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Parasite biodiversity in four Cyprinid fishes from Beni-Haroun dam (Mila city) North-East of Algeria.

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Abstract Herein, the examination of 776 fishes related to 4 species of cyprinid fishes (*Luciobarbus callensis* ,*Cyprinus carpio*,*Carassuis carassuis* and *Abramis brama*) and collected from Beni-Haroun dam promoted us to identify 99 infested individuals by 249 copepod parasites belonging to eight species, namely *Ergasilus peregrinus* ,*Ergasilus briani* ,*Ergasilus megaceros, Ergasilus sielboldi, Paraergasilus brevigiditus, Neoergasilus longispinosus Neoergasilus japonicus* and *Lernea cyprinacea*. The epidemiological study showed that the highest parasite indices were noticed in *Cyprinus carpio* (P% =23,7, I=3,96 and A=0,94) followed by *Luciobarbus callensis* (P%= 12, 84, I=2,36 and A=0,30), since the lowest values were observed in *Abramsi abrama* (P%=5,63%,I=1 and A=0,05). Moreover, the parasite biodiversity based on the diversity indices that one time is related to the species host and, at other times to season have shown that the determined parasite diversity is considered weak in its group, as well as *Luciobarbus callensis* showed the very significant values of specific richness, followed by *Carassuis carassuis* and *Cyprinus carpio*, whereas *Abramis brama* hosts only two species. According to season, the very important values of parasite diversity was determined during summer followed by spring and fall, while the low values were noticed in winter. According to host fish criterion, the study showed two indicator species for *Carassuis carassuis* and three for *Cyprinus carpio*, in addition to three indicator species found during spring and three others during summer

Keywords: Beni-Haroun dam, Cyprinid, parasite indices, diversity indices

Introduction

The determination of specific richness level is a preliminary study in the understanding of parasite communities, as well as the regulation mechanisms of host populations. In fact, the host environment can affect the evolution of parasite life traits **(Combes 1995),** and vice versa, the parasites act on the selective value of their hosts **(Hochberg et *al.*,1992).** To understand the ecosystem structure and function, it would be mandatory to know the different ecosystem elements and distribution of organisms in time and space. According to **Morand et *al.*, (1999)**, some factors would directly or indirectly affect the richness of parasite hosts, and here, the reported factors by these authors would be related to the ecosystem compartments (dietary….). Moreover, the species can be identified as bio-indicators when their presence or abundance in the ecosystem becomes high, and hence the different parasite species evidenced by the indicator test value could serve as bio-indicators **(Sindermann, 1987).** Further, **Ludwing (1982)** has reported that the parasite specificity ranges from the more strict (narrow) to more loose (broad) specificity. Herein, the author identified that the strict specificity indicates that the species can only live depending to species host and to species parasitizing related hosts, since the large specificity indicates that the parasite may be applied in several hosts whose similarly is more ecological than systematic. Several studies have been conducted on fresh water ectoparasites in various regions of northeast Algeria, including Bounamoussa river (**Meddour et *al*., 1989)**, Oubeira lake (**Meddour, 2009 ; Meddour et *al*., 2010; Brahmia et *al*., 2015**), adverse water bodies in El-Kala National Park **(Boukhalfa, 2008)** of E-Taraf city, Aures region of Batna city (**Boucenna et *al*., 2015; 2018; Allalgua et *al*., 2015),** Ain Dalia and Foum El-Khanga of Souk Ahras city, and Beni-Haroun dam of Mila city (**Tolba et *al*., 2018; Berrouk et *al*., 2018; Berrouk, 2019).** The present study was, therefore aimed to investigate the epidemiological parameters through determination of parasite indices, diversity and specificity, in addition to the parasitic indicator species of a host species and a season in the four host species.

