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Population dynamics of *Pseudophoxinus callensis* (Guichenot, 1850) (Cyprinidae) in the National Park of El Kala (Northeast Algeria)

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ABSTRACT

This study concerns the assessment of the morphological parameters, growth and abundance indices of two populations of *Pseudophoxinus callensis* in Bouhchicha wadi and the Bleu lake within the National Park of El-Kala (North-East Algeria). According to its environment, *P.callensis* shows an adaptation through different strategies. In Bouhchicha wadi, several cohorts coexist all around the year then gradually join during the summer season to form pseudo cohorts. In the Blue Lake, *P.callensis* shows an annual cycle with a single cohort that begins its cycle in April-May then diminishing gradually in late autumn. The FISAT II analysis reveals that for a 95% confidence interval, the growth parameters of *P.callensis* are 67.39-80.08 mm in Bouhchicha wadi, but lower with 43.31-61.20 mm in the Blue Lake. In Bouhchicha wadi, the asymptotic length L_{∞} reaches the highest value (79.80 mm) with a growth coefficient K of 0.480 years⁻¹. In the Blue lake, L_{∞} reaches 59.85 mm with a growth coefficient K of 0.180 years⁻¹. In the Total Length-Weight relationship, the regression equation shows a clear difference between Bouhchicha wadi ($R = 0.91$) and the Blue lake ($R = 0.64$). Both populations exhibit sexual maturity at different times of the year.

Key words: *Pseudophoxinus callensis*, Dynamics, Adaptation, Blue Lake, National Park of El Kala, Algeria

Introduction

Pseudophoxinus callensis (= *Leuciscus callensis* Guichenot, 1850), (Teleostei, Cyprinidae) is endemic to the freshwaters of the northern Maghreb. Supporting temperatures ranging from 12 °C to 24 °C, it exhibits an excellent adaptation to different biological habitats (Boumendjel *et al.*, 2015). Not reported in Morocco, this species occurs only in the north of

Tunisia (Kraiem, 1983, Dkhil-Abbes and Kraiem, Djemali, 2008; Romdane *et al.*, 2012). In Algeria, this species has not been yet reported in the West of the country. It has been described as having a wide endemic distribution in the central continental hydro systems (current and stagnant freshwaters) from Algiers to Setif (Bacha and Amara, 2007; Zouakh, 2009). Indeed, others authors indicated its abundance in the North-Eastern freshwater systems of

the country especially in wadis, ponds and lakes, particularly in the wetlands of the National Park of El Kala (NPEK) (Pellegrin, 1911, 1920, 1921, 1933; Meddour and Bouderd, 2001; Meddour, 2009). The Red List of the International Union for the Conservation of Nature (IUCN) indicates the relative risks of species extinction (Smith and Darwall, 2006). Within this list, *P. callensis* has a status of "Deficient Data". It is important to indicate that in Algeria, there is a great lack of works on the dynamics of the local freshwater fishes particularly *P. callensis*. The few available works concern a comparative study of the diet of *Gambusia Holbrooki* in the Numidian area (Gebailia, 2012). A review on the ichthyofauna in the remote areas of the Aures and the Northern Sahara (Chaibi, 2014), and an investigation on the ecology and the polymorphism of *Aphanius fasciatus* (Boumendjel *et al.*, 2015) in the NPEK. All these elements motivated this study in order to characterize some ecological aspects through the assessment of the morphological and growth parameters of two populations of *P. callensis* in two different sites of the NPEK, to compare the indices of abundance of this specie, and to evaluate the adaptation strategies developed by *P. callensis* within the two sites.

Materials and Methods

Location of the sampling sites

The area of El Kala is characterized as a bioclimatic stage with a sub-humid vegetation. The main wetlands of the NPEK (Fig. 1) are represented by Lake Tonga, Lake Oubeira and their tributary wadis, as well as by the Mellah Lagoon and the Blue Lake. The two concerned sites by this investigation are Bouhchicha wadi and the Blue Lake.

