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Comparative Study on the Influence of Physicochemical Parameters on Biometric Parameters and Parasitic Infestation in *Cyprinus carpio* (Carp) from Lakes Oubeira and Tonga, Algeria.

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ABSTRACT
This work is a comparative study of two environments, the Oubeira and Tonga Lakes, regarding the influence of the physicochemical parameters on the biometric parameters (weight, size and biometric indices) and the parasitic infestation of the carp *Cyprinus carpio*. The physicochemical parameters characterized by turbidity and suspended matter are important in Tonga Lake compared to Oubeira Lake. This influence showed a negative allometric growth, while an important infestation was recorded by copepods (a negative correlation with monogenes and some biometric parameters such as GSI, HSI and ISS). The carp (*C. carpio*) of Lake Tonga is strongly infested by Monogenes and a high rate of the parameters GSI, HSI and ISS. While, the carp of the lake of Oubeira is characterized by a strong infestation by copepods and low rates of GSI, HSI and ISS

INTRODUCTION

The physicochemical parameters play an essential role in the growth of biota in an aquatic ecosystem **(Murugan et *al.*, 2020)**. Temperature influences all physiological processes occurring in organisms, being particularly determinant for Poikilotherms animals in addition to pH, salinity and dissolved oxygen that have great impacts **(Sampaio & Rosa, 2019)**.

The influence of environmental factors, such as temperature, salinity, oxygen, food availability and population density was addressed in numerous studies **(Pauly, 2010; Cheung *et al.*, 2012**; **Rueda-Roa, 2012; Baudron et *al.*, 2014)**. Their impact on growth variability has been investigated **(Brander, 1995; Mollet *et al.*, 2013; Baudron *et al.*, 2011, 2014)**. Fish growth responds to variability with respect to all those environmental factors.

Female reproductive parameters are accurate indicators of the influence of environmental changes on organisms. Nevertheless, reproductive performance is influenced by many factors, including broodstock size and habitat **(Cavalli *et al.*, 1997)**, environmental conditions **(Otoshi *et al.*, 2003)**, age and season **(Crocos & Coman, 1997, 2004)**, diet **(Lin & Shi, 2002)** as well as genetics and oxygen availability **(Peruzza *et al*., 2018)**.

Additionally, the relationship between length (L) and weight (W) as W = aLb is used to determine reproductve performance **(Ricker, 1975)**. The constant value « a » has the ability to interpret body shape. When the a value is 0.001, it indicates that the fish is more eel-like, 0.008 more elongated, 0.013 more fusiform and 0.018 more short and deep **(Froese, 2006)**. The value of b exponent depicts very important information of fish growth capability to predict the health of the fish. When b is equal to 3, the increase in weight is isometric, which means the fish length and weight increase proportionally **(Santos *et al*., 2002)**. If the value b > 3 (positive allometric), then there is a significant positive relationship between weight and fish length, which indicates that weight will increase with increasing length ; thus the more the fish length increases, the more rotund the fish becomes; When b< 3 (negative allometric), then the weight will decrease with the increase in fish length. The more the fish length increases, the less rotund the fish becomes **(Jones *et al*., 1999)**. Negative allometric growth indicates that there are possibilities of unsuitable environmental conditions, which influence the condition of these species.

According to **Atama *et al*. (2013)**, Fish growth may be influenced by many biotic and abiotic factors, such as phytoplankton abundance, predation, water temperature and dissolve oxygen concentrations among others, which may not favor the survival of all the species in the ecosystem.

Cyprinidae are the richest and the most important family of fish, and its members are distributed worldwide. These family members are widely distributed in fresh water sources. Southeast Asia and China are the actual distribution sites of carp (*Cyprinus carpio L*., 1758) since they occupy an important place in the production of artificial fish, spreading throughout Europe and even in America. The *C. carpio* is a new species that was introduced in Algeria between 1858 & 1931 **(Dieuzeide & Roland, 1951; Kottelat 1997; Kara 2012)**. The wide spreading and effective introduction of *C. carpio* are essentially due to their tolerance under varying environmental conditions **(Forester and Lawrence, 1978)** as well as their capability for early sexual maturity and rapid growth (**Koehn 2004)**. Interestingly, some European countries produce more than 80% of total of *C. carpio* fish **(Woynarovich *et al.*, 2010; Anton-Pardo *et al*., 2014)**.