Materials and Methods

1-. Geographical location of the study zone

Beni-Haroun dam of Mila city (northeast Algeria) is currently, the most impressive hydraulic design, and is a part of a wide mobilization program of surface waters and their inter-basin transfer that was carried out in Algeria in the aim to overcome the strong hydraulic disparities. The dam is located at the confluence downstream along the Oued-Rhumel and Oued-Endja rivers at the north-west part of Grarem Gouga region of Mila city with forty kilometres away from the northeast part of Constantine city, and equivalent distance from the mouth of Oued-Kebir river of Jijel city. Additionally, the water supply of this dam was started from August 2003, and from which the dam became able to storage 960 million cubic water with a useful volume capacity of 732 cubic meter per hectare of water between sides of 172 and 200 m. Also, Beni-Haroun dam promotes to regularize an annual water intake of 435 million cubic meter between the capacity of the reservoir and its surface, providing an average of 24 meter of water blade **(Khelifi et *al*., 2018). Fig 1**

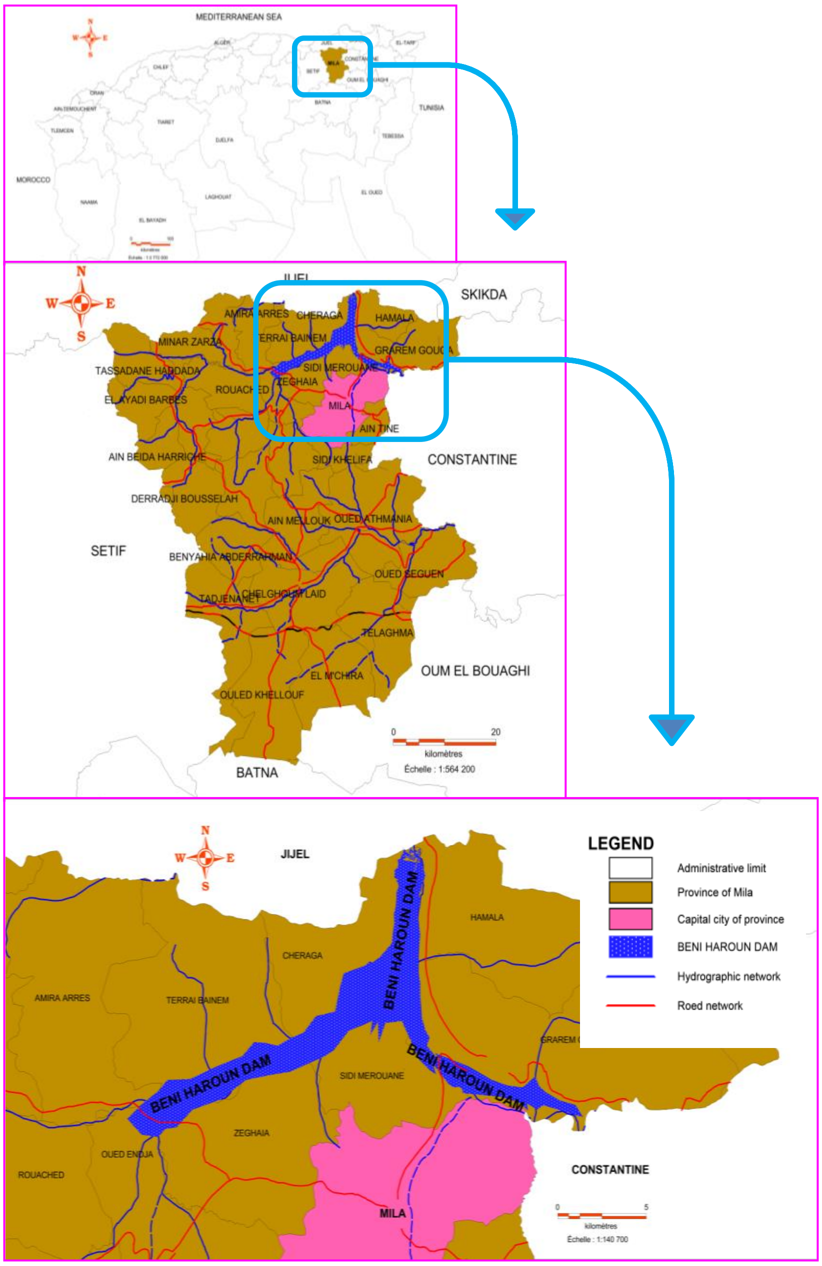

Figure 1: Map of sampling site (Beni-Harroun Dam)

