

Original Research Paper

Morphometric Characteristics of *Luciobarbus mascarensis* and *L. lanigarensis* (teleostei: cyprinidae) in western Algeria

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Abstract

A total of 81 samples captured between November 2017 to September 2019 were morphometrically analyzed as part of this study. In this latter we tried to compare between the population of the dam (artificial environment) and the population of the river (natural environment) in two watersheds for two different species of *Luciobarbus* in western Algeria. Sites A (natural) and B (artificial) are located at almost the same altitude (285-571 m) whereas sites C (artificial) and D (natural) are located in two different altitudes (285-571 m) and (1078-1821 m) respectively. The analysis of variance (ANOVA) was carried out to test the significance of the variations of each morphometric character between the 4 populations (A, B, C and D). The values of all the external morphometric parameters were the highest in the population of the Boughrara dam followed by El-hammam river and Bouhanifia dam while the population of Chouly river showed the lowest morphometric measurements. The mean of total length (TL) and weight (Weight), for example, of the Boughrara dam were the largest of the four populations (33.03 ± 2.02 cm and 474.46 ± 116.76 g respectively) while those of the river Chouly were the smallest (15.44 ± 1.23 cm and 55.55 ± 13.01 g respectively). The sex ratio analysis was performed by studying the overall sex ratio. Females were more abundant than males (1: 1.7). The graphical representation of Quantitative Variables by PCA showed that the morphometric variables are all positively correlated with each other by quite different rates. The Shannon and Weaver index was calculated from the different characters in the four regions studied: A, B, C and D. The region of site B (Bouhanifia dam) had the highest average diversity index with 0.92, followed by the region of site A (El-hammam river) (0.88). The lowest mean value was found in site C (Chouly river) (0.29).

Keywords: *Luciobarbus mascarensis*, *L. lanigarensis*, morphometric measurements, West Algeria.

Introduction

Stochastic events, such as climatic and geological changes, are the primary determinants of the current distribution of fauna, particularly freshwater fish (Lévêque & Paugy, 2006). Indeed, some species have had the opportunity to colonize other habitats through ancient interconnections between watersheds (Sydenham, 1977; Bianco, 1990). Otherwise, the geographic isolation of some aquatic systems has led to species extinction (Stiassny & Raminosoa, 1994) or has allowed genetic lineage differentiation through founder effect, lack of gene flow or genetic drift (Mayr, 1963; Harrison, 1993; Kirkpatrick & Barton, 1997). The basic characterization and inventory of zoogenetic resources, as well as systematic monitoring of populations for variability are essential to breed improvement strategies and programs and conservation programs (FAO 2007).

Several recently methods have been developed to distinguish within species, subspecies and populations, that include various molecular methods such as polymorphism of mitochondrial and nuclear DNA sequences (Whitfield et al., 2006; Sah et al. 2011). However, molecular methods require relatively expensive laboratory equipment and reagents (Bartolommei et al., 2016). Morphometric analysis is the most common method used to identify, and discriminate populations, due to its practicality and low cost (Bartolommei et al., 2016). Morphometric analysis methods are generally based on multiple measurements of various parts of the body, on several individuals (Rattanawanee et al., 2012). The field of geometric morphometrics has matured into a rich and cohesive discipline for the study of shape variation and covariation (Adams et al., 2013). In fish, morphological characterization represents a means to determine growth variability, systematics, and ontogenetic trajectories (Kováč et al., 1999). Some researchers have suggested that phenotypic variation is a dynamic, and flexible concept, that affects the structure of the population in a short period of time, as it is being influenced by environmental conditions (Tudela, 1999). Explaining morphological differences within fish populations is difficult. Genetics, environmental factors and the interactions within them, can be used to explain morphological characteristics (Pinheiro et al., 2005).

The diversity of *Luciobarbus* represents an important species in North Africa biodiversity, that has recently received considerable attention (Geiger et al., 2014). Casal-Lopez et al. (2015) described *L. rifensis* as the long-known, but unnamed, species from the northern part of Morocco. Doadrio et al. (2016) described the species previously known as *L. nasus* in the Moulouya river watershed, as *L. guercifensis*. Finally, Brahimi et al. (2017) presented an identification key for all *Luciobarbus* species found in the African watershed that flows into the Mediterranean Sea.

According to Doadrio (1994), there are three biogeographical zones in North Africa:

- The Atlantic zone to the northwest, characterized by the presence of hexaploid Cyprinids, such as *Carasobarbus*, *Labeobarbus* and *Cobitidae*;
- The Mediterranean area, characterized by Cyprinidae: *Luciobarbus* and *Pseudo-phoxinus*, which is absent from the rest of Africa; (the area from which we have selected our samples)
- The tropical zone in the east, including the artesian wells of the Sahara, where Cichlids and Clariids are found (Teugels, 1986).

