EFFECT OF PARASITIC COPEPODS ON THE LENGTH-WEIGHT RELATIONSHIP AND THE CONDITION FACTOR OF CRUCIAN CARP (*CARASSIUS CARASSIUS*) IN THE BENI-HAROUN DAM, MILA CITY, NORTHEAST ALGERIA

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ABSTRACT

Ectoparasites are commonly the largest group of fish pathogenic organisms, and among these, crustaceans cause considerable pathogenic effects on farmed freshwater fishes. The present study was undertaken to investigate the effect of parasitic copepods on the growth of Carassuis carassuis, from the Beni-Haroun Dam, Mila city, Northeast Algeria. The study was conducted on 242 fish individuals sampled between July 2015 – October 2016. The sex was macroscopically determined and age was specified by the scalimetry method. The identified gill ectoparasites were six ectoparasitic species belonging to four genera and two families, namely Ergasilus briani, E. megaceros, E. sieboldi, Paraergasilus brevigiditus, Neoergasilus japonicas and Lernea cyprinacea. Further, the fishes growth under the effect of parasitic copepods was carried out by the mathematical method of Von Bertalanffy, and accordingly, the growth parameters in C. carassuis were L∞ = 34.1 cm; K = 0.65; t0 =-1.01; Ø' = 2.87, in the non-parasitized fishes, and L∞= 29.47 cm; K=0.92; t0= -0.80; Ø'= 2.90, in the parasitized fishes. In addition, the parasites slow down the absolute growth in length of the parasitized fishes which, in turn, suffer from a drop in their condition factor (K = 1.26) compared to the non-parasitized fishes (K = 1.34). The evolution of the total weight of the studied fishes in relation to their length revealed minor allometry (b<3) for the non-parasitized and parasitized fishes (without distinction between the two sexes).

Keywords: *Carassius carassius,* Copepod parasites, Von Bertallanffy growth model, Condition factor, Beni-Haroun Dam

INTRODUCTION

In Algeria, the continental waters provide excellent fish diversity, and hence, the richness and diversity of this biological heritage have slowly built up over time and should be protected to ensure better conservation (Kara, 2012). *Carassuis carassuis* Linnaeus, 1758 (Cypriniformes: Cyprinidae) is a new Algerian fish species found for the first time in the Ain Zada Reservoir, Bordj-Bou-Arreridj City, Algeria, and was newly introduced in the Beni-Haroun Dam, Northeast, Algeria, and has wide ecological distribution (Khelifi, 2018). Within the dam, the growth of this fish is affected by many factors of which one of such is parasitic

infestation. Crustacean parasites are the most dreadful parasites causing serious stress to aquatic organisms due to their high infestation and morbidity potentials.

The result of parasitism is not only the physiological cost for the development and maintenance of the parasite, but also can alter the physiological and the immune reaction of the host (Ebert, 2005). Parasites can affect host physiology, behavior, physical shape, and survival (Ebert, 2005). Interestingly, better conservation requires following the guidelines and management activities leading to the elimination of direct or indirect pathologies, mainly induced by parasites (Thompson *et al.*, 2010).

The study of the effect of parasites on growth promotes describing a change per unit of time, and noteworthy, the growth of a population or an individual is often represented by a mathematical model of individual growth for length or weight elaborated by Von Bertalanffy (1938).

In this regard, the present research studied the effect of the parasites from both gills of *C. carassuis* in the Beni-Haroun dam, Mila city, Northeast Algeria on the fish linear and weight growth.

MATERIALS AND METHODS

The Study Area: Algeria has 114 large and small dams, making her to be classified in the front row in the Arab world and second place in Africa after South Africa in terms of dam richness. The total capacity is around 5200 million cubic metres which, consequently ensuring an annual water volume of 2500 million cubic metres (Drouiche *et al.*, 2012).

The Beni-Haroun dam in Mila city, Northeast Algeria, is a large strategic hydraulic complex in Algeria and controls the waters of the Kebir-Rhumel basin. Also, it is the main large hydraulic transfer system provided by a gigantic pumping station with a flow rate of 21 m^3/s by 700 m of elevation. This dam provides water for five eastern Algeria cities (Mila, Constantine, Batna, Oum e-lbouaghi and Khenchela), whose reserve capacity is around 960 million cubic metres for a dike of 710 m in length and 120 m in height, and its total drained area is 7725 km^3 (Marouf and Remini, 2019) (Figure 1).

