the analysis revealed a moderate negative correlation (Figure 27) between parasite burden and fork length (r = -0.51); however, this correlation was not statistically significant (p = 0.658).

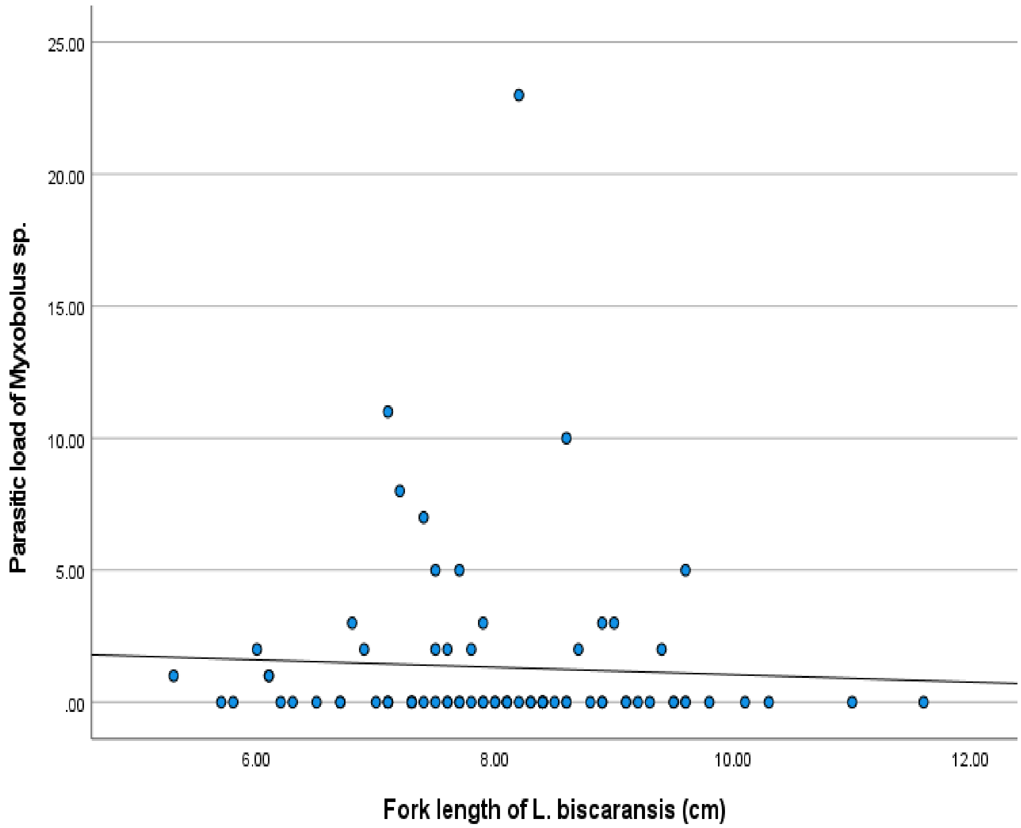


Figure 27. Relationship between the fork length of *Luciobarbus biscarensis* and *Myxobolus* sp.

The relationship between *B. acheilognathi* parasite burden and host fish total length was statistically significant (p < 0.001), and suggested a moderate positive association, as indicated by the correlation coefficient of 0.429. This association is also reflected in Figure 28, showing the relationship between *B. acheilognathi* and the fork length.

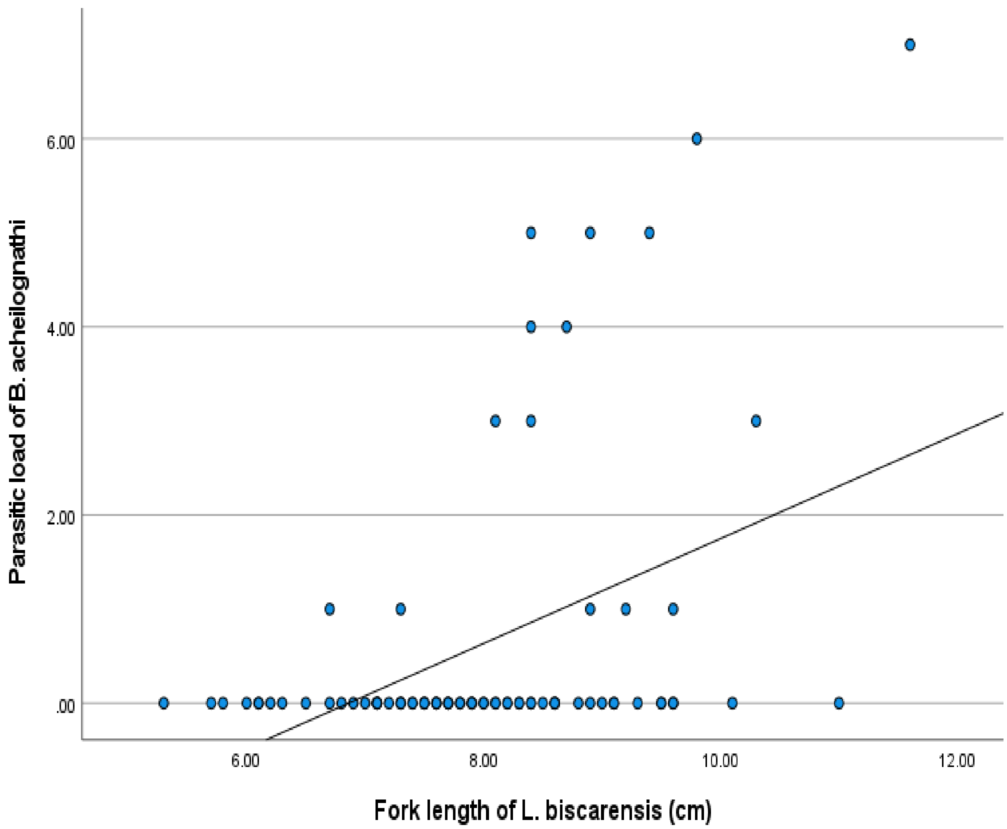


Figure 28. Relationship between the fork length of *Luciobarbus biscarensis* and *Bothriocephalus acheilognathi*

Of the 78 samples of *L. biscarensis* examined during the study, 45 were males and 33 were females. The analysis of parasite infection levels revealed differences between male and female fish individuals for both parasite species. *D. fimbriphallus* was recorded in 17 male hosts with prevalence, mean intensity and abundance of 37.78%, 7.88 ± 10.22 and 2.98 ± 7.28, respectively. The parasite was recorded in 16 female individuals, giving a prevalence of 48.48% and a mean intensity of 10.75 ± 14.74 parasites per fish, the recorded abundance was 5.21 ± 11.47. *Myxobolus* sp. was found in 15 male samples with prevalence of 33.33% and mean intensity and abundance of 1.2 ± 2.37 parasites per fish and 1.2 ± 2.37, respectively. Seven female fish were infected with *Myxobolus* sp. giving prevalence, mean intensity and abundance of 21.21%, 7 ± 7.64 parasites per fish and 1.48 ± 4.40 respectively. The last recorded parasite, *B. acheilognathi*, infected five female hosts out of 33 examined samples; the abundance was 0.33 ± 1.02, the mean intensity 2.20 ± 1.79 and the prevalence 15.15%. The parasite also infected 10 male individuals and showed higher infection values than in females, the prevalence, mean intensity and abundance were 22.22%, 3.90 ± 1.97 and 0.87 ± 1.87, respectively (Table 17).

The number of all three parasites; *D. fimbriphallus*, *Myxobolus* sp. and *B. acheilognathi* did not differ significantly between male and female hosts (Mann–Whitney U-test = 655.500 and p = 0.327, Mann–Whitney U-test = 667.500 and p = 0.339, Mann–Whitney U-test = 678.000 and p = 0.343, respectively).

Table 18. Distribution of infection values of parasites recorded in *Luciobarbus biscarensis* from Djelfa region according to host sex.

	Sex Groups	
Parasites type	**Males**	**Females**
Number of examined fish	45	33
Number of infected fish	28	20
D. fimbriphallus		
Number of infected Fish	17	16
Infection Prevalence (%)	37.78	48.48
Mean Intensity ±SD	7.88 ± 10.22	10.75 ± 14.74
Mean Abundance ±SD	2.98 ± 7.28	5.21 ± 11.47
Min – Max. Parasite Numbers	1–45	2–53
Total Number of Parasites	134	172
***Myxobolus* sp.**		
Number of infected Fish	15	7
Infection Prevalence (%)	33.33	21.21

Mean Intensity ±SD	3.6 ± 2.90	7 ± 7.64
Mean Abundance ±SD	1.2 ± 2.37	1.48 ± 4.40
Min – Max. Parasite Numbers	1–11	1–23
Total Number of Parasites	54	49
B. acheilognathi		
Number of infected Fish	10	5
Infection Prevalence (%)	22.22	15.15
Mean Intensity ±SD	3.90 ± 1.97	2.20 ± 1.79
Mean Abundance ±SD	0.87 ± 1.87	0.33 ± 1.02
Min – Max. Parasite Numbers	1–7	3–5
Total Number of Parasites	39	11

2.3.3.2 *Cyprinus carpio*

During this study, a total of 223 parasites were recorded in the fish species *C. carpio*, which are *D. extensus, B. acheilognathi* and *Trichodina* sp. The most common parasite is *D. extensus* species that was encountered in all sampling seasons with a total of 171 parasite individuals found in 32 fish samples, and abundance, prevalence and mean intensity of 6.95 ± 9.10, 75% and 9.27 ± 9.46, respectively. The maximum infection levels were recorded during summer with a maximum of 37 parasites recorded in one host fish, with abundance of 6.95 ± 9.10, prevalence of 75% and mean intensity of 9.27 ± 9.46. The second recorded parasite species is *B. acheilognathi*, giving values of 2.11 ± 1.36, 0.95 ± 1.39 and 45% for the mean intensity, abundance and prevalence, respectively. Also found in all four seasons and infected 21 fish hosts out of the total 81 samples with 36 parasite individuals, and the infection was the highest during summer, with a maximum of 5 parasites recorded in one host fish and infection levels of mean intensity, prevalence and abundance of 2.11 ± 1.36, 45% and

0.95 ± 1.39. The levels of the abundance, mean intensity and prevalence recorded for *D. extensus* were 2.11 ± 5.32, 5.34 ± 7.43 parasites per fish and 39.51%, respectively. However, the infection values for *B. acheilognathi* were as follows; prevalence: 25.93%, mean intensity: 1.71 ± 1.01 parasites per fish and abundance: 0.44 ± 0.91. *Trichodina* sp. was also infecting the gills of *C. carpio*. It was found in 8 out of the 81 total examined fish samples, from which 18 parasite individuals were collected. The levels of the infection parameters reached; prevalence 9.88 %, mean intensity 2 ± 0.76 and abundance 0.20 ± 0.64. This parasite was found during all four seasons and peaked during spring, where it infected 8 host fish and recorded abundance, prevalence and mean intensity of 0.38 ± 0.99, 14.29 and 2.67 ± 0.58, respectively (Table 18).

Seasonal variations in parasite numbers were assessed using the Kruskal-Wallis test; the result indicated that there is a statistically significant difference in the number of *D. extensus* detected across the different seasons ($p < 0.001$). As for *B. acheilognathi* and *Trichodina* sp. no statistically significant difference in the number of parasites were detected across the four seasons ($p = 0.385$ and $p = 0.749$, respectively).

Table 19. Distribution of infection values of parasites recorded in *Cyprinus carpio* from Djelfa region according to seasons.

	Autumn	**Winter**	**Spring**	**Summer**
Number of examined fish	20	20	21	20
Number of infected fish	8	11	13	16
D. extensus				
Number of infected Fish	4	3	10	15
Infection Prevalence (%)	20	15	47.62	75
Mean Intensity ±SD	1.25 ± 0.50	1.67 ± 1.15	2.20 ± 1.47	9.27 ± 9.46
Abundance ±SD	0.25 ± 0.55	0.25 ± 0.72	1.05 ± 1.50	6.95 ± 9.10

Min – Max. Parasite Numbers	1–2	1–3	1–5	1–37
Total Number of Parasites	5	5	22	139
B. acheilognathi				
Number of infected Fish	3	4	5	9
Infection Prevalence (%)	15	20	23.81	45
Mean intensity ±SD	1.33 ± 0.58	1.25 ± 0.50	1.60 ± 0.55	2.11 ± 1.36
Abundance ±SD	0.20 ± 0.52	0.25 ± 0.55	0,38 ± 0.74	0.95 ± 1.39
Min – Max. Parasite Numbers	1–2	1–2	1–2	1–5
Total Number of Parasites	4	5	8	19
***Trichodina* sp.**				
Number of infected Fish	2	1	8	2
Infection Prevalence (%)	10	5	14.29	10
Mean Intensity ±SD	1.5 ± 0.71	1	2.67 ± 0.58	2
Abundance ±SD	0.15 ± 0.49	0.05 ± 0.22	0.38 ± 0.99	0.2 ± 0.62
Min – Max. Parasite Numbers	1–2	1–1	2–3	2–2
Total Number of Parasites	3	1	8	4

The significance of the difference per season was evaluated using the Mann–Whitney U-test (Table 19), a significant difference was recorded between infection of *D. extensus* in spring and summer ($p = 0.003$, $U = 100.500$), between summer and winter ($p < 0.001$, $U = 62.000$) and when comparing spring and autumn ($p = 0.044$, $U = 145.000$). The test revealed no significant difference between the infection of *B. acheilognathi* in spring and summer ($p = 0.371$, $U = 182.500$), no significant difference between summer and winter ($p = 0.215$, $U = 164.000$) and between spring and autumn ($p = 0.439$, $U = 189.500$). The Mann-Whitney U test revealed no statistically significant variations in *Trichodina* sp. infection across the analyzed seasons: spring and summer ($p = 0.614$, U =

199.000), summer and winter (p = 0.515, U = 189.000), and spring and autumn (p = 0.598, U = 198.500).

Table 20. Results of Mann-Whitney U-test comparing seasonal parasite infection values in *Cyprinus carpio* from Djelfa region.

	Spring and summer	**Summer and winter**	**Spring and autumn**
D. extensus			
P value	0.003	< 0.001	0.044
Mann–Whitney U value	100.500	62.000	145.000
B. acheilognathi			
P value	0.371	0.215	0.439
Mann–Whitney U value	182.500	164.000	189.500
***Trichodina* sp.**			
P value	0.614	0.515	0.598
Mann–Whitney U value	199.000	189.000	198.500

There is a statistically significant relationship between fish total length and parasitic load of *D. extensus* and a weak positive correlation exist between them (r = 0.222, p = 0.046), as represented in Figure 29, as fish length increases, there's a slight tendency for the parasitic load to increase.

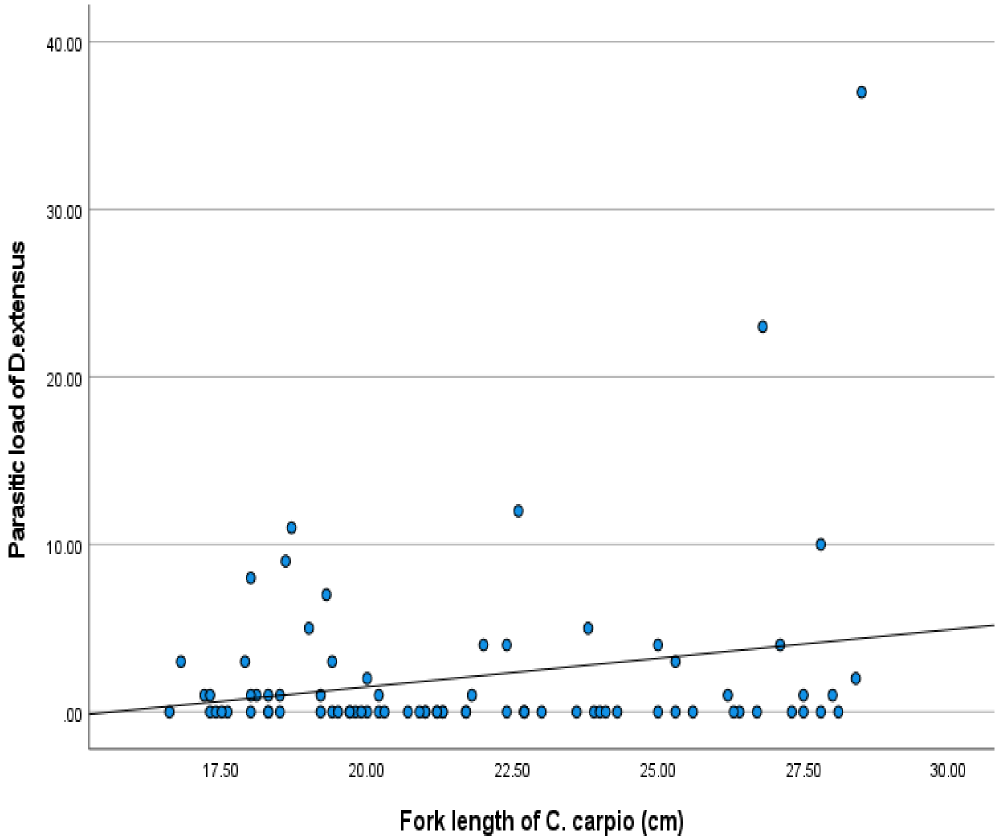


Figure 29. Relationship between the fork length of *Cyprinus carpio* from the Djelfa region and *Dactylogyrus extensus.*

The maximum number of *B. acheilognathi*, which is 5 parasite individuals, was recorded in the fish host with the total length of 27.8 cm. There was a moderate positive correlation between the fork length of *C. carpio* and the parasitic load of *B. acheilognathi* (Figure 30), and it is statistically significant ($r = 0.434$, $p < 0.001$).

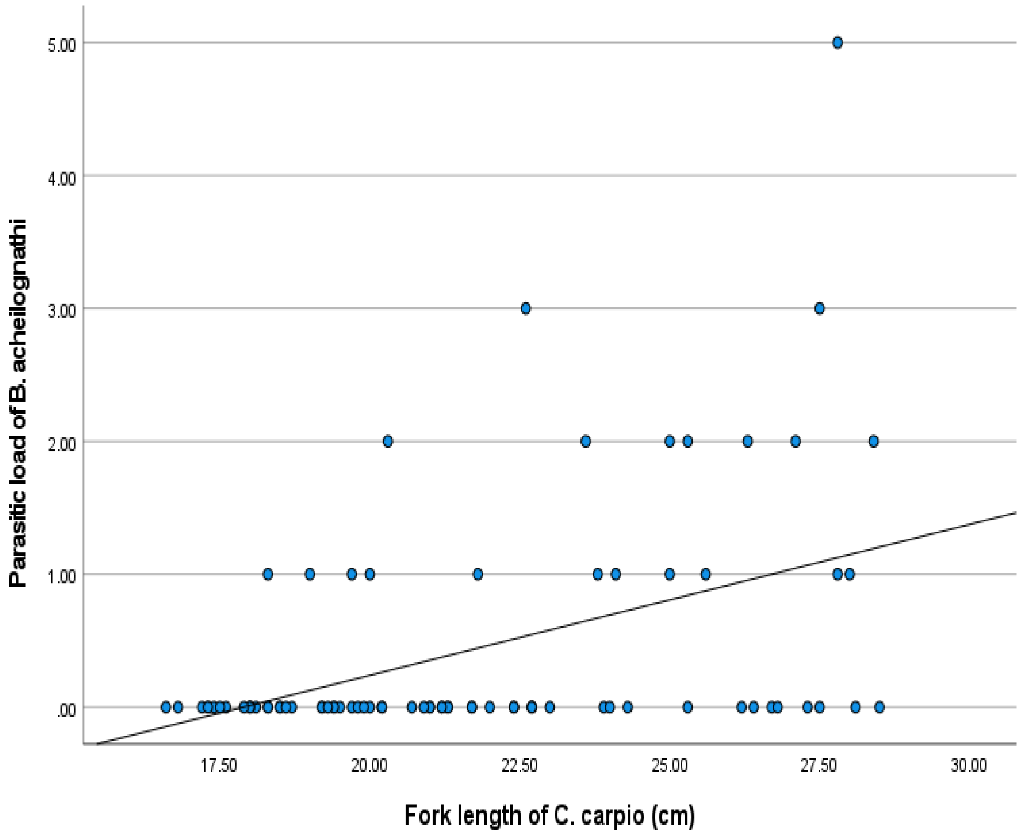


Figure 30. Relationship between the fork length of *Cyprinus carpio* from the Djelfa region and *Bothriocephalus acheilognathi*.

A statistically significant, moderate positive correlation ($r = 0.459$, $p < 0.001$) was found between the host fish total length and the *Trichodina* sp. parasite abundance. These results, that larger fish tend to harbor more *Trichodina* sp. parasites, is visually represented in Figure 31, showing the relationship between fish fork length and parasitic load of *Trichodina* sp.

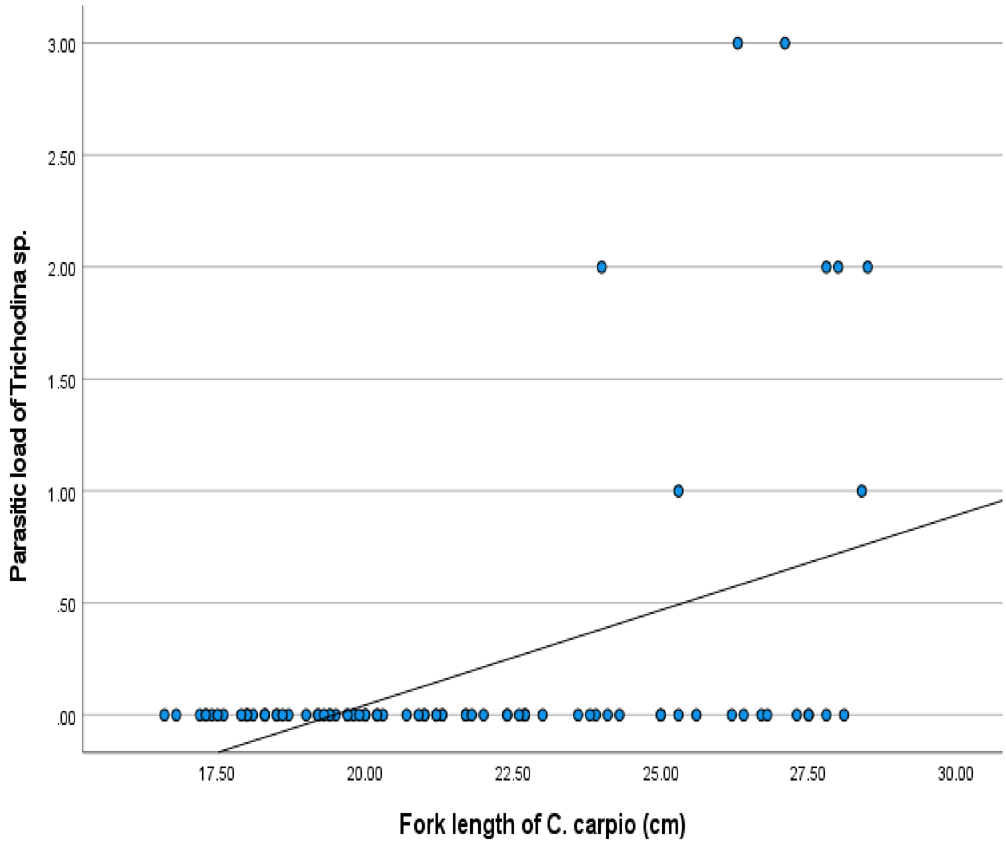


Figure 31. Relationship between the fork length of *Cyprinus carpio* from the Djelfa region and *Trichodina* sp.

Of the 81 *C. carpio* examined within the scope of the study, 35 were identified as females and 46 as males. The relationships between the sex groups of the fish and the infection values of the parasite species recorded in the host fish are shown in Table 20. It is seen that the infection values of *D. extensus* were higher in female individuals. *D. extensus* parasites were recorded in 17 female hosts with prevalence, mean intensity and mean abundance of 48.57%, 6.65 ± 9.40 parasites per fish and 3.23 ± 6.75, respectively. The parasite was also recorded in 15 male hosts, giving infection values of: prevalence 32.61%, mean intensity 3.87 ± 2.97 parasites per fish and mean abundance 1.26 ± 3.68. The number of male fish hosts infected with *B. acheilognathi* was 13, showing a 28.26% prevalence of infection with a mean intensity of 1.92 ± 1.19 parasites per fish and abundance of 0.54 ± 1.15, these infection values were found to be higher in male hosts than females, as the infection values for them were of 22.86% for the prevalence, 1.38 ± 0.52 for the mean intensity and 0.31 ± 0.58 for the abundance. *Trichodina* sp. infected five male hosts, giving prevalence, mean intensity and abundance of 10.87%, 2 ± 0.71 and 0.22 ± 0.72, respectively. And three female hosts, showing lower infection values then in male fish samples, with abundance 0.17 ± 0.56, prevalence 8.57% and mean intensity 2 ± 1.

No statistically significant difference in the number of *D. extensus*, *B. acheilognathi* and *Trichodina* sp. depending on the sex of the host (Mann–Whitney U-test = 804.000, p = 0.889, Mann–Whitney U-test = 748.000, p = 0.378 and Mann–Whitney U-test = 766.500, p = 0.356, respectively).

Table 21. Distribution of infection values of parasites recorded in *Cyprinus carpio* from Djelfa region according to host sex.