Fish are closely associated with their environment; physical and chemical changes in the environment are rapid and uncontrollable and can result in measurable physiological changes in fish **(Fazio et *al.*, 2013)**.

Lake Oubeïra is a freshwater body, located in the central part of El-Kala National Park, which includes another freshwater lake, Lake Tonga and a saltwater lagoon.

Parasites acquire resources from their hosts, which are then further limited in the energy reserves available for fueling their own behavior, growth and reproduction. The

exploitation of nutrient resources by parasites can result in decreased fitness **(Masson *et al.*, 2002; Chen *et al.*, 2004; Moon *et al.*, 2013)**, reduced growth (**Cooke et *al.*, 2004)** and/or body size **(Popa *et al.*, 2015)**. It is often associated with lower host survival rate **(Douda, 2015)**. Ectoparasite infestations can cause severe skin damage, such as abrasions and ulcerations on the body surface, hemorrhagic spots on the skin and eroded fins, resulting in economic losses due to reduced growth of fecundity, increased morbidity and susceptibility to secondary infections. Production in Ethiopia as other developing countries is strengthened by the availability of extensive land water systems made up of streams, rivers and lakes which support a large number of fish species, many of which are of economic importance **(Raugue *et al*., 2003)**.
The objective of this work was to determine the influence of physio-chemical parameters of the two environments, Tonga and Oubeira, on the biometric parameters and the parasitic infestation.

MATERIALS AND METHODS

Our research was carried out on 2 waterbodies, the two lakes of Oubeira and Tonga.

1. Study area

1**)** The Tonga Lake is located in the El-Kala National Park in the extreme north-east of Algeria (36°53'N and 08°31' E). It occupies a vast coastal depression of 2600 hectares, with a length of 7.5km and width of 4km (Fig. 1); it has been classified as a World Heritage Site and a RAMSAR site of international importance since 1983. This endorheic freshwater lake is currently the result of various works carried out over the past century and has become a marsh pond, communicating with the sea through an artificial channel, the Messida **(Gehu *et al.*, 1993)**.

The Tonga Lake's catchment area occupies a water volume of about 28,000,000 m^3, which is significantly higher during periods of high water. This area includes two major rivers that flow all year round (Oued El Hout, 14km long, and Oued El Eurg, 10km long) and an outlet, which is Oued Messida **(Bentouili, 2007)**. The study region is subject to a Mediterranean climate characterized by two different seasons: a humid season, marked by heavy rainfall and low temperatures from October to May, and another dry and hot season, with high temperatures reaching their maximum in August **(Labar, 2004; Mebarki, 2010)**.

2) The Oubeira Lake (Lat. 36° 50' N, Long. 8° 23' E) is located at an altitude of about 25 m, with a surface area of 2200 ha (6km on the North-South axis, 5km on the East-West axis), and a depth of 1.5 m that can reach 3m at the end of the rainy season. Its average salinity is about 0.1ppm, and its pH varies from 7.72 to 8.26. The concentration of

dissolved oxygen is 5.80 to 6.7 ppm, with an average temperature ranging from 9°C in January to 28.40°C in August **(Meddour, 1988; Meddour et *al.*, 1989)**. The total volume of the lake estimated by the calculation of different water depths is 32. 031. 078,82m^3. The nature of the bottom is variable (fine sand, fine or black mud). Due to its international importance, the RAMSAR - Wetlands Convention of 1971 conferred on it the status of Integral Zone within the National Park of El Kala (PNEK) (Fig. 1). This lake represents one of the most important natural reserves of fresh water in Algeria, with unique floristic and faunistic value in North Africa. The richness of the biodiversity of the PNEK and its wetlands has been of particular interest over the past two decades.