Bouhchicha wadi

It is located in the municipality of Aïn El Assel (Wilaya El Tarf). Samples were taken near the valve bridge of Bouhchicha wadi ($36^{\circ} 8' 41'' \text{N}$; $8^{\circ} 23' 56'' \text{E}$) (Fig. 2A, 2B) which is a small outlet wadi of Lake Oubeira (2200 ha). The later is a RAMSAR site known to be a home to very rare flora species, the water chestnut *Trapa natans* and the yellow water lily *Nuphar lutea*. Lake Oubeira is also a home to diverse migratory wintering populations of various species of birds. During the drought of 1988, the lake has dried up causing the disappearance of the ichthyofauna; *Lampetra fluviatilis*, *Anguilla anguilla*, *Alosa algeriensis* (= *A. fallax fallax* ?), *Mugil cephalus*,

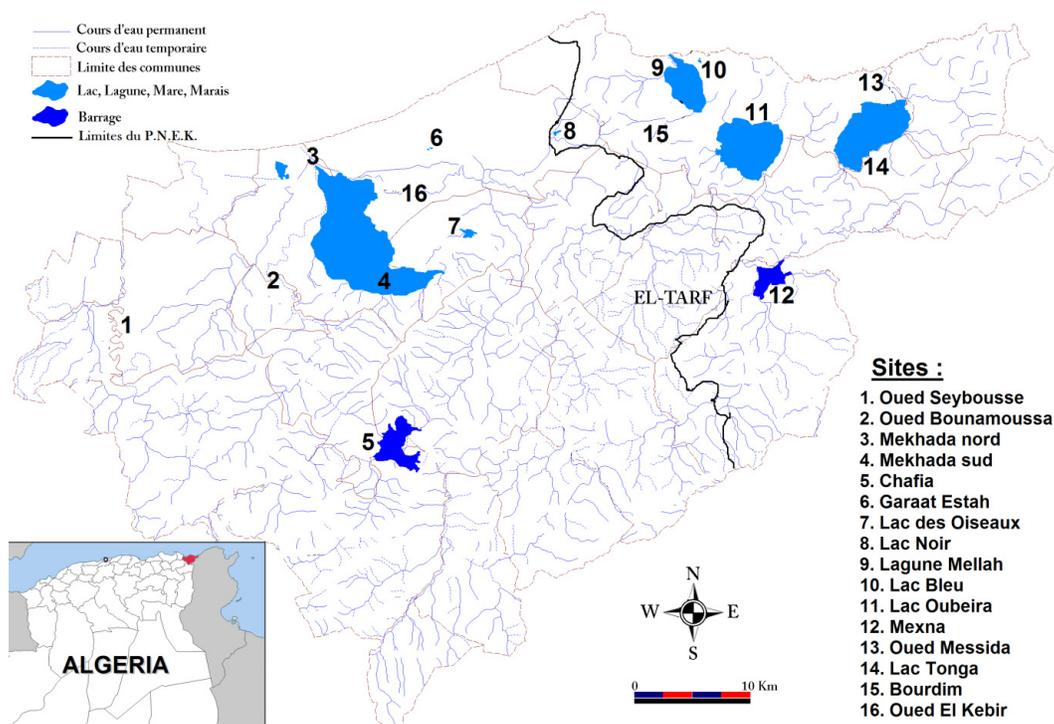


Fig. 1. The wetlands in the district of El Kala (Boumendjel *et al.*, 2015)

Gambusia holbrooki, *Pseudophoxinus callensis*, *Pseudophoxinus punicus*, *Pseudophoxinus guichenoti*, *Luciobarbus callensis*, *Cyprinus carpio*, *Arithichthys nobilis*, *Hypophthalmichthys molitrix*, *Ctenopharyngodon idella*, *Sander lucioperca* and *Lepomis gibbosus* (Meddour, 2009). Today, the ichthyofauna of this lake has not been yet revised.

b) The Blue Lake

Situated in a North position to the Mellah Lagoon, the Blue Lake (36 ° 54 '34.57 "N; 8 ° 20' 17.80" E) is located in a sandy inter-dune depression (Fig. 2C). This lake is fed by the ground freshwater upwelling and by the rainwater (Benyacoub *et al.*, 2007). The flora of the Blue Lake consists essentially of the common reed *Phragmites australis*, and the centre of the lake is entirely covered with *Nymphaea alba* (Boumendjel *et al.*, 2015).

Sampling method

From December 2012 to May 2013, five random samples were taken; three in Bouhchicha wadi and two in the Bleu Lake. Specimens of *P.callensis* were captured using a double monofilament device (1.2m x 0.35m) composed of two monofilament nets, with a 15 mm mesh for the first one and 1.5 mm for the second net. In order to minimize stress and mortalities, the captured fishes were quickly recovered from the nets then stored in a cooler container under optimal conditions of water temperature and oxygenation. Immediately transferred to the Laboratory within one hour after their capture, the individuals were dispatched and kept alive in 70-litre aquari-

ums. From both sites, 543 specimens were captured, including 408 from Bouhchicha wadi and 135 from the Blue Lake.