1-2-Sampling design procedure

The used fish samples in the frame of this study, were collected from Beni-Haroun dam using gillnets. Fishes were, afterwards identified according to the nomenclature and criteria provided by **Leveque et *al*., (1990)** and then the gills were carefully removed by two incisions (dorsal and ventral) and transferred into Petri dishes containing ethanol of 70% concentration. All samples with the numbers of each species and the method of sampling season are shown in **Table1.**

Table 1. Detailed data of sampling of all host species

***N: Sample size; Nt: Size of the total samples; Lt: Total length**.

Season / Host sp	Winter	Spring	Summer	Autumn	Total	Mean of fishing
Luciobarbus callensis	N= 30	N= 77	N= 110	N= 40	Nt= 257	Gillnets
	15≥ Lt <45					
Carassuis carassuis	N= 60	N= 75	N= 47	N= 60	Nt= 242	
	15≥ Lt <35					
Cyprinus carpio	N= 37	N= 30	N= 38	N= 30	Nt= 135	
	15≥ Lt <50					
Abramis brama	N= 41	N= 22	N= 74	N= 32	Nt = 142	
	15≥ Lt <35					

- **Parasite collection and identification**

The extraction and the observation of parasites take place when each pillbox containing gills is poured into a Petri dish, then subjected to precise observation by binocular loupe. Thereafter, parasites were extracted using a fine brush, and placed into other pillboxes containing formol of 5% concentration.

- **Determination of parasite species**

The kept samples in pillboxes were re-examined, and then each parasite was identified through a comprehensive study for the species determination.**Yamaguti (1963)**

Data treatment

Parasite indices

Three parasite indices, namely prevalence (P), intensity (I) and abundance (A) were used to evaluate parasitism as reported elsewhere **(Bush et *al*.,1997).** Further, the specific richness (S), Shannon Weaver index, Simpson index and Equipartition index, as the main parasite indices, are involved in the diversity evaluation of the identified parasite populations of the four studied host species, once for the host species and once for the season. The indicator value index (*IndVal*) was determined in relation with measurement of specificity (relative abundance of a parasite) and fidelity (occurrence frequency of this parasite), and worth noting that when the parasite specificity increases, the parasite species becomes significantly indicator

Results

. Identification of ectoparasite copepods collected from the four host species

The examination of 776 fish individuals belonged to four host species (*Luciobarbus callensis, Carassuis carassuis, Cyprinus carpio and Abramis brama*) and collected from Beni-Haroun dam leads to harvest 249 copepod parasites. We notice, indeed, the absence of total individuals belonging to isopod class. The morpho-anatomical criteria of the collected parasites lead to inventory eight species related to four genera and two families **(Table 2).**

Table 2. List of identified parasites in the four host species.

Parasites			Hosts
Family	**Genus**	**Species**	
Ergasilidae (Thorell, 1859).	*Ergasilus* (Nordmann, 1832).	*Ergasilus peregrinus* (Haller, 1865).	*Luciobarbus callensis*
		Ergasilus briani (Markewitsch, 1933).	*Luciobarbus callensis* *Carassuis carassuis* *Cyprinus carpio* *Abramis brama*
		Ergasilus megaceros (Willson, 1916).	*Luciobarbus callensis* *Carassuis carassuis*
		Ergasilus sielboldi (Nordmann, 1832).	*Luciobarbus callensis* *Carassuis carassuis* *Cyprinus carpio* *Abramis brama*
	Paraergasilus (Markevich, 1937).	*Paraergasilus brevigiditus* (Yin, 1954).	*Luciobarbus callensis* *Carassuis carassuis*
	Neoergasilus (Yin, 1956).	*Neoergasilus longispinosus* (Yin, 1956).	*Luciobarbus callensis* *Cyprinus carpio*
		Neoergasilus japonicus (Harada, 1930).	*Luciobarbus callensis;* *Carassuis carassuis ;* *Cyprinus carpio*
Lernaeidae (Coddold, 1879).	*Lernea* (Linnaeus, 1758).	*Lernea cyprinacea* (Linnaeus, 1758).	*Luciobarbus callensis;* *Carassuis carassuis.* *Cyprinus carpio*