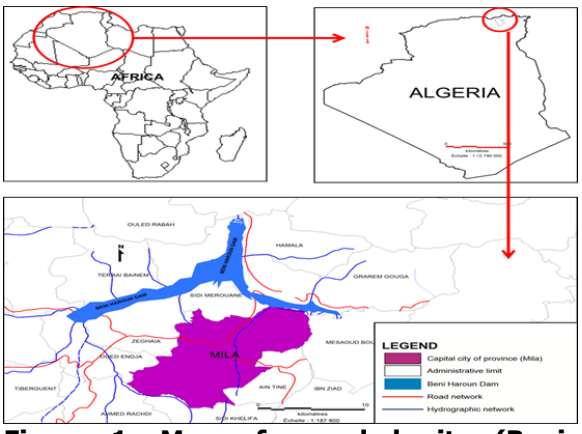

Figure 1: Map of sampled site (Beni-Haroun Dam, Mila city, Algeria)

Experimental Methods

Sampling and identification of host fish: 242 fish individuals of the *C. carassuis* species collected randomly and seasonally from fishermen between July 2015 – October 2016 at the landing sites provided a source of fresh fish supply. Upon receipt, the captured fishes were quickly transported to the laboratory for species identification according to the nomenclature and the criteria reported by Fischer *et al.* (1987).

Length and weight measurements of fish: The fishes were weighed and length measured before being dissected. The biometric data; (i) total length (TL), described as the distance between the end of the muzzle tip and the end of the longest part of the caudal fin was recorded in centimetre (cm) using ichthyometre, and (ii) the total weight (TW) of fishes were measured in gram using an OIML electronic balance (precision of 5 – 10 g and maximum capacity 30 kg).

Determination of fish age: As the body of the captured fish species is covered with scales, the age of fishes was determined by the scalimetric method. Accordingly, the readability, the ease of sampling, and the preparation of quick reading of the scales make it a valuable tool in determining the individual age of the fish. To study the age and linear growth of

fishes, five to ten scales were taken from the flanks of the first dorsal fin of each fish, processed and the annual rings read according to the method of Lux (1971).

Determination of fish sex: The fish sex was determined by the macroscopic observation of the shape and color of the gonads or testicles after dissection of the abdominal cavity. Females have pinkish color ovaries filled with ova (vascularized and more or less grainy in appearance), while males possess milky whitish color testicles without vascularization.

Collection and identification of parasites: The extraction and the observation of the parasites were microscopically determined. Here, each pill box containing the gill arches was poured into a petri dish, placed under the binocular magnifying microscope for very precise observation, and then the parasites were extracted using a fine brush and placed in other pill boxes containing 5 % formalin. Of note, each pill box contains a referenced label indicating the initials of the observer, the date of sampling, and the number of the sample. After that, a sampling sheet for each fish was filled in with the fish number, biometric parameters, and the identified parasite species found in its gills. In addition, the kept samples in pillboxes were re-examined and each identified parasite was the subject of an in-depth study to determine the species. The identification of the parasitic species was based on the examination of the morphometric criteria as defined by Yamaguti (1963).

Fish Growth Modeling

Linear growth: The growth parameters were determined using STATISTICA (Windows version 8) Software. The asymptotic length (L∞) and the growth coefficient (K) of Von Bertalanffy (1938) were determined using ELEFAN (Pauly and David, 1981). Based on Von Bertalanffy model, growth is considered to be the simultaneous action of an anabolic factor proportional to the surface area, and a catabolic factor proportional to the volume level of the body, where the linear growth is displayed by the following formula: $Lt = L\infty\ [1\text{-}e^{-k(t\text{-}to)}]$. The parameters; L∞, K, and t0 characterize the achieved adjustment, and so the current definitions can be given as follows: L(t): Length of the studied fish at time t. L∞: Asymptotic size also called the asymptotic length of L∞ when t tends to infinity. t0: Theoretical age known also as the hypothetical age that a fish of zero length would have when it had grown all its life using the Von Bertalanffy equation.