The diversity of fish in dams is higher due to the more stable environmental conditions in which the fish evolve. Substantial empirical data have shown that genetic diversity rapidly deteriorates in small and isolated populations, due to genetic drift, leading to reduction in adaptive potential and fitness, and increase in inbreeding (Pavlova et al., 2017), and these factors could influence the morphological plasticity of riverine fish species (Gaston and Lauer, 2015). The phenotypic plasticity of fish is very high, with greater variances in morphological traits both within and between populations than any other vertebrates. The cause of variation in the morphometric and meristic characters can be partly attributed to intraspecific variability, which is under the influence of environmental parameters (Wimberger, 1992). Fish are very sensitive to environmental changes and quickly adapt by changing necessary morphometric character (Cabral et al., 2003; Hossain et al., 2010).

Aim of this study is to examine the morphological variations and to observe the altitude effect of the populations of *Luciobarbus mascarensis* and *L. lanigarensis*, one of the main freshwater fish of Cyprinidae, sampled in four different localities of the region of western Algeria using morphometric methods and statistical analyzes.

Materials and methods

In this study, the populations of two different species of *Luciobarbus* in western Algeria, were compared in dams (artificial environment) and in rivers (natural environment) for two watersheds Site A (natural), the El-hamman river, and Site B (artificial), the Bouhgrara dam, are located at almost the same altitude (285 to 571 m), whereas Site C (artificial), the Bouhanifia dam, and Site D (natural), the Chouly river, are located on two very different altitudes 285 to 571 m and 1078 to 1821 m, respectively (Figure 1).

Description of study area

The basin of Macta and Tafna have never been the subject of ichthyological study. The objective of our work is to facilitate the identification and characterization of freshwater fish existing in these basins. Knowing well that this last decade, these water bodies have known large operations of introduction of fish within the framework of populating and repopulating them. No study has been made to know the impact of these introductions.

Macta basin (Habitat of *L. mascarensis*)

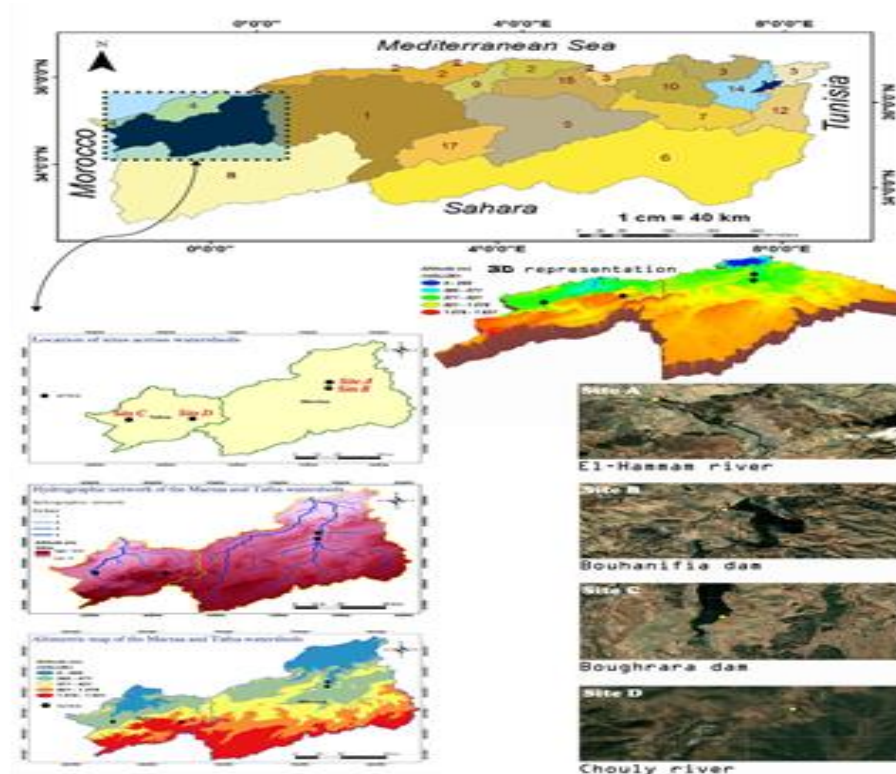


Figure 1. Location and description of the study area

The watershed of El Hammam river (Site A) is located in the northwest of Algeria. Covering an area of 8,348 km², it belongs to all of the Oran coastal basins, and more particularly to the large Macta basin (Figures 1 and 2). The El Hammam river originates 16 km southwest of Ras Elma, and travels a distance of 175.5 km from southeast to northwest. The flow of the El Hammam river is regulated by the three dams of tributaries, on the Fergoug, Bouhanifia and Ouizert rivers (Meddi et al., 2009).