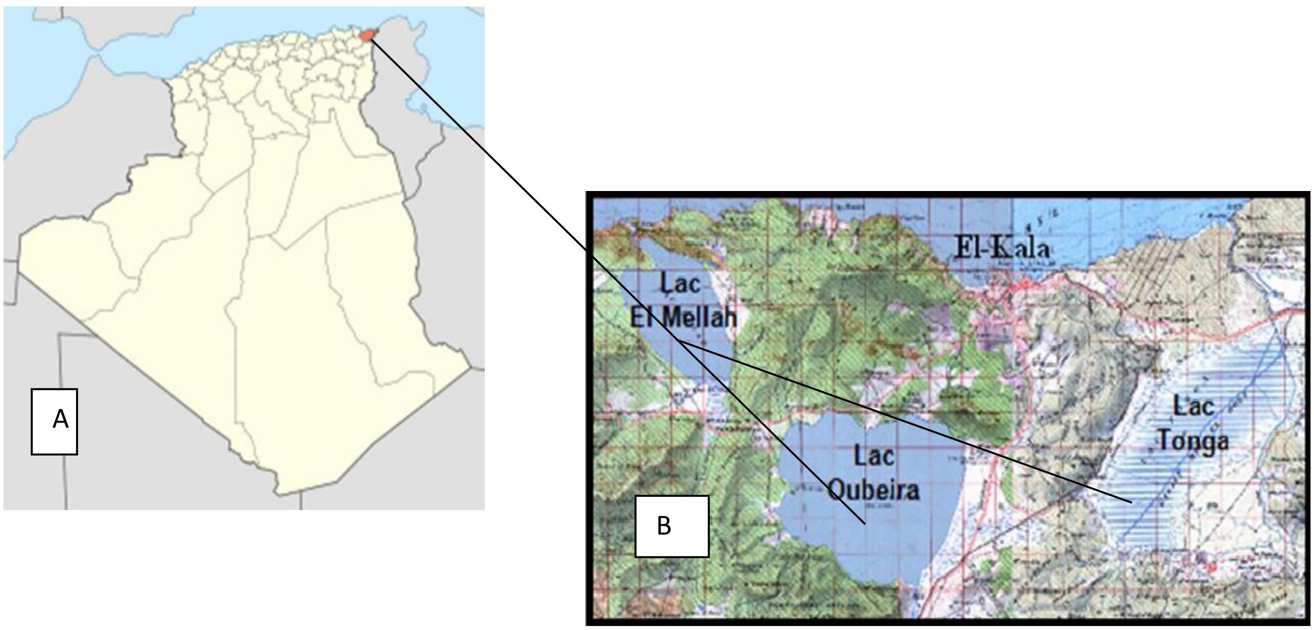

Fig. 1. A) Geographical location of El-Kala National Park **(Benyacoub,1996)**; **B)** Study Area

2. Study of growth

Length-weight relationships were determined according to the allometric equation of **Bagenal and Tesch (1978): W=aL^b**, where W is the body weight (g); L is the body length (Cm), while a and b are constants.

3. Biometric study

Liver and gonad weight were measured and determined in grams. The relative body weight (condition factor, K) was calculated using the equation: K = constant × somatic weight (g)/(standard length [cm])^3 according to **Bolger and Connolly (1989)** (**K = WL-3**

× 100), where K is the condition factor ; W is the weight (g) ; L is the total length (mm) and -3 is the coefficient.

The relative size of gonad (i.e. gonado-somatic index, GSI) was calculated as follows: GSI = gonad weight (g)/ body weight (g) × 100, and the relative size of liver (i.e. hepato-somatic index, HSI) was calculated as follows: HSI = liver weight (g)/ body weight (g) × 100. Spleno-somatic index (ISS): ISS (%) = (Ws/Wf) x100, with Ws: Spleen weight (g) and Wf (g): weight of fish (g).