	Sex Groups	
Parasites type	**Males**	**Females**
Number of examined fish	46	35
Number of infected fish	18	24
D. extensus		
Number of infected Fish	15	17
Infection Prevalence (%)	32.61	48.57
Mean Intensity ±SD	3.87 ± 2.97	6.65 ± 9.40
Mean Abundance ±SD	1.26 ± 3.68	3.23 ± 6.75
Min – Max. Parasite Numbers	1–12	1–37
Total Number of Parasites	58	113
B. acheilognathi		
Number of infected Fish	13	8
	28.26	22.86

Infection Prevalence (%)	1.92 ± 1.19	1.38 ± 0.52
Mean Intensity ±SD	0.54 ± 1.15	0.31 ± 0.58
Mean Abundance ±SD		
Min – Max. Parasite Numbers	1–3	1–5
Total Number of Parasites	25	11
***Trichodina* sp.**		
Number of infected Fish	5	3
Infection Prevalence (%)	10.87	8.57
Mean Intensity ±SD	2 ± 0.71	2 ± 1
Mean Abundance ±SD	0.22 ± 0.72	0.17 ± 0.56
Min – Max. Parasite Numbers	1–3	1–3
Total Number of Parasites	10	6

2.4. Study of the biodiversity of parasites in the freshwater ichthyofauna of the Laghouat region

2.4.1 Identification of parasites detected in host fish in the study region

Seasonal determination was conducted of the parasitic fauna of *C. carpio* and *Barbus*. sp from the hillside reservoir of Lalmaia in Laghouat governorate. The parasite species collected have been identified using the previously mentioned keys of identification.

The findings of this study demonstrate the presence of the following parasite species: one Monogenea species; *D. extensus*, one species of Copepoda (*Ergasilus* sp.) and one species of *Myxobolus* sp (Table 21).

Table 22. The parasite species detected in the fish species examined in Laghouat region and their distribution in hosts.

Fish species	Monogenea	Copepoda	Cnidaria
	Dactylogyrus extensus	*Ergasilus* sp.	*Myxobolus* sp.
C. carpio	132	63	80
Barbus sp.	_	124	_

2.4.2 Parasite description

The same parasite species identified in the Djelfa region were also found in fish from the Laghouat region. The descriptions of these parasites (*D. extensus* and *Myxobolus* sp.) can be found in the 'Parasite Description' section under ' Study of the biodiversity of parasites in the freshwater ichthyofauna of the Djelfa region'. *Ergasilus* sp. was found in this study region and was absent in the Djelfa region.

2.4.2.1 Copepoda

- ***Ergasilus* sp.**

Phylum: Arthropoda

Subphylum: Crustacea

Superclass: Multicrustacea

Class: Copepoda

Infraclass: Neocopepoda

Superorder: Podoplea

Order: Cyclopodia

Suborder: Ergasilida

Family: Ergasilidae

Genus: *Ergasilus* (Figure 32)

- **Host**: *C. carpio, Barbus* sp. and *C. gibelio*
- **Location**: Gills

Figure 32. *Ergasilus* sp. collected from the gills of *Cyprinus carpio* (original photo).

2.4.3 Parasitism of studied fish species

In the context of this research, the gills of the fish species studies in the Laghouat region (*C. carpio* and *Barbus* sp.), collected from the Lalmaia hillside reservoir, were both infected with *Ergasilus* sp., as for *C. carpio* species, two more parasite species were found in the gills of this fish host; *D. extensus* and *Myxobolus* sp., no parasites were found in the intestines of both fish species.

2.4.3.1 *Cyprinus carpio*

Throughout the seasonal sampling, *D. extensus* was identified as the most dominant monogenean parasite infecting *C. carpio* with a total of 132 collected parasite individuals from 31 infected fish, out of the total 79 examined fish. The parasite was present in autumn, spring and summer, and absent in winter. The prevalence of this parasite was 39.24%, the abundance was 1.67 ± 4.02 and the mean intensity was 4.26 parasites per fish. The parasite reached its highest levels of infection during summer season where 15 of 20 examined fish were infected with 97 parasite individuals, giving values of mean intensity, abundance and prevalence of 6.47 ± 7.41, 4,85 ± 6.98 and 75%, respectively. During this season a maximum level of parasites was recorded with 27 individuals found in one fish host with a total length of 140 cm. The second most abundant parasite was *Myxobolus* sp., it showed an abundance of 1.01 ± 1.98, a mean intensity of 2.5 ± 2.45 parasites per fish and a prevalence of 40.51%, and was present during all four seasons, with a peak during autumn, where its infection levels reached 68.46%, 3.62 ± 3.5 and 2.47 ± 3.34 for the prevalence, mean intensity and abundance, respectively. The highest number of *Myxobolus* sp. was recorded during this same month and was of 13 parasite individuals in the fish host with the total length of 136 cm. The parasite with the lowest infection values recorded in *C. carpio* collected from the Laghouat region was *Ergasilus* sp., which was absent during winter and present during the other three seasons, giving mean intensity, abundance and prevalence of 2.74 ± 2.05 parasites per fish, 0,80 ± 1.66 and 29.11%, respectively. Autumn was the season during which the parasite was most abundant with a mean intensity of 3.73 ± 2.53, abundance of 2.16 ± 2.67 and prevalence of 57.89%. During the same season, a maximum of 10 parasites belonging to *Ergasilus* sp. were collected from the fish individual with 136 cm total length (Table 22).

Seasonal variations in parasite abundance were assessed using the Kruskal-Wallis test. Significant differences were observed, with *D. extensus* numbers varying significantly across seasons ($p < 0.001$). Similarly, *Myxobolus* sp. and *Ergasilus* sp. abundances showed significant seasonal correlation ($p = 0.002$ and $p < 0.001$, respectively).

Table 23. Distribution of infection values of parasites recorded in *Cyprinus carpio* from Laghouat region according to seasons.

	Autumn	**Winter**	**Spring**	**Summer**
Number of examined fish	19	20	20	20
Number of infected fish	16	3	11	15
D. extensus				
Number of infected Fish	7	–	9	15
Infection Prevalence (%)	36.84	–	45	75
Mean intensity ±SD	2.14 ± 0.90	–	2.22 ± 0.83	6.47 ± 7.41
Abundance ±SD	0.79 ± 1.18	–	1 ± 1.26	4.85 ± 6.98
Min – Max. Parasite Numbers	1–3	–	1–3	1–27
Total Number of Parasites	15	–	20	46
***Myxobolus* sp.**				
Number of infected Fish	13	3	6	10
Infection Prevalence (%)	68.42	15	30	50
Mean intensity ±SD	3.62 ± 3.50	1.33 ± 0.58	1.83 ± 0.45	1.8 ± 1.03
Abundance ±SD	2.47 ± 3.34	0.20 ± 0.54	0.55 ± 0.84	0.90 ± 1.17
Min – Max. Parasite Numbers	1–23	1–2	1–2	1–4
Total Number of Parasites	47	4	11	18
***Ergasilus* sp.**				
Number of infected Fish	11	–	4	8
Infection Prevalence (%)	57.89	–	20	40
Mean intensity ±SD	3.73 ± 2.53	–	1.75 ± 0.96	1.88 ± 0.83

Abundance ±SD	2.16 ± 2.67	–	0.35 ± 0.81	0.75 ± 1.07
Min – Max. Parasite Numbers	1–10	–	1–3	1–3
Total Number of Parasites	41	–	7	15

Seasonal differences in the three parasites infection were analyzed using the Mann-Whitney U test (Table 23). For *D. extensus*, significant differences were found between spring and summer ($p = 0.009$, $U = 107.500$) and summer and winter ($p < 0.001$, $U = 50.000$). No significant difference was observed between spring and autumn ($p = 0.590$, $U = 173.000$). *Myxobolus* sp. showed no significant differences between spring and summer ($p = 0.282$, $U = 165.000$), and the comparison between summer and winter ($p = 0.016$, $U = 126.500$) and spring and autumn ($p = 0.010$, $U = 105.000$) showed significant difference. As for *Ergasilus* sp., the results indicated that the infection levels differ significantly between summer and winter ($p = 0.002$, $U = 120.000$) and between spring and autumn ($p = 0.006$, $U = 105.000$). However, no significant difference was detected when comparing spring and summer ($p = 0.165$, $U = 158.500$).

Table 24. Results of Mann-Whitney U-test comparing seasonal parasite infection values in *Cyprinus carpio* from Laghouat region.

	Spring and summer	**Summer and winter**	**Spring and autumn**
D. extensus			
P value	0.009	< 0.001	0.590
Mann–Whitney U value	107.500	50.000	173.000
***Myxobolus* sp.**			
P value	0.282	0.016	0.010
Mann–Whitney U value	165.000	126.500	105.000

***Ergasilus* sp.**			
P value	0.165	0.002	0.006
Mann–Whitney U value	158.500	120.000	105.000

The relationship between total fish host length and *D. extensus* parasite abundance was analyzed and revealed a statistically significant, yet weak, positive correlation (r = 0.297, p = 0.008). These results suggest that increasing host size may correspond to marginally high parasite loads, which is supported by the relationship between fish fork length and *D. extensus* abundance shown in Figure 33.

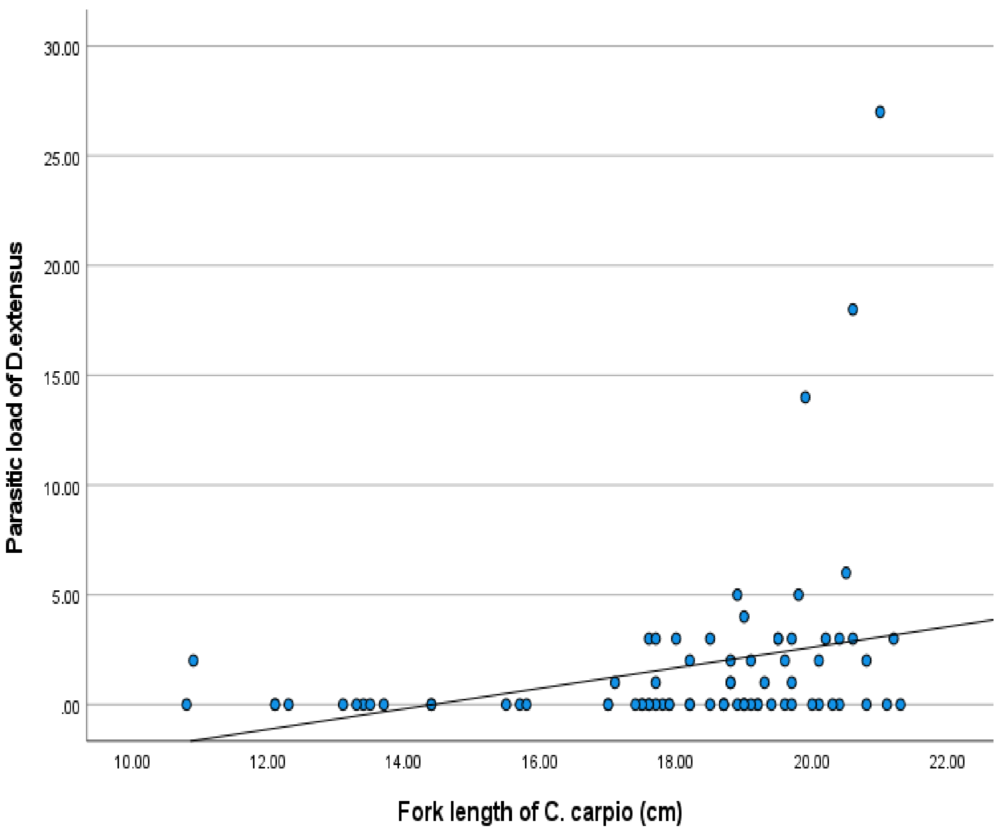


Figure 33. Relationship between the fork length of *Cyprinus carpio* from the Laghouat region and *Dactylogyrus extensus*.

The relationship between the abundance of *Myxobolus* sp. and the total length of *C. carpio* was examined and revealed a weak to moderate, statistically significant positive correlation (r = 0.346, p = 0.002). This implies that larger fish may have a slightly higher Myxobolus parasite load, which is also shown in Figure 34.

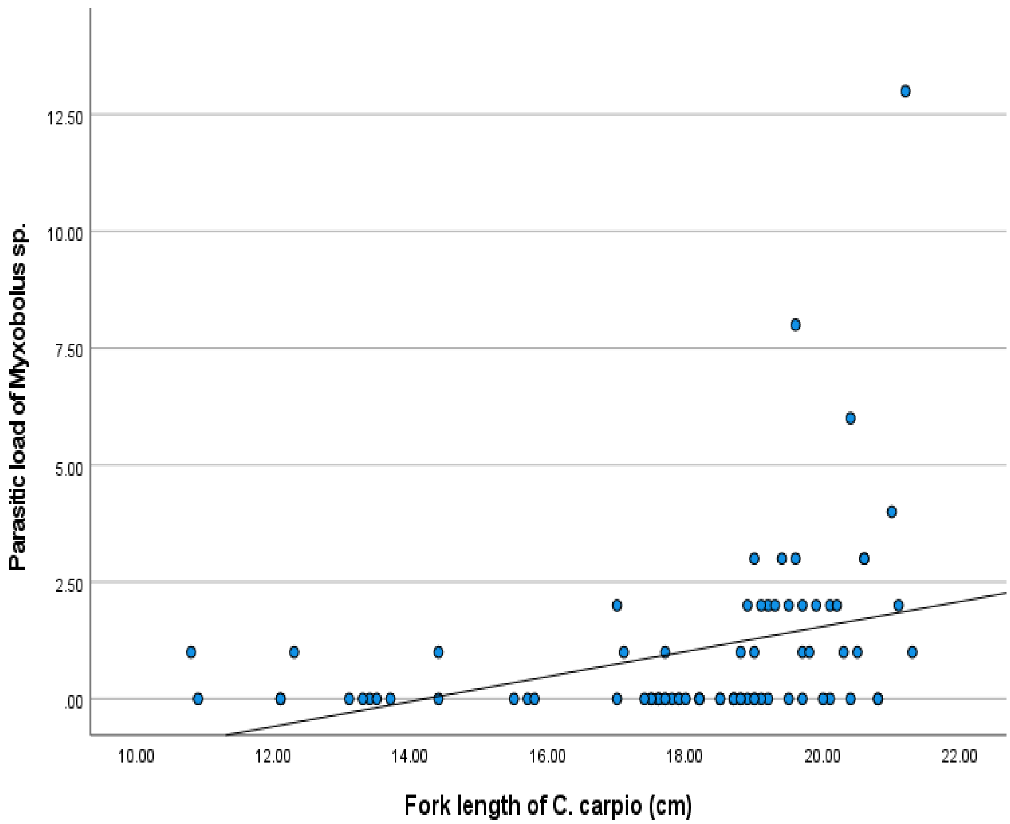


Figure 34. Relationship between the fork length of *Cyprinus carpio* from the Laghouat region and *Myxobolus* sp.

Using the correlation analysis, a statistically significant, weak to moderate, positive correlation (r = 0.327, p = 0.003) was established between host fish total length and *Ergasilus* sp. parasite load. The trend for larger fish to have a slightly greater number of parasites is also visually represented in Figure 35.

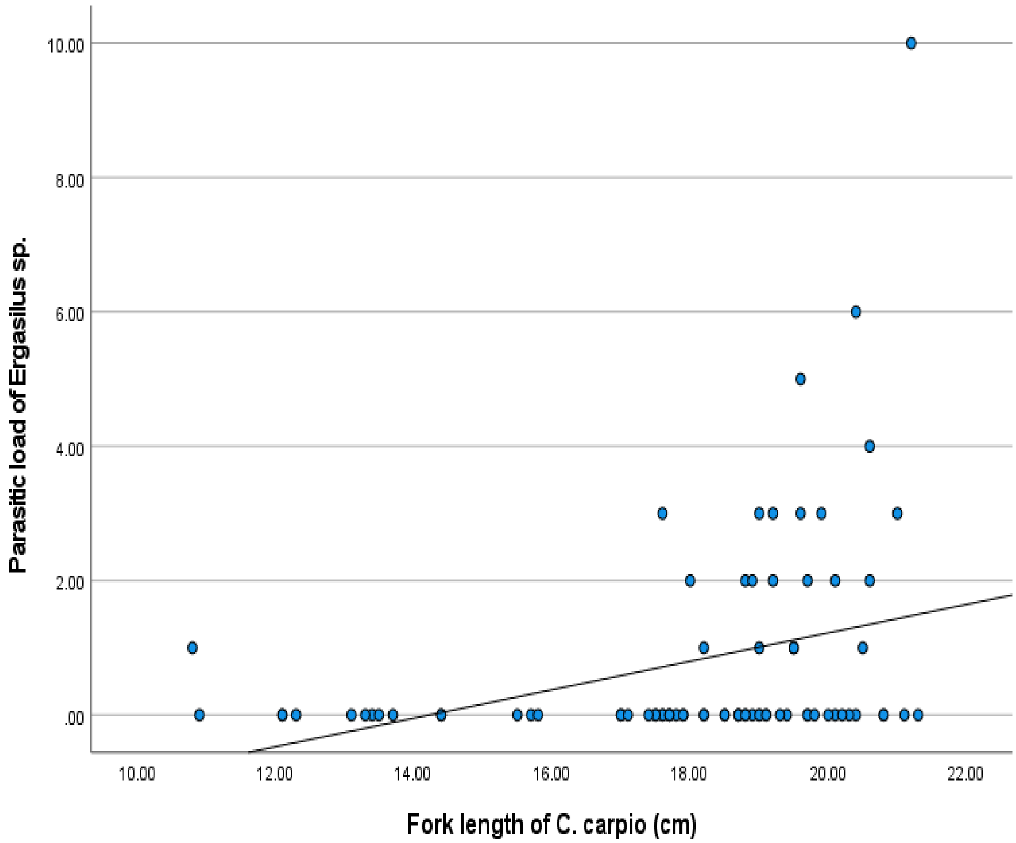


Figure 35. Relationship between the fork length of *Cyprinus carpio* from the Laghouat region and *Ergasilus* sp.

The distribution of the infection values of the parasites collected from *C. carpio* according to sex groups is detailed in Table 24. According to Table 24, all infection values of *D. extensus*, *Myxobolus* sp. and *Ergasilus* sp. were higher in female fish individuals. *D. extensus* was recorded in 18 of 34 female samples, with abundance, mean intensity and prevalence of 2.5 ± 5.40, 4.72 ± 6.74 and 52.94%, respectively, and in 13 male individuals, showing abundance of 1.04 ± 2.44, mean intensity of 3.62 ± 3.43 and prevalence of 28.29%. A total of 20 female samples were infected with *Myxobolus* sp. and the levels of infection recorded were 58.82% for the prevalence, 2.8 ± 2.89 for the mean intensity and 1.65 ± 2.60 for the abundance of this parasite species, male individuals showed lower infection levels (prevalence 26.67%, mean intensity 2 ± 1.41, abundance 0.53 ± 1.14). As for the last parasite species, the number of infected male fish samples with *Ergasilus* sp. reached 9 and showed abundance, mean intensity and prevalence of 0.44 ± 1.12, 2.22 ± 1.56 and 20%, respectively. However, 14 female fish were infected giving an abundance of 1.26 ± 2.11, mean intensity of 3.07 ± 2.30 and prevalence of 41.18%.

The distribution of *D. extensus*, *Myxobolus* sp., and *Ergasilus* sp. parasites was found to be significantly associated with host sex, as evidenced by Mann-Whitney U tests: *D. extensus* (U = 579.500, p = 0.037), *Myxobolus* sp. (U = 499.500, p = 0.003), and *Ergasilus* sp. (U = 584.000, p = 0.025).

Table 25. Distribution of infection values of parasites recorded in *Cyprinus carpio* from Laghouat region according to host sex.

	Sex Groups	
Parasites type	**Males**	**Females**
Number of examined fish	45	34
Number of infected fish	20	25
D. extensus		
Number of infected Fish	13	18
Infection Prevalence (%)	28.29	52.94
Mean Intensity ±SD	3.62 ± 3.43	4.72 ± 6.74
Mean Abundance ±SD	1.04 ± 2.44	2.5 ± 5.40
Min – Max. Parasite Numbers	1–14	1–27
Total Number of Parasites	47	85
***Myxobolus* sp.**		
Number of infected Fish	12	20
Infection Prevalence (%)	26.67	58.82
Mean Intensity ±SD	2 ± 1.41	2.8 ± 2.89

Mean Abundance ±SD	0.53 ± 1.14	1.65 ± 2.60
Min – Max. Parasite Numbers	1–6	1–13
Total Number of Parasites	24	56
***Ergasilus* sp.**		
Number of infected Fish	9	14
Infection Prevalence (%)	20	41.18
Mean Intensity ±SD	2.22 ± 1.56	3.07 ± 2.30
Mean Abundance ±SD	0.44 ± 1.12	1.26 ± 2.11
Min – Max. Parasite Numbers	1–6	1–10
Total Number of Parasites	20	43

2.4.3.2. *Barbus* sp.

In *Barbus* sp. samples, 124 parasite individuals were collected from 35 fish samples out of the total 80 examined fish. Seasonal variations in *Barbus* sp. parasite are summarized in Table 25 which includes data on infection parameters, the number of parasitized fish, infection rates (%), the minimum and maximum parasite numbers, and the total parasite count. Accordingly, only one parasite species was recorded in *Barbus* sp., which is *Ergasilus* sp. This parasite species was found during all seasons, and infected 35 of 80 examined samples with mean intensity of 3.54 ± 2.23, prevalence of 43.75% and abundance of 1.55 ± 2.06. *Ergasilus* sp. was most abundant during spring, with a total of 13 infected fish, and prevalence, mean intensity and abundance of 65%, 4.15 ± 1.77 and 2.70 ± 2.47, respectively. A maximum of 8 parasites were collected in the fish sample with the total length of 25.6 cm during summer, which is the season during which the second highest infection values were recorded.

To determine if parasite abundance varied significantly across seasons, a Kruskal-Wallis test was conducted. The results showed a statistically significant seasonal effect on *Ergasilus* sp. abundance ($p < 0.001$).

Table 26. Distribution of infection values of parasites recorded in *Barbus* sp. from Laghouat region according to seasons.

	Autumn	**Winter**	**Spring**	**Summer**
Number of examined fish	20	20	20	20
***Ergasilus* sp.**				
Number of infected Fish	7	3	13	12
Infection Prevalence (%)	35	15	65	60
Mean intensity ±SD	1.71 ± 0.76	1.67 ± 0.58	4.15 ± 1.77	4.42 ± 2.23
Abundance ±SD	0.6 ± 0.94	0.25 ± 0.67	2.70 ± 2.47	2.65 ± 2.80
Min – Max. Parasite Numbers	1–3	1–2	1–7	1–8
Total Number of Parasites	12	5	54	53

The results of the Mann–Whitney U-test indicated that no significant difference was observed between spring and summer (p = 0.878, U = 194.500). However, significant differences were found between summer and winter (p = 0.001, U = 97.000) and between spring and autumn (p = 0.006, U = 105.500) (Table 26).

Table 27. Results of Mann-Whitney U-test comparing seasonal parasite infection values in *Barbus* sp. from Laghouat region.

	Spring and summer	**Summer and winter**	**Spring and autumn**
***Ergasilus* sp.**			
P value	0.878	0.001	0.006
Mann–Whitney U value	194.500	97.000	105.500

The correlation analysis revealed a statistically significant, moderate positive correlation between host fish total length and the number of *Ergasilus* sp. parasites ($r = 0.545$, $p < 0.001$). This indicates that larger fish tend to have a higher abundance of *Ergasilus* sp. parasites, which is also observed in Figure 36.

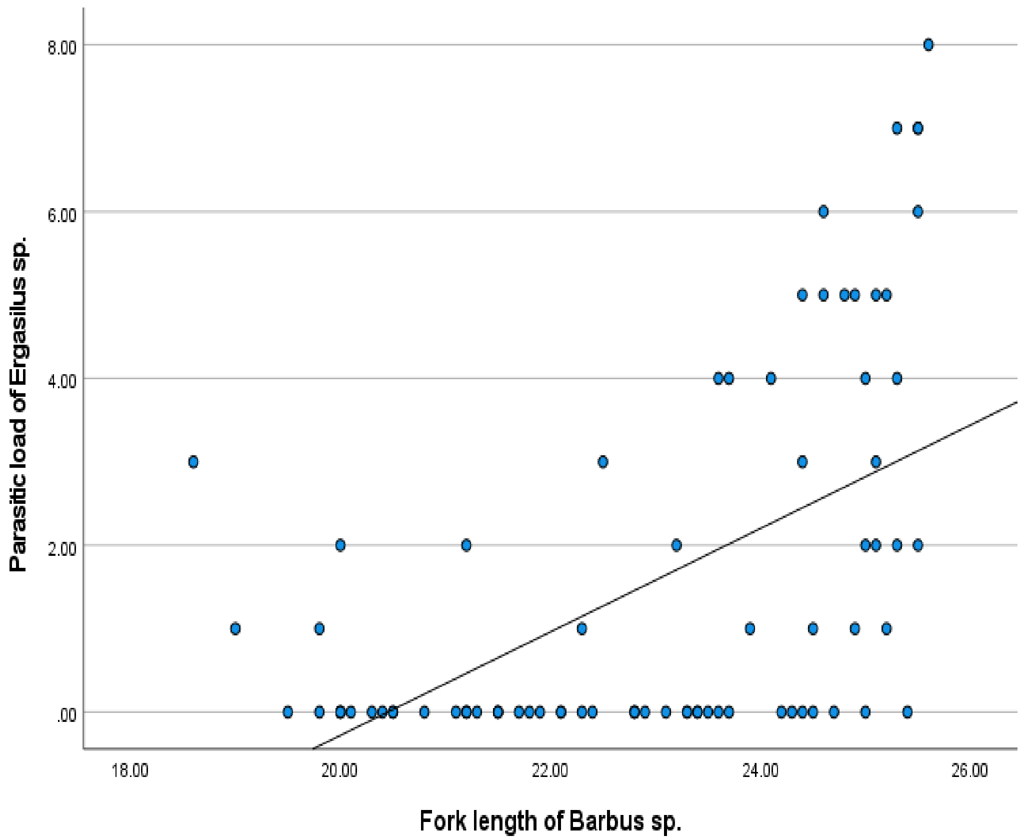


Figure 36. Relationship between the fork length of *Barbus* sp. from the Laghouat region and *Ergasilus* sp.

From the total number of examined *Barbus* sp. fish samples, 47 samples were identified as female individuals and 33 as males. The relationships between host fish sex and the recorded infection values of the parasite species are presented in Table 27, demonstrating the influence of host sex on parasite infection. It shows the male hosts are less infected than females with only 12 infected samples, giving prevalence, mean intensity and abundance of 36.36%, 3.17 ± 1.85 and 1.15 ± 1.89, respectively. As for female host fish, the number of infected samples are almost double the male infected hosts as 23 infected fish were recorded, the abundance reached 1.83 ± 2.42, the prevalence 48.94% and the mean intensity 3.74 ± 2.18. Additionally, the maximum number of recorded parasite samples was found in a female host.