Bouhanifia dam (Site B) is located in the northwest of Algeria, about 100 km south of Oran, and 25 km from Mascara (Figures 1 and 2). Bouhanifia dam reservoir is supplied mainly by the El Hammam river, which has its source at the level of the three rivers, the point of confluence of the wadis Melrir, Hounet (formed by the confluence of the wadis Sefioum and Berbour), and Sahouet (formed by the confluence of the Taria and Saïda wadis), and is enlarged by Fekane wadi.

Tafna basin (Habitat of *L. lanigarensis*)

Boughrara Dam (Site C), is located in the far northwest of the Wilaya of Tlemcen (northwest of Algeria), and belongs to the watershed of Oued Mouillah, whose length (widely shared with Morocco) is 2,000 km² (Figures 1 and 2). This basin has a perimeter of 241 km, and composed in its majority by the plains of Angad (located in Oujda, in Morocco territory), and those of Zrigua (located in Maghnia in Algeria territory). Following a drought of over two decades, permanent flow has disappeared, and rivers have become mere channels for wastewater discharges, with direct impacts on the environment (Bouزيد-Lagha and Djelita, 2012).

The Chouly river (Site D) watershed is a tributary of Tafna basin. It occupies an area of 288.91 km² (3.98% of the area of Tafna), 170 km² of which is controlled (Figures 1 and 2). This basin is characterized by

permanent, and variable flow that depends upon the seasons. The bottom of the river bed is dominated by boulders and pebbles covered with bryophytes, (*Fontinalis antipyretica*), mint (*Mentha rotundifolia*), and aquatic arch (*Apium graveolens*). Many trees and shrubs exist on the banks of the stream, including poplars, oleanders (*Neurium oleander*), ash *Fraxinus axelisia*), and fig trees (*ficus carica*).

Sampling

At each site (A, B, C and D), samples were collected, while taking into account the importance of fishing activities. Fish were identified using identification keys, and photographs (Hugueny et al., 2010; Brahimi et al., 2017; Brahimi et al., 2018).



Figure 2. Habitats of the *Luciobarbus* spp. showing Site (A) El-hammam river; Site (B) Bouhanifia dam; Site (C) Boughrara Dam; Site (D) Chouly river, western Algeria.

A total of 81 samples were caught between November 2017 and September 2019 (Table 1), using a fishing net known as Trémail. The net was made up of three sheets of net with unequal mesh, with a width of 20 m, a drop of 1.8 m, and a mesh gap of 20 mm. For each fishing event, the net was set during the day, and fishing effort averaged about 10 hours. we have stored the fishes separately by station (4 sites : A, B, C and D)

Table 1. GPS coordination of the sampling locations in different sites

	Location	species N	Sex(F\M)
Site A	El-Hammam River, Mascara, Algeria	30	25\05
Site B	Bouhanifia Dam, Mascara, Algeria	24	13\11
Site C	Boughrara Dam, Tlemcen, Algeria	13	12\01
Site D	Chouly River, Tlemcen, Algeria	14	01\13

Morphometric measurements

The samples were measured to the nearest millimeter (mm) using an electronic caliper, and weighed to the nearest 0.1 gm using a precision balance. Measurements and abbreviations follow Holcik (1989), (Kottelat & Freyhof, 2007).The following morphometric data was taken from the left side of the fish body (Figure 3): total length (TL), standard length (SL), fork length (FL), dorsal fin length (DL), length of the anal fin (AL), length of the pectoral fin (PL), length of the ventral fin (VL) and the total weight (weight). The total of 8 quantitative parameters were analyzed for the current study.

After dissection and naked eye examination of the gonads, the sex of each fish was determined and only sexually mature individuals were used for data analysis.

Sex Ratio

We adopted the definition of sex ratio as the proportion of males and females in the population (Kartas and Quignard, 1984).

$$SR = Nf / Nf + Nm * 100$$

Where Nf = number of females; and Nm = number of males

The result was verified by a statistical conformity test of the X² type (Sokal and Rohlf, 1987).

Data analysis

Statistical analysis was performed with version 3.5.1 of the R "feather spray" software, using a wide variety of packages and scripts. These packages were downloaded from the official R-CRAN database. Primary Component Analysis (PCA), a multivariate analysis model, was performed using the FactoMineR package, in order to group homogeneous individuals with selected measurements. Finally, the ascending hierarchical classification (CAH), based on Euclidean distances and the centroids method, was applied using the Factoextra package, in order to classify the animals, and to build a correct typology that consisted of identifying individuals according to their similarities.