Evaluation of Total Length, Total Weight and age

Measurements concerned the Total Length (TL); Total weight using a balance (precision: ± 0.1 mg) and determination of age through scale observation.

Statistical Analysis

The measurements were analyzed using the fish population analysis method of Bhattacharya (1967) and the software FISAT II Version 1.2.2 (Gayanilo *et al.*, 2005) enabling the estimation of the parameters of the growth L' , K and t^0 and the relation Overall Length-Weight. This later tool, based on the Von Bertalanffy equation (1938) and recommended by FAO, provides assessments of different parameters through iterative algorithms.

Results

Results of the 1st sampling - Bleu Lake (20th/12/2012)

In this first sampling, the FISAT II results indicate that the population of *P.callensis* shows the existence of 3 cohorts with an average Total Length ranging from 19.12 mm to 34.61 mm (Table 1).

Results of the 2nd sampling - Bouhchicha wadi (24th/03/2013)

During March 2013 and for the raw TL data, the FISAT II results indicate the presence of different classes of the mean TL corresponding to the presence of 5 cohorts (Table 2).

Results of the 3rd sampling - Bouhchicha wadi (11th/04/2013)

During April 2013, the FISAT II results indicate that the population of *P.callensis* shows a decrease in the number of cohorts reaching only three cohorts (Table 3) with the disappearance of the cohorts whose average Total Length is between 43.03 mm and 58.40 mm.

Results of the 4th sampling - Bouhchicha wadi (14th/05/2013)

For this sampling, the FISAT II results indicate the presence of three cohorts whose average Total Length varies between 45.51 mm and 59.81 mm



Fig. 2. Sampling sites of *Pseudophoxinus callensis* in the complex Mellah Lagoon - Lake Oubeira. (2A); Oued Bouhchicha (2B) and Blue Lake (2C)
(Google Earth - July 2013, Modified)

Table 1. Age-Total Length key of classes of *Pseudophoxinus callensis* in the Blue Lake (20th/12/2012)

Age groups (year)	Mean Total Length (mm)	S.D.	Population (Sample Ni)	S.I.
1	19.12	1.320	18.96	n.a
2	25.15	2.550	43.69	2.210
3	34.61	1.590	06.39	2.380

S.D.: Standard Deviation, S.I : Separation Index

Table 2. Age-Total Length key of classes of *Pseudophoxinus callensis* in Bouhchicha wadi (24th/03/2013).

Age groups (year)	Mean Total Length (mm)	S.D.	Population (Sample Ni)	S.I.
1	34.00	2.220	08.54	n.a
2	40.54	1.690	15.69	2.150
3	49.84	2.840	58.03	2.230
4	57.59	2.710	35.68	2.080
5	65.60	1.290	19.25	2.130

S.D.: Standard Deviation, S.I : Separation Index

Table 3. Age-Total Length key of classes of *Pseudophoxinus callensis* in Bouhchicha wadi (11th/04/2013).

Age groups (year)	Mean Total Length (mm)	S.D.	Population (Sample Ni)	S.I.
1	43.03	2.730	57.24	n.a
2	50.59	1.970	33.69	2.130
3	58.40	1.150	07.99	2.180

S.D.: Standard Deviation, S.I : Separation Index

(Table 4).

Results of the 5th sampling - Blue Lake (23rd/05/2013)

For this period of sampling, the FISAT II results indicate the presence of a single and unique cohort (Table 5) with an average Total Length of 23.22 mm.

Linear growth of *P. callensis* in both sites

As a reminder, the linear growth expressed by the von Bertalanffy equation (1938) is:

$$L_t = L_{\infty} (1 - e^{-k(t-t_0)})$$

In the estimation of the growth parameters obtained by the Bhattacharya method, the data couples Age-Total Length are introduced in the FISAT II program. The obtained results (Table 6) indicate the following values:

Growth parameters of *P.callensis*

The asymptotic length L_{∞} reaches the highest value (79.80 mm) with a growth coefficient (K) of 0.480 years⁻¹. The growth curve (Fig. 3) represents a restructured distribution.