The Mann-Whitney U test showed no statistically significant difference in *Ergasilus* sp. abundance between male and female fish (U = 658.500, p = 0.207).

Table 28. Distribution of infection values of parasites recorded in *Barbus* sp. from Laghouat region according to host sex.

	Sex Groups	
Parasites type	**Males**	**Females**
Number of examined fish	33	47
***Ergasilus* sp.**		
Number of infected Fish	12	23
Infection Prevalence (%)	36.36	48.94
Mean Intensity ±SD	3.17 ± 1.85	3.74 ± 2.18
Mean Abundance ±SD	1.15 ± 1.89	1.83 ± 2.42
Min – Max. Parasite Numbers	1–7	1–8
Total Number of Parasites	38	86

2.5 Study of the biodiversity of parasites in the freshwater ichthyofauna of the Biskra region

2.5.1 Identification of parasites detected in host fish in the study region

A seasonal analysis of the parasitic fauna inhabiting *C. gibelio* in Foum El Kherza dam was performed. *Oreochromis* sp. fish samples from a fish farm in the commune of Sidi Okba and a fish farm in the commune of El Outaya, were also examined for the presence of parasites. Taxonomic identification of parasite species was conducted using the aforementioned identification keys. The results of this investigation revealed the occurrence of one copepoda species (*Ergasilus* sp. 1) in *C. gibelio*. The examination of the *Oreochromis* sp. fish samples from both fish farms revealed the absence of parasitic organisms.

2.5.2 Parasite description

Parasites from the genus *Ergasilus* sp. 1 previously identified in the Laghouat region were also detected in fish from the Biskra region. The description of this parasite can be found in the 'Parasite Description' section under 'Study of the biodiversity of parasites in the freshwater ichthyofauna of the Laghouat region'.

2.5.3 Parasitism of studied fish species

The gills of the fish species under investigation, collected from Foum El Kherza dam, Biskra region, were determined to be infected with *Ergasilus* sp. 1. Parasites belonging to the genus *Ergasilus* were identified in the previous study region, as it was found to be infecting both fish species collected from Lalmaia hillside reservoir, which are *Barbus* sp. and *C. carpio*.

2.5.3.1 *Carassius gibelio*

Ergasilus sp. 1 was identified as a parasite of *C. gibelio* throughout the seasonal sampling as it was found in 14 out of the total 82 examined samples. A total of 25 individuals were collected from 14 infected fish out of 82 examined, indicating a prevalence of 17.07%, an abundance of 0.30 ± 0.76 and a mean intensity of 1.79 ± 0.89. The parasite was present during only three seasons, and absent during winter, with corresponding data in Table 28. *Ergasilus* sp. 1 was abundant during spring and summer. It recorded the highest levels of infection during summer with mean intensity, prevalence and abundance of 1.86 ± 0.9, 35% and 0.65 ± 1.04, respectively. The maximum number of recorded parasites within the same sample is three, and it was found in samples collected during spring and summer. Detailed seasonal infection parameters (abundance, mean intensity, and prevalence) are presented in Table 28.

To examine the hypothesis that *Ergasilus* sp. 1 abundance varies seasonally, a Kruskal-Wallis test was performed. The results confirmed a significant seasonal effect ($p = 0.018$)

Table 29. Distribution of infection values of parasites recorded in *Carassius gibelio* from Biskra region according to seasons.

	Autumn	**Winter**	**Spring**	**Summer**
Number of examined fish	20	20	22	20
***Ergasilus* sp. 1**				
Number of infected Fish	2	_	5	7
Infection Prevalence (%)	10	_	22.73	35
Mean intensity ±SD	1.00	_	2.00 ± 1.00	1.86 ± 0.90
Abundance ±SD	0.1 ± 0.31	_	0.45 ± 1.00	0.65 ± 1.04
Min – Max. Parasite Numbers	1–1	_	1–3	1–3
Total Number of Parasites	2	_	10	13

The Mann-Whitney U test demonstrated a significant disparity in *Ergasilus* sp. 1 abundance between the summer and winter seasons ($U = 130.000$, $p = 0.004$). Conversely, comparisons between spring and summer ($U = 194.500$, $p = 0.420$) and spring and autumn ($U = 189.000$, $p = 0.229$) yielded no statistically significant differences (Table 29).

Table 30. Results of Mann-Whitney U-test comparing seasonal parasite infection values in *carassius gibelio* from Biskra region.

	Spring and summer	Summer and winter	Spring and autumn
***Ergasilus* sp. 1**			
P value	0.420	0.004	0.229
Mann–Whitney U value	194.500	130.000	189.000

The relationship between host fish total length and *Ergasilus* sp. 1. parasite abundance was examined, revealing a statistically significant, moderate positive correlation ($r = 0.422$, $p < 0.001$). This positive trend, where larger fish have a higher parasite load, is further shown in Figure 37, which shows the relationship between *C. gibelio* fork length and *Ergasilus* sp. 1.

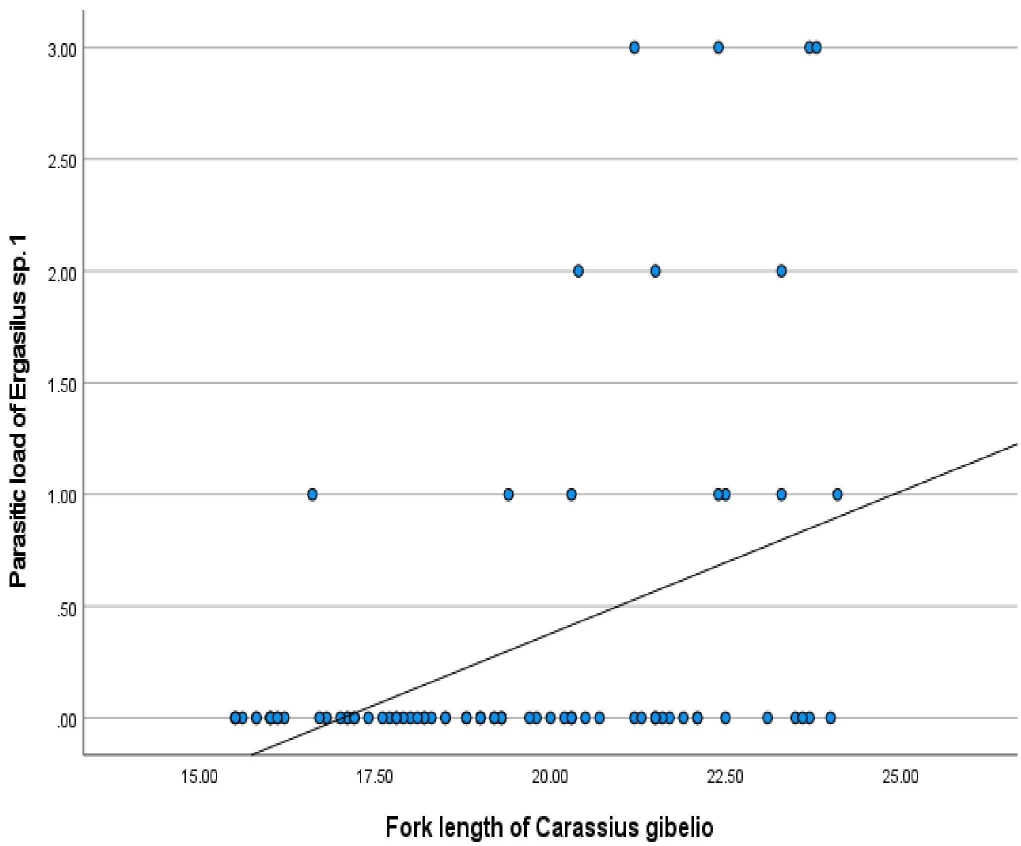


Figure 37. Relationship between the fork length of *Carassius gibelio* from the Biskra region and *Ergasilus* sp. 1.

The number of all examined fish is of 80 samples, of which, 50 were females and 32 were males. Table 30 illustrates the relationship between host fish sex and parasite infection values, demonstrating the impact of host sex on parasite infection. It can be observed that female host fish were more infected than males, as nine samples were infected with one or more *Ergasilus* sp. parasites, giving infection levels of prevalence, mean intensity and abundance of 18%, 1.78 ± 0.83 and 0.32 ± 0.77, respectively. Five male hosts were infected with the parasite identified in this fish species, the level of abundance was 0.28 ± 0.77, the prevalence 15.63% and the mean intensity 1.8 ± 1.10.

A Mann-Whitney U test revealed no significant difference in *Ergasilus* sp. 1 abundance between male and female fish (U = 780.500, p = 0.777).

Table 31. Distribution of infection values of parasites recorded in *Carassius gibelio* from Biskra region according to host sex.

	Sex Groups	
Parasites type	**Males**	**Females**
Number of examined fish	32	50
***Ergasilus* sp. 1**		
Number of infected Fish	5	9
Infection Prevalence (%)	15.63	18
Mean Intensity ±SD	1.80 ± 1.10	1.78 ± 0.83
Mean Abundance ±SD	0.28 ± 0.77	0.32 ± 0.77
Min – Max. Parasite Numbers	1–3	1–3
Total Number of Parasites	9	16

2.6. Nutrition

2.6.1 Stomach content

A comprehensive seasonal sampling effort was carried out to investigate the diet composition of *C. carpio* form the artificial lake of Chbika. The analyses of the vacuity index of the *C. carpio* samples according to the seasons are represented in Figure 38. Out of the total examined guts of the fish samples, 30 guts were found to be empty, representing 38.46% of the total number. The season during which a highest rate of empty guts was found is spring, giving a value of 75%, followed by summer with a rate of 66.67% and the lowest value of empty guts reached 5% and was recorded during winter season.

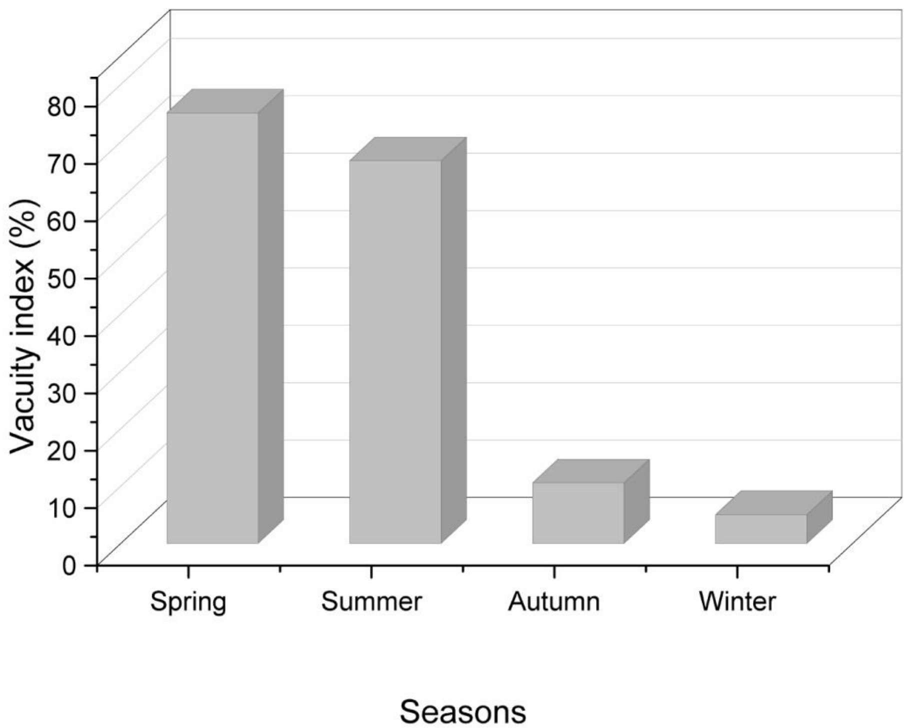


Figure 38. Seasonal variations of vacuity index (VI %) in *Cyprinus carpio*.

The gut contents of 78 specimens were subjected to analysis, a total of 1229 preys were identified, which revealed the presence of six distinct major groups: phytoplankton (green algae and diatom), zooplanktons (Copepoda, Cladocera and Rotifera), Insects, Ostracoda, detritus and macrophytes (Figure 39, 40, 41).

Figure 39. Copepoda from the gut of *Cyprinus carpio* (original photo).

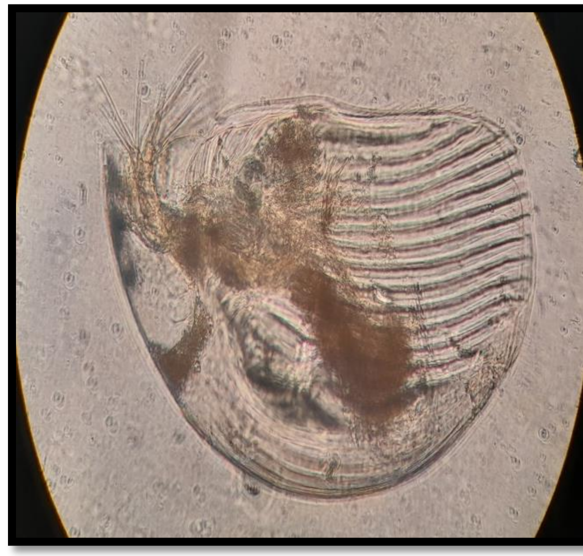


Figure 40. Cladocera from the gut of *Cyprinus carpio* (original photo).

Figure 41. Rotifera from the gut of *Cyprinus carpio* (original photo).

The relative dietary importance of each group was then quantified using frequency of occurrence (%F), numerical abundance (%N) and percentage index of relative importance (%IRI), the results of which are presented in Table 31. Copepoda and Cladocera are the most abundant during all seasons followed by phytoplankton. All five major groups were found during summer with the abundance of Copepoda, giving a value of %IRI 48.98 and Cladocera with %IRI of 45.10, the least abundant food item during this season is macrophytes. Rotifera, green algae, diatom and Ostracoda were all absent in winter season and macrophytes were also the least found during winter. Both autumn and spring were missing only one food item, macrophytes and Rotifeda, respectively (Table 31). The value of 48.89% represents the maximum recorded rate of numeric abundance, and was found for Copepoda during winter, followed by 43.97%, also found for the same consumed item. However, this value was recorded during summer.

Table 32. Seasonal food composition of *Cyprinus carpio* individuals.

		Zooplankton			Phytoplankton					
		Copepoda	**Cladocera**	**Rotifera**	**Green algae**	**Diatom**	**Macrophytes**	**Insects**	**Detritus**	**Ostracoda**
Spring	%F	20	20	_	15	15	10	20	10	5
	%N	22.55	11.91	_	24.68	32.34	0.85	4.68	0.85	2.13
	%IRI	27.08	14.30	_	22.22	29.12	0.51	5.62	0.51	0.64
Summer	%F	33.33	33.33	5.56	11.11	11.11	5.56	11.11	22.22	5.56
	%N	43.97	40.48	0.54	4.29	6.17	0.27	1.07	1.61	1.61
	%IRI	48.98	45.10	0.10	1.59	2.29	0.05	0.40	1.20	0.30
Autumn	%F	78.95	84.21	5.26	42.11	42.11	_	15.79	31.58	5.26
	%N	23.96	25.52	0.17	19.62	27.95	_	0,87	1.74	0.17
	%IRI	30.94	35.15	0.01	13.51	19.25	_	0.22	0.90	0.02
Winter	%F	25	30	_	_	_	5	15	20	_
	%N	48.89	33.33	_	_	_	2.22	6.67	8.89	_
	%IRI	48.67	39.82	_	_	_	0.44	3.98	7.08	_

-- : Absence

The highest value of the frequency of occurrence recorded in all guts was 84.21% and was recorded for Cladocera during autumn followed by 78.95% for Copepoda, and also found during the same season. Based on the results shown in Table 31 and Figure 42, it was determined that the most consumed food items by *C. carpio* during spring were Copepoda (20%), Cladocera (20%) and insects (20%), followed by phytoplanktons, represented by green algae (15%) and diatom (15%). During summer, Copepoda (33.33%) and Cladocera (33.33%) represent the most consumed food items, followed by detritus (22.22%), and the least consumed items during this season are Rotifera (5.56%), macrophytes (5.56%) and Ostracoda (5.56%). Cladocera (84.21%) and Copepoda (78.95%) are the most consumed by *C. carpio* during autumn, followed by green algae (42.11%) and diatom (42.11%) and followed by detritus (31.58%). *C. carpio* consumed only five food items during winter out of the total nine items found, and the most consumed items are Cladocera (30%) and Copepoda (25%), followed by detritus (20%) and insects (15%) and the least consumed group is macrophytes (5%).

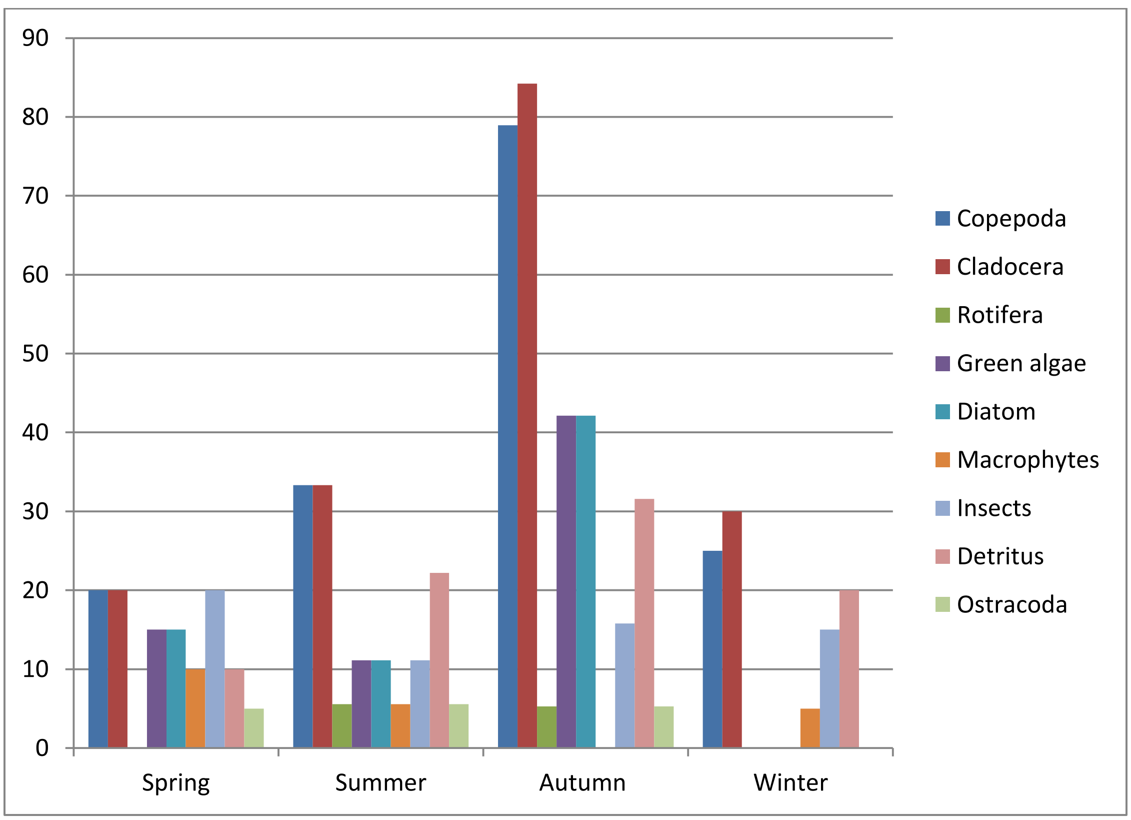


Figure 42. Frequency of occurrence (% F) of food items of *Cyprinus carpio* according to seasons.

The general dietary composition of *C. carpio* individuals indicated that Copepoda and Cladocera were the primary dietary component for this fish species, showing a high Index of Relative Importance (%IRI = 38.92, %IRI = 33.59, respectively). They were followed by diatom (%IRI = 12.67) and green algae (%IRI = 9.33), demonstrating their secondary importance in the species nutritional status. The least value of the %IRI were recorded for macrophytes (%IRI = 0.25), Ostracoda (%IRI = 0.24) and Rotifera (%IRI = 0.03). The distribution of these food groups is detailed in Figure 43.

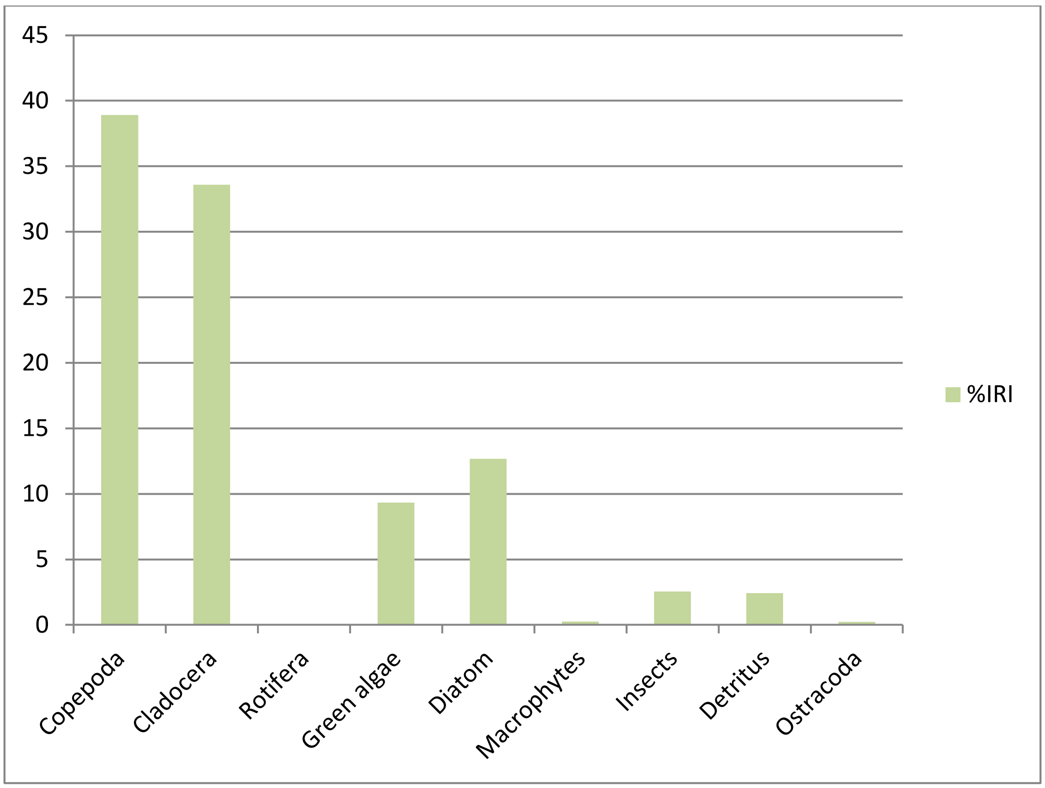


Figure 43. Relative importance index (%IRI) of food items in the guts of *Cyprinus carpio* individuals.

DISCUSSION

3. Discussion

The following study was conducted in three different regions, Biskra, Laghouat and Djelfa. Within the scope of this research, the first seasonal study of the parasitic fauna of the endemic fish species, *Luciobarbus biscarensis* from the Oued Tadmit River was conducted, along with the study of parasitic fauna of the fish species of *Cyprinus carpio* from two study regions, Chbika artificial lake, Djelfa, and the Lalmaia hillside reservoir, Laghouat, in addition to *Barbus* sp. also from the Lalmaia hillside reservoir, and *Carassius gibelio* from the Foum El Kherza dam, Biskra and *Oreochromis* sp. from three different fish farms in two study regions, two in the Biskra region and one in Djelfa region. Morphometric measurements, fish sex and weight along with their interactions were also evaluated for each fish species during this study using the ANCOVA analysis.

The ANCOVA analysis in *Oreochromis* sp. samples revealed that total length was a significant predictor of fish weight, which is consistent with the general understanding that larger fish tend to be heavier. Interestingly, sex also had a significant main effect, suggesting that there was a difference in average weight between male and female fish even after accounting for their size. The most notable finding was the significant interaction between sex and body depth, indicating that the relationship between this fish species body depth and its weight, as it varied depending on whether the fish was male or female. This suggests that body depth might contribute differently to overall weight in the two sexes, potentially reflecting differences in body shape or composition related to sex-specific roles or growth patterns. While standard length and cephalic length did not show significant independent effects on weight in this model, the strong influence of total length likely captures much of the overall size-related variation.

As for *C. carpio*, the significant model indicates that fish weight was influenced by the measured variables and their interactions with sex. Standard length and body depth significantly predicted weight overall. Importantly, the relationship between total length and weight, and standard length and weight, differed significantly between male and female fish. Other factors and their interactions with sex were not significant, suggesting their influence on weight was less pronounced in this model.

The significant overall model indicates that fish weight in *Barbus* sp. was well-explained by the measured variables and their interactions with sex. Total length and body depth were significant predictors of weight across all individuals. However, the lack of significant main effects for sex, standard length, and cephalic length suggests these factors did not have a substantial overall influence on weight in this model. Furthermore, the non-significant interaction terms indicate that the relationship between the morphometric variables (total length, standard length, body depth, and cephalic length) and weight did not significantly differ between male and female fish in this study.

L. biscarensis weights were significantly predicted by the overall model, with cephalic length being a key individual predictor. Furthermore, the significant interaction between sex and cephalic length indicates that the impact of head size on weight varied between male and female fish, suggesting a sex-specific relationship. Other individual factors and their interactions with sex did not significantly influence weight in this model.

The highly significant model indicates that *C. gibelio* fish weights were strongly predicted by the measured variables and their interactions with sex. Total length was a significant predictor of weight across all individuals. While sex and the other morphometric variables did not show significant main effects in this model, the near-significant interaction between sex and cephalic length suggests a potential trend where the relationship between head size and weight might differ slightly between male and female fish.

