

# Study of the growth of blue barbel (*Pterocapoeta maroccana*) in the Oued Oum Errabia River (Morocco).

Loubna Mahougan<sup>1</sup>, Hassan Nhhala<sup>2</sup>, Abdelkhalek Zraouti<sup>3</sup>, Nazha Laadel<sup>3</sup>, Hammou El Habouz<sup>4</sup>, Saida Bouzid<sup>5</sup> and Miriam Wahbi<sup>1</sup>.

<sup>1</sup>Applied Geoscience Research and Development Laboratory, Abdelmalek Essaâdi University, Faculty of Science and Technology, Tangier, Morocco.

<sup>2</sup> Expert consultant in Aquaculture, Morocco.

<sup>3</sup> Ichthyology Laboratory, National Center for Hydrobiology and Fish Farming (CNHP), Azrou, Morocco.

<sup>4</sup> Fisheries Laboratory, Regional Center of the National Institute for Fisheries Research (INRH), Agadir, Morocco.

<sup>5</sup> Marine Environment and Natural Hazards Research Team, Abdelmalek Essaâdi University, Faculty of Science and Technology, Tangier, Morocco.

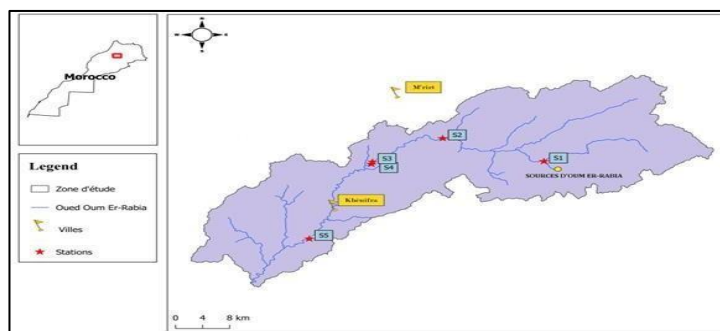
**Abstract.** The blue barbel (*Pterocapoeta maroccana*, Günther 1902) is an endemic Moroccan species classified as Critically Endangered (CE) by the international union for conservation of nature (IUCN) and Data Deficient (DD), [1,6]. This study aims to characterize its growth to support conservation and management efforts. A total of 314 individuals were sampled in the upper Oued Oum Er-Rabia River between November 2022 and May 2024. Growth was analysed using scalimetry and modelled with the Von Bertalanffy Growth Model. Asymptotic length ( $L_{\infty}$ ) and growth coefficient (K) were estimated at 402.8 mm and  $0.201 \text{ yr}^{-1}$  for males, 463.7 mm and  $0.145 \text{ yr}^{-1}$  for females, and 566.9 mm and  $0.106 \text{ yr}^{-1}$  for combined sexes, indicating faster growth in males and larger asymptotic size in females. The length–weight relationship showed isometric growth in males ( $b = 3.00$ ) and negative allometry in females ( $b = 2.91$ ) and combined sexes ( $b = 2.98$ ). These results provide key biological reference parameters for the conservation and sustainable management of this endangered species. These findings provide an important basis for biological knowledge of the species and may contribute to the development of appropriate management and conservation strategies.

**Key words.** *Pterocapoeta maroccana*, growth, age, scalimetry, Oued Oum Er-Rabia.

## 1 Materials and Methods

### 1.1 Study Area

The current study was carried out in the upper reaches of the Oued Oum Er-Rbia River, one of Morocco's principal fluvial systems. Originating in the Middle Atlas near the city of Khénifra, the river extends for approximately 550 km before discharging into the Atlantic Ocean at Azemmour city (Fig.1). The study area, located within the Moroccan Middle Atlas, exhibits a characteristic montane hydrological regime defined by cool, well-oxygenated, and fast-flowing waters. The riverbed is predominantly composed of rocky and gravel substrates.