In Bouhchicha Wadi, the maximum TL of

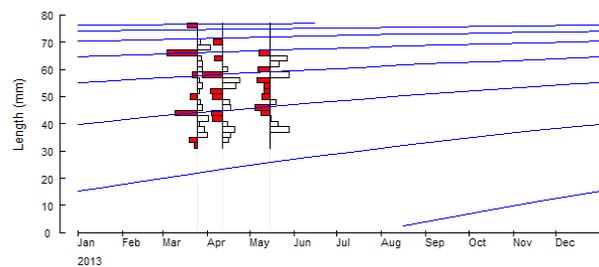


Fig. 3. Restricted Total Length frequency distribution and *P.callensis* growth curve (Data obtained under FISAT II using the ELEFEN⁻² method for $L_{\infty} = 79.80$ mm and $K = 0.480$ years⁻¹).

P.callens is 76.00 mm against 57.00 mm at the Blue Lake. The mean TL is 73.74 mm with a 95% confidence interval from 67.39 mm to 80.08 mm in Bouhchicha wadi whereas it is 52.26 mm with a 95% confidence interval from 43.31 mm to 61.20 mm in the Blue Lake (Fig. 4).

At the Blue Lake, the asymptotic Length L_{∞} of *P.callensis* reaches 59.85 mm with a growth coefficient (K) of 0.180 years⁻¹ (Fig. 5). The plot of the growth curve is represented through the restructured distribution in Fig. 6.

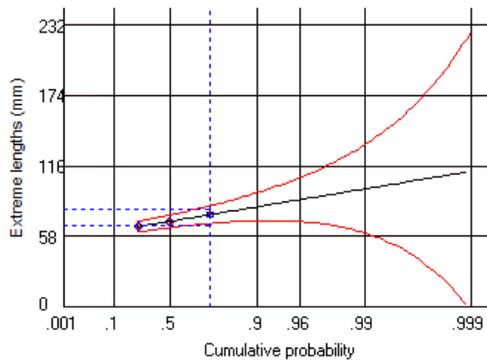


Fig. 4. Estimated Maximum Total Length of *P.callensis* in Bouhchicha Wadi.

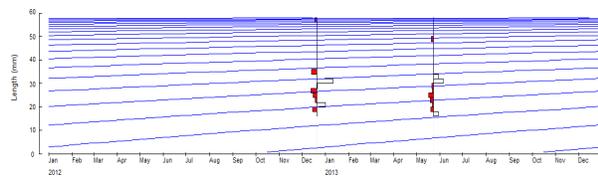


Fig. 5. Distribution of restructured length frequencies and *P.callensis* growth curve at the Blue Lake (for $L_{\infty} = 59.85\text{mm}$ and $K = 0.180 \text{ year}^{-1}$).

Relationship Total Length-Weight

The relation between the Total Length (TL) and the Total Weight (Tw) is exponential with

$$Tw = a TL^b$$

By logarithmic transformation: $\log Tw = \log a + b \log TL$

Let: $y = a + bx$. The obtained results from FISAT II are as follows (Table 7):

Discussion

The 1st sampling (Blue Lake)

In the Blue Lake, the decomposition of the average TL frequency distribution of all sexes (Fig. 7) shows three age groups ranging from 17 mm to 37 mm. This consolidates the presence of different average TL within the three cohorts.

The 2nd sampling (Bouhchicha wadi)

For Mars 2013 and for both sexes combined, the breakdown of the mean Total Length frequency distribution (Fig. 8) indicates the existence of 5 age groups ranging from 34.00 mm to 65.60 mm.

These results indicate the presence of several co-habiting cohorts in this wadi. These cohorts follow each other one after the other with an interval of 6 mm. The maximum average LT is 77.23 mm. The average minimum LT (31mm) is represented by the last fry from the last reproduction of the group of individuals making up the adult population. This

Table 4. Age-Total Length key of classes of *Pseudophoxinus callensis* in Bouhchicha wadi (14th/05/2013).

Age groups (year)	Mean Total Length (mm)	S.D.	Population (Sample Ni)	S.I.
1	45.51	3.130	71.00	n.a.
2	52.59	2.740	70.00	2.410
3	59.81	1.380	13.00	3.500

S.D.: Standard Deviation, S.I.: Separation Index

Table 5. Age-Total Length Key of classes of *P.callensis* in the Blue Lake (23rd/05/2013)

Age group (year)	Mean Total Length (mm)	S.D.	Population (Sample Ni)	S.I.
1	23.22	3.150	76.02	n.a.

S.D.: Standard Deviation, S.I.: Separation Index

Table 6: Growth parameters of *P.callensis* in Bouhchicha wadi and the Blue Lake.