1-Parasite indices

The highest values of the parasite indices were noticed in *Cyprinus carpio* (P% =23,7, I=3,96 and A=0,94), meanwhile the lowest values were found in *Abramsi abrama* (P%=5,63%,I=1 and A=0,05).**(Table 3)**

Table 3. Distribution of the all parasite indices in the host species

P =Prevalence I=Intensity A= Abundance

	Luciobarbus callensis	*Carassius Carassius*	*Cyprinus carpio*	*Abramis brama*	*Total*
NHE	257	242	135	142	776
NHI	33	26	32	8	99
NP	78	36	127	8	249
P%	12.84	10.74	23.7	5.63	12.76
I	2.36	1.38	3.96	1	2.51
A	0.30	0,15	0.94	0.05	0.38

2-Diversity index

2-1- Variation of parasite diversity indices in host species

A- Specific richness

The marked value of specific richness characterizes the host species *Luciobarbus callensis* (RS=8 species), followed by *Carassuis carassuis* (RS=6 species), and *Cyprinus carpio* (RS=5 species), since *Abramis brama* hosts only two species. It's appeared that differences in the parasite specific richness values are not important from host species to other **(Tab 4).**

B- Shannon-Weaver index

As shown in table 4, the diversity values of Shannon-Weaver index vary between 0,662 and 1,337 for all host species, indicating that *Carassuis carassuis* (H'=1,337) and *Cyprinus carpio* (H'=1,329) as the most diversified parasite communities, followed by *Luciobarbus callensis (*H'=1,146), meanwhile *Abramis brama* hosts a low parasite community ('=0,662).(**Table 4)**

C- Simpson Index

The Simpson index varies from 0 to 1, and is frequently used to describe the fish parasite diversity. When Simpson Index increases, the parasite diversity becomes significant. In this study, the index values were found between 0,4688 and 0,6888 in the different studied fishes, suggesting thus that the diversity is considered as a whole average in the four host species (*C.carassuis*, (D= 0,6267) ; *L. callensis* (D= 0,5411); *C. carpio* (D=0,6888) and *A. brama* (D=0,4688) **(Table 4).**

D-Equitability Index

The equitability was found to be varied between 0,589 in *Luciobarbus callensis* and 0,954 in *Abramis brama*, while average values of equitability index were noticed in *Cyprinus carpio* (E=0,826) and *Carassuis carassuis* (E=0,687**).(Table 4)**

Table 4. Parasite diversity indices per host species

.RS= Specific richness, H'= Shannon-Weaver Index, D= Simpson Index, E= Equitability

	Carassuis carassuis	*Luciobarbus callensis*	*Cyprinus carpio*	*Abramis brama*
RS	6	8	5	2
H'	1.337	1.149	1.329	0.662
D	0.6267	0.5411	0.6888	0,4688
E	0.687	0.589	0,826	0,954

1.2. Variation of parasite diversity indices per season

A- Specific richness

The whole four host fishes reveal a marked specific richness during summer (RS= 8), then spring and autumn (RS=5), but is less significant during winter (RS=3) (**Tab 5**).

B- Shannon-Weaver Index

As indicated in **Table 5**, the all studied fishes show a very small variation in Shannon-Weaver index from season to season, and hence the highest value was observed during summer (H'=1,391), then spring (H'=1,149) and autumn (H'=1,252), noting also that the lowest value was noticed during winter (H'=1,030).

C- Simpson index

The values of Simpson index were high during summer (D=0,6588), autumn (D=0,6745), medium during winter (D= 0,62) and less important during spring (D=0,5898) **(Table 5).**

D-Equitability index

The values of equitability differ from season to season, where the most significant value was observed in winter (E=0,937), followed by values recorded in autumn (E=0,778) and spring (E=0,714), but the slightly low values were noticed in summer (E= 0,669) **(Table 5).**

Table 5. Parasite diversity indices per season

RS= Specific richness, H'= Shannon-Weaver index, D= Simpson index, E= Equitability

Season / Indices	Winter	Springs	Summer	Autumn
RS	3	5	8	5
H'	1.03	1.149	1.391	1.252
D	0.62	0.5898	0.6588	0.6745
E	0.937	0.714	0.669	0.778

2. Indicator species

The method of indicator species was used to analyse the statistical data of the obtained parasites from 776 host fishes belonging to the family of cyprinidea (*Luciobarbus callensis*, *Cyprinus carpio*, *Carassuis carassuis* and *Abramis brama*), and so the indicator value (*IndVal*) was determined in based on measurement of specificity (relative abundance of parasite) and fidelity (frequency of occurrence of this parasite), and thus the parasite species becomes significantly indicator when specificity and fidelity are high.