The examination of the *Oreochromis* sp. samples indicated an absence in parasitic infection in all three fish farms. These results are consistent with the reported water treatment protocols, such as the use of salt, used by the farm owners, which aimed to minimize the spread of parasites and ensure optimal fish health. Previous studies also confirmed the effect of Sodium chloride as an antiparasite agent, as it is widely used in fish farms to control parasites such as Argulids (Kabata, 1985; Dewi et al., 2018). Additionally, the second most frequently used product in the treatment of *Ichthyophthirius multifiliis* infections, which are one of the most virulent ectoparasites in freshwater fish with a global distribution, is NaCl, it was found to be effective in the control and treatment of this and other protozoan parasites such as *Chilodonella* spp. and *Trichodina* spp. (Tavares-Dias, 2022).

As a result of the research, two species of Monogenea were identified, which are *Dactylogyrus extensus* from the gills of *C. carpio* and *Dactylogyrus fimbriphallus* from the gills of *L. biscarensis*, one species of Cestoda (*Bothriocephalus acheilognathi*) in the intestines of *L. biscarensis* and *C. carpio*, one genus of *Ergasilus* in the gills of *C. carpio*, *Barbus* sp. and *C. gibelio*, two species of protozoa, *Trichodina* sp. found in the gills of *C. carpio* and *Myxobolus* sp. in the gills of *L. biscarensis* and *C. carpio*. Among the parasites identified, *D. fimbriphallus* is a new record for the helminth fauna of Algeria, and the second case reported globally, as it has been recorded previously only in Morocco, further expanding its known geographical range.

Many species belonging to the *Dactylogyrus* genus are identified in freshwater fish, they can be distinguished from each other based on their characteristic features such as the hard parts of the haptor and the characteristics of the reproductive organs. Individuals belonging to this genus are identified to species level using these characteristics (Pugachev et al., 2010). *D. fimbriphallus* and *D. extensus* were identified using the abovementioned features. Dactylogyrids are frequently occurring monogeneans, demonstrating a high degree of host specificity (Ozer, 2002). Indeed, *D. fimbriphallus*, found in this study, is specific to fish species belonging to *Luciobarbus* and *Barbus* genera, as it was found in 33 of the total 78 *L. biscarensis* sample examined in the course of this study, with a total of 306 parasite individuals. This parasite species was recorded in the fish species of *Luciobarbus issenensis*, *Luciobarbus massaensis*, *Luciobarbus figuigensis*, *Luciobarbus pallaryi*, *Luciobarbus lepineyi* and *Luciobarbus moulouyensis*, from Oum Er-Rbia, Sebou and Moulouya rivers, and from Draa, Noun, Massa, Guir and Souss basins in Morocco (El Gharbi et al., 1994; Benovics et al., 2020; Dlapka, 2020; Rahmouni et al., 2020). Since *D. fimbriphallus* was only recorded in the previously mentioned fish species and only in Morocco, and based on this study, *L. biscarensis* is considered a new host for this parasite species, and Algeria, specifically, the Oued Tadmit River, is considered new locality record for its geographical distribution (Chabira et al., 2025).

The second reported Monogenea species is *D. extensus*, which a species frequently associated with cyprinid fishes, and widely distributed in Europe, Asia and North America (Pugachev et al., 2010), it has been reported in *C. carpio* in many countries across the world such as Egypt by Attia et al. (2022), Turkey by Ozer (2002), Germany by Dzika et al. (2009). However, it has been reported in three fish species in Algeria, in *Barbus callensis*, *Barbus setivimensis* (Meddour, 2009) in and in *C. carpio* (Allalgua et al., 2015), and all three species have been collected from the north-eastern part of Algeria. This study documents the first recorded occurrence of *D. extensus* in the Northern Sahara region of Algeria, expanding the known distribution of this species.

An analysis of the seasonal variation of the monogenean parasite species within their fish hosts was conducted, demonstrating that the infection values by these parasites are subject to seasonal changes. The data from both study regions (Laghouat and Djelfa) revealed a similar pattern in the infection of *C. carpio* with *D. extensus*, with peak parasitic infection values in summer and minimum values in winter (not recorded during winter in Laghouat region). Similarly, *D. fimbriphallus* infection values were at their lowest in winter. However, the maximum values were recorded during autumn.

Only one previous study was conducted regarding the infection values of *D. fimbriphallus* (Dlapka, 2020). According to this study, a mean intensity of 91% and a prevalence of 2.1 ± 1.5, were for *D. fimbriphallus* infecting *L. massaensis* fish species in Morocco. In light of the present study, the infection parameters of this parasite species in *L. biscarensis* were 42.31% , 9.27 ± 12.50 parasites per fish and 3.92 ± 9.28 for the prevalence, mean intensity and abundance. Due to the absence of prior studies on this dactylogyrid infection parameters in freshwater fish within our country, a direct comparison with existing studies was not possible. However, the mean intensity observed in this investigation aligns closely with the 2.1 ± 1.5 value reported for in *L. massaensis* Morocco. Many factors could lead to the change in the values of the infection parameters including, abundance, mean intensity and prevalence. They could be related to the host sex, behaviour, age, the biology of the parasite and the environmental changes, wich could influence the proliferation and the establishment of the parasite (Tombi and Bilong, 2004; Šimková et al., 2005; Khan, 2012; Koyun et al., 2015; Sarabeev et al., 2019).

D. extensus was previously reported by Meddour (2009) the gills of *C. carpio* caught from Lake Oubeira. This species was also reported in Foum El-Khanga dam in *C. carpio* fish samples, yet the overall infection values were not mentioned. However, a seasonal investigation was conducted, showing a maximum prevalence of 60% during summer, and absence during autumn and winter. These findings are in accordance with the established results of this study as the prevalence also peaked during summer and reached 75% in both regions, and the parasite during winter was absent in Laghouat and reached its lowest values in Djelfa (Allalgua et al., 2015), these findings are also in agreement with those of Aydogdu et al. (2001). Several studies have demonstrated the infections caused by many *Dactylogyrus* species, generally have a tendency to increase in spring and early summer when these parasites proliferate (Kennedy, 1975; Koskivaara et al. 1991; Abdullah and Nasraddin, 2020). These findings align with our results regarding *D. extensus* species. Other investigations have reported that during autumn, high dactylogyrid infection levels are found (Raissy et al., 2013; Aydoğdu and Kubilay, 2017; Tunç and Koyun, 2018). Our results for *D. fimbriphallus* were consistent with these findings.

The relationships between the changes in the infection values (prevalence, mean intensity and abundance) of the Monogenea parasite species identified in our study and the length of the host fish individuals were also determined. This relationship was found in many studies. In the analyses made within the scope of this study, a statistically significant, weak positive association between the length of host fish and the quantity of dactylogyrid parasites was found for *D. extensus* in *C. carpio* in Djelfa ($r = 0.222$, $p = 0.046$) and in Laghouat ($r = 0.346$, $p = 0.002$) and *D. fimbriphallus* in *L. biscarensis* ($r = 0.287$, $p = 0.011$), as larger host fish tended to have more parasite individuals. Our results are consistent with the studies conducted by Kurupınar and Öztürk, 2009; *Öztürk, 2014;* Allalgua et al. (2015); Aydoğdu et al. (2015); Attir et al. (2017), that have demonstrated that the number of *Dactylogyrus* parasites increases with host fish length, implying a direct link between these two variables across diverse freshwater fish species in many countries.

Some authors including Bilong-bilong (1995); Bakke (2002); Aydoğdu et al. (2003); Özer and Öztürk (2005), have suggested that this positive correlation between the infection parameters and the host length could be due to the fact that larger fish possess greater gill surface area. This provides a more extensive habitat for the parasites to attach and proliferate. Additionally, larger fish have had longer time of exposer to potential parasite infections, therefore accumulating more parasitic loads.

Furthermore, the study investigated how Monogenean parasite infection values varied with the sex of host fish individuals, giving that host sex is considered as an important biotic factor (Pickering and Christie, 1980; Singhal and Gupta, 2009; Vankara et al., 2011; Gupta et al., 2012; Elbay and Öztürk, 2021). Within this investigation regarding the effect of host sex on the three dactylogyrid parasites identified in the course of this study, the infection levels of *D. extensus* in *C. carpio* and *D. fimbriphallus* collected from *L. biscarensis*, were found to be higher in female host fish, as they showed levels of abundance and mean intensity higher than those recorded in male samples. These results corroborate the findings of Attir et al. (2017), where the prevalence of infection of *Cichlidogyrus cubitus* in *Tilapia zillii* was higher in female than in male hosts. Other studies also supported these findings including those of Ozer and Öztürk (2005); Açikel and Öztürk 2012; Aydoğdu and Kubilay (2017), the aforementioned authors suggested that these variations could be attributed to the hormone status, mucus secretion and the parasite biology. Furthermore, authors also link the female fish vulnerability to the fact that the reproductive investment and producing eggs requires a substantial energy investment, which can divert resources away from the immune system, increasing vulnerability (Šimková et al., (2005); Koenigbauer and Höök, 2023).

During this study one species belonging to the Cestoda class was identified; *B. acheilognathi*, it was found in the intestines of *L. biscarensis* and in *C. carpio*. This parasite species belongs to the Botheriocephalidae family characterized with its elongated, rectangular-shaped scolex. It was identified for the first time in Japan (Yamaguti, 1934), and is known to parasitize a wide range of fish species of belonging to the Cyprinid group (Scholz and Cave, 1992). The geographical range of this species, was initially restricted to Japan, China and Russia until the mid-20th century, it was expanded significantly due to its introduction, via *Ctenopharyngodon idella* and *C. carpio* for breeding. It is now known to parasitize fish in numerous countries across New Zealand, Africa, South and North America and Europe (Scholz and Cave, 1992). This species have been reported previously in our country, in the Oubeira Lake, in the northeastern region of Algeria in Cyprinidae by Meddour et al. (2010), in *C. carpio* in the same lake by Brahmia et al. (2016) and in *L. callensis* in Beni Haroun Dam (Tolba, 2019).

Additionally, Attir (2018) reported the presence of Cestoda parasites in Cyprinidae fish species; *Barbus biscarensis*, *C. gibelio*, *C. carpio* from the Fountain of the Gazelles and the Foum El-Kherza dams in Biskra, Algeria. And in Cichlidae fish species including *Tilapia nilotica*, *T. zillii* collected from the Megarine Lake and the Drains of Zaouia Labedia in Touggourt, Algeria. Chaibi (2013) also mentioned the presence of *Bothriocephalus* sp. in *Barbus* sp. in Batna, Djelfa and Laghouat regions also in Algeria. To our knowledge, this study documents the first occurrence of *B. acheilognathi* parasite species in the Algerian Northern Sahara and also the first record of this parasite species in the endemic fish *L. biscarensis*. In light of these data it is thought that *L. biscarensis* is a new host record for *B. acheilognathi* and that a new locality has been added to the distribution of this species in our country, which is the Oued Tadmit River in the region of Djelfa.

During the study of the seasonal variation of *B. acheilognathi* in both host fish, *C. carpio* and *L. biscarensis*, it was found that the infestation levels were highest during spring and summer for both hosts. This seasonal pattern is consistent with observations from other researchers in diverse geographical locations. For example, Tekin-Özan et al. (2008) reported increased *B. acheilognathi* infection in *C. carpio* from Beyşehir Lake, Turkey, during these warmer months. Similarly, Koyun et al. (2015) documented elevated *B. acheilognathi* prevalence in *Barbus lacerta* within the Murat River, Turkey, during the same period. Further supporting this trend, *C. carpio* from Kovada Lake, Turkey, also exhibited higher infestation levels during summer (Kır and Tekin-Özan, 2007).

The life cycle of this parasite involves several copepod species, including *Cyclops abyssorum*, *Mesocyclops leuckarti*, *Ectocyclops phaleratus*, and *Thermocyclops taihokuensis*, which act as intermediate hosts. These copepods ingest the parasite's liberated larval stage, allowing the procercoid to develop within them (Hoole et al., 2001). Fish, such as *C. carpio*, become infected by consuming these infected copepods (Hoole et al., 2001). *C. carpio* is known to consume a diverse range of plant and animal matter, and particularly, carp fry, which rely heavily on zooplankton, are more susceptible to infection (Skelton, 2001). This suggests that the seasonal dynamics of parasite infection may be influenced by fluctuations in food availability, particularly infected copepod sources, as various copepod genera serve as compatible intermediate hosts (Hoole et al., 2001). Korting (1974) indicated that the period of early spring, when plankton and subsequently copepods proliferate, represents a significant period for seasonal incidence and infective transmission. In temperate regions, it is hypothesized that Cestoda parasites overwinter within the intestines of their definitive fish hosts (Kır and Tekin-Özan, 2007). Consequently, younger fish may exhibit two distinct populations of parasites: smaller worms resulting from recent infections and larger individuals acquired during the preceding spring or summer (Kır and Tekin-Özan, 2007). Moreover, other researchers have documented the utilization of planktonic or benthic copepods as intermediate hosts by metacestodes (Marcogliese and Esch, 1989; Williams and Jones, 1994). These findings corroborate with our own observations in Djelfa, Algeria, where we found higher levels of *B. acheilognathi* infestation occurring during spring and summer.

However, it is important to note that some researchers have also reported increased *B. acheilognathi* infestation during winter months. For instance, Brahmia et al. (2016) found that *B. acheilognathi* parasites were essentially present during winter season in *C. carpio* samples from Oubeira Lake, Algeria. Similarly, Sheikh et al. (2014) reported an increase in *B. acheilognathi* infection in *C. carpio* from Dal Lake, Kashmir during winter. This suggests that the seasonal dynamics of *B. acheilognathi* infection may be influenced by a complex interplay of environmental and host-related factors, varying across different geographical regions and aquatic ecosystems.

The evaluation of host size and sex effects on the infestation level of *B. acheilognathi* in both *C. carpio* and *L. biscarensis* revealed that the infection parameters were higher in male hosts than female fish samples. Sheikh et al. (2014) found lower numbers of infected *C. carpio* females than in males with this Cestoda parasite. The observed pattern, consistent across both studies, may be attributed to the immunocompetence handicap hypothesis which suggests that the steroid hormones, such as those responsible for the development of sexual characteristics in males can induce immunosuppression especially during the reproductive phase. This could theoretically heighten the susceptibility of carp male individuals to parasitic infection during their breeding (Rohlenová et al., 2011). As for the host size, it was observed that fish with larger size of both fish species; *C. carpio* and *L. biscarensis*, tend to have more parasitic loads of *B. acheilognathi* than smaller sized fish. This aligns with the observations of Tekin-Özan et al. (2008), who also reported *B. acheilognathi* in all fish sizes, but with higher prevalence in the largest size classes of *C. carpio* from the Beyşehir Lake, Turkey. Tekin-Özan et al. (2008) suggested that this trend may be attributed to the age of the fish, a factor that could also contribute to the increased prevalence observed in our study.

Parasites belonging to the Copepoda class were also identified to genus level in the course of this study. The genus *Ergasilus* was recorded from the gills of *C. carpio* and *Barbus sp*. collected from the Lalmaia hillside reservoir, from the second study region, which is Laghouat. It was also recorded from *C. gibelio* samples collected from Biskra study region, from the Foum El Kherza dam. This copepod genus was first described by von Nordmann in 1832. Subsequently, Burmeister established the family Ergasilidae in 1835 to which *Ergasilus* belongs, it is widely distributed in freshwater, brackish and marine environments (Míč et al., 2023), yet the majority of its species are found on freshwater fishes (Varella et al., 2019).

The copepod parasite *Ergasilus* sp. has been previously documented in various regions of Algeria (Chabira et al., 2024), indicating its established presence and wide distribution across different aquatic ecosystems. Notably, Chaibi (2013) reported its occurrence in *Barbus* sp. within Oued el Ghaicha, highlighting its presence in riverine habitats. Further investigations have confirmed its presence in lentic environments, as evidenced by Boucenna et al. (2015), who found *Ergasilus* sp. in *C. carpio* within the Foum El Khanga dam in Souk-Ahras. More extensive studies conducted at the Beni-Haroun Dam in Mila by Berrouk et al. (2019, 2020a, 2020c) revealed a broader host range, with *Ergasilus* sp. infecting *Luciobarbus callensis*, *Carassius carassius*, *C. carpio*, and *Abramis brama*. These studies collectively demonstrate the parasite's adaptability to diverse host species and aquatic environments within Algeria, underscoring its ecological significance.

Seasonal variations in infection parameters of parasites belonging to the *Ergasilus* genus were evaluated during this study. The results indicated a notable common point between the three fish species examined, as there was a high prevalence of the parasites during the summer months. While *C. carpio* showed a peak in autumn and summer, *Barbus* sp. and *C. gibelio* showed their highest parasite loads during summer and spring. This consistent summer peak among various fish species strongly suggests that environmental factors associated with the summer period, such as increased water temperatures and potential changes in copepod populations, play a critical role in the dynamics of *Ergasilus* parasites in the aquatic ecosystem of the three studied regions, Biskra, Djelfa and, Laghouat. This observation is consistent with findings from other studies in the region. For instance, Berrouk et al. (2019), studying the Beni-Haroun Dam in Mila, Algeria, reported significant numbers of Ergasilidae and Lernaeeidae parasites. Similarly, Boucenna et al. (2015) noted higher infestation rates and parasite loads during spring and summer, with minimal infestation in autumn and no parasites found in winter. These results align with research on other fish species and copepod parasites, such as Anvarifar et al. (2014) on *Capoeta gracilis*, Rohlenova et al. (2011) on *C. carpio*, and Nematollahi et al. (2013) on *C. carpio* and *Lernea cyprinacea*, all of which reported peak parasite prevalence during spring and summer. Collectively, these studies, including our own, highlight the significant impact of summer-related environmental factors on copepod parasite dynamics across diverse fish species and aquatic ecosystems in Algeria and beyond.

Our investigation into the influence of host sex on *Ergasilus* parasites infestation levels revealed a consistent trend across all three examined fish species collated from two study regions: females exhibited higher parasite loads compared to males. This pattern aligns with findings from Berrouk (2019), who also reported increased parasitic indices in female *C. carpio* from the Beni-Haroun Dam in Mila, Algeria, however, these differences were not significant. On the other hand, our study, conducted in Djelfa, Laghouat and Biskra, revealed a statistically significant increase in the parasites infestation levels in larger host fish across all three species examined*: C. carpio*, *Barbus* sp., and *C. gibelio*. This finding is consistent with previous research demonstrating a positive correlation between host size and parasite load. Berrouk (2019), for example, reported that in *C. carpio* from the Beni-Haroun Dam in Mila, Algeria, fish in the larger size range of 45-50 cm exhibited significantly higher parasite infestation. Similarly, Boucenna (2015) found that larger *C. carpio* (37-47 cm) in Algeria were more heavily parasitized. This trend is not limited to *C. carpio*; Ibrahimi (2012) in *T. zillii*, Stavrescu-Bedivan et al. (2014) in *Lepomis gibbosus*, Perez-Bote (2000) in three Cyprinidae species (*Leuciscus alburnoides*, *Chondrostoma willkommii*, *Barbus sclateri*), and Talib Mansoor and Jawad Al-Shaikh (2011) in *C. carpio* all reported increased parasite loads in larger fish. These consistent observations, across various fish species and parasite types, suggest that larger fish may offer a more favorable environment for parasite establishment and proliferation, potentially due to factors such as increased habitat area, longer exposure time, or physiological changes associated with age and size, as mentioned previously.

In the fish species examined from Djelfa and Laghouat regions, the protozoan parasite *Myxobolus* sp. was identified during this study in the gills of *L. biscarensis* and *C. carpio* collected form Oued Tadmit River, Djelfa, and Lalmaia hillside reservoir, Laghouat, respectively.

Myxozoans, a large and diverse group of microscopic obligate endoparasites, have been a subject of scientific interest since their discovery in the early 19th century. Recent morphological and phylogenomic analyses have placed Myxozoa within the phylum Cnidaria, a group that also includes corals, sea anemones, jellyfish, and hydroids (Atkinson et al., 2018). However, unlike their free-living relatives, myxozoans exhibit highly reduced body plans. Myxosporeans (Myxozoa: Myxosporea) are particularly common parasites of fishes (Kent et al., 1993). They affect both wild and farmed populations and cause diseases such as whirling disease and proliferative kidney disease (Okamura et al., 2015). To date, over 2,600 myxozoan species have been described worldwide, representing approximately 20% of cnidarians (Okamura et al., 2018; Eiras et al., 2021), with the genus *Myxobolus* Bütschli, 1882, being the largest, comprising almost 900 valid species (Eiras et al., 2005, 2014, Liu et al., 2014, Naldoni et al., 2015, Székely et al. 2015). These parasites are diverse and widespread (Eiras et al., 2021), and their presence in fish populations, as observed in our study, within both the natural Oued Tadmit River and the artificial Lalmaia hillside reservoir, underscores their ecological significance in both natural and managed aquatic ecosystems.

The genus *Myxobolus* has been widely documented in Algeria, indicating its established presence and diverse host range across the country's aquatic ecosystems. Notably, Chaibi (2013) reported *Myxobolus* sp. in *Barbus* sp. from Laghouat and Djelfa, as well as in *Barbus* sp., *Carassius* sp., *C. carpio*, and *Pseudorasbora parva* from Batna, highlighting the parasite's adaptability to various fish species and geographical locations. Attir (2018) further expanded the known distribution and host range of *Myxobolus* in Algeria, documenting its presence in *Aphanius fasciatus*, *Barbus* sp., *C. carassius*, *P. parva*, and *Pseudophoxinus* sp. from El Oued, M'sila, Laghouat, and Batna. Additionally, Ghazi et al., (2018) reported *Myxobolus* sp. in *A. fasciatus* from El M'Ghair. These studies, including our own findings in Laghouat, Algeria, collectively demonstrate the widespread distribution and ecological significance of *Myxobolus* parasites in Algerian fish populations, underscoring the need for further research into their impact on fish health and biodiversity in the region.

Our investigation into the seasonal dynamics of *Myxobolus* sp. infection levels revealed a distinct pattern of parasite abundance across the studied fish populations. Specifically, we observed that both *C. carpio* and *L. biscarensis* exhibited the highest *Myxobolus* sp. infection levels during the autumn season. This peak in autumn was followed by a secondary, yet still substantial, increase in parasite abundance during the summer months. Notably, the spring and winter seasons showed comparatively lower infection levels in both fish species. These findings align with observations from Guitang et al. (2003), who noted similar seasonal patterns in myxosporean parasite abundance.

They cited studies showing that *Myxobolus gibelioi* and *Thelohanellus wuhanensis* exhibited higher prevalence in autumn and summer, respectively, and lower prevalence in spring. Guitang et al. (2003) explained that the seasonality of myxosporean infections is influenced by factors such as the parasite's life cycle. *Myxobolus* parasites have a complex lifecycle, involving two hosts: fish and oligochaete worms. In the fish host, *Myxobolus* forms spores. These spores, when released into the water, infect oligochaete worms, where they undergo a developmental phase called the actinosporean stage. The actinosporean forms are then released from the oligochaete and infect fish, completing the cycle (Okamura et al., 2015). The synchronized development of these stages with the seasonal cycles of both oligochaete and fish populations, as well as the developmental rates of the parasite within these hosts, significantly impacts the observed seasonal fluctuations of parasite abundance (Guitang et al., 2003). The consistent trend of higher myxosporean prevalence in autumn and summer, observed in both our study and the cited research, underscores the influence of these environmental and biological factors on parasite dynamics.

During this study, varying effects of host sex and size on *Myxobolus* sp. infection levels were observed. In *L. biscarensis*, while infection prevalence was higher in males, mean intensity and abundance were elevated in females, and parasite numbers were slightly higher in smaller fish; however, these differences were not statistically significant. In contrast, *C. carpio* exhibited significantly higher infection levels in females and larger-sized individuals. These findings highlight the complex and often species-specific nature of *Myxobolus* infections, a pattern echoed in other studies. Zhang et al. (2010) found no host sex specificity for *Myxobolus turpisrotundus* in *Carassius auratus auratus*, but observed a significant increase in prevalence and abundance with host size, suggesting a cumulative effect of parasite load in larger fish. Conversely, Flores and Viozzi (2001) reported that *Myxobolus magellanicus* infection in their study was independent of host sex and decreased with host length, similar to observations with *Ceratomyxa* spp. in sea bass. Gbankoto et al. (2003) noted a significantly higher infection rate in male *Sarotherodon melanotheron melanotheron* and *T. zillii*, attributing this to potential testosterone-related immunosuppression, and found that medium-sized fish were most affected, possibly due to mortality of heavily infected larger individuals. These contrasting results across different fish species and *Myxobolus* species underscore the influence of host physiology, size-related factors, and potentially environmental variables on parasite susceptibility.

In our study, the significant differences observed in *C. carpio*, collected from an artificial site, suggest that these factors, perhaps including the unique conditions of an artificial aquatic environment, may play a more pronounced role in this species compared to *L. biscarensis*, which was collected from the a riverine ecosystem. The differing environmental conditions between these two habitats in Djelfa and Laghouat, Algeria, could contribute to the observed disparities in parasite infection patterns.

The second identified protozoa parasite during this study is *Trichodina* sp., this parasite species was found in *C. carpio* fish samples collected from the artificial lake of Chbika. The genus *Trichodina* (Ehrenberg, 1838), belonging to the family Trichodinidae, represents the largest group of these ciliate protists, recognized as significant agents of trichodiniasis in a wide range of aquatic animals (Marcotegui et al., 2018; Martins et al., 2015). With a substantial number of described species, exceeding 200 according to Asmat (2004) and approaching 300 as reported by Tang and Zhao (2011; 2012), *Trichodina* species are globally distributed across diverse aquatic environments. These ciliate protozoans are frequently encountered as ectocommensals and are considered among the most common protozoan parasites of fish in both marine and freshwater ecosystems (Martins and Ghiraldelli, 2008). The wide geographical dispersal of trichodinid ectoparasites is significantly influenced by human activities, particularly the transportation of aquaculture and ornamental fish species (Albaladejo and Arthur, 1989, Van As and Basson, 1989). Within Algeria, this group has been extensively documented across various fish species and geographical regions. Attir (2018) reported *Trichodina* sp. in *A. fasciatus*, *C. carpio*, and *Barbus* sp. from Djelfa, Batna, and El Oued. Salhi (2022) identified *Trichodina* sp. in *Pseudophoxinus* sp. from M'sila. Chaibi (2013) also found *Trichodina* sp. in *Barbus* sp. from Djelfa, Batna, and Laghouat, as well as in *Pseudophoxinus* sp. from M'sila and *A. fasciatus* from El Oued. Furthermore, Ghazi (2018) documented *Trichodina* sp. in *A. fasciatus* from El Oued. These studies collectively demonstrate the widespread presence and diverse host range of *Trichodina* species within Algerian aquatic ecosystems.