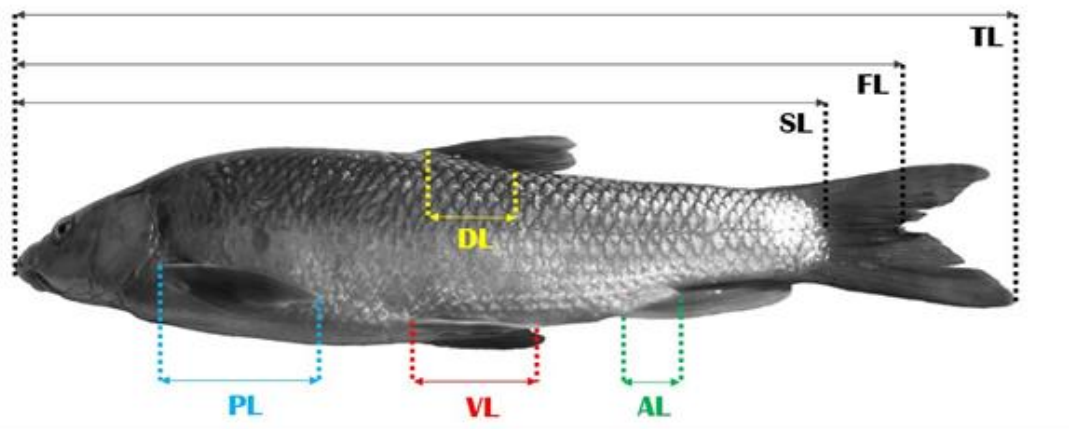


Figure 3. Morphometric measurements of fish followed during this study (Holcik 1989) (Kottelat & Freyhof, 2007).

TL : The length measured from the tip of the snout to the tip of the long lobe of the caudal fin; SL : The length measured from the tip of the muzzle to the posterior end of the last vertebra or to the posterior end of the mid-lateral part of the hypural plate; FL : The length measured from the tip of the snout to the fork of the caudal fin; DL: The length of the base of the dorsal fin; AL : The length of the base of the anal fin; PL : The length of the pectoral fin: length from the joint of the first ray to the end of the longest ray; VL : The length of the ventral fin: length from the first ray joint to the end of the longest ray; Weight : The total weight.

Shannon-Weaver diversity index

The 08 characters were assigned to classes, and analyzed using the Shannon-Weaver diversity index (H'; Shannon and Weaver, 1949) as defined by Jain et al. (1975) to calculate phenotypical variation of each fish.

For the morphometric characteristics of fish to make the diversity index, our work on the diversity of fish (Shannon-Weaver diversity index) is original. After consulting a lot of data we did not find similar works.

the work of the authors Jain et al. (1975) is for all species, that's why we take them as references.

$$H = - \sum_{i=1}^n P_i \ln P_i$$

H = Shannon and Weaver diversity index

Pi = Frequency of each phenotypic class i of a given character

n = Number of phenotypic classes of each character

H was standardized by converting it to a relative phenotypic diversity index (H') after dividing it by Hmax : H max (Ln (n)) to obtain 0 to 1 values.

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$$H' = \frac{-\sum_{i=1}^n P_i \ln P_i}{\ln(n)}$$

Results and discussion

Descriptive statistics

The analysis of variance (ANOVA) was carried out to test the significance of variations of each morphometric characteristic, among 4 populations A, B, C and D (Table 3).

The regression analysis of variance for the four populations showed morphometric differences among the populations. All the morphometric variables showed a significant variation ($p < 0.000$) among the populations (Table 3), except in *L. mascarensis*, where the variables for TL, DL, AL and weight were between the Sites A and B ($p > 0.05$).

Table 2. Morphometric characteristics observed for the *L. mascarensis* and *L. lanigarensis* for this study. (Overall descriptive statistics)

Traits	Mean	Median	SE	Variance	Min	Max	F. stat 1 <i>L. mascarensis</i>	p-value 1 <i>L. mascarensis</i>	Sig.	F. stat 2 <i>L. lanigarensis</i>	p-value 2 <i>L. lanigarensis</i>	Sig.
TL(cm)	25.50	24.4	0.83	56.58	10.2	51.2	5.625	0.02	*	56.895	.000	***
SL(cm)	21.59	20.6	0.72	43.11	8.2	44	8.70	0.01	**	53.375	0.00	***
FL(cm)	23.34	22.5	0.77	48.92	9.5	47.2	8.55	0.01	**	57.465	0.00	***
DL(cm)	2.97	2.8	0.12	1.27	0.7	6.1	6.162	0.02	*	69.562	0.00	***
AL(cm)	1.74	1.6	0.08	0.52	0.32	4.2	6.09	0.02	*	58.664	0.00	***
PL(cm)	5.39	5.6	0.15	1.98	1.6	8.6	7.418	0.01	**	47.362	0.00	***
VL(cm)	3.65	3.5	0.11	1.05	1.3	6.5	7.439	0.01	**	66.988	0.00	***
Weight(gm)	238.74	166	26.10	55216.19	10	1770	3.675	0.06		13.705	0.001	**