2. 1.Indicator species per host species

Among a total of eight inventoried parasitic crustacean species, only two species having significant indicator value for the fish host species *Paraergasilus brevigiditus* exhibit a very strong parasite specificity (100%) for the fish species *Carassuis carassuis.* species *Luciobarbus callensis,* We notice, besides, that *Ergasilus peregrinus* and *Ergasilus mégaceros* have shown very remarkable specificity (100% and 65% respectively) in the species *Luciobarbus callensis*. Whilst, *Cyprinus carpio* includes three parasite species of strong specificity values; *Ergasilus sieboldi* (84%), *Ergasilus briani* (81%) and *Neoergasilus longispinosus* (76%), however, *Abramis brama* show very low specificity and fidelity values along with no significant indicator value was noticed **(Table 6).**

Table 6. Indicator parasite species of the four host species

S: Specificity F: Fidelity. ***Indval: Indicator value***

Host sp / Parasites	*Carrasuis carassuis*			*Luciobarbus callensis*			*Cyprinus carpio*			*Abramis brama*		
Parasite species	S	F	*Ind Val*	S	F	*Ind Val*	S	F	*Ind Val*	S	F	*Ind Val*
E. peregrins	0	0	0	100	0	0	0	0	0	0	0	0
E. briani	6	1	0	9	3	0	81	3	2	4	2	0
E. megaceros	35	0	0	65	1	1	0	0	0	0	0	0
E. sieboldi	4	1	0	2	0	0	84	4	4	10	4	0
N. longispinosus	8	0	0	16	1	0	76	2	2	0	0	0
N. japonicus	22	3	1	49	5	2	28	4	1	0	0	0
P. brevigiditus	100	0	0	0	0	0	0	0	0	0	0	0
L. cyprinacae	9	1	0	23	3	1	67	6	4	0	0	0

2.2. Indicator species per season

Table 7 shows significant differences in the parasite specificity between the four seasons, indicating the species; *Ergasilus peregrinus*, *Paraergasilus brevigiditus* and *Ergasilus megaceros* as indicator species for spring with specificity values ranging between 57% and 100%. Nevertheless, *Ergasilus sieboldi*, *Ergasilus briani* and *Neoergasilus longispinosus* are considered as indicators of summer with specificity values of 91 %, 83% and 76% respectively. Conversely, the fidelity and the indicator value are low and less important during the four seasons, since the specificity values are low in autumn and null in winter for all parasite species.

Table 7. Indicator parasite species per season

S : Specificity, F : Fidelity, IV : ***IndVal : Indicator Value***

Season / Parasites	Winter			Springs			Summer			Autumn		
Indices	S	F	*Ind val*	S	F	*Ind val*	S	F	IV	S	F	*Ind val*
E. peregrins	0	0	0	100	0	0	0	0	0	0	0	0
E. briani	0	0	0	10	3	0	83	5	4	7	2	0
E. megaceros	43	0	0	57	1	0	0	0	0	0	0	0
E. sieboldi	6	1	0	4	1	0	91	6	5	0	0	0
N.longispinosus	10	0	0	13	1	0	76	2	2	0	0	0
N. japonicus	18	3	1	33	4	1	44	5	2	5	1	0
P. brevigiditus	0	0	0	100	0	0	0	0	0	0	0	0
L. cyprinacae	23	2	1	41	4	1	22	1	0	14	1	0

3. Parasite specificity

Two parasite species, *Ergasilus briani* and *Ergasilus sieboldi* have no preference for the host species compared to other ones, by which the parasites species become able to infest the four host species and, so they are known as Euryxenic species. Also, the species *Neoergasils longispinosis*, *Neoergasils japonicus*, *Ergasilus peregrinus* and *Lernea cyprinacea* are called as stenoxenic parasites because they have a narrower range of infestation, meanwhile the species *Paraergasilus brevigiditus* are oioxenic parasites owning to their dependence to a single host fish species. (**Table 8)**