Trichodina sp. infection levels in *C. carpio* peaked during the spring season, with the lowest levels observed in winter. This finding is consistent with observations reported by Blazhekovikj-Dimovska and Stojanovski (2020), who also documented the highest mean intensity of *Trichodina* sp. in *C. carpio* from Macedonian aquaculture facilities during spring. Similarly, Ôzer (2000) found that *Trichodina mutabilis* and the *Trichodina acuta*-*Trichodina nigra* group infestations in *C. carpio* reached their highest levels in spring, further supporting the existence of a spring-dominant seasonal pattern. However, it is important to note that Migala (1971) reported a contrasting trend in Poland, observing higher *T. acuta* and *T. nigra* levels in *C. carpio* during summer and autumn, with a decrease in spring. The preference of trichodinids for spring, as seen in our study and those of Blazhekovikj-Dimovska and Stojanovski (2020) and Ôzer (2000), is generally attributed to the weakened condition of fish hosts after wintering and the onset of the spawning season, potentially making them more susceptible to parasitic infections. These varied results highlight that seasonal patterns in *Trichodina* infection can be influenced by geographical location, environmental factors, and host physiology.

The evaluation of the effect of host size and sex on the level of parasitism revealed that *Trichodina* sp. infection levels in *C. carpio* were significantly influenced by both host size and sex. A significant increase in parasite numbers in larger-sized fish was recorded, and male hosts exhibited higher infection levels compared to females. While Ôzer (2020) reported no statistically significant preference for either carp sex, they did note that male carp tended to have higher intensities of infestation, a trend consistent with our findings. The observed increase in parasite numbers with host size may reflect the cumulative effect of parasite exposure over time in larger, older fish. The higher infection rates in male fish could be attributed to physiological factors, as suggested by Pickering and Christie (1980), such as mucus, color, and hormonal status. Male fish, particularly during the spawning season, experience changes in epidermis thickness and a reduction in mucus cells, potentially making them more susceptible to ectoparasitic infections. These results suggest that both host size and sex play a role in *Trichodina* infection dynamics in *C. carpio* within the Chbika Artificial Lake of Djelfa, and are likely influenced by a complex interplay of ecological and physiological factors.

Within the scope of the current study, the gut contents of 78 *C. carpio* individuals form the artificial lake of Chbika were examined seasonally. The result of this evaluation revealed a significant seasonal pattern in the vacuity index of *C. carpio*, with the highest index (75%) observed in spring and the lowest (5%) in winter, resulting in an annual average of 38.46%. This annual average is consistent with findings from other Algerian water bodies, such as Foum El-Khanga dam (43.80%) reported by Sahtout et al. (2018), and Lake Oubeira (34.16%) reported by Brahmia (2016), as well as values reported from Keddara dam (35.29% to 42.31%) by Hadou-Sanoun et al. (2013). The observed spring peak in vacuity index, similar to the 83.33% reported by Sahtout et al. (2018) for May, the 53.33% reported by Brahmia (2016), and the 56.67% reported by Manon and Hossain (2011) for April, strongly suggests a link to the *C. carpio* breeding period. As noted by Shukla & Patel (2013), feeding intensity in *C. carpio* is notably reduced during spawning. This phenomenon is likely due to the increased gonad weights during spring, which can compress the digestive tract, as suggested by Boet (1980), and the increased energy demands for breeding, as highlighted by Froese and Pauly (2000). Conversely, the minimal vacuity observed in winter (5%), aligning with the 3.33% reported by Sahtout et al. (2018) for December, indicates a period of heightened feeding activity, potentially to compensate for energy expenditure during breeding, as mentioned by Darbal et al. (2007). These seasonal patterns in *C. carpio* feeding activity, observed in our study and corroborated by research from other Algerian aquatic ecosystems, underscore the influence of reproductive cycles and environmental factors on fish trophic ecology.

Gut content analysis of *C. carpio* samples in this study revealed a diverse diet, comprising phytoplankton (green algae and diatoms), zooplankton (Copepoda, Cladocera, and Rotifera), insects, ostracods, detritus, and macrophytes. This broad dietary spectrum is consistent with findings from other studies. Ayalew et al. (2025) also identified a wide range of prey items in *C. carpio* diets, including macrophytes, gastropods, ostracods, fish eggs, sand particles, detritus, phytoplankton, zooplankton, insects, and digested materials. Similarly, Sahtout et al. (2018) reported that *C. carpio* exhibits an extended dietary range, consuming crustaceans (copepods and cladocerans), phytoplankton (algae), plant debris, fish, insects (dipterans), mud, nematodes, and unidentified items. These results align with observations from Wagaw et al. (2024), who found that *C. carpio* in Arekit Lake, Ethiopia, fed on zooplankton, phytoplankton, detritus, and insects. As noted by Sahtout et al. (2018), the qualitative and quantitative composition of the *C. carpio* diet can vary depending on the region and the availability of prey items. The diversity of food sources found in our study, along with the reported variations in other regions, underscores the adaptability of *C. carpio* to different aquatic environments and its ability to exploit a wide range of food resources.

The findings of examination of the gut content of the fish samples revealed that *C. carpio* exhibited a clear preference for zooplankton, specifically crustaceans (Copepoda and Cladocera), across all seasons, as evidenced by their high frequency of occurrence (F%). However, the consumption of these crustaceans peaked during autumn and summer, declining in winter and spring. This seasonal pattern is further supported by our Relative Importance Index (IRI%), which also highlighted the dominance of Copepoda and Cladocera, followed by phytoplankton (green algae and diatoms) in the *C. carpio* diet. This preference for crustaceans aligns with the findings of Sahtout et al. (2018), who identified crustaceans as the primary food item for *C. carpio*, followed by phytoplankton, suggesting a bottom-feeding behavior consistent with other studies (Jan and Das, 1970; Shafi et al., 2012; Naik et al., 2015). Sahtout et al. (2018) also noted the omnivorous nature of *C. carpio*, with a higher consumption of animal-origin food, a trend observed in various other regions (Magalhaes, 1993; Blanco et al., 2003; Saikia and Das, 2008; Dadebo et al., 2015; Brahmia., 2016). Our observation of seasonal variations in zooplankton consumption is also consistent with Ayalew et al. (2025), who reported that zooplankton was the most significant food item during dry months, but decreased during wet months. They attributed this to potential increases in water turbidity and habitat changes due to rainfall, which could affect zooplankton availability and *C. carpio* feeding patterns, a trend supported by other research (Dedabo et al., 2015; Tesfaye et al., 2020; Tessema, 2020). These findings, including our own, further highlight the adaptable feeding strategy of *C. carpio*, which is influenced by both seasonal changes and regional environmental conditions.

In the light of this study, individuals belonging to the Copepoda group, which are intermediate hosts for *B. acheilognathi*, were identified in the gut contents of *C. carpio*. This consistent presence of copepods in the *C. carpio* diet, observed throughout the study period, provided a clear explanation for the infection of *C. carpio* with the *B. acheilognathi* parasite species. The consumption of these copepods, serving as intermediate hosts, directly facilitates the transmission and establishment of *B. acheilognathi* within the *C. carpio* population in the Chbika Artificial Lake of Djelfa, Algeria.

CONCLUSION AND PERSPECTIVES

Conclusion and perspectives

The effect of various morphometric measurements, sex, and their interactions on the weight of the studied fish species has been thoroughly evaluated through statistical analysis. This assessment provides a valuable foundation for understanding the complex relationships between body size, shape, and sex in determining the overall weight of this species. The findings from this evaluation will contribute to a more comprehensive understanding of its biology and potential ecological implications.

In the light of this study, the parasitic fauna of the freshwater fish species studied in three regions in the northern Sahara of Algeria was successfully documented. As a result of this study, six parasite species and genera were identified; *Ergasilus* sp., *Myxobolus* sp., *Trichodina* sp., *Dactylogyrus extensus*, *Dactylogyrus fimbriphallus* and *Bothriocephalus acheilognathi*. Among these identified species, we believe that *B. acheilognathi* is reported for the first time in the endemic fish species of *Luciobarbus biscarensis* and this fish species is also found to be a new host for *D. fimbriphallus* as this parasite is being recorded for the first time outside of Morocco where it has been reported for the first time, this is its second report globally, adding new data to its geographic distribution and its host range. Throughout this study, a detailed evaluation was conducted to understand the dynamics of parasite infections in the examined freshwater fish species. Specifically, the infection values including prevalence, mean intensity and abundance for each of the identified parasite species were assessed in relation to several key factors. These factors included the seasonal variations prevalent in the three study regions (Biskra, Djelfa and Laghouat), allowing for the identification of temporal patterns in parasite occurrence and abundance. Furthermore, the influence of host fish size was thoroughly investigated to determine if larger or smaller fish exhibited differential susceptibility or parasite burdens. Finally, the data were analysed across distinct sex groups within the fish populations to ascertain if any sex-specific differences existed in parasite infection profiles. This multifaceted approach aimed to provide a comprehensive understanding of the ecological and host-related drivers influencing the infection patterns of the diverse parasite community within the freshwater fish of the Northern Sahara.

This study represents a significant step towards expanding the body of knowledge concerning freshwater fish parasites in Algeria, particularly those affecting both common and endemic species. Prior to this research, the literature revealed a conspicuous paucity of investigations into the parasitic fauna of the country's diverse array of natural and endemic fish populations. This disparity in research attention has resulted in a critical gap in our understanding of parasite-host interactions within Algerian aquatic ecosystems. Consequently, this research not only contributes novel data on the biodiversity of copepod, protozoan and helminth parasites of fish in the Northern Sahara region, but also serves to underscore the urgent need for more comprehensive studies across the country and especially in this same study region. By focusing on both widespread and regionally unique fish species, like *Luciobarbus biscarensis,* this work provides a foundation for future investigations into the ecological roles of parasites and their impacts on fish health and ecosystem stability within Algeria's freshwater environments. The data gained from this study is a vital contribution to the limited data available, and opens the door for further studies. Further research should focus on the long-term monitoring of parasite communities in relation to climate change, and investigations into the specific impacts of these parasites on the health of endemic fish populations.

The seasonal analysis of stomach contents in *Cyprinus carpio* collected from the Chbika Lake, provided valuable insights into the dietary habits of this fish species within the Djelfa region across different times of the year, revealing a diet primarily composed of zooplankton (Copepoda, Cladocera, and Rotifera), phytoplankton (green algae and diatoms insects, ostracods, detritus, and macrophytes, and revealing also a clear preference for zooplankton, specifically crustaceans such as Copepoda and Cladocera, across all seasons. This consistent dietary preference is crucial for understanding the dynamic trophic interactions within the aquatic ecosystem and may offer clues regarding potential temporal pathways of parasite transmission. Notably, the observed consumption of copepods was likely related to the observed infection of these fish with the Cestoda *B. acheilognathi*, as copepods serve as intermediate hosts for this parasite. This direct link between the host's diet and parasite infection highlights the intricate ecological relationships within this system. This represents the first study of its kind in the Northern

Sahara region to analyse the seasonal stomach contents of freshwater fish in relation to parasite ecology, including this specific connection between *C. carpio*'s zooplankton diet and *B. acheilognathi* infection. However, due to limitations in sample size and the specific focus on a single fish species, further investigations are warranted. Future studies should expand the scope of seasonal stomach content analysis to include other fish species within the Northern Sahara region to provide a more comprehensive understanding of the food web dynamics and parasite transmission pathways. Additionally, integrating molecular techniques could further confirm the dietary links to parasite infection, and examining the prevalence of *B. acheilognathi* in copepod populations would provide further support for this observed relationship. Furthermore, examining the link between specific seasonal dietary components and parasite infection rates would offer a more comprehensive understanding of the ecological roles of parasites in this ecosystem.

In practical aquaculture terms, we could select species of freshwater fish living in the wild that are resilient and not very sensitive to parasitic infestations, and use them in controlled aquaculture in ponds, with the aim of increasing the yields of aquaculture farms in difficulty. We could thus predict the type of parasitic infestation depending on the species of fish farmed (e.g. *Oreochromis* sp.), in order to propose a veterinary prophylactic plan against parasitic infestations, depending on the season and the species of fish parasitised. There is an urgent need for future researchers to study the zoonotic risks associated with freshwater fish (wild and aquaculture), in order to protect public health (fishermen, sellers and consumers) and the purity of the environment, especially as fish caught by pleasure fishermen in lakes and dams are not subject to veterinary control.

REFERENCES

References

Abbaci, S., Mezni, A., Brahmia, S., Hamouda, B., Bensouilah, M., Al-Mekhlaf, F. A., ... & Boulkenafet, F. (2023). Assessment of the physiological markers, oxidative stress and neurotoxic effects of nematode Anisakis sp. on the *Luciobarbus callensis* (Teleosts, Cyprinids) in northeast of Algeria. *Journal of King Saud University-Science*, *35*(1), 102386.

Abdullah, S. M., & Nasraddin, M. O. (2020). Some ecological aspects of three *Dactylogyrus* species (Monogenea) on gills of three fish species from Lesser Zab river, Kurdistan, Iraq. *Biological and Applied Environmental Research*, *4*(1), 7-17.

Abell, R., Thieme, M. L., Revenga, C., Bryer, M., Kottelat, M., Bogutskaya, N., ... & Petry, P. (2008). Freshwater ecoregions of the world: a new map of biogeographic units for freshwater biodiversity conservation. *BioScience*, *58*(5), 403-414.

Aberkane, B., Touazi, L., & Iguer-Ouada, M. (2018). Reproduction of Algerian Barbel *Luciobarbus callensis* (Cyprinidae) in the Agrioun River, Algeria. *Journal of Ichthyology*, *58*, 851-856.

Açikel, M., & Öztürk, M. O. (2012). Investigations on ectoparasitic helminth fauna of *Squalius cephalus* (L., 1758) linked to ecologic factors in Serban Dam Lake, Turkey. *Fresenius Environmental Bulletin*, *21*(12), 3614-3617.

Adolfsen, P., Bardal, H., & Aune, S. (2021). Fighting an invasive fish parasite in subarctic Norwegian rivers-The end of a long story?. *Management of Biological Invasions*, *12*(1).

Aissaoui, A., Sadoudi-Ali Ahmed, D., Cherchar, N., & Gherib, A. (2017). Assessment and biomonitoring of aquatic pollution by heavy metals (Cd, Cr, Cu, Pb and Zn) in Hammam Grouz Dam of Mila (Algeria). *International Journal of Environmental Studies*, *74*(3), 428-442.

Albaladejo, J. D., Arthur, J. R. (1989). Some trichodinids (Protozoa; Ciliophora: Peritrichida) from freshwater fishes imported into Philippines. *Asian Fish. Sci. 3*, 1-25.

Allalgua, A., Boucenna, I., Menasria, A., Boualleg, C., Bensouilah, M., & Kaouachi, N. (2022). Analyse de la variabilité morphométrique de *Dactylogyrus heteromorphus* El-Gharbi, 1994 (Monogenea: Dactylogyridae). *Bulletin de la Société Zoologique de France*, *147*(3).

Allalgua, A., Guerfi, S., Kaouachi, N., Boualleg, C., & Barour, C. (2015). L'infestation de *Cyprinus carpio* (Cyprinidés) peuplant le barrage Foum El-Khanga (Souk Ahras, Algérie) par les monogènes parasites. *Bull. Soc. zool. Fr.*, *140*(3).

Allalgua, A., Menasrıa, A., Mouaıssıa, W., Bensouılah, M., & Kaouachi, N. (2021). Effect of biotic and abiotic factors on the epidemiological index of *Dactylogyrus heteromorphus* El Gharbi, 1994 (Monogenea) parasitizing the Algerian barbel *Luciobarbus callensis* (Cyprinidae) inhabiting Foum-El-Khanga dam (Souk-Ahras, Algeria). *Acta Aquatica Turcica*, 17(4), 532-540.

Amalou, D., Ider, D., Ramdane, Z., & Moulaï, R. (2020). New biological data for *Salaria fluviatilis* (Asso, 1801)(Blenniidae) from North of Algeria. *Zoology and Ecology*, *30*(2), 89-100.

Amalou, D., & Moulaï, R. (2020). The fish fauna of the inland waters of The Lower Kabylie (Bejaia, northern Algeria): diversity and spatial distribution. *Studia Universitatis Vasile Goldis Seria Stiintele Vietii (Life Sciences Series)*, *30*(2), 76-87.

Amrani, A., Nasri, H., Azzouz, A., Kadi, Y., & Bouaïcha, N. (2014). Variation in cyanobacterial hepatotoxin (microcystin) content of water samples and two species of fishes collected from a shallow lake in Algeria. *Archives of Environmental Contamination and Toxicology*, *66*, 379-389.

Anvarifar, H., Mousavi-Sabet, H., Satari, M., Vatandoust, S., Khiabani, A. (2014). Occurrence and intensity of *Tracheliastes polycolpus* on *Capoeta capoeta gracilis* (Pisces: Cyprinidae) in Tajan River from the Southeast of the Caspian Sea. Eur. J. Zool. Res., 3 (2), 103-107.

Arab, I. Y., Arab, A., & Kara, H. M. (2020). Range expansion of the ruffe (*Gymnocephalus cernuus*) to the southern Mediterranean: First record in Koudiat Medouar reservoir, Algeria. *Journal of Applied Ichthyology*, *36*(5), 705-708.

Arab, I. Y., Arab, A., & Kara, M. H. (2021). Infection caused by the tapeworm *Ligula intestinalis* (Cestoda, Diphyllobothriidae) in the invasive cyprinid *Rutilus rutilus* (L., 1758), in three man-made lakes in Algeria. *Cybium*, *45*(1), 43-52.

Asmat, G. (2004). First record of *Trichodina diaptomi* (Dogiel, 1940) Basson and Van As, 1991, *T. heterodentata* Duncan, 1977 and *T. oligocotti* (Lom, 1970) (Ciliophora: Trichodinidae) from Indian fishes. *Pakistan Journal of Biological Sciences*, *7* (12), 2066–2071.

Atkinson, S.D., Bartholomew, J.L., Lotan, T. (2018). Myxozoans: Ancient metazoan parasites find a home in phylum Cnidaria. *Zoology*, 129, 66–68.

Attia, M. M., Abdelsalam, M., Elgendy, M. Y., & Sherif, A. H. (2022). *Dactylogyrus extensus* and *Pseudomonas fluorescens* dual infection in farmed common carp (*Cyprinus carpio*). *Microbial Pathogenesis*, *173*, 105867.

Attir, B. (2018). Contribution à l'étude bio-écologique des parasites des poissons des eaux continentales douce dans l'Est algérien (Doctoral dissertation, Universiy of Mohamed Khider Biskra, Departement of biology).

Attir, B., Chaibi, R., Meddour, A., & Sibachir, A. (2011a). Contribution à la Biodiversité de la Parasitofaune chez les Poissons d’Eaux Douces Continentales de l’EST Algérien. 13èmes Journées Tunisiennes des Sciences de la Mer et 2ème Rencontre Tuniso-française d’Ichtyologie.Mahdia, 26-29 Nov.Tunisie.

Attir, B., Chaibi, R., Meddour, A., & Sibachir, A. (2011b). Premières Données sur les Parasites du Tilapia du Nil (*Tilapia nilotica*, Linnaeus 1758) dans le Sahara Septentrional Algérien. Atelier International sur la Connaissance, la Valorisation et la Gestion Durable des Ressources Naturelles dans les Zones Arides. Biskra, 16-17 Nov. Algérie.

Attir, B., Chaibi, R. & Sibachir, A. (2012). Parasites Monogènes et Acanthocéphales du Tilapia du Nil (*Tilapia nilotica* : Cichlidés) dans les Drains Agricoles de la Région de Touggourt (Sahara Septentrional, Algérie). Congrès franco-maghrébin de Zoologie et d'Ichtyologie. Marrakech. Maroc.

Attir, B., Meddour, A., Sibachir, A., Ghazi, C., & Ghouri, S. (2017). First report of *Cichlidogyrus cubitus* Dossou, 1982 (Dactylogyridea; Ancyrocephalidae) on *Tilapia zillii* in North West Africa. *Journal of Applied Environmental and Biological Sciences*, *7*(3), 127-138.

Attir, B. & Yekhlef, A. (2018).Parasites des Poissons d'Eaux Douces.1st International Congress of Green Biotechnology, 01-03/Nov.Ibn Zohr University–Morocco.

Attou, F., & Arab, A. (2013). Impact de l'introduction d'*Alburnus alburnus* (Linnaeus, 1759) sur l'espèce autochtone *Barbus setivimensis* (Valenciennes, 1842)(poissons cyprinidés) dans le lac de barrage de Keddara (Algérie). *Revue d'écologie*, *68*(2), 193-202.

Attou, F., & Arab, A. (2019). Biology and ecology of the accidentally introduced bleak, *Alburnus alburnus* (Actinopterygii: Cypriniformes: Cyprinidae), in Keddara Dam Lake, Algeria. *Acta Ichthyologica et Piscatoria*, *49*, 119-132.

Ayalew, T., Teshome, M., & Aemro, D. (2025). Food and Feeding Habits of the Introduced Common Carp (*Cyprinus carpio* L. 1758) in Lake Ardibo, Ethiopia. *Heliyon*.

Aydogdu, A., Keskin, N., Erk'akan, F., & Innal, D. (2015). Occurrence of helminth parasites in the Turkish endemic fish, *Squalius anatolicus* (Cyprinidae). *Bulletin of the European Association of Fish Pathologists*, *35*(5), 185-191.

Aydogdu, A., Kostadinova, A., & Fernandez, M. (2003). Variations in the distribution of parasites in the common carp, *Cyprinus carpio*, from Lake Iznik, Turkey: Population dynamics related to season and host size. Helminthologia, *40(*1), 33-40

Aydogdu, A., Ozturk, M. O., Oğuz, M. C., & Altunel, F. N. (2001). Investigations on metazoon parasites of common carp (*Cyprinus carpio* L. 1758) in Dalyan Lagoon, Karacabey, Turkey. *Acta Veterinaria (Beograd), 51*(5/6), 351-358.

Aydoğdu, N., & Kubilay, A. (2017). Helminth fauna of Simav barbell, *Barbus niluferensis* Turan, Kottelat & Ekmekci, 2009 An endemic fish from Nilüfer river in Bursa (Turkey): new host and locality records. *Bull Eur Assoc Fish Pathol*, *37*, 110.

Azeroual, A., Crivelli, A. J., Yahyaoui, A., & Dakki, M. (2000). L'ichtyofaune des eaux continentales du Maroc. *Cybium*, *24*(3), 17-22.

Bagge, A. M. (2005). Factors affecting the development and structure of monogenean communities on cyprinid fish (No. 149). (Doctoral dissertation, University of Jyväskylä).

Baikeche, L., Lounaci, A., Ford, M., Lounaci-Daoudi, D., & Freyhof, J. (2021). Freshwater fishes of West Kabylia, Algeria. *Biodiversity Journal*, *12*(4), 957-966.

Bakke, T.A., harris P.D. & Cable J. (2002). Host specificity dynamics: observations on gyrodactylid monogeneans. *Int. J. Parasitol.*, *32,* 281-308.

Bakaria, F., Belhaoues, S., Djebbari, N., Tahri, M., Ladjama, I., & Bensaad, L. (2018). Metazoan parasites and health state of european eel, *Anguilla anguilla* (anguilliformes, anguillidae), from Tonga Lake and El Mellah lagoon in the northeast of Algeria. *Vestnik Zoologii*, *52*(4), 279-288.

Barber, I., Hoare, D., & Krause, J. (2000). Effects of parasites on fish behaviour: a review and evolutionary perspective. Reviews in Fish Biology and Fisheries, 10, 131-165.

Barker, D. E., & Cone, D. K. (2000). Occurrence of *Ergasilus celestis* (Copepoda) and *Pseudodactylogryrus anguillae* (Monogenea) among wild eels (*Anguilla rostrata*) in relation to stream flow, pH and temperature and recommendations for controlling their transmission among captive eels. *Aquaculture*, *187*(3-4), 261-274.

Beatty, S. J., Morgan, D. L., Rashnavadi, M., & Lymbery, A. J. (2011). Salinity tolerances of endemic freshwater fishes of south-western Australia: implications for conservation in a biodiversity hotspot. *Marine and Freshwater Research*, *62*(1), 91-100.

Beaufort, I., Caritat, A. K. D., Sourd, C., Gauffier, A., Valingot, M., Chaumien, M., ... & Tittonell, P. (2016). *Living Planet Report 2016-Risk and resilience in a new era. Synthesis* (No. INIS-FR--16-1157).

Beghora, L. (2014). Connaissance et impact de la parasitofaune sur la bio-écologie des poissons des eaux continentales de la région du sahara septentrional Algérie (Doctoral dissertation, Univerisy of Oum-El-Bouaghi).

Behmene, I. E., Bachir Bouiadjra, B., Homrani, A., Daoudi, M., Sánchez-Vázquez, F. J., López-Lopez, A., ... & Galián, J. (2022). Morphometric and genetic diversity of an African catfish (*Clarias gariepinus*) population from Southeast Algeria. *African Journal of Ecology*, *60*(4), 1287-1292.

Benali, S. A., Doukara, K. L., Ghomari, S. M., Mediouni, M. R., Taibi, W., Soualili, D. L., & Gaouar, S. B. S. (2021). Morphometric Characteristics of *Luciobarbus mascarensis* and *L. lanigarensis* (teleostei: cyprinidae) in western Algeria. *Genetics & Biodiversity Journal*, *5*(3), 20-32

Benayache, N. Y., Afri-Mehennaoui, F. Z., Kherief-Nacereddine, S., Vo-Quoc, B., Hushchyna, K., Nguyen-Quang, T., & Bouaïcha, N. (2022). Massive fish death associated with the toxic cyanobacterial *Planktothrix* sp. bloom in the Béni-Haroun Reservoir (Algeria). *Environmental Science and Pollution Research*, *29*(53), 80849-80859.