**Fig. 1.** Geographical Location of the Study Area (Oued Oum Er-Rbia River).

### 1.2 Sampling

A total of 314 specimens of the blue barbel (*Pterocapoeta maroccana*) was collected from the upper section of the Oued Oum Er-Rbia River. Fish were obtained monthly from local fishermen. The sampling period extended from November 2022 to May 2024 and included individuals with total lengths ranging from 130.5 mm to 410 mm.

For each specimen, the following biometric measurements were taken and recorded: total length (TL) and standard length (SL), measured to the nearest 0.01 mm using an ichthyometer, as well as total weight (TW) and eviscerated weight (EW), determined to the nearest gram using an electronic balance.

### 1.3 Age determination

Scales were collected from the laterodorsal region [11], carefully cleaned with distilled water and rubbed to remove dermal and mucus residues [2,13], air-dried and stored individually in paper envelopes. At least eight scales per fish were prepared [7]. Growth rings were analysed using a Canon 100 microfiche reader [8] ( $\times 50$  magnification), with scales mounted dry between two glass plates and observed under reflected light, to distinguish dark zones (closely spaced circuli) from light zones (widely spaced circuli) (Fig.2).

The age of each fish was determined by counting these winter rings observed on the scales. In order to obtain the most accurate estimate of age possible and to minimize potential errors, three independent readings were taken by three different observers. The final age assigned corresponds to the value showing the highest agreement among the different observations.

Accurate individual age determination requires, in addition to observation of winter rings, a minimum knowledge of the biology of the species being studied (growth patterns, environmental conditions (temperature and water flow), feeding habits, and periods of reproduction and migration) [2]. The period when winter rings appear, which is generally in the spring in temperate climates, varies according to the species, age, and maturity of the individual. Finally, a thorough understanding of the criteria for recognizing the different types of growth cessation is necessary to distinguish winter rings (annuli) from additional or supernumerary rings (false rings) [7].



**Fig. 2.** Scale of Blue Barbel (*Pterocapoeta maroccana*).

Furthermore, for each scale, a reading axis was defined, extending from the nucleus of the scale to its edge. Along this axis, the distance between the nucleus and the intersection of the axis with the annuli was measured. Additionally, measurements of scale length and width were taken to study the relationship between scale size and fish length.

In order to ensure the validity of age determination based on calcified structures, it is essential to know the exact chronology of the formation of growth marks on calcified parts, [9]. Therefore, a verification is performed by calculating the increment between the last and penultimate ring, or marginal increment (MI), expressed by the following formula:

$$MI = \frac{(R - R_n)}{R_n - R_{(n-1)}} \quad (1)$$

Where :

- MI : marginal increment ;
- R : maximum radius of the scale
- $R_n$  : radius of the nth ring (last ring) ;
- $R_{(n-1)}$ : radius of the penultimate ring.

The monthly evolution of the average marginal increment (MI) provides the determination of the season in which the rings appear and to ascertain their periodicity.

### 1.4 Linear growth modelling

In the present study, linear growth was modelled using the Von Bertalanffy Growth Model (VBGM), [10], which is the most widely employed mathematical expression for fish growth. This model has been shown, on the one hand, to fit the growth

patterns observed in most fish species, and on the other hand, to serve as a sub-model within more complex frameworks describing fish population dynamics, [12]. Its expression is as follows:

$$L_t = L_{\infty}(1 - e^{-k(t-t_0)}) \quad (2)$$

Where:

- $L_t$ : length of the fish at time  $t$ ;
- $L_{\infty}$ : length of the fish when it continues to grow indefinitely;
- $K$ : growth coefficient;
- $t_0$ : age of the fish when its size is theoretically zero.
- $t$ : age of the fish.

The determination of the parameters  $L_{\infty}$ ,  $k$ , and  $t_0$  was performed using back-calculations. For each scale, we measured the largest radius,  $R$ , extending from the nucleus to the outer edge of the scale along the same axis used to measure the growth arrest rings ( $A_1, A_2, A_3$ , etc.), starting from the nucleus.