4. Study of parasites

The gills were detached by two incisions, one dorsal and one ventral; they frozen overnight to allow the parasites to detach. According to the study of **Mizelle (1938)**, before any fixation, the gills were frozen for 12 hours or more to act as an excellent parasite relaxant.

Parasites are searched for, localized and sampled, by careful examination of the gills using a stereomicroscopic magnifying glass (Olympus SZX 10). The parasites observed were separated from their medium, then placed between slide and coverslip and crushed by aspiration of the water used for assembly. A solution of GAP (ammonium-glycerin picrate) was added under the coverslip by capillarity **(Malmberg, 1957)**. The identification of parasite species depended on the examination of morpho-anatomical characteristics defined by **Yamaguti (1963)**.

5. Physicochemical analysis

The measured parameters in the current study were : the electrical conductivity, turbidity, suspended solid materials, dry residues and dissolved oxygen.

RESULTS

1. The growth of the carp (the relation size weight) in both environments (Tonga and Oubeira)

Table 1 . The growth of the carp (the relation size weight) in both environments (Tonga and Oubeira)

Study site	A	b	R	R^2	Relation	type of growth
Oubeira Lake	1,022	1	0,90	0,95	$W= 1,022L^{1}$	negative allometry
Tonga Lake	0,152	2,235	0,91	0,96	$W=0,115L^{2,235}$	negative allometry

2. Spatial evolution of physico-chemical parameters

Spatial variation in the physico-chemical parameters of the water showed that the pH of both lakes is alkaline. The electrical conductivity and dissolved oxygen are very low in Lake Oubeira compared to Lake Tonga ; however, the suspended matter turbidity values are very high in Lake Oubeira, compared to Lake Tonga (Fig. 2).