Béné, C., Arthur, R., Norbury, H., Allison, E. H., Beveridge, M., Bush, S., ... & Williams, M. (2016). Contribution of fisheries and aquaculture to food security and poverty reduction: assessing the current evidence. *World development*, *79*, 177-196.

Ben Hebireche, R. & Gaamour, M. (2010). Seasonal evolution of gill ectoparasites in *Tilapia nilotica* in the Ouargla region. Final dissertation in view of obtaining the State Engineering Diploma in Aquaculture. University Kasdi Merbah, Ouargla.

Benkouider, F. (2019). Utilisation de l'imagerie sattelitale pour la modélisation et le suivi de l'évolution des systèmes oasiens (Doctoral dissertation, National Polytechnic School, Algers).

Benovics, M., Vukić, J., Šanda, R., Rahmouni, I., & Šimková, A. (2020). Disentangling the evolutionary history of peri-Mediterranean cyprinids using host-specific gill monogeneans. *International Journal for Parasitology*, *50*(12), 969-984.

Benslimane, N., Chakri, K., Haiahem, D., Guelmami, A., Samraoui, F., & Samraoui, B. (2019). Anthropogenic stressors are driving a steep decline of hemipteran diversity in dune ponds in north-eastern Algeria. *Journal of Insect Conservation*, *23*, 475-488.

Berrouk, H., Allalgua, A., Kaouachi, N., & Boualleg, C. (2020a). Parasite biodiversity in four cyprinid fishes from Beni-Haroun Dam (Mila City) north-east of Algeria. *Environment and Ecology, 38* (3A), 513—523

Berrouk, H., Khelifi, N., Tourafia, N., Bouallag, C. (2019). Effect of abiotic factors on copepod parasites from Beni-haroun dam (Mila city) north-east of Algeria. *Journal Of Harmonized Research in Applied Sciences*, *7*(4), 112-122.

Berrouk, H., Sahtout, F., & Boualleg, C. (2020b). Biological parameters of *Luciobarbus callensis* populates Beni-Haroun dam, north-eastern Algeria. *Biodiversitas Journal of Biological Diversity*, *21*(12).

Berrouk, H., Tolba, M., Boucenna, I., Touarfia, M., Bensouilah, M., Kaouachi, N., & Boualleg, C. (2018). Copepod Parasites of the Gills of *Luciobarbus Callensis* (Valencienne, 1842) and *Carassius Carassius* (Linnaeus, 1758)(Cyprinid Fish) Collected from Beni Haroun Dam (Mila, Algeria). *World Journal of Environmental Biosciences*, *7*(4).

Berrouk, H., Tolba, M., Touarfia, M., & Boualleg, C. (2020c). A study of parasitic copepod infesting two freshwater fish populations (Cyprinus carpio and Abramis brama) from Beni-Haroun Dam (Mila) North-East of Algeria. *Annual Research and Review in Biology*, *34*(3), 1-11.

Bianco, P. G. (1995). Mediterranean endemic freshwater fishes of Italy. *Biological conservation*, *72*(2), 159-170.

Bilong-bilong, C.F. (1995).- Les monogènes parasites des poissons d'eau douce du Cameroun : Biodiversité et spécificité ; biologie des populations inféodées à *Hemichromis fasciatus*. (Doctoral dissertation, University of Yaoundé I), 341 pp.

Blanco, S., Romo, S., Villena, M. J., Martınez, S. (2003). Fish communities and food web interactions in some shallow Mediterranean lakes. *Hydrobiologia, 506-509,* 473-480.

Blazhekovikj-Dimovska, D., & Stojanovski, S. (2020). Ectoparasitic species of the genus *Trichodina* (Ciliophora: Peritrichida) parasitizing Macedonian freshwater fish. *Acta Biologica*, *27*, 11-20.

Boet, P. H. (1980). Fish-cats nutrition (*Ictalurus melas*) in the Créteil Lake. *Annals of Limnology*, *16*(3), 255-270.

Boet, P., & Le Louarn, H. (1985). La croissance du poisson. Techniques d'étude. *Gestion piscicole des lacs et retenues artificielles*, 125-142.

Bouamra, A., Belaifa, B., Chaoui, L., Kara, M. H., & Arab, A. (2017). Age and growth of Pike perch *Sander lucioperca* (Percidae) in the Ghrib reservoir (Northwest Algeria). *Revue d'Écologie*, *72*(1), 83-93.

Boucenna, I., Boualleg, C., Kaouachi, N., Allalgua, A., Menasria, A., maazi, M. C., Barour, C., Bensouilah, M. (2015) Infestation of a population of *Cyprinus carpio* (Linnaeus, 1758) by parasitic copepods at the dam of Foum El Khanga (Souk-Ahras, Algeria). *Bulletin de la Société zoologique de France*, v. 140(3), p. 163-179.

Bouhbouh, S. (2002). Bio-ecologie de *Barbus callensis* (Valencienne 1842) & *Barbus fritschi* (Günther 1874) au niveau du reservoir Allal el Fassi (Maroc). (Doctoral dissertation, Hydrobiology, Sidi Mohamed Ben Abdellah University, Fès, Maroc), 197 pages.

Brahimi, A. (2018). Morphologie comparée et phylogéographie des barbeaux endémiques du Maghreb, particulièrement en Algérie (Doctoral dissertation, Université Mohamed Kheider-Biskra).

Brahimi, A., Freyhof, J., Henrard, A., & Libois, R. (2017*).* *Luciobarbus chelifensis* and *L. mascarensis*, two new species from Algeria (Teleostei: Cyprinidae). *Zootaxa*, *4277*(1).

Brahimi, A., Libois, R., Henrard, A., & Freyhof, J. (2018). *Luciobarbus lanigarensis* and *L. numidiensis*, two new species of barbels from the Mediterranean Sea basin in North Africa (Teostei: Cyprinidae). *Zootaxa*, *4433*(3).

Brahimi, A., Tarai, N., Benhassane, A., Henrard, A., & Libois, R. (2016). Genetic and morphological consequences of Quaternary glaciations: A relic barbel lineage (*Luciobarbus pallaryi*, Cyprinidae) of Guir Basin (Algeria). *Comptes Rendus. Biologies*, *339*(2), 83-98.

Brahmia S., (2016). Parasitic ecology of cyprinids of Oubeira Lake (Nord-East of Algeria). (Doctoral dissertation, Animal Ecology, Badji Mokhtar-Annaba University), 117 p.

Brahmia, S., Barour, C., Abbaci, S., Boualleg, C., Bensouilah, M. (2016). Environmental parameters and parasitism in common carp (*Cyprinus carpio* Linnaeus, 1758) caught from Oubeira Lake (North-East of Algeria). *Research journal of fisheries and hydrobiology*, *11*, 27–36.

Bretzinger, A. C. H. I. M., Fischer-Scherl, T., Oumouna, M., Hoffmann, R., & Truyen, U. (1999). Mass mortalities in Koi carp, *Cyprinus carpio*, associated with gill and skin disease.

Bruslé, J., Quignard, J. P. (2001). Biologie des poissons d'eau douce européens, Éditions Tec & Doc, Lavoisier, Paris, 625 p.

Buchmann, K., Slotved, H. C., & Dana, D. (1993). Epidemiology of gill parasite infections in *Cyprinus carpio* in Indonesia and possible control methods. *Aquaculture*, *118*(1-2), 9-21.

Bush, A. O., Lafferty, K. D., Lotz, J. M., & Shostak, A. W. (1997). Parasitology meets ecology on its own terms: Margolis et al. revisited. *The Journal of parasitology*, 575-583.

Bykhovskaya-Pavlovskaya, I.E., Gusev, A.V., Dubinina, M.N., Izyumova, N.A., Smirova, T.S., Sokolovskaya, I.L., Shtein, G.A., Shulman, S.S., Epshtein, V.H. (1962). Key to parasites of freshwater fish of the U.S.S.R. Moscow: Izdatel'stvo Akadamii Nauk S.S.S.R.

Carpenter, S. R., Stanley, E. H., & Vander Zanden, M. J. (2011). State of the world's freshwater ecosystems: physical, chemical, and biological changes. *Annual review of Environment and Resources*, *36*(1), 75-99.

Chabira, D., Attir, B., Aydoğdu, N., & Mammeri, A. (2025). First report of *Dactylogyrus fimbriphallus* (El Gharbi, Birgi & Lambert, 1994) infecting *Luciobarbus biscarensis* (Boulenger, 1911) in Oued Tadmit River of Djelfa Governorate (Algeria). *African Journal of Aquatic Science*, 1–8. https://doi.org/10.2989/16085914.2025.2478015

Chabira, D., Mammeri, A., & Attir, B. (2024). Review of freshwater fish parasitism in Algeria: a synthesis of the main publications from 2013 to 2023. *Brazilian Journal of Animal and Environmental Research*, *7*(4), e75764-e75764.

Chaibi, R. (2013). Connaissance de l'ichtyofaune des eaux continentales de la région des Aurès et du Sahara septentrional avec sa mise en valeur. (Doctoral dissertation, Biology, University of Biskra).

Chebaani, N., Guardiola, F. A., Sihem, M., Nabil, A., Oumouna, M., Meseguer, J., ... & Cuesta, A. (2014). Innate humoral immune parameters in *Tilapia zillii* under acute stress by low temperature and crowding. *Fish physiology and biochemistry*, *40*, 797-804.

Cheghib, Y., Chouahda, S., & Soltani, N. (2020). Side-effects of a neonicotinoid insecticide (actara®) on a non-target larvivorous fish *Gambusia affinis*: growth and biomarker responses. *Egyptian Journal of Aquatic Research*, *46*(2), 167-172

Chenchouni, H. (2012). Diversity assessment of vertebrate fauna in a wetland of hot hyperarid lands. *Arid Ecosystems*, *2*(4), 253-263.

Cooke, S., Paukert, C., & Hogan, Z. (2012). Endangered river fish: factors hindering conservation and restoration. *Endangered Species Research*, 17, 179–191.

Combes, C. (1995). Interaction durable. Ecologie et évolution du parasitisme. Masson, Paris, p.524.

Corner, R., Fersoy, H., & Crespi, V. (2020). Integrated agri-aquaculture in desert and arid lands-Learning from case studies from Algeria, Egypt and Oman. *FAO Fisheries and Aquaculture* Circular No. 1195. Cairo, FAO.

Costanza, R., De Groot, R., Sutton, P., Van der Ploeg, S., Anderson, S. J., Kubiszewski, I., ... & Turner, R. K. (2014). Changes in the global value of ecosystem services. *Global environmental change*, *26*, 152-158.

Dadebo, E., Eyayu, A., Sorsa, S., Girma Tilahun, G. (2015). Food and feeding habits of the common carp (*Cyprinus carpio* L. 1758) (Pisces: Cyprinidae) in Lake Koka, Ethiopia. *Momona Ethiopian Journal of Science, 7(1)*,16-31.

Darwall, W., Bremerich, V., De Wever, A., Dell, A. I., Freyhof, J., Gessner, M. O., ... & Weyl, O. (2018). The Alliance for Freshwater Life: A global call to unite efforts for freshwater biodiversity science and conservation. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *28*(4), 1015-1022.

Darwall, W., Smith, K., Allen, D., Seddon, M., Reid, G. M., Clausnitzer, V., & Kalkman, V. J. (2009). Freshwater biodiversity: a hidden resource under threat. *Wildlife in a changing world–An Analysis of the 2008 IUCN Red List of Threatened Species*, *43*.

Denna, A., Chouahda, S., Berghiche, H., & Soltani, N. (2022). Assessment of water quality of some aquatic systems in northeast Algeria by use a non-target fish *Gambusia affinis* during the breeding period growth and biomarkers responses. *Fresenius Environmental Bulletin*, *31*, 677-688.

Derbal, F., Hamdi, S., Rouag-Laouira, L., Chaoui, L., & Kara, M. H. (2022). Diet of the European eel *Anguilla anguilla* (Linnaeus, 1758) in two transitional waters of Southwestern Mediterranean. *Cybium*, *46*(1), 3-11.

Derbal, F., Nouacer, S., Kara, M. H. (2007). Composition and variations of dietary regime of sparaillon *Diplodus annularis* (Sparidae) in Annaba golf (East of Algeria). *Cybium*, *31*(4), 443-450.

Derrag, Z., & Youcef, N. D. (2014). Bioaccumulation of heavy metals in the *Cyprinus carpio* organs of the El Izdihar dam (Algeria). *Desalination and Water Treatment*, *52*(10-12), 2293-2300.

Dewi, R. R., Siallagan, W., & Suryanto, D. (2018). The efficacy of sodium chloride application in the control of fish lice (Argulus sp) infection on tilapia (*Oreochromis niloticus*). *Acta Aquatica: Aquatic Sciences Journal*, *5*(1), 4-7.

Dickson, M. (2022). Regional review on status and trends in aquaculture development in the Near East and North Africa–2020. FAO Fisheries and Aquaculture Circular No. 1232/5. Rome, FAO.

Dijkstra, K. D. B., Monaghan, M. T., & Pauls, S. U. (2014). Freshwater biodiversity and aquatic insect diversification. *Annual review of entomology*, *59*(1), 143-163.

Djebbari, N., Boudjadi, Z., & Bensouilah, M. (2009). L'infestation de l'anguille Anguilla anguilla L., 1758 par le parasite Anguillicola crassus Kuwahara, Niimi & Itagaki, 1974 dans le complexe de zones humides d'El Kala (Nord-Est algérien). *Bulletin de l'institut Scientifique, Rabat, section Sciences de la vie*, *31*(1), 45-50.

Djezzar, M., Mortillaro, J. M., Doumandji, S. E., & Meziane, T. (2021). Links between introduced fish and zooplanktonic and zoobenthic food sources in the food webs of two reservoirs of a semi-arid zone in Algeria. *African Journal of Aquatic Science*, *46*(1), 33-44.

Djouahra, C., & Arab, A. (2017). Biological parameters and parasite loads of eel populations (*Anguilla anguilla* l.) inhabiting two water bodies in coastal Algeria. *Revue d'Écologie*, *72*(3), 293-302.

Djoudad-Kadji, H., Benslimane, S., Chevalier, C., Kadji, B., Exbrayat, J. M., & Iguer-Ouada, M. (2012). First observation of intersex in barbel *Barbus callensis* (Valenciennes, 1842) collected in Soummam River (Algeria). *Cybium, 36*(4), 531-538.

Dlapka, V. (2020). Diverzita a evoluce monogeneí parazitujících kaprovité ryby vybraných oblastí Afriky.

Do-Chi, T. (1977). Détermination statistique de l'âge: quelques méthodes de décompositions d'un échantillon en composante gaussienne. *Océanis*, *3*(10), 505-530.

DSA, Biskra (2022). Donnés statistiques sur l'agriculture et l'élevage dans la wilaya de Biskra.

Dubinina, M. N. (1981). Tapeworms (Cestoda, Ligulidae) of the fauna of the USSR. Delhi, Amerind Publishing Co.Pvt. Ltd.

Dudgeon, D., Arthington, A.H., Gessner, M.O., et al. (2006). Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological Reviews*, 81, 163–182.

Duncan, J. R., & Lockwood, J. L. (2001). Extinction in a field of bullets: a search for causes in the decline of the world's freshwater fishes. *Biological conservation*, *102*(1), 97-105.

Dzika, E., Dzikowiec, M., & Hoffmann, R. W. (2009). Description of the development of the attachment and copulatory apparatus of *Dactylogyrus extensus* from *Cyprinus carpio* var. koi. *Helminthologia*, *46*, 39-44.

Echi, P. C., Eyo, J. E., Okafor, F. C. (2009a): Co-parasitism and morphometrics of three clinostomatids Digenea: Clinostomatidae; in Sarotherodon melanotheron from a tropical freshwater lake. *Animal Research International, 6*, 2, 982-986.

Echi, P. C., Okafor, F. C., Eyo, J. E. (2009b): Co-infection and morphometrics of three clinostomatids Digenea: Clinostomatidae; in *Tilapia guinensis* Bleeker, 1862 from Opi lake, Nigeria. *BioResearch, 7,* 1, 432-436.

Edmondson, W.T. (1959). Fresh-water biology. 2nd ed. John Wiley & Sons Inc., NY.

Eiras, J. C., Cruz, C. F., Saraiva, A., Adriano, E. A. (2021). Synopsis of the species of *Myxobolus* (Cnidaria, Myxozoa, Myxosporea) described between 2014 and 2020. *Folia Parasitologica*, 2021(68):012

Eiras, J. C., Molnár, K., & Lu, Y. (2005). Synopsis of the species of *Myxobolus bütschli*, 1882 (Myxozoa: Myxosporea: Myxobolidae). *Systematic parasitology*, *61*, 1-46.

Eiras, J. C., Zhang, J., & Molnár, K. (2014). Synopsis of the species of *Myxobolus Bütschli*, 1882 (Myxozoa: Myxosporea, Myxobolidae) described between 2005 and 2013. *Systematic Parasitology*, *88*, 11-36.

Elbay, M. Z., & Öztürk, M. O. (2021). *Squalius recurvirostris* Özuluğ & Freyhof, 2011'in Dactylogyrid Parazit Faunası Üzerine Bir Araştırma. *Mehmet Akif Ersoy Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, *12*(2), 255-262.

El Gharbi, S., Birgi, E., & Lambert, A. (1994). Monogènes Dactylogyridae parasites de Cyprinidae du genre Barbus d'Afrique du Nord. Systematic Parasitology, 27(1), 45-70.

Elvira, B. (1995). Conservation status of endemic freshwater fish in Spain. *Biological Conservation*, *72*(2), 129-136.

Ergens, R., Dulmaa, A. (1969). Monogenoidea from *Cyprinus carpio* haematopterus and *Carassius auratus* gibelio (Cyprinidae) from Mongolia. Folia Parasitologica, v. 16(3), p. 201-206.

European Parliament. (2015). The water framework directive and the marine strategy framework directive - implementation challenges, 8-11

Euzet, L., Combes, C. (1998). The selection of habitats among the Monogenea. *International Journal for Parasitology*, *28*(10), p. 1645-1652.

Farhi, A. (2001). Macrocéphalie et pôles d’équilibre: la wilaya de Biskra. *Espace géographique*, *3*, 245-255.

Fergani, H., & Arab, A. (2017). Effects of pollution on the activity of acetylcholinesterase in the brain and heart of *Barbus setivimensis* (fish, Cyprinidae) in El Harrach stream (North of Algeria). *Revue d'Écologie*, *72*(1), 73-82.

Fernando, C.H., Furtado, J.I., Gussev, A.V., Hanek, G. and Kakonge, S.A. (1972). Methods for the study of freshwater fish parasites. Canada – Ontario: Department of Biology, University of Waterloo, Waterloo.

Ferreira, K. C. S., de Oliveira, J. E. Z., & Salvio, G. M. M. (2023). IUCN's red list of threatened species: its importance in the conservation of mammals in Brazil: Listas vermelhas de espécies ameaçadas de extinção da UICN: sua importância na conservação de mamíferos no Brasil. *Brazilian Journal of Animal and Environmental Research*, *6*(2), 1802-1831.

Flores, V., & Viozzi, G. (2001). Redescription, seasonality and distribution of *Myxobolus magellanicus* (Myxosporea) in *Galaxias maculatus* (Osmeriformes, Galaxiidae) from Patagonian Andean lakes (Argentina). *Acta Parasitol*, *46*(3), 159-163.

Froese, R., Pauly, D. (2000). Concepts, design and data sources. ICLARM, Los Banos Laguna, 344 p.

Gabagambi, N. P., Salvanes, A. G. V., Midtøy, F., & Skorping, A. (2019). The tapeworm *Ligula intestinalis* alters the behavior of the fish intermediate host Engraulicypris sardella, but only after it has become infective to the final host. *Behavioural Processes*, *158*, 47-52.

Gbankoto, A., Pampoulie, C., Marques, A., Sakiti, G. N., & Dramane, K. L. (2003). Infection patterns of Myxobolus heterospora in two tilapia species (Teleostei: Cichlidae) and its potential effects. *Diseases of aquatic organisms*, *55*(2), 125-131.

Ghazi, C., Si Bachir, A. (2021). Growth and reproduction of two cichlids *Tilapia zillii* and *Hemichromis bimaculatus* (Teleostei: Cichliformes) in the Saharan hydrosystems (Algeria). *Iranian Journal of Ichthyology*, *8*(4), 322-333.

Ghazi, C., Si Bachir, A., & Idder, T. (2019). New record and biology of the Molly *Poecilia sphenops* (Poeciliidae), discovered in the Northern Sahara of Algeria. *Journal of Ichthyology*, *59*, 602-609.

Ghazi, C., Si Bachir, A., Santoul, F., & Céréghino, R. (2018). Potential ectoparasites of the endemic Mediterranean banded killifish (*Aphanius fasciatus*, Valenciennes, 1821) of the northern Sahara (Algeria). *Iranian Journal of Fisheries Sciences*, *17*(2), 435-442.

Giari, L., Castaldelli, G., Gavioli, A., Lanzoni, M., & Fano, E. A. (2021). Long-term ecological analysis of *Anguillicola crassus* occurrence and impact on the European eel population in a Mediterranean lagoon (North Italy). *Estuarine, Coastal and Shelf Science*, *249*, 107117.

Gibson, D. I., Timofeeva, T. A., & Gerasev, P. I. (1996). A catalogue of the nominal species of the monogenean genus Dactylogyrus Diesing, 1850 and their host genera. *Systematic Parasitology*, *35,* 3-48.

Giemsa, G. (1904). Eine Vereinfachung und Vervollkommnung meiner Methylenblau-Eosin-Färbemethode zur Erzielung der Romanowsky-Nocht'schen Chromatinfärbung. *Centralblatt für Bakteriologie*, *32*, 307-313.

Gómez, D., Bartholomew, J., & Sunyer, J. O. (2014). Biology and mucosal immunity to myxozoans. *Developmental & Comparative Immunology*, *43*(2), 243-256.

Grabda, J. (1991). Marine fish parasitology: An outline. Verlagsgesellschaft mbH, Weiheim, Germany.

Guettaf, M., Rachedi, M., Gueroui, Y., Bousbia, A., Chelaghmia, M. A., & Maoui, A. (2019). Age and growth of common bream, *Abramis brama* (L.), caught at Hammam Debagh Reservoir (Guelma, northeast Algeria). *Fisheries & Aquatic Life*, *27*(3).

Guezi, R., Chaoui, L., & Kara, M. H. (2017). Life history of the Mediterranean killifish *Aphanius fasciatus* in brackish water habitat of Algerian low Sahara. *Environmental Biology of Fishes*, *100*, 481-491.

Guezi, R., & Kara, M. H. (2015). Age, growth and reproduction of the endangered jewelfish *Hemichromis bimaculatus* (Cichlidae) in the valley of Oued Righ (South-eastern Algeria). *Cybium*, *39*(4), 301-307.

Guitang, W., Weijian, Y., Xiaoning, G., Jianguo, W., & Pin, N. (2003). Seasonal fluctuation of *Myxobolus gibelioi* (Myxosporea) plasmodia in the gills of the farmed allogynogenetic gibel carp in China. *Chinese Journal of Oceanology and Limnology*, *21*(2), 149-153.

Gupta, N., Singhal, P., Gupta, D. K. (2012). Population dynamics of a parasite Pallisentis in two species of fish *Channa punctatus* and *Channa Striatus*. *Journal of Environmental Biology*, *33,* 195–199.

Gussev, A.V. (1985). Monogenea in: Key to parasites of the freshwater fishes of the USSR. Fauna, Vol. 2. (ed. By ON Bauer) Publ. House Nauka. Leningrad.

Gussev, A.V., Poddubnaya, A.V. and Abdeeva, V.V. (1987). Key to parasites of the freshwater fishes of the USSR''. Fauna, Vol. 3 (ed. By ON Bauer) Publ. House Nauka. Leningrad.

Habila, S., Leghouchi, E., Valdehita, A., Bermejo-Nogales, A., Khelili, S., & Navas, J. M. (2017). Induction of EROD and BFCOD activities in tissues of barbel (*Barbus callensis*) from a water reservoir in Algeria. *Ecotoxicology and Environmental Safety*, *142*, 129-138.

Hacunda, J. S. (1981). Trophic relationships among demersal fishes in a coastal area of the Gulf of Maine. *Fish. Bull*., 79, 775-788.

Hadou-Sanoun, G., Arab, A., Lek-Ang, S., & Lek, S. (2012). Impact de *Ligula intestinalis* (L. 1758)(Cestode) sur la croissance de *Barbus setivimensis* (Cyprinidae) dans un système lacustre Algérien. *Comptes Rendus Biologies*, *335*(4), 300-309

Hadou-Sanoun G., Lazizi N., Yahia Cherif S., Bidi S., Cherbi M., (2013). Contribution study of diet regime for two cyprinids: *Barbus setivimensis* (Valenciens, 1842) and *Cyprinus carpio* (Linnaeus, 1758) of keddara dam. USTHB-FBS-4th International

Congress of the Populations & Animal Communities “Dynamics & Biodiversity of the terrestrial & aquatic Ecosystems (CIPCA4), TAGHIT (Bechar)-ALGERIA, 19-21 November, 2013, pp. 1-10.

Hashim, M., Abidin, D. A. Z., Das, S. K., Mazlan, A. G. (2017). Length- weight relationship, condition fact or and TROPH of *Scatophagus argus* in Malaysian coastal waters. *AACL Bioflux*, 10(2): 297-307.

Hassan, A. A., Akinsanya, B., & Adegbaju, W. A. (2010). Impacts of helminth parasites on *Clarias gariepinus* and *Synodontis clarias* from Lekki Lagoon, Lagos, Nigeria. *Report and Opinion*, *2*(11), 42-48.

Hermoso, V., & Clavero, M. (2011). Threatening processes and conservation management of endemic freshwater fish in the Mediterranean basin: a review. *Marine and Freshwater Research*, *62*(3), 244-254.

Hoffman, G.L. (1999). Parasites of North American freshwater fishes. Comstock Publishing Associates a division of Cornell University Press lthaca and London, 1- 527.