First, a linear regression is established between the fish length and the maximum scale radius, expressed by the following relationship:

$$L = a + b \times R \quad (3)$$

Where:

- $L$ : total length of the fish;
- $R$ : largest radius of the fish scale measured;
- $a$ : ordinate at the origin;
- $b$ : slope of the linear regression line.

Using the values of  $a$  and  $b$  obtained from this linear regression and the measurements of the rings ( $A_1, A_2, \dots, A_n$ ) corresponding to ages (1, 2, ...,  $n$  years), the different fish lengths ( $L_1, L_2, \dots, L_n$ ) were calculated. This procedure is referred to as back-calculation.

$$L_i = a + b \times A_i \text{ for } i=1,2,\dots,n \quad (4)$$

Using Ford WalFord regression, [4], expressed by the following formula:

$$L_{t+1} = A + B \times L_t \quad (5)$$

Where  $L_t$  and  $L_{t+1}$  are the lengths of the fish at age  $t$  and  $t+1$ , respectively. The parameters  $K$ ,  $L_{\infty}$ , and  $t_0$  are estimated as follows:

$$K = -\ln(B) \quad (6)$$

$$L_{\infty} = \frac{A}{(1-B)} \quad (7)$$

$$t_0 = t + \left(\frac{1}{K}\right) \times \ln\left(\frac{(L_{\infty}-L_t)}{L_{\infty}}\right) \quad (8)$$

For each age observed, the corresponding  $t_0$  value is calculated. The average of the  $t_0$  values calculated by age is used for Van Bertalanffy's linear growth equation.

### 1.5 Comparison of linear growth curves within the same species

The comparison of linear growth curves for the same species, the same stock, or different stocks is assessed using the  $\Phi'$  (phi-prime) test, [4], defined by the following expression:

$$\Phi' = \text{Log}(K) + 2 \times \text{Log}(L_{\infty}) \quad (9)$$

This test is based on the discovery by PAULY [5], that Phi-prime values are highly similar within closely related taxa and that they have narrow normal distributions [12].

### 1.6 Relative growth: size-weight relationship

The relationship between fish size (L, mm) and weight (W, g) according to Ricker, 1980 [14], is expressed as follows:

$$W = a \times L^b \tag{10}$$

Where:

- W: weight in grams
- L: length in mm
- a: proportionality constant
- b: growth coefficient, a factor that reflects allometry (in fish, it is always close to 3):
- If  $b = 3$ , weight increases proportionally to length, there is isometry,
- If  $b > 3$ , weight increases proportionally, but faster than length, and allometry is therefore upper bounding,
- If  $b < 3$ , weight increases proportionally, but slower than length, and allometry is therefore lower bounding.

### 1.7 Absolute weight growth

The weight-growth model expresses the individual weight of fish ( $W_t$ ) as a function of their age. The formula for this model is derived from the length growth model (linear growth), using the length–weight relationship [3]. The weight-growth relationship is established using the two equations from the previous models. The weight growth relationship can then be expressed as follows :

$$W_t = W_{\infty}(1 - e^{-k(t-t_0)})^b \tag{11}$$

$$\text{with : } W_{\infty} = a \times W_{\infty}^b \tag{12}$$

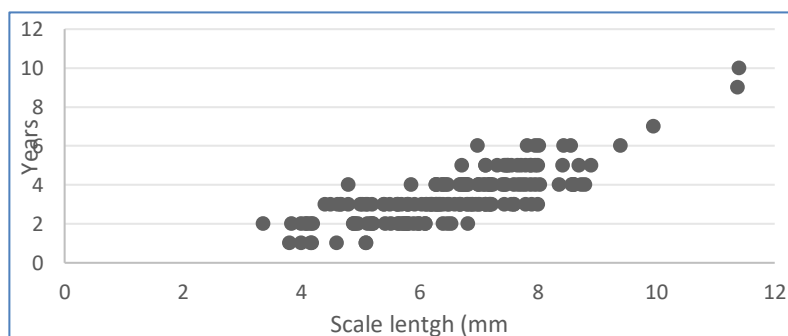
Where :

- $W_t$  et  $W_{\infty}$  are the weights (g) corresponding to  $L_t$  and  $L_{\infty}$ , respectively;
- $K$  is the growth coefficient from Von Bertalanffy's equation;
- $b$ : the allometry coefficient extracted from the size-weight relationship.