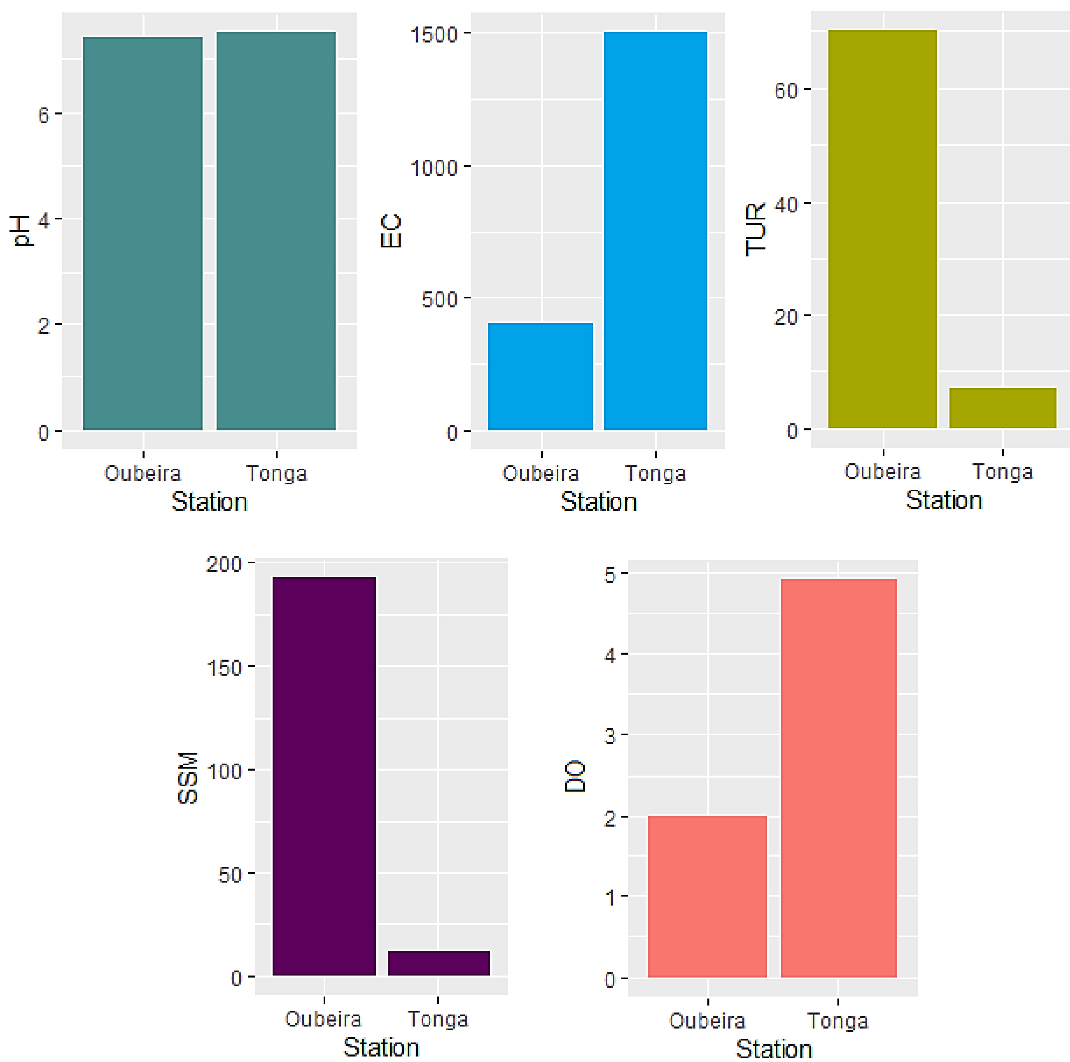

Fig. 2. Spatial evolution of physico-chemical parameters in lakes under study (Tonga and Oubeira)

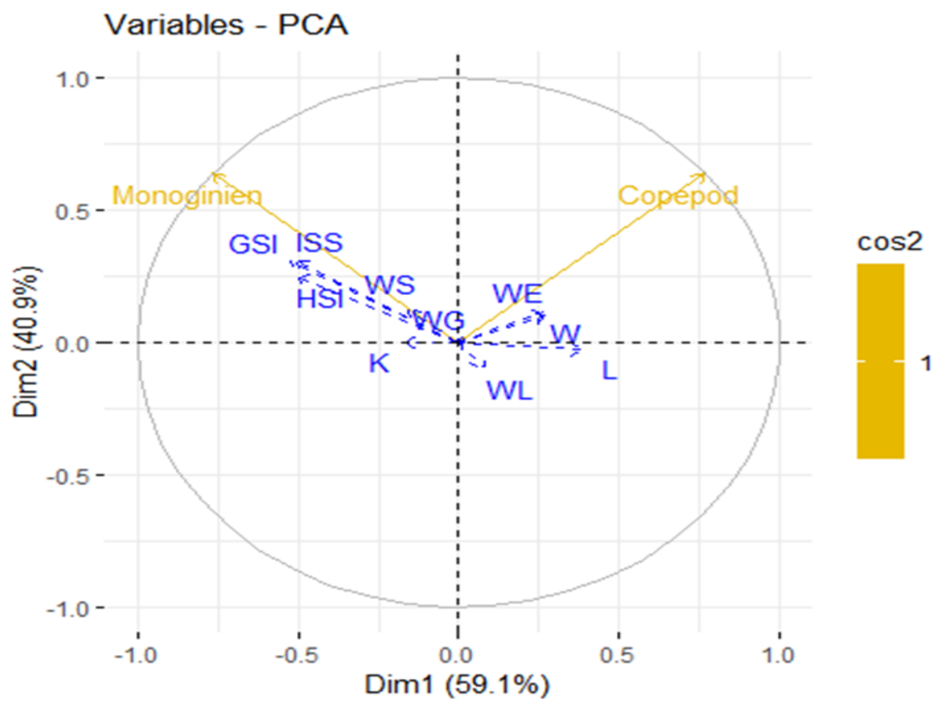

Fig. 3. Correlation circle of biological parameters (morphometric and parasitic fish) with the first two axes of PCA for the two lakes, Oubeira and Tonga

The in-depth PCA analysis for the two factors "station" and "sex" showed that the factors station and sex weakly influence the biology of the fish (morphometry and parasitic infestation). However, from the first axis itw as noticed that, fish from Lake Oubeira are strongly infested by copepods with low ISS, GST and HSI rates, compared to those from Lake Tonga (high monogenes infestation with high ISS, GST and HSI) (Fig. 4-A).