1 : *L. mascarensis* (Site A + Site B)

2 : *L. lanigarensis* (Site C + Site D)

(*: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$)

Previous study of morphometric and meristic variation of *Zenarchopterus buffonis* had showed that it was influenced by several factors (Abidin et al., 2019). Therefore, significant difference in the results for the variables observed is indicative of variation between *L. mascarensis* and *L. lanigarensis*. The morphometric characteristic in our study showed plasticity, which it is postulated could be linked to both the habitat and food changes throughout the life of the fish, and/or to the specific genetics of each population (Gaouar et al., 2016; Peres-Neto, 2004; Mungai, 2011).

The values of all external morphometric parameters were higher in the population of Boughrara dam, followed by El-hammam river and the Bouhanifia dam, while morphometric measurements of the population of Chouly river were the lowest (Table 4). Mean of total length (TL) and mean of total weight of Boughrara dam, for example, were the largest values recorded for the four populations (33.03 ± 2.02 cm, and 474.46 ± 116.76 gm, respectively). Recorded values for the Chouly river were the smallest (15.44 ± 1.23 cm, and 55.55 ± 13.01 , respectively). All other measured morphometric characteristics varied similarly among the four populations.

Table 3. Descriptive statistics by study site

	El-hammam river (Site A) N=30		Bouhanifia dam (Site B) N=24		Boughrara dam (Site C) N=13		Chouly river (Site D) N=14	
Traits	Min-Max	Mean±S.D.	Min-Max	Mean±S.D.	Min-Max	Mean±S.D.	Min-Max	Mean±S.D.
TL(cm)	20.4-41.1	27.73±0.98	17.4-34.2	24.51±0.88	24.3-51.2	33.03±2.02	10.2-22.5	15.44±1.23
SL(cm)	17.1-35.4	23.77±0.87	14.5-29.2	20.32±0.72	20.5-44	28.17±1.78	8.2-19.9	13.01±1.12
FL(cm)	18.7-37.9	25.69±0.91	15.4-31	22.07±0.77	22.4-47.2	30.35±1.88	9.5-20.8	13.98±1.13
DL(cm)	2.2-5.4	3.35±0.15	1.7-4.2	2.8±0.14	2.6-6.1	4.05±0.26	0.7-2.4	1.46±0.16
AL(cm)	1.1-3.3	1.96±0.1	0.7-2.4	1.6±0.09	1.5-4.2	2.46±0.19	0.32-1.4	0.85±0.09
PL(cm)	5.2-7.4	5.93±0.1	4-6.6	5.49±0.12	5.4-8.6	6.45±0.23	1.6-5.4	3.06±0.42
VL(cm)	3.1-5.5	4.02±0.11	2.1-4.6	3.54±0.12	3.5-6.5	4.62±0.21	1.3-3.5	2.15±0.21
Weight(gm)	79-693	261.73±28.83	64.9-460	189.2±22.08	140-1770	474.46±116.76	10-142	55.55±13.01

The two Sites (A and D) had different water depths, which could also have been partly responsible for the variation in morphology of the two species (Murta, 2000). Depth is related to the volume of water, and affects the velocity and other flow characteristics of river water. The fish in high volume waters like El-hammam river were generally larger compared to those in low volume waters (Oued Chouly). This is considered likely to represent an adaptive mechanism in fish, that may facilitate movement, feeding, or even provide defense against predation, considering as well that larger water bodies have a greater diversity of interdependent organisms.

Morphological characterization revealed a specific intravariation of *L. mascarensis* in the Macta watershed, and suggested the existence of morphologies specific to the river, possibly indicative of adaptation to change in the watershed. Genetic and phylogenetic studies have suggested the existence of genetically differentiated populations within the same watershed (Rutaisire et al., 2005). The changing environmental conditions in the Macta basin could therefore be a major factor in adaptation of this species, in the Bouhanifia dam system (Site B). Some studies have shown that fish species exhibit changes in their populations, such as: decreased abundance and biomass (Perälä & Kuparinen, 2015), changes in length-at-age structure, rapid growth (Rochet & Trenkel, 2003; Rochet, 2009), early maturity, or changes in their geographic distribution (Overholtz, 2002; Andersen & Brander, 2009). These variations have been attributed to environmental changes (Perry, 2005; Cheung et al., 2009). It is therefore considered urgent to undertake studies of the habitat of *L. mascarensis* since the use of habitat influences development and adaptation of various morphological characteristics. It is imperative for management and conservation measures to be taken manage anthropogenic impacts on this environment, and its diversity