## 2 Results

### 2.1 Age determination

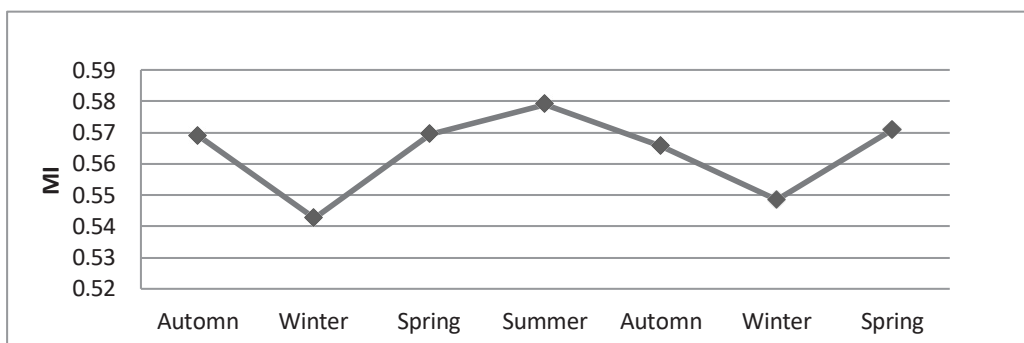
Based on the analyzed samples, whose total length ranges from 130 to 480 mm, ten growth rings were identified and localized. with a progressive increase in mean scale radius across successive annuli, reflecting continuous growth throughout the species' lifespan. The linear regression calculated between age and scale size shows a significant correlation (Fig.3).



**Fig. 3.** Representative age–scale size relationship curve for the blue barbel.

### 2.2 Marginal increment

In calculating the mean marginal increment (MI) by season, it was observed hat marginal increment values close to zero ( $MI = 0$ ) were frequently observed during winter.



**Fig. 4.** Seasonal variation of the marginal increment of scales in the blue barbel (*Pterocapoeta maroccana*).

The graphical representation of marginal increment (Fig. 4) shows a clear seasonal pattern, characterized by regular variations throughout the year. Lower MI values correspond to periods of reduced growth, while higher values indicate phases of active growth. This cyclic variation reflects the annual rhythm of growth of the blue barbel. The observed pattern confirms that the growth rings visible on the scales are formed periodically and can be considered as reliable annual growth marks. Therefore, the marginal increment analysis validates the use of scale annuli for age determination and confirms their relevance in describing seasonal growth dynamics of the species.

### 2.3 Age-length relationship key

Age readings showed that the oldest individuals were ten years old, while the youngest were one year old. Table 2 presents the distribution of age frequencies by size class (mm), for both sexes combined (Table 1).

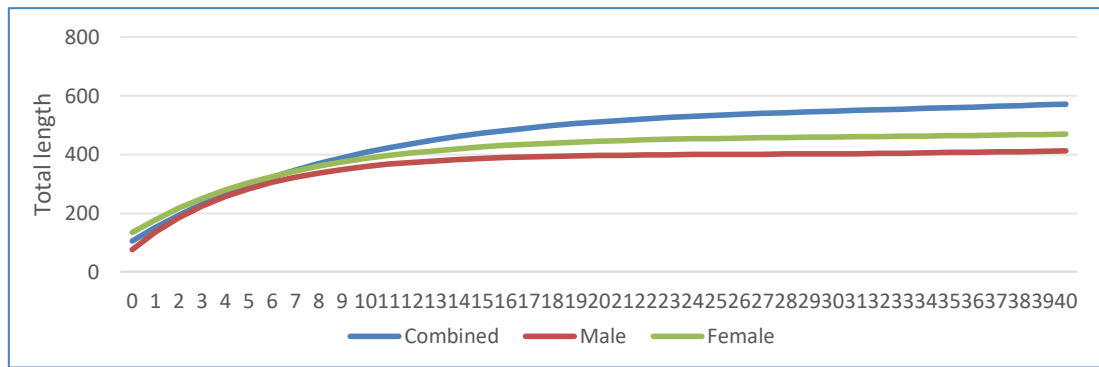
**Table 1.** Age-length key of the blue barbel (*Pterocapoeta maroccana*).