Table 8. Global specificity of parasites collected from the four host species

(+) : Present ; (-) :Absent

Host sp / Parasites	*Luciobarbus Callensis*	*Carassius carassius*	*Cyprinus carpio*	*Abramis brama*	***Specificity***
Ergasilus peregrinus	+	_	-	-	**Oioxenic**
Ergasilus briani	+	+	+	+	**Euryxenic**
Ergasilus megaceros	+	+	-	-	**Stenoxenic**
Ergasilus sieboldi	+	+	+	+	**Euryxenic**
Neoergasils longispinosis	+	_	+	-	**Stenoxenic**
Neoergasils japonicus	+	+	+	-	**Stenoxenic**
Paraergasilus brevigiditus	+	+	-	-	**Stenoxenic**
Lernea cyprinacea	+	+	+	-	**Stenoxenic**
Specificity richness	**8**	**6**	**5**	**2**	

Discussion

Study of biodiversity and parasite specificity

- **Diversity index**

The relationship between biodiversity and ecosystems function is a fundamental ecological issue, as well as the knowing of different ecosystem elements and organism distribution in time and space is essential in understanding the ecosystem structure and function. According to **Morand et *al*., (1999**), some factors could have a direct or indirect effect on the parasite richness of host, and here the factors would be related to social behaviour of host such as life traits, size, habitat and dietary behaviour ..etc. We notice, indeed, in accordance to **Mouillot et *al*., (2002)** that the species are identified as bio-indicator species when their presence or abundance is high. Many indices could be used in studying the parasite diversity. Also, each diversity index having its own characteristics, would be subjected to discussion. As reported by **Magurran (1988),** there is no index was unanimously approved by ecologists, in addition that the simplicity in using Shannon-Weaver index makes it one of the most widely used indices. Several authors prefer using Simpson index, unlike to others suggesting equitability index as highly important index.

- **Diversity index per host species**
  - ✓ **Specific richness**

The specific richness is the measure of the most simple diversity index, owning to its relation to the number of the identified parasites species. The evaluation of specific richness of the parasite populations collected from Beni-Haroun dam revealed very high specific richness in *Lucibarbus callensis* (RS=8 species), followed by *Carassuis carassuis* (RS=6 species) and *Cyprinus carpio* (RS=5 species), while *Abramis brama* hosts only two species. The work of **Boucenna (2017)** carried out in Ain Dalia and Foum El Kanga dams showed a significant differences in the specific richness between host species and between study sites. In this regards, several authors have reported that the specific richness is related to the experimentation, like the effort of the examined host individuals (**Walther et *al*., 1995)**. As reported by **Mordan et *al*., (1999)**, the specific richness is related to host and its social behaviour, such as life traits, size and habitat. Several authors **(Poulin, 1995; Guegan and Morand, 1996; Sasal et *al.*, 1997)** have reported that the specific richness is related to phylogeny of hosts and parasites, and according to **Lester (1984),** it may be related to the use of relatively low sample sizes. **Sasal (1997**) has also showed the importance of the sampling effort in estimating the specific richness. In the last few years, an increasing interest was drawn on the determination of specific richness of a community from a community sample **(Colwell et Coddington , 1994 ; Walther et *al*, 1995 ; Walther et Morand, 1998 ; Dove, 2000).**

  - ✓ **Shannon-Weaver index**

According to **Margalef (1972**), Shannon –Weaver index varies overall from 1,5 to 3,5, and rarely exceeds 4,5. In our case study, this index ranges from 0,662 to 1,337, and when compare with the theoretical values, the calculated parasite diversity by Shannon-Weaver is considered low, as a whole. Our results are in line with those found by **Boucenna (2017)** who proved that the low parasite diversity is due to the reason that Shannon-Weaver index does not exceed 1,67 in all the studied host fishes.