Sex effect

A total of 30 males and 51 females were observed out of 81 samples examined. The sex ratio analysis was performed studying the overall sex ratio. Females were more abundant than males, with the sex ratio being 1: 1.7 in favor of females. The size of females greatly exceeded that of males for all characteristics studied (e.g. TL = 28.55 + 0.89 in females, and TL = 20.33 + 1.17 in males). These results confirm research carried out on *L. callensis* by Bouhbouh (2002).

It is necessary to determine whether there were quantitative differences between female and male individuals in the morphometric studies performed. In this study, it was determined that gender was not important in the expression of these traits, neither in population, nor among populations ($p > 0.05$). Many studies have shown that gender is not important in the expression of quantitative traits between female and male individuals. This was the case for studies conducted on entire populations in Portugal, Turkey, and Vietnam respectively (Pinheiro et al., 2005; Zengin et al., 2015; Doung et al., 2017).

Principal component analysis (PCA)

Multivariate analysis (PCA) was used to define the distinctions of individual populations, and to determine which morphometric traits best reflected these distinctions. This technique has been used by many researchers such as: Turan et al. (2006), Vatandoust et al. (2014), and Özdemir (2015). The formulae produced by Elliott et al. (1995) were used to standardize the data. Many studies have used these formulae (Motamedi et al., 2014; Mir et al., 2015). At the conclusion of the principal component analysis (PCA) for the 8 quantitative variables (Figure 4), the factorial plane (1x2) formed by the first and the second component totaled an inertia value of 98.3% and 99.1% for *L. mascarensis* and *L. lanigarensis*, respectively.

Graphical representation of the quantitative variables using PCA showed that the morphometric variables are all positively correlated with each other, at different rates (Figure 4). The first PCA (a), of the eight morphometric studied characteristics, explained 98.3% of the total variation in the *L. mascarensis* population (54 samples; Figure 4a). Formation of three groups of characters (VL, PL, AL, and DL), (TL) and (FL, SL, and weight) was distinguished, and a strong correlation among traits within the same group, and a weak correlation among traits in different groups, was observed.

The second PCA analysis, explained 99.1% of the total variation among the 27 samples of *L. lanigarensis* (Figure 4b). Formation of three groups of characters (weight), (AL, DL, FL, TL, SL, and VL) and (PL) showed a strong correlation among the traits within the same group, and a weak correlation among the traits of different groups.

It was clear from the PCA analysis (Figures 4a and b) that there was a difference between river fish and dam fish, in the two studied species. The population of *L. mascarensis* in Site A (El-hammam river) seemed to perform better in terms of both the size (TL), and weight (weight), compared to the population of Site B (Bouhanifia dam). On the other hand, the population of *L. lanigarensis* in Site D (Chouly river) showed very much reduced performance with respect to all characteristics (TL, SL, FL, DL, VL, PL, AL and weight) when compared to the population of Site C (Bouhrara dam). This can be explained by the very high altitude of the population of Site D (Chouly river, between 1078 m and 1821 m) compared with Site C (Bouhrara dam), with elevation between 285 m and 571 m (Figure 2).

Morphometric differences observed between populations of the dams and rivers for the two species showed how much these studied characteristics are influenced by the environment, and probably by abiotic pressures (fishing and pollution) exerted on their habitats.