Size class (mm)	I	II	III	IV	V	VI	VII	VIII	IX	X	Count
140	2	5	3								10
160		25	4								29
180		9	23								32
200		2	17	6							25
220		2	9	18	2						31
240			10	25	16	1					52
260			4	12	16	2	1				35
280				4	24	5	1				34
300				2	17	4	1	1			25
320					7	3	5	3	1	1	20
340					3	8	2				13
360							2				2
380							1	1	2		4
>400									2		2
Total	2	43	70	67	85	23	13	5	5	1	314

### 2.4 Linear growth

#### 2.4.1. Parameter estimation for the Von Bertalanffy linear growth model.

The linear growth parameters calculated using the von Bertalanffy growth model revealed clear differences between sexes. Females exhibited a higher asymptotic length ( $L_{\infty} = 463.734$  mm) than males ( $L_{\infty} = 402.845$  mm), indicating a maximum growth potential in length. However, males showed a higher growth coefficient ( $k = 0.201$ ) compared to females ( $k = 0.145$ ), suggesting faster growth during early life stages. When sexes were combined, the estimated asymptotic length was higher ( $L_{\infty} = 566.852$  mm), while the growth coefficient was lower ( $k = 0.106$ ), reflecting the overall population growth pattern. The negative values of  $t_0$  observed for all groups indicate that theoretical length at age zero is consistent with early growth dynamics of the species. The von Bertalanffy growth curves illustrating linear growth for males, females, and combined sexes are presented in Fig.5.