Regarding the sex factor, male fish are highly infested with copepods with low ISS, GST and HSI, compared to female fish (high monogenes infestation with high ISS, GST and HSI) (Fig. 4-B).

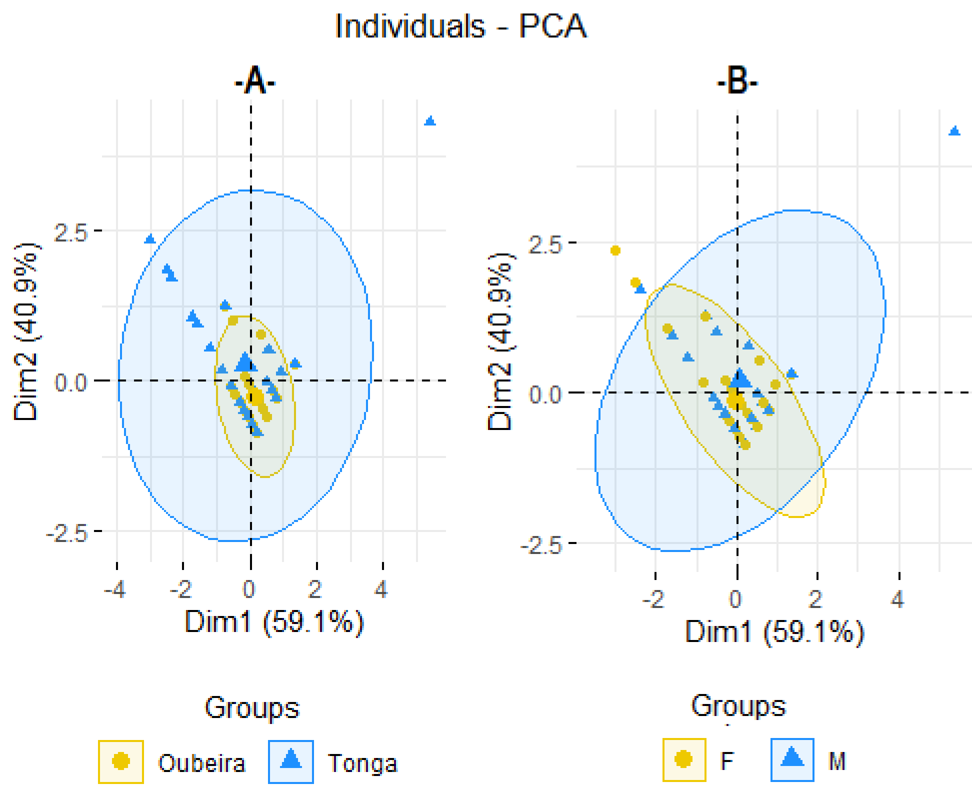

Fig. 4. Principal component analysis (PCA) on the standardized data matrix; **A**: Factorial design (Dim 1 vs Dim2) according to the factor "station", **B**: Factorial design (Dim 1 vs Dim2) according to the factor "sex"

DISCUSSION

Regarding the size/weight relationship of carps in the two environments, Oubeira and Tonga, the growth is negative allometric with b<3. Our results agree with other results on fish biometry. **Bouchereau *et al.* (1999)** reported negative allometric growth for *Epinephelus marginatus* from the Lavezzi Islands (b= 2.60), while **Akyol *et al.* (2007)** reported negative allometry for *Epinephelus costae* from the Aegean Sea in Turkey (b= 2.736). In addition, the present results coincide with those of **Morey *et al*. (2003)**. In addition, negative allometric growth (b = 2.165) was detected for Liza ramada in eastern Libya **(Mohammed et *al*., 2016)**.