Relative weight growth: The model enables the measurement of the fish weight from the size or vice versa (Beyer, 1991), and the weight from the age (Petrakis and Stergiou, 1995), in addition to the expression of the growth equation in linear weight models (Pauly, 1993). This relationship is used to describe shapes and to provide evidence for the overweight of specimens (fish) and their evolution over a given period (Richter *et al.,* 2000). The relative growth can be applied in various fields of biology, ecology, and physiology, and importantly, promotes verifying the existence of a correlation between the weights to the lengths of the fish and even modeling this relationship. If the fish keeps the same general shape and the same weight throughout its life, its weight would be proportional to the cube of its length thus: $TW = a.TL^{b}$ Where TW is the total weight (g), TL is the total length (cm), "a" is a Constant, and "b" is the allometry coefficient. The values of a and b generally provide information on the weight variation of an individual fish in relation to its size. These parameters were calculated for the parasitic and non-parasitic specimens, and three cases can be displayed with respect to the slope (b) of the regression line thus: (i) when b = 3, it means that the weight changes proportionally with the cube of the length, this is a perfect isometry, (ii) when b is either > or < than 3 it means that the growth is allometric, (iii) when b > 3, it means that the weight increases faster than the cube of the length, and thus the allometry is major (positive), and when b < 3, it means that the weight increases less quickly than the cube of the length, and thus the allometry is negative (minor). The performance index (Ø) test was

used to compare the growth parameters of the same species of the same or different inventory.

Von Bertalanffy's absolute weight growth model: From the linear growth equation on the one hand, and the height/weight relationship, on the other hand, we can establish the Von Bertalanffy weight growth equation or weight growth. The descriptive model of the weight growth of Von Bertalanffy (1938) is given by the following relation: $TW = W\infty\ (1- e^{-k(t-to)}]$, Where "TW" is the total weight in grams at time t, "W∞" is the asymptotic weight corresponding to L∞, "b" is the allometry coefficient, and K and t0 are parameters of the Von Bertalanffy equation.

Fulton's condition factor (K): The condition factor (K) characterizes an individual's excess weight, nutritional status, and energy reserves. This morphometric index supposes that the heavier fish for a given length is in a better condition. The K was calculated according to Fulton's formula: $K = (W)/TL^b$, where "b" is an allometric coefficient.

RESULTS

Identification of Parasitic Crustaceans Collected from *Carassius carassius*: The examination of the gills of 242 *C. carassuis* fishes caught from the Beni-Haroun dam led to the collection of 37 parasitic copepods. The identification of the collected parasites based on their morpho-anatomical criteria led to the inventory of six parasitic copepod species namely; *Ergasilus briani* Markewitsch, 1993 (Poecilostomatoida: Ergasilidae) (seven individuals), *Ergasilus sieboldi* Von Nordmann, 1832 (Poecilostomatoida: Ergasilidae) (three individuals), *Ergasilus megaceros* C. B. Wilson, 1916 (Poecilostomatoida: Ergasilidae) (one individual), *Paraergasilus brevigiditus* Yin, 1954 (Poecilostomatoida: Ergasilidae) (one individual), *Neoergasilus longispinosus* Yin, 1956 (Poecilostomatoida: Ergasilidae) (one individual), *Neoergasilus japonicus* Harada, 1930 (Poecilostomatoida: Ergasilidae) (21 individuals) and *Lernea cyprinacea* Blainville, 1822 (Cyclopoida: Lernaeidae) (three individuals), in addition to four genera (*Ergasilus, Paraergasilus, Neoergasilus* and *Lernea*) included in two families (Ergasilidae and Lernaeidae).

Effect of Parasitic Copepods on *Carassius carassuis* Growth

Effect on the fish linear growth: Marked variations were observed in the growth parameters, including L∞, K, and t0, and the performance index Ø of parasitized and non-parasitized specimens of *C. carassuis* collected from the Beni-Haroun Dam in Mila city, Algeria using the linear growth equation of Von Bertalanffy (Tables 1, 2 and 3). The asymptotic size (L∞) obtained for non-parasitized and parasitized *C. carassuis* were 34.1 cm and 29.47 cm respectively, with a difference of almost 5 cm (Table 1). The b values of the parasitized *C. carassus* were higher than the b values of the non-parasitized *C. carassuis* (Table 4). The b values obtained for the non-parasitized and the parasitized *C. carassuis* indicated that both species had negative (minor) allometric growth respectively (Table 5).

Relative Weight Growth

Condition factor: The effect of parasitism on the population of *C. carassuis* shows a higher K value in non-parasitized specimens (K = 1.34) than that of parasitized specimens (K=1.26) (Table 6).

DISCUSSION

The examination of both gills of 242 individuals of *C. carassuis* led to the recovery of 37 parasitic copepod individuals. Additionally, the observation of the anatomical and biological features of the parasites collected from the both gills of *C. carassuis* led to identifying six species of parasitic copepods, namely *L. cyprinacea E. sieboldi*, *E. briani*, *E. megaceros*, *N. japonicus* and *P. brevigiditus*.