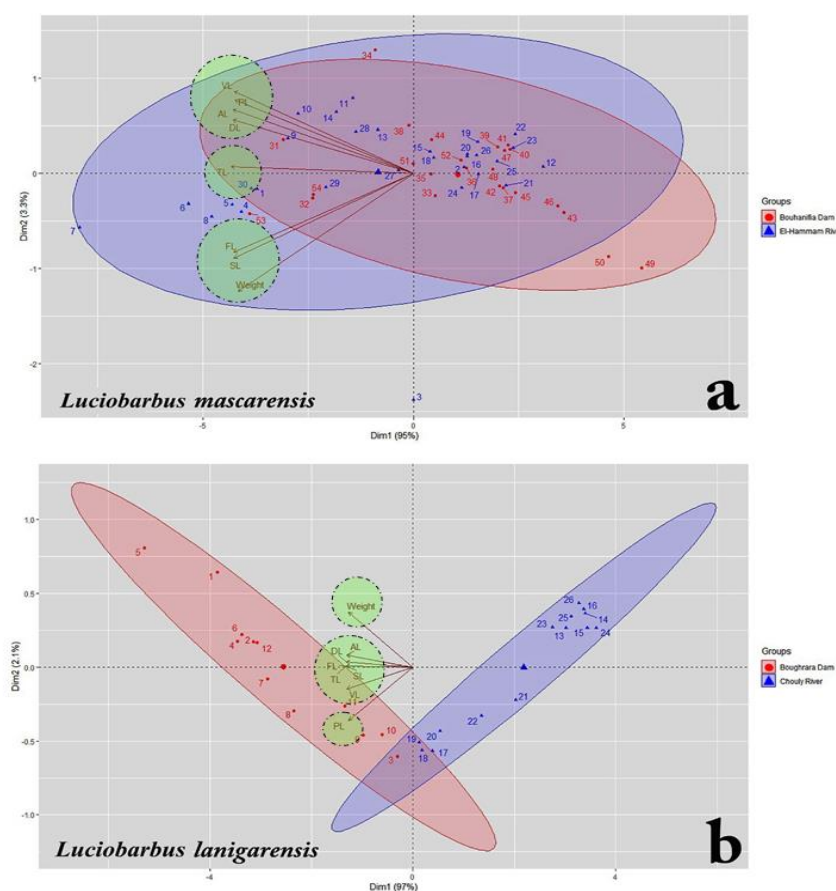


Figure 4. Principal component analysis (PCA) based on morphometric measurements among the population of dam and river of : a) *L. mascarensis*, b) *L. lanigarensis*

Analysis of the hierarchical ascending classification (HAC)

The HAC analysis showed no grouping of individuals, neither by contribution to specific sites, nor by contribution of either two species (Figure 5). This is probably due to the fact that the two species are genetically very close. In addition, the relationships, and affinities, within *Luciobarbus* species from the watersheds of African Mediterranean Sea remain uncertain (Brahimi et al., 2018).

Several evolutionary models have been established for Maghreb barbel, on the basis of the application of a molecular clock, which had made it possible to approximate the divergence among the different clades (Tsigenopoulos et al., 2003; Gante, 2011). The oldest separation within populations of *Luciobarbus* in North Africa is that of the Atlantosaharian clade of *L. lepineyi*, probably during the Pliocene, about 4.5 M years ago. These analyzes also suggest that the Mediterranean and Atlantic phylogroups would have separated during this period (Brahimi, 2018)

Relative diversity index (Shannon and Weaver's index)

The relative diversity index (mean H') of all individuals studied was 0.67 for the measured traits (Table 5). At the population level, this index varied respectively from 0.29 to 0.92, for individuals at Site D and Site B, respectively. The index varied from 0.63 for the FL and PL characteristic, to 0.72 for weight parameter (Table 5).

For The characters (DL), (TL), (VL) and (AL) ,we found ($H'=0.66$), ($H'=0.67$),($H'=0.68$)and ($H'=0.69$) respectively. According to all characteristics, and all individuals, the highest diversity index ($H' = 0.97$) was obtained for weight and VL traits, at Site B in the region of the Bouhanifia dam.

The Shannon and Weaver index were calculated from the different characteristics, observed in the four regions studied (Sites A, B, C and D). Site B (Bouhanifia dam) had the highest average diversity index (0.92), followed by the Site A (El-hammam river; 0.88). The lowest mean value was found at Site C (Chouly river; at 0.29). These different values of the Shannon and Weaver index were probably a reflection of the different selective pressure from one site to another, where low values were expressed where the diversity pressure is the greatest.

according to many works The diversity indices are based on morphology, therefore we have based on 4 populations of fish (found in 4 different sites)

Table 4. Estimation of Shannon diversity indices for the morphometric characteristics studied

Station	Characters								mean H'
	TL	SL	FL	DL	AL	PL	VL	Weight	
Site A (<i>L. mascarensis</i>)	0.91	0.94	0.94	0.87	0.88	0.78	0.82	0.94	0.88
Site B (<i>L. mascarensis</i>)	0.95	0.96	0.8	0.91	0.88	0.96	0.97	0.97	0.92
Site C (<i>L. lanigarensis</i>)	0.62	0.62	0.62	0.57	0.57	0.57	0.44	0.67	0.58
Site D (<i>L. lanigarensis</i>)	0.19	0.3	0.19	0.3	0.43	0.2	0.47	0.3	0.29
mean H'	0.67	0.7	0.63	0.66	0.69	0.63	0.68	0.72	0.67

Other studies on the relative diversity index have shown that human activities such as urbanization, agriculture, impoundment, and the introduction of exotic species, have directly, and indirectly influenced the relative diversity index, by disturbing the natural spatial structure of fish population (Parks et al., 2014; Kautza and Sullivan, 2015; Mohamed and Al-Jubouri, 2017).