Hogans, W. E. (1989). Mortality of cultured Atlantic salmon, *Salmo salar* L., parr caused by an infection of *Ergasilus labracis* (Copepoda: Poecilostomatoida) in the lower Saint John River, New Brunswick, Canada. *Journal of Fish Diseases*, *12*(5).

Hoole, D., Bucke, D., Burgess, P., Wellby, I. (2001). Diseases of carp and other cyprinid fishes. MPG Books Ltd, Bodmin, Corn-wall, 264 pp.

Hoole, D., Carter, V., & Dufour, S. (2010). *Ligula intestinalis* (Cestoda: Pseudophyllidea): an ideal fish-metazoan parasite model?. *Parasitology*, *137*(3), 425-438.

Houda, B., Fatiha, S., Nouha, K., & Chahinaiz, B. (2021). Effect of parasitic copepods on the growth of *Abramis brama* fish from Beni-Haroun dam of Mila city (Northeast Algeria). *Ukrainian Journal of Ecology*, *11*(8), 79-88.

Hureau, J. C., (1970). Comparative biology of some Antarctic fish (*Nototheniidae*). *Bulletin of the Oceanographic Institute*, 68: 1- 224.

Hynes, H. B. N. (1950). The food of freshwater sticklebacks (*Gasterosteus aculeatus* and *Pygosteus pungitius*), with a review of methods used in studies of the food of fishes. *Journal of Animal Ecology,* 19, 36-58.

Hyslop, E. J. (1980). Stomach contents analysis—a review of methods and their application. *Journal of fish biology*, *17*(4), 411-429.

Ibrahim, M.M. (2012). Variation in parasite infracommunies of *Tilapia zillii* in relation to some biotic and abiotic factors. *Int. J. Zool. Res.*, 8 (2), 59-70.

IUCN. (2009). IUCN Red List of Threatened Species. Version 2009.2. . Downloaded on 16 December 2009.

Iyaji, F. O., & Eyo, J. E. (2008). Parasites and their freshwater fish host. *Bio-Research*, *6*(1), 328-338.

Jalali, B., & Barzegar, M. (2005). Dactylogyrids (Dactylogyridae: Monogenea) on common carp (*Cyprinus carpio* L.) in freshwaters of Iran and description of the pathogenicity of *D. sahuensis*.

Jan, N. A., Das, S. M. (1970). Qualitative and quantitative studies on the food of eight fishes of Kashmir valley. *Ichthyologica, 10,* 20-26.

Jarkovský, J., Morand, S., Šimková, A., & Gelnar, M. (2004). Reproductive barriers between congeneric monogenean parasites (Dactylogyrus: Monogenea): attachment apparatus morphology or copulatory organ incompatibility?. *Parasitology Research*, *92*, 95-105.

Jayraj, P., Machavaram, R., Sahu, G., & Paradkar, V. (2019). Measurement of morphometric dimensions and mechanical properties of Rohu fish for design of processing machines. *Journal of Aquatic Food Product Technology*, *28*(2), 150-164.

Kabata, Z. (1985). Parasites and diseases of fish cultured in the tropics. Taylor & Francis. London.

Kabata, Z. (1981). Relegation of *Hatschekia acuta* Barnard, 1948, to synonymy with *Hatschekia conifera* Yamaguti, 1939 (Copepoda: Siphonostomatoida). *Canadian Journal of Zoology*, *59*(11), 2080-2084.

Kaddouri, M. A. (2021). Ecologie trophique du hérisson du désert *Hemiechinus aethiopicus ehrenberg* 1833 (mammalia: erinaceidae) dans la région de Laghouat (Doctoral dissertation, National Higher School of Agronomy El Harrach – Algers, Department of Agricultural and Forest Zoology).

Kara, H. M. (2012). Freshwater fish diversity in Algeria with emphasis on alien species. *European journal of wildlife research*, *58*(1), 243-253.

Kara, H. M., Lacroix, D., Sadek, S., Blancheton, J. P., Rey-Valette, H., & Kraiem, M. (2016). Vingt ans d'aquaculture en Afrique du Nord: évolutions, bilan critique et avenir. *Cahiers Agricultures*, *25*(6), 64004.

Karim, B., Yousria, G., & Wyllia, K. (2019). Influence of total length, sex and seasonal variations on hema-tological parameters in *Cyprinus carpio* (Linnaeus, 1758)(Pisces Cyprinidae) in Lake Tonga (Algeria). *Biodivers. J.*, *10*, 593-600.

Kasembele, G. K., Manda, A. C., Abwe, E., Pariselle, A., Bukinga, F. M., Huyse, T., ... & Vanhove, M. P. M. (2023). First record of monogenean fish parasites in the Upper Lufira River Basin (Democratic Republic of Congo): dactylogyrids and gyrodactylids infesting *Oreochromis mweruensis, Coptodon rendalli* and *Serranochromis macrocephalus* (Teleostei: Cichlidae). *Parasites & Vectors*, *16*(1), 48.

Keith, P., Allardi, J. (2001). Atlas des poissons d'eau douce de France. *Patrimoines Naturels*, *47*,387 p.

Kennedy, C. R. (1975). Ecological Animal Parasitology, Blackwell Sci. Publ., Oxford.

Kennedy, C. R. (2007). The pathogenic helminth parasites of eels. *Journal of fish diseases*, *30*(6), 319-334.

Kent, M. L., Whitaker, D. J., & Margolis, L. (1993). Transmission of *Myxobolus arcticus* Pugachev and Khokhlov, 1979, a myxosporean parasite of Pacific salmon, via a triactinomyxon from the aquatic oligochaete *Stylodrilus heringianus* (Lumbriculidae). *Canadian Journal of Zoology*, *71*(6), 1207-1211.

Khan, R.A. (2012). Host-parasite interactions in some fish species. *Journal of Parasitology Research 2012*, article 237280. https://doi.org/10.1155/2012/237280

Khélifi, N., Boualleg, C., Sahtout, F., Kaouachi, N., Mouaissia, W. A. H. I. B. A., & Bensouillah, M. (2017). Feeding habits of *Carassius carassius* (Cyprinidae) in Beni Haroun Dam (north-east of Algeria). *Aquaculture, Aquarium, Conservation & Legislation*, *10*(6), 1596-1609.

Kır, I., & Tekin-Özan, S. (2007). Helminth infections in common carp, *Cyprinus carpio* L., 1758 (Cyprinidae) from Kovada Lake (Turkey). *Türkiye Parazitoloji Dergisi*, *31*, 232-236.

Knotková, Z., Doubek, J., Knotek, Z., & Hájková, P. (2002). Blood cell morphology and plasma biochemistry in Russian tortoises (Agrionemys horsfieldi). *Acta Veterinaria Brno*, *71*(2), 191-198.

Koenigbauer, S.T., & Höök, T.O. (2023). Increased offspring provisioning by large female fish and consequences for reproductive efficiency. *Ecology and Evolution*, *13*(10), e10555.

Korting, W. (1974). Bothriocephalosis of the carp. *Veterinary Medical Review, 2*,165-171.

Koskivaara, M., Valtonen, E. T., Prost, M. (1991). Dactylogyrids on the gills of roach in Central Finland: features of infection and species composition. *International Journal forParasitology*, *21*, 565–572. https://doi.org/10.1016/0020-7519(91)90061-B

Kottelat, M. and Freyhof, J. (2007). Handbook of European freshwater fishes. Publications Kottelat, Cornol and Freyhof, Berlin. 646

Koussa, M. (2017). Apport d'un système d'information géographique pour la gestion des ressources en eau de la région de Djelfa (Doctoral dissertation, Université Mohamed Khider-Biskra).

Koyun, M., Ulupınar, M., & Gül, A. (2015). Seasonal Distribution of Metazoan Parasites on Kura Barbell (*Barbus lacerta*) in Eastern Anatolia, Turkey. *Pakistan Journal of Zoology*, *47*(5).

Kraïem, M. M. (1983). Les poissons d'eau douce de Tunisie. Inventaire commenté et répartition géographique. *INSTM Bulletin: Marine and Freshwater Sciences*, *10*, 107-124.

Kritsky, D. C., & Heckmann, R. (2002). Species of *Dactylogyrus* (Monogenoidea: Dactylogyridae) and *Trichodina mutabilis* (Ciliata) infesting koi carp, *Cyprinus carpio*, during mass mortality at a commercial rearing facility in Utah, USA. *Comparative Parasitology*, *69*(2), 217-218.

Kurupinar, E., & Oztürk, M. O. (2009). A study on the helminth fauna linked to seasonal changes and size of the fish host, Leuciscus cephalus L., from Lake Dam Orenler, Afyonkarahisar. *Turkiye Parazitolojii Dergisi*, *33*(3), 248-253.

Kuwahara, A., Niimi, A., & Itagaki, H. (1974). Studies on a nematode parasitic in the air bladder of the eel. I. Description of *Anguillicola crassa* n. sp.(Philometridea, Anguillicolidae). *Japanese Journal of Parasitology*, *23*(5), 275-279.

Labbaci, A., Chaoui, L., Bahri-Sfar, L., Hammami, I., & Kara, M. H. (2021). Morphogeometric and genetic variations among North African populations of the Mediterranean killifish *Aphanius fasciatus* (Valenciennes, 1821) from different habitats. *Cybium*, *45*(3): 225-238. https://doi.org/10.26028/cybium/2021-453-007

Lafferty, K. D. (2008). Ecosystem consequences of fish parasites. *Journal of fish Biology*, *73*(9), 2083-2093.

Laporte, M., Leblois, R., Coulon, A., Bonhomme, F., Magnan, P., & Berrebi, P. (2015). Genetic structure of a vulnerable species, the freshwater blenny (*Salaria fluviatilis*). *Conservation Genetics*, *16*, 571-581.

Lefebvre, F., Wielgoss, S., Nagasawa, K., & Moravec, F. (2012). On the origin of *Anguillicoloides crassus*, the invasive nematode of anguillid eels. *Aquatic Invasions*, *7*(4).

Lévêque, C., Oberdorff, T., Paugy, D., Stiassny, M.L.J., & Tedesco, P.A. (2008). Global diversity of fish (Pisces) in freshwater. *Hydrobiologia*, 595, 545–567.

Lisnerová, M., Blabolil, P., Holzer, A., Jurajda, P., & Fiala, I. (2020). Myxozoan hidden diversity: the case of *Myxobolus pseudodispar* Gorbunova, 1936. *Folia Parasitologica*, *67*(19), 1-12.

Liu, S., Luo, L., Zuo, F., Geng, Y., Ou, Y., Chen, D., ... & Huang, X. (2022). Immunosuppression and apoptosis activation mediated by p53-Bcl2/Bax signaling pathway-The potential mechanism of goldfish (*Carassius auratus* Linnaeus) gill disease caused by *Myxobolus ampullicapsulatus*. *Frontiers in Immunology*, *13*, 998975.

Liu, Y., Whipps, C. M., Nie, P., & Gu, Z. (2014). *Myxobolus oralis* sp. n.(Myxosporea: Bivalvulida) infecting the palate in the mouth of gibel carp *Carassius auratus gibelio* (Cypriniformes: Cyprinidae). *Folia parasitologica*, *61*(6), 505.

Llewellyn, J. (1960). Amphibdellid (monogenean) parasites of electric rays (Torpedinidae). *Journal of the Marine Biological Association of the United Kingdom*, *39*(3), 561-589.

López-Olvera, J. R., Montané, J., Marco, I., Martínez-Silvestre, A., Soler, J., & Lavín, S. (2003). Effect of venipuncture site on hematologic and serum biochemical parameters in marginated tortoise (*Testudo marginata*). *Journal of Wildlife Diseases*, *39*(4), 830-836.

Lundberg, J. G., Kottelat, M., Smith, G. R., Stiassny, M. L., & Gill, A. C. (2000). So many fishes, so little time: an overview of recent ichthyological discovery in continental waters. *Annals of the Missouri Botanical Garden*, 26-62.

Lynch, A. J., Cooke, S. J., Deines, A. M., Bower, S. D., Bunnell, D. B., Cowx, I. G., ... & Beard Jr, T. D. (2016). The social, economic, and environmental importance of inland fish and fisheries. *Environmental reviews*, *24*(2), 115-121.

Magalhaes, M. F. (1993). Feeding of an Iberian stream Cyprinid assemblage: seasonality of resources in a highly variable environment. *Oecologia, 96*, 253-260.

Mahmoud, M. A., Attia, M. M., Abdelsalam, M., Abdel-Moneam, D. A., & Zaki Ewiss, M. A. (2021). *Ergasilus extensus* and bacterial co-infection in flathead grey mullet, *Mugil cephalus* (Linnaeus, 1758), are associated with pathological changes and immunological gene expression alterations. *Aquaculture Research*, *52*(12), 6143-6151.

Malmberg, G. (1957). On the occurrence of Gyrodactylus on Swedish fishes. Skrifterutgivna av Sodra Sveriges Fiskeriforening,(1956), 19–76.

Mammeri, A. (2016). Contribution à l'étude des facteurs de risque des pathologies dominantes en élevage laitier dans les wilayas de Biskra et de Constantine (Doctoral dissertation, Université Frères Mentouri-Constantine 1).

Manon M. R., Hossain M. D., 2011 Food and feeding habit of *Cyprinus carpio* var. specularis. *Journal of Science Foundation 9*(1&2):163-181.

Marcogliese, D. J., Esch, G. W. (1989). Experimental and natural infection of planktonic and benthic copepods by the Asian tapeworm, Bothriocephalus acheilognathi. *Proceedings of the Helminthology Society of Washington*, *56*, 151-155.

Marcotegui, P.S., Montes, M.M., Barneche, J., Ferrari, W., Martorelli, S. (2018). Geometric morphometric on a new species of Trichodinidae. A tool to discriminate trichodinid species combined with traditional morphology and molecular analysis. International Journal for Parasitology. *Parasites and Wildlife, 7* (2), 228–236.

Markevic, A.P. (1951). Parasitofauna of freshwater fishes in USSR. Ukrain Academy of science SSSR, Kiev.

Martins, M., Ghiraldelli, L. (2008). *Trichodina magna* Van As and Basson, 1989 (Ciliophora: Peritrichia) from cultured Nile tilapia in the state of Santa Catarina, Brazil. *Brazilian Journal of Biology, 68* (1), 169–172.

Martins, M. L., Cardoso, L., Marchiori, N., Benites de Pádua, S. (2015). Protozoan infections in farmed fish from Brazil: diagnosis and pathogenesis. *Revista Brasileira de Parasitologia Veterinária, 24*, 1–20.

Mbega, J. D., & Teugels, G. G. (2003). Guide de détermination des poissons du bassin inférieur de l'Ogooué. SLACK Incorporated.

Meddour, A. (2009). Pisciculture et biodiversité de la parasitofaune des poissons dans le Nord-Est de l'Algérie. (Thèse Doctorat sciences. Institut des sciences vétérinaires. Centre universitaire d'EL Taref).

Meddour, A., Meddour, B. K., Brahim-Tazi, N.A., Zouakh, D.E. & Mehennaoui S., (2010). Microscopie Electronique à Balayage des Parasites des Poissons du lac Oubeira - Algérie European Journal of Scientific Research, ISSN 1450-216X Vol.48.

Medjani, F., Aissani, B., Labar, S., Djidel, M., Ducrot, D., Masse, A., & Hamilton, C. M. L. (2017). Identifying saline wetlands in an arid desert climate using Landsat remote sensing imagery. Application on Ouargla Basin, southeastern Algeria. *Arabian Journal of Geosciences*, *10*, 1-11.

Menasria, A., Barčák, D., Kaouachi, N., Bensouilah, M., Scholz, T., & Hernández-Orts, J. S. (2020). Redescription of *Acanthogyrus* (Acanthosentis) *maroccanus* (Dollfus, 1951)(Acanthocephala: Quadrigyridae), a parasite of the Algerian barb *Luciobarbus callensis* (Valenciennes)(Cyprinidae) in Algeria, and first molecular data. *Journal of Helminthology*, *94*, e82.

Meunier, F. J. (1988). Determination de l'age individuel chez les Osteichthyens a l'aide de la squelettochronologie: historique et methodologie [scalimetrie, otolithometrie, marque de croissance, annuli, ligne d'arret de croissance]. *Acta Oecologica Oecologia Generalis*, *9*.

Mhaisen, F. T., Ali, A. H., & Khamees, N. R. (2013). Checklists of monogeneans of freshwater and marine fishes of Basrah province, Iraq. *Basrah Journal of Agricultural Sciences*, *26*(1), 26-49.

Míč, R., Řehulková, E., & Seifertová, M. (2023). Species of Ergasilus von Nordmann, 1832 (Copepoda: Ergasilidae) from cichlid fishes in Lake Tanganyika. *Parasitology*, *150*(7), 579-598.

Migala, K. (1971) Studies on natural populations of parasitic protozoa on *Cyprinus carpio* L., in pond culture. Carps in the first year of life. *Acta Protozool. 8*: 309-339.

Mimeche, F., Biche, M., Ruiz-Navarro, A., & Oliva-Paterna, F. J. (2013). The population structure, age and growth of *Luciobarbus callensis* (Cyprinidae) in a man-made lake in the Maghreb (NE Algeria). *Limnetica, 32*(2), 391-404.

Mimeche, F., & Oliva-Paterna, F. J. (2018). Temporal variations in abundance and biomass of fish species inhabiting the K'sob reservoir (Eastern of Algeria). *Studia Universitatis Babeș-Bolyai Biologia*, *63*(2), 131-138.

Mimeche, F., Zedam, A., Chafaa, S., Mimeche, H., & Biche, M. (2018). Étude saisonnière du régime alimentaire du barbeau *Luciobarbus callensis* (Valencienne 1842) dans le réservoir de K'sob (M'Sila, Algérie). *Revue des sciences de l'eau*, *31*(2), 163-171.

Mittermeier, R. A., Farrell, T. A., Harrison, I. J., Upgren, A. J., & Brooks, T. M. (2010). Fresh water: The essence of life (Vol. 18). *Arlington, United States: Conservation International, US*

Molnár, K. (2012). Fifty years of observations about the changes of Dactylogyrus infection of European common carp (Cyprinus carpio carpio L.) in Hungary. *Magyar Àllatorvosok Lapja, 134*(2), p. 111-118.

Molnár, K., Székely, C., & Baska, F. (1991). Mass mortality of eel in Lake Balaton due to Anguillicola crassus infection. *Bulletin of the European Association of Fish Pathologists, 11*(6), p. 211-212.

Molnár, K., Székely, C., & Perényi, M. (1994). Dynamics of Anguillicola crassus (Nematoda: Dracunculoidea) infection in eels of Lake Balaton, Hungary. *Folia Parasitologica*, *41*(3), 193-202.

Morand, S., & Gonzalez, E. A. (1997). Is parasitism a missing ingredient in model ecosystems?. *Ecological Modelling*, *95*(1), 61-74.

Moravec, F. (1994). Parasitic nematodes of freshwater fishes of Europe. London: Kluwer Academic Publishers Dordrecht, Boston.

Moravec, F. (2006). Dracunculoid and anguillicoloid nematodes parasitic in vertebrates (pp. 634-pp). Academia, Praha, Czech Republic.

Morsi, A., Mimeche, F., & Biche, M. (2015). Age structure and growth of Algerian barbel *Luciobarbus callensis* (Valenciennes, 1842)(Cyprinidae) in El-Harrach River (North of Algeria). *Aquaculture, Aquarium, Conservation & Legislation*, *8*(4), 475-484.

Morsi, A., Nouidjem, Y., & Mimeche, F. (2021). Morphological Parameters of the Maghreb Bleak *Tropidophoxinellus callensis* (Leuciscidae) in an Algerian Mediterranean Stream. *Journal of Ichthyology*, *61*(6), 818-824.

Mouaissia, W., Kaouachi, N., Chahinez, B., Tolba, M., Naima, K., Sahtout, F., & Bensouilah, M. (2017). Reproductive biology of Algerian barb *Luciobarbus callensis* (Valenciennes, 1842) (Cyprinidae) in Beni Haroun dam, north-east of Algeria. *AACL Bioflux*, *1*0, 1671-1682.

Mounia, T., Ramzi, H., Mohamed, C. B., Houda, B., & Nouha, K. (2022). Length-Weight Relationships of the Bream *Abramis Brama* (Linnaeus, 1758) in Beni-Haroun Dam of Mila City (North-East Of Algeria). *Journal of Bioresource Management*, *9*(4), 3.

Myrenås, E., Näslund, J., Persson, J., & Sundin, J. (2023). Effects of the invasive swim bladder parasite *Anguillicola crassus* on health and condition indicators in the European eel. *Journal of Fish Diseases*, *46*(10), 1029-1047.

Naik, G., Rashid, M., Balkhi, M. H., Bhat, F. A. (2015). Food and feeding habits of *Cyprinus carpio* Var. communis: a reason that decline Schizothoracine fish production from Dal Lake of Kashmir Valley. *Fisheries and Aquaculture Journal 6*: 155. doi:10.4172/2150- 3508.1000155.

Naiman, R. J., & Turner, M. G. (2000). A future perspective on North America's freshwater ecosystems. *Ecological applications*, *10*(4), 958-970.

Naldoni, J., Zatti, S. A., Capodifoglio, K. R., Milanin, T., Maia, A. A., Silva, M. R., & Adriano, E. A. (2015). Host-parasite and phylogenetic relationships of *Myxobolus filamentum* sp. n.(Myxozoa: Myxosporea), a parasite of *Brycon orthotaenia* (Characiformes: Bryconidae) in Brazil. *Folia Parasitologica*, *62*, 1.

Nazarizadeh, M., Nováková, M., Loot, G., Gabagambi, N. P., Fatemizadeh, F., Osano, O., ... & Štefka, J. (2023). Historical dispersal and host-switching formed the evolutionary history of a globally distributed multi-host parasite–The *Ligula intestinalis* species complex. *Molecular Phylogenetics and Evolution*, *180*, 107677.

Nel, J. L., Roux, D. J., Maree, G., Kleynhans, C. J., Moolman, J., Reyers, B., ... & Cowling, R. M. (2007). Rivers in peril inside and outside protected areas: a systematic approach to conservation assessment of river ecosystems. *Diversity and Distributions*, *13*(3), 341-352.

Nematollahi, A., Ahmadi, A., Mohammadpour, H., Ebrahimi, M. (2013). External parasite infection of common carp (*Cyprinus carpio*) and big head (*Hypophthalmichthys nobilis*) in fish farms of Mashhad, northeast of Iran. *J. Parasit.*, *37* (1), 131-133.

Nicacio, G., & Juen, L. (2015). Chironomids as indicators in freshwater ecosystems: an assessment of the literature. Insect Conservation and Diversity, 8(5), 393-403.

Nmor, J. C., Egwunyenga, A. O., & Ake, J. E. G. (2003). Observations on the intestinal helminth parasites of cichlids in the upper reaches of River Orogodo, a freshwater body in Delta State, southern Nigeria. *Tropical Freshwater Biology*, *12*, 131-136.

Okamura, B., Gruhl, A., Bartholomew, J.L. (2015). Myxozoan Evolution, Ecology and Development; Springer: Cham, Switzerland, Volume I, pp. 1–441.

Okamura, B., Hartigan, A., Naldoni, J. (2018). Extensive uncharted biodiversity: the parasite dimension. *Integrative and Comparative Biology* 58(6):1132–1145.

Olson, D. M., & Dinerstein, E. (2002). The Global 200: Priority ecoregions for global conservation. *Annals of the Missouri Botanical garden*, 199-224.

Olson, D. M., Dinerstein, E., & Wikramanayake, E. D. (2002). Conservation biology for the biodiversity crisis. *Conservation Biology*, *16*(1), 1-3.

Ombredane, D., & Baglinière, J. L. (1992). Les écailles et leurs utilisations en écologie halieutique. In *Tissus durs et âge individuel des vertébrés. Colloque national, Bondy. Colloques et Séminaires ORSTOM-INRA, Paris. p* (pp. 151-192).

Ould Bilal, O. S. A. (2005). *Étude écobiologique d'oreochromisniloticus (teleosteen, cichlidae) du fleuve Sénégal* (Doctoral dissertation in animal biology. University of Dakar. Sénégal. 98p).

Oulhiz, A. (2018). Évaluation, valorisation et utilisation des coproduits de la crevette rouge *Aristeus antennatus* (Risso, 1816) et du thon *Thunnus thynnus* (Linné, 1758) pour l'alimentation du tilapia rouge (*Oreochromis* sp). (Doctoral dissertation, University of Abdelhamid Ibn Badis Mostaganem, Departement of biology).

Ôzer, A. (2000). The occurrence of three species of *Trichodina* (Ciliophora: Peritrichia) on *Cyprinus carpio* in relation to culture conditions, seasonality and host characteristics. *Acta Protozoologica*, *39*(1), 61-66.

Ozer, A. (2002). Co-existence of Dactylogyrus anchoratus Dujardin, 1845 and *D. extensus* Mueller & Van Cleave, 1932 (Monogenea), parasites of common carp (*Cyprinus carpio*). *Helminthologia*, *39*(1), 45-50.

Özer, A., Öztürk, T. (2005). *Dactylogyrus cornu* Linstow, 1878 (Monogenea) Infestationson vimba (*Vimba vimba tenella* (Nordmann, 1840)) Caught in the inop Region of Turkey in Relation to the Host Factors, *Turkish Journal of Veterinary Animal Science*, *29,* 1119–1123.

Öztürk, M. O. (2014). Metazoan parasite fauna of the chub, *Squalius cephalus* (Linnaeus, 1758) linked to environmental factors from Akçay stream, Turkey. Fresenius Environmental Bulletin, *23*(10a), 2610-2614.

Palstra, A. P., Heppener, D. F. M., Van Ginneken, V. J. T., Székely, C., & Van den Thillart, G. E. E. J. M. (2007). Swimming performance of silver eels is severely impaired by the swim-bladder parasite *Anguillicola crassus*. *Journal of Experimental Marine Biology and Ecology*, *352*(1), 244-256.

Paperna, I. (1975). Parasites and diseases of the grey mullet (Mugilidae) with special reference to the seas of the Near East. *Aquaculture*, *5*(1), 65-80.