A previous study conducted on the fishes collected from Bounamoussa River and Obeira Lake both in Northeast Algeria, has shown the presence of the members of the

Table 1: Parameters of the Von Bertalanffy linear growth equation of parasitized and non-parasitized *Carassuis carassus* from Beni-Haroun Dam, Mila city, Algeria

Parameters	N	L∞	K (year^{1})	t0 (year)	Ø'	Lmin-Lmax
Non-parasitized *C. carassuis*	216	34.1	0.65	-1.01	2.87	20 – 32.4
Parasitized *C. carassuis*	26	29.47	0.92	-0.80	2.90	19 – 28

Table 2: Von Bertalanffy's linear growth equation for parasitized and non-parasitized *Carassuis carassus* from Beni-Haroun Dam, Mila city, Algeria

Parameter	Equation
Non-parasitized *C. carassuis*	$TL = 34.1[1-e^{-0,65}(t+1.01)]$
Parasitized *C. carassuis*	$TL = 29.47[1-e^{-0,92}(t+0.8)]$

Table 3: The linear growth equation of Von Bertalanffy of parasitized and non-parasitized *Carassuis carassus* from Beni-Haroun Dam, Mila city, Algeria

Parameter	Equation
Parasitized *C. carassuis*	$TW = 1.13 \times TL^{0.82}$
Non-parasitized *C. carassuis*	$TW = 0.69 \times TL^{2.15}$

Table 4: Parameters of the length-weight relationship for non-parasitized and parasitized *Carassuis carassus* from Beni-Haroun Dam, Mila city, Algeria

Parameters	N	A	b	r^2	R^2
Non-parasitized *C. carassuis*	216	0.69	2.15	0.63	0.39
Parasitized *C. carassuis*	26	1.33	0.82	0.27	0.07

Table 5: Total length-weight allometry of parasitized and non-parasitized *Carassuis carassus* from Beni-Haroun Dam, Mila city, Algeria

Parameters	b	Length-weight allometry
Non-parasitized *C. carassuis*	2.15	Negative (minor) allometric growth
Parasitized *C. carassuis*	0.82	Negative (minor) allometric growth

The "b" value of non-parasitized and parasitized fishes is inferior to 3, and this is explained by a minor (negative) allometry

Table 6: Condition factor in parasitized and non-parasitized *Carassuis carassus* from Beni-Haroun Dam, Mila city, Algeria

Parameters	N	K (g cm^{3})
Non-parasitized *C. carassuis*	216	1.34
Parasitized *C. carassuis*	26	1.26

genera *Ergasilus and Lernea* in the gills of *Luciobarbus callensis* Valenciennes, 1842 (Cypriniformes: Cyprinidae) and *Cyprinus carpio* Linnaeus, 1758 (Cypriniformes: Cyprinidae) (Meddour, 2009). Similarly, Sara *et al.* (2016) and Sara (2017) has reported a great diversity of gill ectoparasites and endoparasites in cyprinids *L. callensis* and *C. carpio* fished from Obeira Lake. Also, the ectoparasite genera; *Ergasilus, Paraergasilus*, *Neoergasilus* and *Lernaea* were found in the gills of *C. carassuis* in Ain Eldalia and Foum Elkhounga dams (Boucenna *et al.*, 2015; Boucenna, 2017). Further, the endoparasites were found in *L. callensis*, *C. carpio, Abramis brama* Linnaeus, 1758 (Cypriniformes: Cyprinidae) and *C. carassuis* (Tolba *et al.*, 2018), and the gills of *L. callensis* and *C. carpio* in Beni-Haroun dam (Berrouk, 2019). In this regard, Nedić *et al.* (2018) have reported the presence of two species of gill ectoparasites, namely *Chilodonella cyprini* Moroff, 1902 (Cyrtophorida: Chilodonellidae) and *Ichthyophthirius multifiliis* Fouquet, 1876 (Hymenostomatida: Ichthyophthiriidae) in 22 fish species in the Sava River in Bosnia and Herzegovina. Similarly, Innal and Stavrescu-Bedivan (2022) have found various ectoparasites species in different species of the Crucian genus inhabiting different lakes in Turkey.