  - ✓ **Simpson index**

The obtained results showed minimal values of 0, 4688 in *Abramis brama* and maximal values as 0,6888 in *Cyprinus carpio*. Based on the theoretical values of Simpson index usually ranging from 0 to 1, the diversity in Beni-Haroun dam is considered as medium. Our findings are in a good agreement with those of **Boucenna (2017)** who reported Simpson values varied from 0,47-0,75 in *Carassuis carassuis* and *Cyprinus carpio.* Importantly, Simpson values do not reflect the low parasite diversity indicated by Shannon – Weaver index. Additionally, **Peet (1974)** has classified this index among the affected indices by the specific richness, and although is widely used, it is particularly criticized**(Magurran , 1988).**

- **Equitability**

The equitability values were found between 0,589 in *Luciobarbus callensis* and 0,954 in *Abramis brama*. Indeed, we have noticed a difference in parasite distribution in each host fish species, and thus the distribution of the abundance closest to equilibrium characterizes the species, *Abramis brama* and *Cyprinus carpio* (0,826), whereas this distribution tends to be hierarchical and indicates pronounced imbalance in the distribution of parasite abundance in *Lucibarbus callensis*. **Boucenna (2017)** has reported similar equitability results in *Carassuis carassuis, Luciobarbus callensis* and *Cyprinus carpio* in Ain El Dalia and Foum El Khanga dams. According to **Zandre (2005**), the equitability values are up than 0,6, which indicates the existence of homogeneity of parasites population in fishes, but when it exceeds 0,7, the homogeneity is considered as important.

- ***.Diversity index per season***

- **Specific richness**

The specific richness during the four seasons in the all host species shows high values in summer, followed by spring and autumn, but the low values were noticed in winter. **Boucenna (2017)** has estimated that the specific richness in *Luciobarbus callensis* was noticed during spring, summer and autumn, and the low value was observed during winter in *Luciobarbus callensis* and *Cyprinus carpio*. As previously reported **(Poulin, 1995; Poulin and Rhode, 1997; Rhode, 1977; 1978; Rhode et *al.*,1995; Rhode and Heap, 1998),** the temperature is a limiting factor of specific richness, by which the species diversity increases to the tropics when the water temperature is higher, and also it can increase from deeper waters to the very hot water surface. In addition, the work of **Bouallag et *al.*, (2010)** conducted in the eastern coast of Algeria, have shown that the specific richness of copepod parasites is related to diet, habitat and host behaviour.

- **Shannon-Weaver index**

The results of Shannon-Weaver index values were found to be close in the four seasons, and varied from 1,030 in winter to 1,391 in summer. When the Shannon-Weaver index is greater than 1, it reflects the diversification of the parasite community throughout the year in all the studied host fishes **(Boucenna, 2017)**.

- **Simpson index**

Simpson index showed that the specific richness is highly important in autumn in the host fishes. **Boucenna (2017)** has indicated that the highest values of Simpson index were recorded during spring in *Cyprinus carpio,* and during winter and summer in *Luciobarbus callensis* .

- **Equitability**

The equitability values in all the host species are ranged from 0,669 in summer to 0,937 in winter, and in this regard **Boucenna (2017)** has reported that the equitability values were found to be close in *Luciobarbus callensis* and *Cyprinus carpio,* and consequently the distribution of parasite abundance in these species was homogeneous.

- **Indicator species**

In accordance with **McGeoch and Chown (1998),** the method of the indicator value indices reveals an ecological benefits, and this statistical approach leads to designate an indicator species among the species having specificity (relative abundance), fidelity and similar occurrence frequency, as well as to designate a rare species as an indicator species (**Mouillot et *al.*, 2002).** Though, **Sindermann, (1987)** has reported that the different parasite species evidenced by the indicator value test could be served as bio-indicators.