Growth Parameters	Bouhchicha wadi	Blue Lake
asymptotic Total Length L_{∞} (mm)	79.80	59.85
Growth coefficient K (year^{-1})	0.480	0.180
Maximum Total Length (mm)	76.00	57.00
Mean Total Length (mm)	73.74	52.26
Confidence Interval at 95% (mm)	67.39 - 80.08	43.31 - 61.20

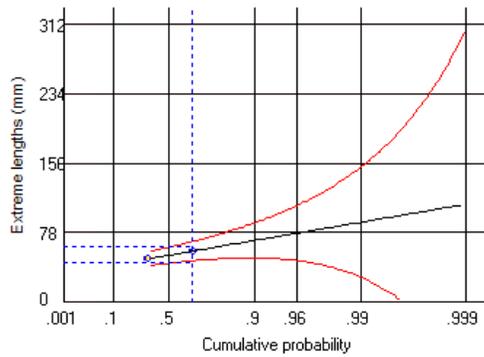


Fig. 6. Maximum Total Length estimation for *Pseudophoxinus callensis* at the Blue Lake.

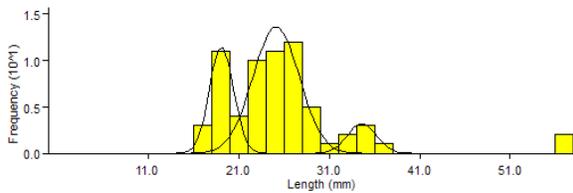


Fig. 7. Frequency distribution of the TL of *P. callensis* in the Blue Lake (20th/12/2012)

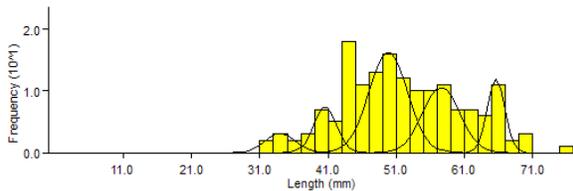


Fig. 8. Decomposition of the frequency distribution of the TL of *P. callensis* in Bouhchicha wadi (24th/03/2013)

occurrence of several cohorts confirms the permanent presence of *P.callensis* in this wadi throughout the year.

The 3rd sampling (Bouhchicha wadi)

All sexes combined, the decomposition of the TL frequency distribution (Fig. 9) indicates three main age groups ranging in class average from 43.00 mm to 58

mm. This expresses the presence of several cohorts cohabiting in Bouhchicha wadi. These cohorts follow one after the other with an interval of 8 mm. The minimum TL (33 mm) represents the length gain of the last fry from the last reproduction of the group of individuals making up the adult population whose maximum size is 70.2 mm.

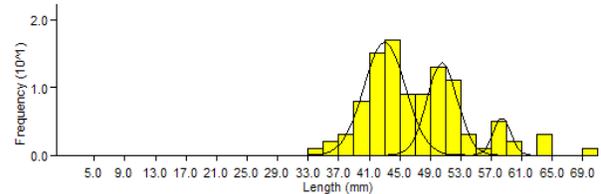


Fig. 9. Size frequency distribution of *P.callensis* in Bouhchicha wadi (11th/04/2013)

The existence of these numerous cohorts confirms the permanent presence of *P.callensis* in Bouhchicha wadi throughout the year. The growth of individuals of the first classes of the average LT leads to the appearance of only three classes.

The 4th sampling (Bouhchicha wadi)

For both sexes combined, the decomposition of the TL frequency distribution (Fig. 10) shows three main classes of mean TL ranging from 45 mm to 60 mm. This expresses the presence of several cohorts cohabiting within this site with an interval of 7 mm. The mean minimum TL (37 mm) represents the size of individuals from the last breeding. The maximum TL is 67 mm.

The existence of several cohorts confirms the per-

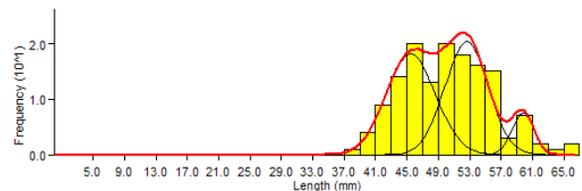


Fig. 10. Decomposition of the TL frequency distribution of *P. callensis* in Bouhchicha wadi (14/05/2013)

Table 7. Regression equation of the Total Length-Total Weight Relationship of *P.callensis*.