Effect of Parasitic Crustaceans on the Growth of *Carassius carassius* in the Beni-Haroun Dam, Mila City, Algeria: The term "growth" includes a number of different concepts, from the analysis of cellular growth to

the study of populations growth, and indeed, a good understanding of the general biology and fish population dynamics is mainly based on the determination of the growth parameters (Dolbeth, 2021). In this study, the model of Von Bertalanffy (1938) was used to analyze the effect of parasitic crustaceans on the growth of *C. carassuis* in the Beni-Haroun Dam, as well as the comparison of the growth data for the parasitic and non-parasitized species. In this study, the parasitic crustaceans slow down the absolute growth in length of parasitized fish host, and this was in agreement with the report of Cassier *et al.* (1998) who observed a reduction in the growth of mullet infected with *Ergasilus lizae* Krøyer, 1863 (Cyclopoida: Ergasilidae), a haematophagous copepod in a northwestern Russian lake. In addition, the study of Hajji *et al.* (1994), reporting reduced absolute growth in length of host fish infested with *Peroderma cylindricum* Heller, 1865 (Copepoda: Pennellidae). As several groups of parasitic crustaceans can negatively affect fishes, Iyaji and Eyo (2008) has reported serious infections associated with weight loss and often mortality in different fish species.

In this context, some ectoparasitic species members of the family Cymothoidae fixed in the oral cavity and on the body surface were found to exert a significant effect on the growth of their hosts in the natural environment (Romestand and Trilles, 1979). Also, a strong infestation of ectoparasitic species belonging to the family Gnathiidae was reported to induce deleterious effects on teleosts (Cressey, 1983). Similarly, parasitic isopod *Cymothoa eremita* Brünnich, 1783 (Isopoda: Cymothoidae) were found to slow down the growth of the host fish (black pomfret) *Parastromateus niger* Bloch, 1795 (Carangiformes: Carangidae) in the southeast coast of India (Vigneshwaran *et al.*, 2019). . Similarly, the effect of eight parasitic copepods on the growth of *C. carpio* in the same study zone (Berrouk, 2019), and the effect of *E. sieboldi* and *E. briani* on the growth of *A. brama* in Beni-Haroun dam, Mila city, Northeast Algeria (Berrouk *et al.*, 2021) have been investigated. Likewise, Tolba *et al.* (2018) has reported no effect of endohelminths on the growth of *L. callensis*, *C. carpio,* and *A. brama* in the Beni-Haroun dam. On the other hand, the condition factor (K) was found to vary depending on the infestation (presence or absence of the parasite) level. The condition factors of the parasite free-specimens were higher than that of parasitized individuals. Ramdane *et al.* (2013) reported the presence of significant differences in the Fulton's condition factor between parasitized and non-parasitized *Boops boops* Linnaeus, 1758 (Perciformes: Sparidae) from Algeria. Our results agree with those of Boucenna (2017) who reported that the condition factor of parasite free-specimens were higher than that of parasitized individuals of *L. callensis, C. carpio* and *C. Carassuis.* Likewise, Berrouk (2019) recorded that *C. carpio* infested by parasitic copepods had a drop in their condition factor, since *E. sieboldi* and *E. briani* were reported to decrease the condition factor of *A. brama* (Berrouk *et al.*, 2021). Whilst, Tolba *et al.* (2018) found that similarity between the condition factor and the allometry study in non-parasitized and endo-helminths parasitized individuals in the three studied host species (lowering allometry), showed no effect of the internal parasitism on the biological performance of the three studied species. In this context, the pathogenicity of parasites was reported to be related to several factors, including the host (size, age, and health), the parasite (developmental stage and size), and the environment (stress, pollution, etc.). There is less stress, less confinement, and the potential for adaptation and immunity to infection in an open environment.

Conclusion: In the study highlights, the effect of parasitic copepods on the growth of *C. carassuis* in the Beni-Haroun dam can be summarized in the following points: (i) The growth parameters determined by the equation of Von Bertalanffy (1938) showed marked variations in the asymptotic length L∞, growth coefficient K, and performance index Ø' in non-parasitized and parasitized specimens. (ii) The length-weight relationship revealed minor allometry for parasitized and non-parasitized *C. carassuis* specimens, and this is explained by the fact that size increases faster than weight. (iii) The non-parasitized fishes grow better and

faster than parasitized fishes as evidenced by the obtained value of the condition factor K. In perspective, it would be interesting to include the following suggestions: (i) Increase the sampling effort to provide effective insight into the effect of parasitism on the growth of *C. carassuis* population in Beni-Haroun dam. (ii) Performed similar work on the growth of other cyprinid fish, such as *C. carpio* and *L. callensis*. (iii) Study the general growth and growth under the effect of parasites in cyprinids in other water bodies in Algeria.

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