Conclusion

It is concluded from the current study that a large intra-population and inter-population, variation occurs within species belonging to the genus *Luciobarbus*. With increase in number of samples, the observed variation becomes greater.. Consideration of intermediate populations is key in the assessment, and reduces the probability of error in groups with higher ecological tolerance, and with wider range of variation, such as in the case of genus *Luciobarbus* observed in these studies. Assessment of populations, found at geographically different points from each other, may lead to suspicion as to whether these two populations are of different species, or to suggestion that they belong to the same group, but have been exposed to differentiation.

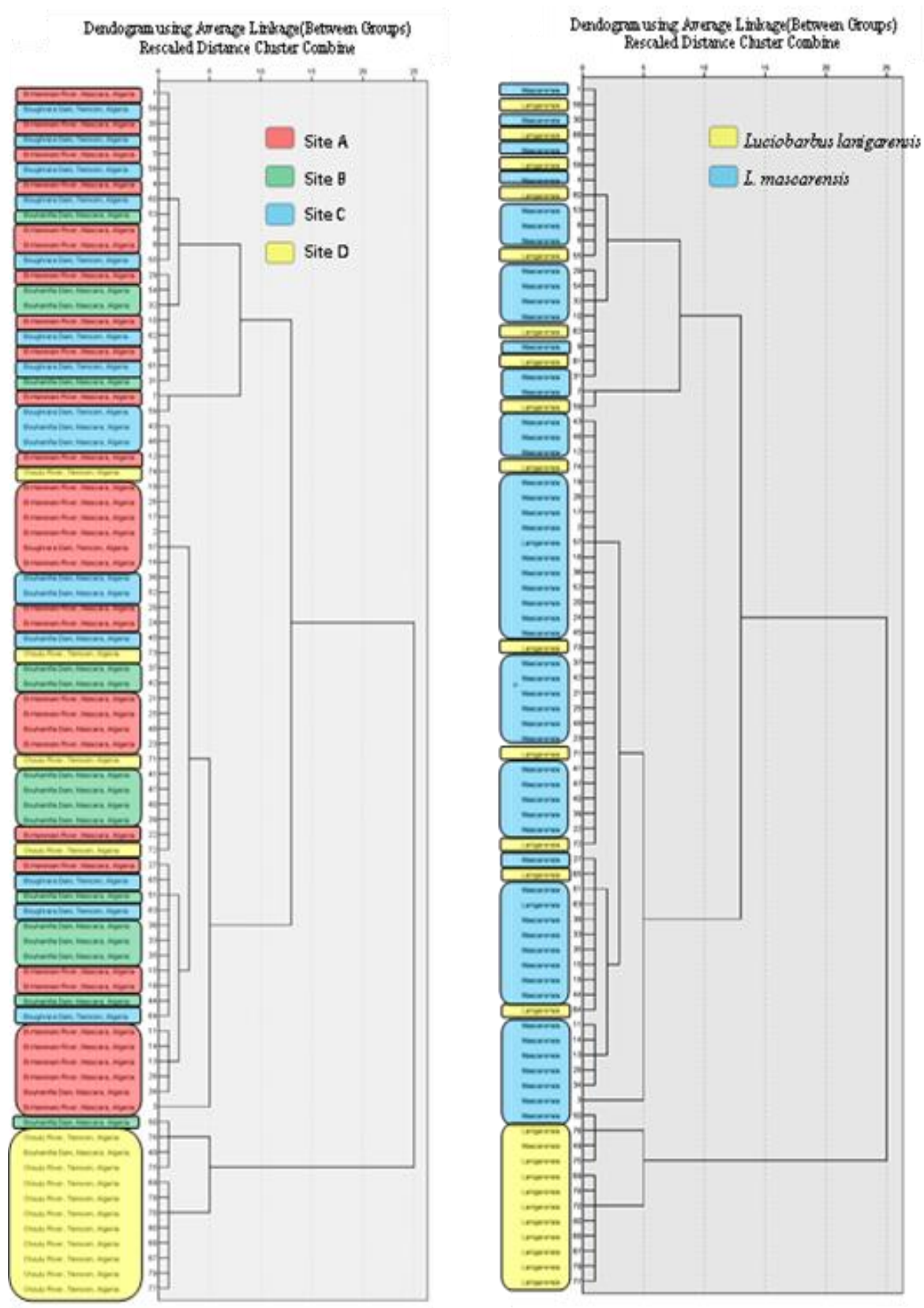


Figure 5. Hierarchical ascending classification (HAC) for the different Sites (A, B, C and D) and for the two studied species

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