Sites	N	X	Y	Biometric Equation	R ²	R	Biometric Relation	t _{obs}
Bouhchicha wadi	408	TL	Tw	Y = - 5.42 + 3.16 x	0.84	0,91	Positive Allometry (Hyperallometry)	2.58
Blue Lake	135	TL	Tw	Y= - 4.52935826 + 2.74 x	0.41	0.64	Negative Allometry (Hypoallometry)	1.34

TL = Total Length; Tw = Total Weight

manent presence of *P.callensis* in this site throughout the year. The evolution of the average TL for all classes leads to a gathering into three classes. This confirms a variation of the growth depending on the age.

The 5th sampling (Blue Lake)

For both sexes, the decomposition of the TL frequency distribution (Fig. 11) shows a single age group ranging from 17 mm to 33 mm. This expresses the presence of a single cohort within this site. The minimum TL (17 mm) represents the TL gain of the last fry from the last reproduction of the group of adult individuals. The maximum TL is 33 mm.

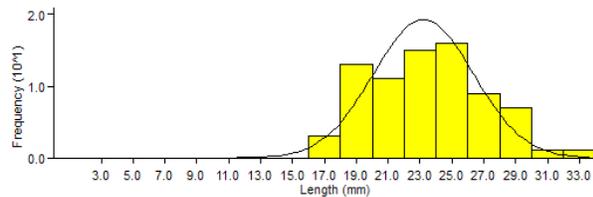


Fig. 11. Size frequency distribution of *P.callensis* in the Blue Lake (23/05/2013)

Total Length-Total Weight Relationship at *P.callensis* in both sites

For all the specimens sampled from both sites, the analysis of the mean TL and Tw (Fig. 12) expresses a strong correlation ($r^2 = 0.84$). In Wadi Bouhchicha, the regression equation indicates that growth of individuals is regular and that the weight gain depends mainly on the size of the individual.

However, in the Blue Lake, the regression analysis indicate a greater data dispersion with $r^2 = 0.41$

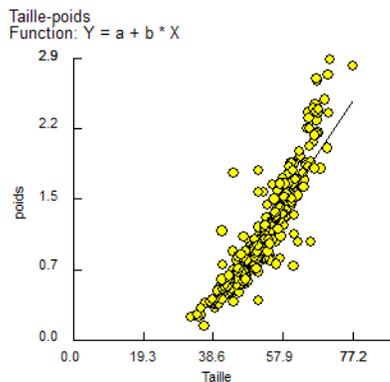


Fig. 12. Regression between Total Length and Total Weight of *P.callensis* Bouhchicha wadi.

(Fig. 13). This dispersion suggests a weight gain regardless of the growth, probably owing to environmental conditions.

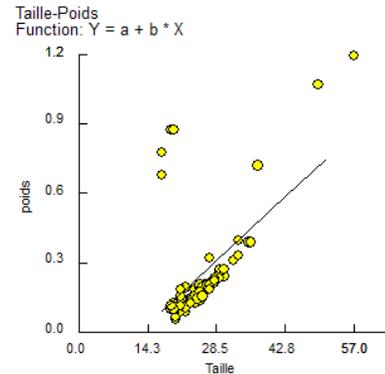


Fig. 13. Regression between Total Length and Total Weight of *P.callensis* - Blue Lake

These results show a series of cohorts indicating the permanent presence of populations of *P.callensis* in Bouhchicha wadi whereas in the Blue Lake, the grouping of cohorts suggests the presence of only one generation per year. This consolidates the idea of the adaptation of *P.callensis* according to the conditions of its aquatic environment.

Conclusion

In this study, the evaluation of the morphological parameters and the growth of the different populations of *Pseudophoxinus callensis* made it possible to compare the indices of abundance of this specie in the two sampling sites within the National Park of El-Kala. Indeed, this investigation on the dynamics of the populations of *P.callensis* offers a better understanding of the evolution and the adaptation of this specie to the fluctuations of its environment. These findings will enable further studies of predictive models on the evolution of the populations of *P.callensis* in various aquatic environments subject to specific constraints. The lack of research works and data on the bio-ecology of *P.callensis* and its different populations opens a wide subject of research within the NPEK, but also in the surrounding wetlands. In fact, several populations of *P.callensis* exist within various geographical sites, with different living conditions than in Bouhchicha wadi and the Blue Lake. It's obviously possible to conceive that different adaptation systems are deployed by this endemic species in these sites. It is important to emphasize that the conservation of this species represents signifi-

cant ecological and ecosystemic values. As a highly voracious specie, *P. callensis* plays an important role in the biological control of the malaria disease, particularly in the north of Algeria where several wetlands are recorded. On the other hand, the morphological and the genetic polymorphism of *P. callensis* should also be considered in further investigations.

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