- ✓ **Indicator species per host**

The matrix analysis of the indicator species showed that several parasites are described only by a host species, suggesting thus that these species are strongly dependent to their hosts. In fact, only one species namely, *Paraergasilus brevigiditus* has exhibited a very high specificity (100%) for *Carassuis carassuis,* alike to two other parasite species (*Ergasilus peregrinus* and *Ergasilus megaceros*) found in *Luciobarbus callensis* showing respectively, 100% and 65%. Also, three parasites species (*Ergasilus sieboldi ,Ergasilus briani* and *Neoergasilus longispinosus*) were found in *Cyprinus carpio* with high specificity values (84%,81% and 76% respectively). On the other hand, **Boucenna (2017)** has reported the *E sieboldi* and *Neoergasilus longispinosus* as two indicator species of *Cyprinus carpio.* No significant indicator value was noticed in *Abramis brama*. According to **Mouillot et *al* (2002) and Williams et *al.*, (1992),** the species are identified as bio-indicators, when their presence or abundance is high. Overall, the parasites are used as bio-indicators to provide sufficient knowledge about various biological aspects of their hosts. Moreover, **Ternengo (2004)** has suggested that the indicator species study leads to know the host species bringing together the most favourable conditions for the installation and the life of various parasites**. (Tab 6)**

- ✓ **Indicator species per season**

In this study, many indicator parasites species of season were observed, and the method of *IndVal* has identified three parasite species (*Ergasilus peregrinus, Ergasilus megaceros* and *Paraergasilus brevigiditus*) having indicator values for spring. However, *Ergasilus sieboldi, Ergasilus briani* and *Neoergasilus longispinosus* are found to be indicator species for summer with specificity values of 91%,83% and 76% respectively, but the specificity values and fidelity were low in autumn and null in winter. Here, **Quilchini et *al.*, (2010)** have shown that *Spinitectus gardoni* is characterized by high specificity in summer and low fidelity. **Boucenna (2017)** has proved that *Lerneae cyprinacea* and *E. peregrinus* are indicator species in summer time. Likewise, **Foate et *al.*, (2006)** have reported *Hyalommae gyptium* as an indicator species of spring season, despite of the fact that the species exhibits high specificity and fidelity in summer time, and what's more, is **Norton and Carapenter, (1998)** have found that the specificity varies in space and during time following zones and periods. (**Tab 7)**

Parasite specificity

Our results revealed that *Ergasilus briani* and *Ergasilus sieboldi* are two euryxenic copepod parasite species able to infest the four host species. On another note, the species, *Neoergasils longispinosis, Neoergasils japonicus, Ergasilus peregrinus* and *Lernea cyprinacea* are qualified as stenoxenic due to its less large host spectre, since the species *Paraergasilus brevigiditus* was proved as oioxenic due to its dependence to single host fish species. Noteworthy, the specificity of a parasite could be measured by the number of hosts it has, and basically with less hosts, the parasite exhibits high specificity degree **(Lymbery, 1989).** According to **Ludwing (1982),** the parasite specificity ranges from the more strict (narrow) to more loose (wide) specificity. Further, the strict specificity indicates that a parasite species can only live in a single host species and corresponds to the species parasitizing related host species. Besides, the wide specificity indicates that a parasite can meet in many hosts whose resemblance is more ecological than systematic, and nonetheless the specificity has been measured by **Rohde (1982 ; 1984)** from two parasite indices (prevalence and intensity of parasite infestation).

Conclusion

The examination of 776 Cyprinidae fish individuals belonged to four species (*Luciobarbus callensis, Cyprinus carpio*, *Carassuis carassuis* and *Abramis brama*) from Beni-Haroun dam of Mila city (northeast Algeria) led us to collect 249 copepod parasites related to eight species, namely *Ergasilus sieboldi*, *Ergasilus briani ,Neoergasilus japonicas*, *Neoergasilus longispinosis, Lernaea cyprinacae. Ergasilus megaceros*, *Parergasilus brevigiditus* and *Ergasilus peregrinus*. We notice, indeed, the absence of individuals belonging to isopod parasites class. Conclusively, the highlighted results of our study are:

- The highest values of parasite indices were noticed in *Cyprinus carpio*, followed by *luciobarbus callensis*, since the lowest values were found in *Abramis brama*.
- The parasite biodiversity indices per host species revealed a very significant parasite diversity in *Carassuis carassuis*, followed by *Cyprinus carpio.*
- The parasite biodiversity analysis per season showed higher values during summer and autumn.
- The method of the indicator species revealed, in accordance to the host fish criterion, two indicator species for *Carassuis carassui* and three others for *Cyprinus carpio*, since this method following the season criterion revealed three indicator species for spring and three others for summer.

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