Paperna, I. (1996). Parasites, infections and diseases of fishes in Africa—an update. Central Institute of Freshwater Aquaculture, Technical Paper no. 31, Food and Agriculture Organization, United Nations, Rome, 122–142.

Paperna, I., & Zwerner, D. E. (1974). Massive leech infestation on a white catfish (*Ictalurus catus*): a histopathological consideration. *Proceedings of the Helminthological Society of Washington*, *41*(1), 64-67.

Pennak, R.W. (1978). Freshwater invertebrates of the United States. 2nd ed. John Wiley & Sons, New York.

Pérez-Bote, J.L. (2000). Occurrence of *Lernaea cyprinacea* (Copepoda) on three native cyprinids in the River Guadiana (SW Iberian Peninsula), *Res. Rev. Parasitol., 60* (3-4), 135-136.

Petithory, J. C., Ardoin, F., & Ash, L. R. (2005). Rapid and inexpensive method of diluting Giemsa stain for diagnosis of malaria and other infestations by blood parasites. *Journal of clinical microbiology*, *43*(1), 528-528.

Pickering, A. D., Christie, P. (1980). Sexual differences in the incidence and severity of ectoparasitic infestation of the brown trout, *Salmo trutta* L. *J Fish Biol*. 16: 669-683.

Pimm, S. L., Russell, G. J., Gittleman, J. L., & Brooks, T. M. (1995). The future of biodiversity. *Science*, *269*(5222), 347-350.

Pinkas, L, Oliphant, M. S., Iverson, I. L. K. (1971). Food habits of albacore, bluefin tuna and bonito in Californian waters. *California Department of Fish and Game Fish Bulletin*, 152, 1-105.

Poulet, N. (2004). Le sandre (*Sander lucioperca* (L.)): biologie, comportement et dynamique des populations en Camargue (Bouches du Rhône, France) (Doctoral dissertation, University of Paul Sabatier-Toulouse III).

Pugachev, O. N., P.. I. Gerasev, A. V. Gussev, R. Ergens & I. Khotenowsky (2010). Guide to the Monogenoidea of Freshwater Fish of Palaearctic and Amur Regions. Edizioni Ledizioni Ledi Publishing, Milan.

Rabie, G., Ahlem, M., & F Mehanna, S. (2021). Reproductive dynamics of the redbelly tilapia (*Tilapia zillii* gervais, 1848) in ayata lake as a ramsar site in south-eastern algeria. *Egyptian Journal of Aquatic Biology and Fisheries*, *25*(2), 253-265.

Radinger, J., Britton, J. R., Carlson, S. M., Magurran, A. E., Alcaraz-Hernández, J. D., Almodóvar, A., ... & García-Berthou, E. (2019). Effective monitoring of freshwater fish. *Fish and Fisheries*, *20*(4), 729-747.

Rahmouni, I., Rkhami, O. B., Benhoussa, A., & Pariselle, A. (2020). *Markewitschiana agdazensis* n. sp. (Monogenea: Dactylogyridae) from Cyprinids (Teleostei: Cypriniformes) in Morocco (Northern Africa): first record and new site of infection. *Comparative Parasitology*, *87*(1), 68-73.

Raissy, M., Azizi, H., Fadaeifard, F., & Pour, S. Y. (2013). Parasites of some native fish from Kaaj river, Chaharmahal va Bakhtiari province, Iran. *World J. Fish Mar. Sci*, *5*(1), 84-87.

Reaka-Kudla, M. L. (1997). The global biodiversity of coral reefs: a comparison with rain forests. *Biodiversity II: Understanding and protecting our biological resources*, *2*, 551.

Reghaissia, N., Maxamhud, S., Laatamna, A., Samari, H., Dahmane, A., Berima, R., ... & Tsaousis, A. D. (2022). First epidemiological report on the prevalence and associated risk factors of *Cryptosporidium* spp. in farmed marine and wild freshwater fish in central and eastern of Algeria. *Acta Parasitologica*, *67*(3), 1152-1161.

Revenga, C., Campbell, I., Abell, R., De Villiers, P., & Bryer, M. (2005). Prospects for monitoring freshwater ecosystems towards the 2010 targets. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *360*(1454), 397-413.

Rohlenová, K., Morand, S., Hyršl, P., Tolarová, S., Flajšhans, M., & Šimková, A. (2011). Are fish immune systems really affected by parasites? An immunoecological study of common carp (*Cyprinus carpio*). *Parasites & vectors*, *4*(1), 120.

Rouis, S. O., Rouis, A. O., Dumont, H. J., Magellan, K., & Arab, A. (2016). Dynamics and effects of *Ligula intestinalis* (L.) infection in the native fish *Barbus callensis* Valenciennes, 1842 in Algeria. *Acta Parasitologica*, *61*(2), 307-318.

Sadouni, S., & Iguer-Ouada, M. (2019). Factors limiting successful reproduction in wild silver carp, *Hypophthalmichtys molitrix*, in Kherrata Reservoir, Algeria. *Fisheries & Aquatic Life*, *27*(3).

Sahtout, F., Boualleg, C., Kaouachi, N., Khélifi, N., Menasria, A., & Bensouilah, M. (2018). Feeding habits of *Cyprinus carpio* in Foum El-Khanga Dam, Souk-Ahras, Algeria. *AACL Bioflux,*, *11*(2.).

Sahli, A., Ahmed, M., Mebarki, L., & Malainine, H. (2020). Nutritional valorization and health risk assessment of metal pollution of Nile Tilapia fish cultured in Bechar region, Southwest of Algeria. *Advances in food sciences, 42*, 87-94.

Sahtout, F., Boualleg, C., Khelifi, N., Kaouachi, N., Boufekane, B., Brahmia, S., ... & Bensouilah, M. (2017). Study of some biological parameters of *Cyprinus carpio* from Foum El-khanga Dam, Souk-Ahras, Algeria. *Aquaculture, Aquarium, Conservation & Legislation*, *10*(4), 663-674

Saikia, S. K., Das, D. N. (2008). Feeding ecology of common carp (*Cyprinus carpio* L. 1758) in a rice–fish culture system of the Apatani Plateau (Arunachal Pradesh, India). *Aquatic Ecology 23*(6), 513-524.

Salhi, S. (2022). Bio-écologie et phénomène de parasitisme chez les cyprinidés : cas du genre Pseudophoxinus. (Doctoral dissertation, University of Amar Telidji Laghouat, Departement of biology).

Salhi, S., Chaibi, R., Badache, H., Hamidouche, M., & Laouar, R. (2021). Seasonal variation in the diet and the morphometric parameters of the genus *Pseudophoxinus* sp.(Cyprinidae) in Eastern Algeria. *Biosystems Diversity*, *29*(4), 326-333.

Saoudi, A., Brient, L., Boucetta, S., Ouzrout, R., Bormans, M., & Bensouilah, M. (2017). Management of toxic cyanobacteria for drinking water production of Ain Zada Dam. *Environmental Monitoring and Assessment*, *189*, 1-11.

Sarabeev, V., Balbuena, J. A., Morand S. (2019). Aggregation patterns of helminth populations in the introduced fish, *Liza haematocheilus* (Teleostei: Mugilidae): disentangling host–parasite relationships. *International journal for parasitology, 49,* 83–91. https://doi.org/10.1016/j.ijpara.2018.10.004

Sasal, P., Taraschewski, H., Valade, P., Grondin, H., Wielgoss, S., & Moravec, F. (2008). Parasite communities in eels of the Island of Reunion (Indian Ocean): a lesson in parasite introduction. *Parasitology Research*, *102*, 1343-1350.

Sellaoui, N., & Bounaceur, F. (2020). Growth and length-weight relationships of *Gambusia affinis* (Baird et Girard, 1853) population in Algeria (Cyprinodontiformes Poeciliidae). *Biodivers J, 4,* 951-9.

Scholz, T., & Di Cave, D. (1992). *Bothrlocephalus acheilognathi* (Cestoda: pseudophyllldea) parasite of freshwater fish in Italy. *Parassitologia*, *34,* 155-158.

Shafi, S., Bhat, F. A., Yousuf, A. R., & Parveen, M. (2012). Biology of *Cyprinus carpio* communis from Dal Lake, Kashmir with reference to food and feeding habits, length-weight relationship, and fecundity. *Nature, Environment and Pollution Technology*, *11*(1), 79-87.

Sellaoui, N. (2021). Ecologie de Gambusia affinis (Baird & Girard, 1853) dans quelques biotopes humides en Algérie (Doctoral dissertation, Université Ibn Khaldoun-Tiaret-).

Sheikh, B. A., Sofi, T. A., & Ahmad, F. (2014). Ecology of the Asian tapeworm, *Bothriocephalus acheilognathi* Yamaguti, 1934 of fishes in the Dal lake of Srinagar, Kashmir. *International Journal of Fisheries and Aquatic Studies*, *2*, 164-171.

Shukla S. N., Patel V., 2013 Studies on food and feeding behaviour of *Cyprinus carpio* and their gastrosomatic index from Govindgarh Lake, Rewa (M.P.), India. *Online International Interdisciplinary Research Journal*, *3*,116-122.

Šimková, A., Jarkovský, J., Koubková, B., Baruš, V., & Prokeš, M. (2005). Associations between fish reproductive cycle and the dynamics of metazoan parasite infection. *Parasitology research*, *95*, 65-72.

Singhal, P., & Gupta, N. (2009). Genarchopsis infestation in relation to host length and sex in freshwater murrel, Channa. *Biospectra*, *4*, 257-260.

Skelton, P., A. (2001). Complete guide to the freshwater fishes of Southern Africa, 2nd ed. Halfway House: Southern Book Publishers.

Smith, K. G., & Darwall, W. R. (Eds.). (2006). The status and distribution of freshwater fish endemic to the Mediterranean Basin (Vol. 1). Gland, Switzerland and Cambridge, UK: IUCN, p. 34.

Spillmann, C. J. (1961). Faune de France: poissons d'eau douce. Editions chevalier, P. Fédération Française des sociétés de sciences Naturelles, Paris, 303 pp.

Stavrescu-Bedivan, M.M., Popa, O.P., Popa, L.O. (2014). Infestation of *Lernaea cyprinacea* (Copepoda: Lernaeidae) in two invasive fish species in Romania, *Lepomis gibbosus* and *Pseudorasbora parva*. *Knowl. Managt. Aquatic Ecosyst.*, 414, 12, DOI: 10.1051/kmae/2014024.

Stojanovski, S., Hristovski, N., Cakic, P., Cvetkovic, A., Atanassov, G., & Smiljkov, S. (2008). Fauna of monogenean trematodes-parasites of cyprinid fish from Lake Dojran (Macedonia). *Natura Montenegrina*, *7*(3), 389-398.

Strayer, D.L., & Dudgeon, D. (2010). Freshwater biodiversity conservation: recent progress and future challenges. *Journal of the North American Benthological Society*, 29, 344–358.

Székely, C., Molnár, K., & Cech, G. (2015). Description of Myxobolus balatonicus n. sp.(Myxozoa: Myxobolidae) from the common carp *Cyprinus carpio* L. in Lake Balaton. *Systematic Parasitology*, *91*, 71-79.

Taguemount, R., Selmani, R., & Imami, M. (2023). Aquaculture in Algeria: Current Status, Analysis, and Considerations for Commercial Development. *Asian Journal of Fisheries and Aquatic Research*, *25*(5), 53-68.

Tahri, M., Belhaoues, S., Nouara, N., Ladjama, I., & Tania, A. (2017). Scenario for parasitic infestation of the European eel (*Anguilla anguilla* L.) in Oubeïra Lake (northeastern Algeria). *International Journal of Biosciences*, *11*(3), 10-19.

Tahri, M., Bensaad-Bendjedid, L., Dahel, A., Djebbari, N., Nouara, N., & Bensouilah, M. (2018). Site specificity-not everything is everywhere-case of gill ectoparasites of European eel *Anguilla anguilla* (Linnaeus, 1758)(Park National of El Kala, Algeria). *Cah. Biol. Mar*, *59*, 71-78.

Tahri, M., & Bensouilah, M. (2023). The European eel *Anguilla anguilla* (Anguillidae) invasion by the allochthone nematode *Anguillicoloïdes crassus* in southern Mediterranean. *Journal of Ichthyology*, *63*(1), 103-111.

Tahri, M., Crivelli, A. J., Panfili, J., & Bensouilah, M. (2016). Health status of the swim bladder of the European eel *Anguilla anguilla* in northeastern Algeria's Lake Oubeïra. *International Journal of Fisheries and Aquatic Studies*, *4*(1), 364-369.

Talib-Mansoor, N., Jawad Al-Shaikh, S.M. (2011). Isolate two Crustaceans which infect *Cyprinus carpio* L. from Bab Al-Muatham fish markets, Baghdad City. Iraq J. Vet. Med., 35 (1), 52-59.

Tancredo, K. R., Marchiori, N. D. C., Pereira, S. A., & Martins, M. L. (2019). Toxicity of formalin for fingerlings of *Cyprinus carpio* var. koi and in vitro efficacy against

Dactylogyrus minutus Kulwièc, 1927 (Monogenea: Dactylogyridae). *Journal of Parasitic Diseases*, *43*, 46-53.

Tang, F.H., Zhao, Y.J. (2011). Study of trichodinids (Protozoa, Ciliophora) parasitic on gills of freshwater fishes from Chongqing, China, and identication of a new species, *Trichodina cyprinocola* sp. nov. *African Journal of Microbiology Research, 5 (26),* 5523–5527.

Tang, F.H., Zhao, Y.J. (2012). Two trichodinids of Paratrichodina (Ciliophora, Peritrichida, Trichodinidae) infecting gills of *Ietalurus punetaus* from Chongqing, China. *African Journal of Microbiology Research*, *6 (9),* 2145–2149.

Taraschewski, H. (2006). Hosts and parasites as aliens. *Journal of Helminthology*, *80*(2), 99-128.

Tavares-Dias, M. (2022). Toxicity, physiological, histopathological, handling, growth and antiparasitic effects of the sodium chloride (salt) in the freshwater fish aquaculture. *Aquaculture Research*, *53*(3), 715-734.

Teixeira Alves, M., & Taylor, N. G. (2020). Models suggest pathogen risks to wild fish can be mitigated by acquired immunity in freshwater aquaculture systems. *Scientific Reports*, *10*(1), 7513.

Tekin-Özan, S., Kir, İ., & Barlas, M. (2008). Helminth parasites of common carp (*Cyprinus carpio* L., 1758) in Beyşehir Lake and population dynamics related to month and host size. *Turkish Journal of Fisheries and Aquatic Sciences*, *8*(2).

Terofal, F. (1987). Les Poissons d'eau douce. Edition Solar, Paris 287 pp.

Tessema, A. (2020). Effect of Water Quality, Common Carp (*Cyprinus carpio*) Invasion, and Fishing Activities on the Population of Nile tilapia (*Oreochromis niloticus*) in Lake Hayq, Ethiopia. (Doctoral Dissertation. Addis Ababa University, Ethiopia).

Tesfaye, A., Fetahi, T., Getahun, A. (2020). Food and feeding habits of juvenile and adult nile tilapia, *Oreochromis niloticus* (L.) (Pisces: Cichlidae) in Lake Ziway, Ethiopia. *Sinet: Ethiop. J. Sci.*, *43*(2), 88–96.

Tolba, M. (2019). L'effet des Helminthes parasites sur la biologie de quelques poissons d'eau douce (*Cyprinus carpio*, *Luciobarbus callensis* et *Abramis brama*) peuplant le Barrage de Beni Haroun (Wilaya de Mila, Est d'Algérie). (Doctoral Dissertation, Parasitology, Larbi Ben M'hidi Oum El Bouaghi University, Algeria).

Tombi, J., & Bilong, C. B. (2004). Distribution of gill parasites of the freshwater fish *Barbus martorelli* Roman, 1971 (Teleostei: Cyprinidae) and tendency to inverse intensity evolution between Myxosporidia and Monogenea as a function of the host age. *Revue d'Élevage et de Médecine Vétérinaire des Pays Tropicaux, 57(1/2)*, 71-76.

Touil, A., Casal-Lopez, M., Bouhadad, R., & Doadrio, I. (2019). Phylogeny and phylogeography of the genus *Luciobarbus* (Haeckel, 1843) in Algeria inferred from mitochondrial DNA sequence variation. *Mitochondrial DNA Part A*, *30*(2), 332-344.

Tunç, A. Ö., & Koyun, M. (2018). Seasonal infection of metazoan parasites on mosul bleak (*Alburnus mossulensis*) inhabiting Murat River and its tributaries in Eastern Anatolia, Turkey. *Türk Tarım ve Doğa Bilimleri Dergisi*, *5*(2), 153-162.

Turgut, E., & Akin, Ş. (2003). A review on Gyrodactylidae and Dactylogyridae (monogeneans) and their importance in aquaculture. *Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Dergisi*, *20*(2), 43-48.

Tuuha, H., Valtonen, E. T., & Taskinen, J. (1992). Ergasilid copepods as parasites of perch *Perca fluviatilis* and roach *Rutilus rutilus* in Central Finland: Seasonality, maturity and environmental influence. *Journal of Zoology*, *228*(3), 405-422.

Vankara, A. P., Mani, G., & Vijayalakshmi, C. (2011). Metazoan parasite infracommunities of the freshwater eel, *Mastacembelus armatus* Lacèpede, 1800 from River Godavari, India. *International Journal of Zoological Research*, *7*(1), 19.

Van As. J.G., Basson L. (1989) A further contribution to the taxonomy of the Trichodinidae (Ciliophora: Peritrichia) and a review of the taxonomic status of some fish ectoparasitic trichodinids. *Syst. Parasitol. 14*,157-179

Varella, A. M. B., Morey, G. A. M., de Oliveira Malta, J. C. (2019). *Ergasilus tipurus* n. sp. (Copepoda: Ergasilidae), a parasite of Brazilian Amazon fish species. *Acta parasitologica*, *64*, 187-194.

Wagaw, S., Enawgaw, Y., Wendimu, I., & Weldemichael, H. (2024). Seasonal Feeding Activity and Ontogenetic Dietary Shifts of the Common Carp (*Cyprinus carpio*) in Lake Arekit, a Small, Eutrophic Lake in Ethiopia. *Aquaculture, Fish and Fisheries*, *4*(5), e70003.

Wagner, M., Zogaris, S., Berrebi, P., Freyhof, J., Koblmüller, S., Magnan, P., & Laporte, M. (2021). Diversity and biogeography of Mediterranean freshwater blennies (Blenniidae, Salaria). *Diversity and Distributions*, *27*(9), 1832-1847.

Williams, H., Jones, A. (1994). Parasitic worms of fish. London: Taylor & Francis.

Yamaguti, S. (1958). Systema Helminthum. Vol. I, The Digenetic Trematodes of Vertebrates - Part I. New York: Interscience Publishers, INC. 250 Fifty Avenue.

Yamaguti, S. (1959). Systema Helminthum. Vol. II. The Cestodes of Vertebrates. London: Interscience Publishers, Inc.

Yamaguti, S. (1961). Systema Helminthum. Vol. III, The Nematodes of Vertebrates – Part I. New York: Interscience Publishers, INC. 250.

Yamaguti, S. (1963). Systema Helminthum. Vol. V, Acanthocephala. London: Interscience Publishers, Inc.

Youn, S. J., Taylor, W. W., Lynch, A. J., Cowx, I. G., Beard Jr, T. D., Bartley, D., & Wu, F. (2014). Inland capture fishery contributions to global food security and threats to their future. *Global Food Security*, *3*(3-4), 142-148.

Zaidi, N., & Soltani, N. (2011). Environmental risks of two chitin synthesis inhibitors on Gambusia affinis: chronic effects on growth and recovery of biological responses. *Biological Control*, *59*(2), 106-113.

Zhang, J. Y., Wang, J. G., Li, A. H., & Gong, X. N. (2010). Infection of *Myxobolus turpisrotundus* sp. n. in allogynogenetic gibel carp, *Carassius auratus gibelio* (Bloch), with revision of *Myxobolus rotundus* (sl) Nemeczek reported from *C. auratus auratus* (L.). *Journal of Fish Diseases*, *33*(8), 625-638.

Zhang, J. Y., Yokoyama, H., Wang, J. G., Li, A. H., Gong, X. N., Ryu-Hasegawa, A., ... & Ogawa, K. (2010). Utilization of tissue habitats by *Myxobolus wulii* Landsberg & Lom, 1991 in different carp hosts and disease resistance in allogynogenetic gibel carp: redescription of M. wulii from China and Japan. *Journal of Fish Diseases*, *33*(1), 57-68.

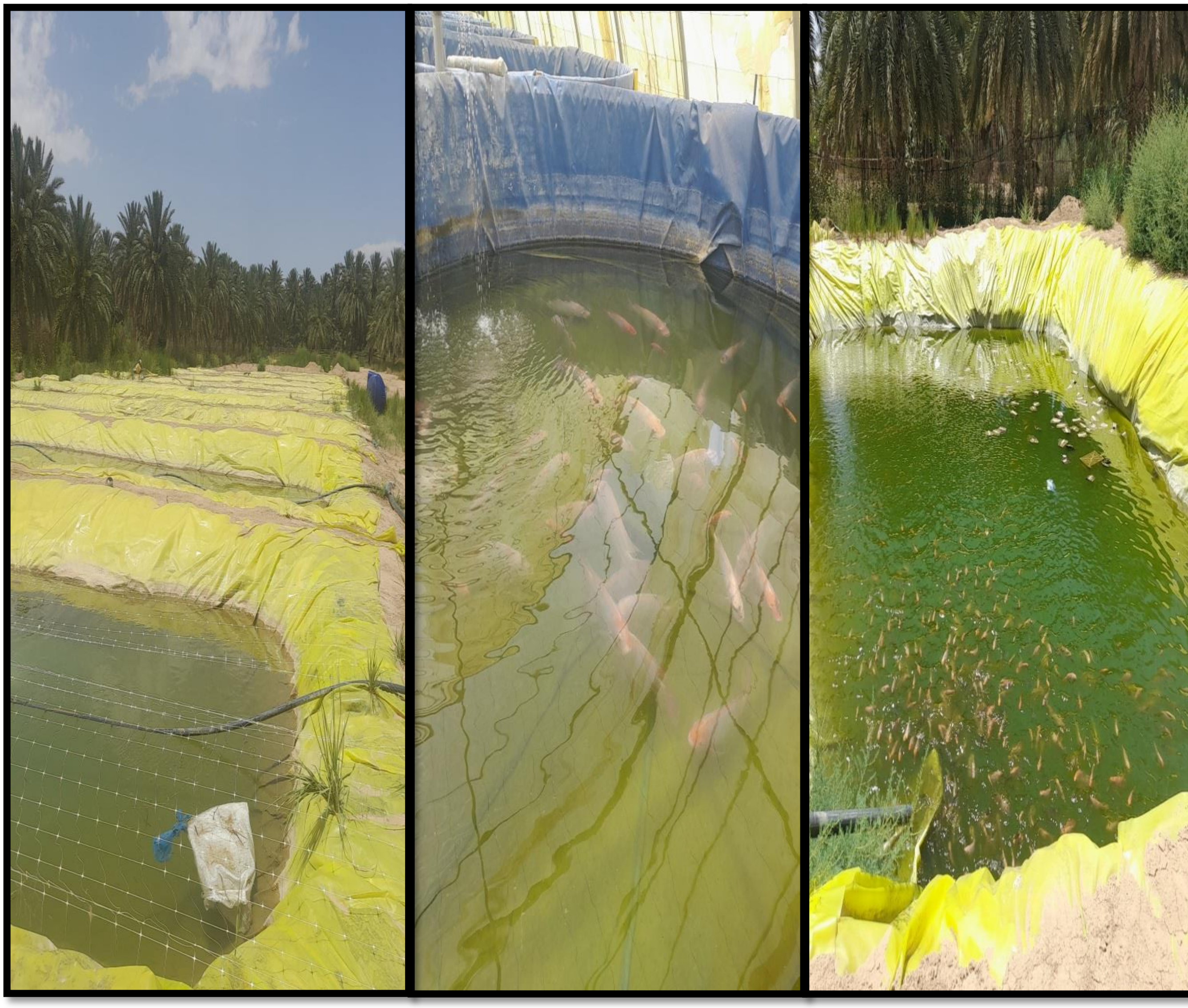
Zouakh, D., Chebel, F., Bouaziz, A., & Kara, M. H. (2016). Reproduction, age and growth of *Tilapia zillii* (Cichlidae) in Oued Righ wetland (southeast Algeria). *Cybium*, *40*(3), 235-243.

APPENDICES

Appendices

Picure 1. Chbika sampling site in the Djelfa region (original photo).

Picure 2. Lalmaia sampling site in the Laghouat region (original photo).



Picure 3. Fish farms sampling site in the Biskra region (original photo).

Picure 4. Oued Tadmit sampling site in the Djelfa region (original photo).

Scientific publications and productions

International communication

- Chabira D., Attir B., Mammeri A. (2023). Premières données sur la parasitofaune de la carpe peuplant la retenue collinaire Lalmaia (Laghouat, Algérie). First International Seminar on Valorization of Bioresources in Environment and Health. University of Echahid Hamma Lakhdar El Oued, May 11th and 12th, 2023.

- Chabira D., Attir B., Mammeri A. (2024). First data on carp parasitofauna inhabiting the artificial lake of Chbika (Djelfa, Algeria). International Congress on Applied Zoology. Laboratory of Applied Zoology and Animal Echophysiology, Faculty of Natural and Life Sciences, University of Bejaia, October 14th , 15th and 16th , 2024.

Publications

- Chabira, D., Mammeri, A., & Attir, B. (2024). Review of freshwater fish parasitism in Algeria: a synthesis of the main publications from 2013 to 2023. *Brazilian Journal of Animal and Environmental Research*, *7*(4), e75764-e75764.
- Chabira, D., Attir, B., Aydoğdu, N., & Mammeri, A. (2025). First report of *Dactylogyrus fimbriphallus* (El Gharbi, Birgi & Lambert, 1994) infecting *Luciobarbus biscarensis* (Boulenger, 1911) in Oued Tadmit River of Djelfa Governorate (Algeria). *African Journal of Aquatic Science*, 1–8. https://doi.org/10.2989/16085914.2025.2478015