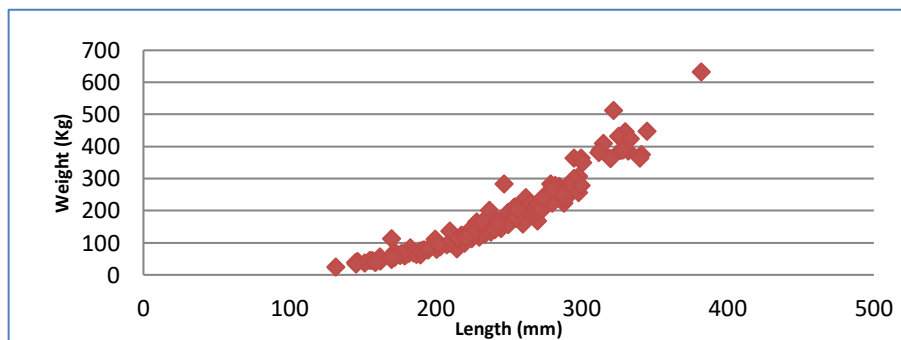


**Fig. 5.** Von Bertalanffy linear growth curves for *Pterocapoeta maroccana*

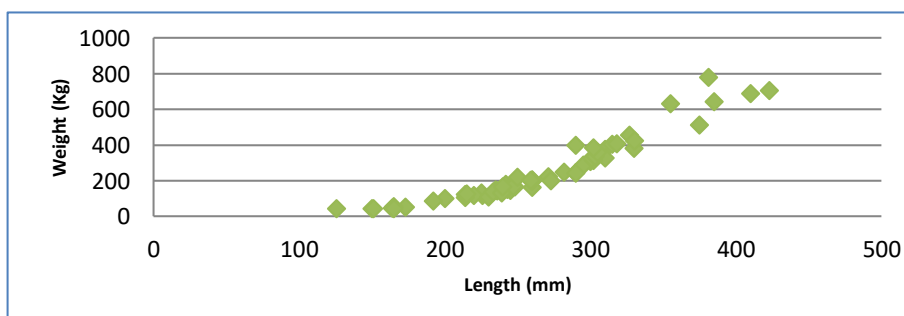
## 2.5 Weight growth

### 2.5.1. Relative growth: weight-length relationship

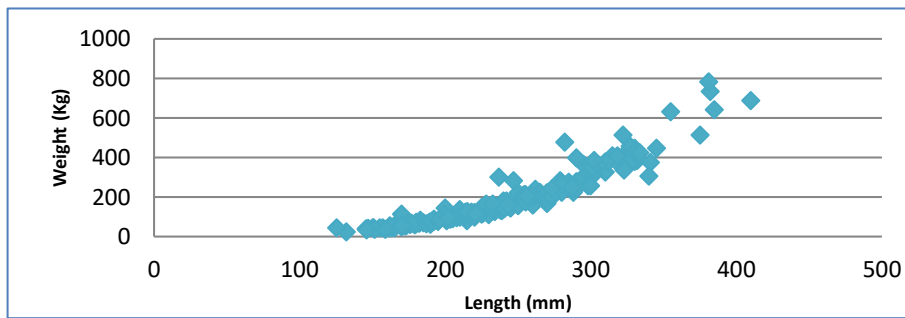
The estimated parameters showed strong relationships between length and weight for all groups, with coefficients of determination higher than 0.90. Separate analyses were performed for males, females, and combined sexes based on total body weight. In males, the estimated exponent  $b$  was equal to 3.00, indicating an isometric growth pattern. In contrast, females exhibited negative allometric growth ( $b = 2.91$ ), while combined sexes also showed negative allometry ( $b = 2.98$ ). Figures 6, 7, and 8 present the graphical representation of the length–weight relationship for males, females, and combined sexes of the blue barbel.



**Fig. 6.** Graphical representation of length variation in relation to weight for male Blue Barbels.



**Fig. 7.** Graphical representation of length variation in relation to weight for female Blue Barbels.

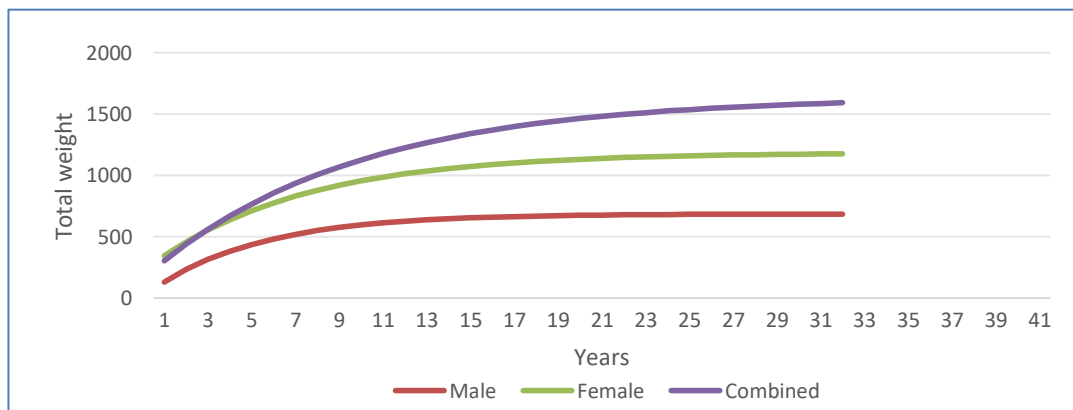


**Fig. 8.** Graphical representation length–weight variation for combined sexes in the Blue Barbel

Figures 6–8 illustrate a strong positive relationship between length and weight for males, females, and combined sexes. The distribution of data points shows a consistent increase in body weight with increasing length, with slight differences in dispersion among groups, reflecting variability in growth patterns.