Length-weight relationships in fish are a key component in fish stock assessment to inform growth status and assess the management of fish **(Ujjania *et al.*, 2012)**. The length-weight relationship of *C. carpio* in both environments (Lakes Oubeira and Tonga) revealed a minor growth for confused sexes (a negative allometric growth). This may be caused by several factors, including seasonality, habitat type, degree of stomach filling, gonadal maturity, sex, health, conservation techniques, food availability, differences in observed adiposity ranges and species, and physical factors such as temperature and salinity **(Wootton, 1998; Rahman *et al.*, 2012; Hossain *et al.*, 2016)**.

However, some studies have reported a negative correlation between host body size and parasite abundance **(Poulin & Morand, 2000)**. According to **Saha *et al.* (2013**), low pH, dissolved oxygen and high temperature cause infestation in tropical fish, *Labeo rohita*.

According to **Copp *et al.* (2013)**, isometric body growth switches to the allometric type when it reaches a certain standard length. This indicates that the body growth type sometimes changes according to physiological needs. LWRs were used as indicators of environmental changes and ecological health of freshwater fish in Malaysia **(Radhi *et al.*, 2018)**.

The Fulton condition factor K is a measure involving the length and weight of a particular fish ; it could be influenced by the same factors as LWR. The K-value is influenced by the age of the fish, sex, season, stage of maturation, gut fullness, type of food consumed, amount of fat reserve and degree of muscle development. In females, the K-value decreases rapidly as the eggs are expelled **(Barnham & Baxter, 1998)**.

Barnham and Baxter (1998) proposed that, if the K-value is 1.40, it is a good, well-proportioned fish. While, 1.20 as a K- value indicates an average fish, which acceptable to many anglers. 1.00 records a mediocre fish, long and thin ; 0.80 : an extremely mediocre fish with large head and narrow, thin body. The k-condition index for carp from Lake Oubeira is 1.5 and from Lake Tonga is 1.3.

There is a correlation between environmental conditions and fish health. The decrease or increase of pollution in the aquatic ecosystem has a direct impact on the presence or absence of parasites. Fish living in optimal environmental conditions and well nourished are more resistant to diseases than fish weakened by malnutrition caused by parasitic infestation or by deteriorating environmental conditions due to pollution **(Un Nissa *et al*., 2022)**.

Changes due to parasitic infection cause melding of gill lamellae, replacement of tissue (mechanical impairment), proliferation of cells, immunomodulation, alteration of growth, negative behavioral reactions (physiological damage) and damage in reproduction **(Buchmann & Lindenstrom, 2002 ; Knudsen *et al*., 2004; Al-Jahdali & Hassanine, 2010)**.

Fish parasites have been recognized as important sentinel organisms capable of detecting changes in environmental conditions **(Combes 1996; Palm & Ruckert, 2009; Palm, 2011; Palm *et al*., 2011)**.

Under eutrophic water conditions, parasite infection increases, but parasite load may decrease under high eutrophication conditions, representing the detrimental effect of increased eutrophication on parasite load **(Zargar *et al.*, 2012 ; Gilbert & Avenant-Oldewage, 2017)**.

CONCLUSION

It was interesting to conduct a comparative study on the two environments of the lakes of Oubeira and Tonga, addressing their impact on the morphometric and parasitological parameters of the carp *C.caprio*.

Both environments are characterized by alkaline pH, low dissolved oxygen, turbidity and low suspended matter in Lake Oubeira, compared to Lake Tonga.

This study showed the followings : minority growth characterized by negative allometry; a positive correlation with copepods, and a negative correlation with monogeneans and some biometric parameters (GSI, HSI and ISS) in addition to a total variability characterized by a positive correlation with copepods and monogeneans.

A thorough study for the 2 factors (physicochemical parameters of the environment and sex parameters) showed that sex has a weak influence on fish biology (morphometry and parasitic infestation). Additionally, the carps of the lake Oubeira are strongly infested by copepods, with a low rate of the parameters GSI, HSI and ISS, compared to that recorded for the Tonga Lake (strong infestation by Monogenes and a high rate of the parameters GSI, HSI and ISS).

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