### 2.5.2. Absolute weight growth

The parameters of the absolute weight-growth model revealed differences among sexes. Females exhibited a higher asymptotic weight ( $P_{\infty} = 1.19 \times 10^3$  g) compared to males ( $P_{\infty} = 6.87 \times 10^2$  g), while males showed a higher growth coefficient ( $k = 0.201$ ) than females ( $k = 0.145$ ). For combined sexes, the estimated asymptotic weight was higher ( $P_{\infty} = 1.64 \times 10^3$  g), associated with a lower growth coefficient ( $k = 0.106$ ), reflecting the overall population growth pattern. Negative values of  $t_0$  were observed for all groups.



**Fig. 9.** Graphs illustrating absolute weight growth in the blue barbel.

The graphical representation of absolute weight growth (Fig.9) highlights clear differences between sexes. Females show higher weight values across all age classes, with a steeper growth trajectory at older ages, indicating a greater capacity for weight accumulation over time. In contrast, males display a faster increase in weight during early growth stages but reach lower asymptotic weights compared to females. The divergence between the two curves becomes more pronounced with increasing age, reflecting a weight-growth advantage in females within the studied population.

## References

1. A.J. Crivelli, *Pterocapoeta maroccana*. The IUCN Red List of Threatened Species 2006, e.T60261A12345678 (2006). <https://www.iucnredlist.org/species/60261/12345678>
2. A. Jearld, Age determination, in: L.E. Nielsen, D.L. Johnson (Eds.), *Fisheries Techniques*, American Fisheries Society, Blacksburg, 301–324 (1983).
3. D. Gascuel, *Dynamique des populations et gestion des stocks halieutiques*, support de cours en ligne, Agrocampus Ouest / Campus numérique ENVA Méd., Rennes, France (2008).
4. D. Pauly, Some simple methods for the assessment of tropical fish stocks, *FAO Fisheries Technical Paper No. 234*, FAO, Rome (1983).
5. D. Pauly, Gill size and temperature as governing factors in fish growth: a generalization of von Bertalanffy's growth formula. *Ber. Dtsch. Wiss. Komm. Meeresforsch.*, 28, 251–282 (1979).
6. J. Freyhof, M. Ford, *Pterocapoeta maroccana* Günther, 1902. IUCN Red List of Threatened Species 2022, e.T60370A137281031 (2022). <https://doi.org/10.2305/IUCN.UK.2022-1.RLTS.T60370A137281031.en>
7. J.-L. Baglinière, J. Castanet, F. Conand, F.J. Meunier (Eds.), *Tissus durs et âge individuel des vertébrés*, ORSTOM/INRA, Paris (1992).
8. J.-L. Baglinière, H. Le Louarn, *Caractéristiques scalimétriques des principales espèces de poissons d'eau douce de France*. *Bull. Fr. Pêche Piscic.*, 306, 1–39 (1987).
9. J. Panfili, H. de Pontual, H. Troadec, P.J. Wright, *Manuel de sclérochronologie des poissons*, Ifremer–IRD, Paris (2002).
10. L. von Bertalanffy, A quantitative theory of organic growth (inquiries on growth laws II). *Hum. Biol.*, 10, 181–213 (1938).
11. P. Boët, H. Le Louarn, *La croissance du poisson : techniques d'étude*, in: D. Gerdeaux, R. Billard (Eds.), *Gestion piscicole des lacs et retenues artificielles*, INRA, Paris, 125–142 (1985).
12. P. Sparre, S.C. Venema, *Introduction à l'évaluation des stocks de poissons tropicaux*, *FAO Fisheries Technical Paper No. 306/1*, Rev. 1, FAO, Rome (1996).
13. S. Bouhbouh, *Étude bioécologique de deux espèces de barbeau (*Barbus callensis* Valenciennes, 1842 et *Barbus fritschi* Günther, 1874) au niveau du réservoir Allal El Fassi*, Ph.D. thesis, Faculté des Sciences, Fès, Morocco (2002).
14. W.E. Ricker, Causes of the decrease in age and size of Chinook salmon (*Oncorhynchus tshawytscha*). *Can. Tech. Rep. Fish. Aquat. Sci.*, 944, 1–25 (1980).