International Journal of Scientific Research Updates

Journal homepage: https://orionjournals.com/ijsru/

ISSN: 2783-0160 (Online)

(RESEARCH ARTICLE)

Length-weight relationships and condition factor of the main species of fish caught on the Bandama River (Ivory Coast)

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International Journal of Science and Research Archive, 2022, 03(02), 037–042

Publication history: Received on 11 March 2022; revised on 23 April 2022; accepted on 25 April 2022

Article DOI: https://doi.org/10.53430/ijsru.2022.3.2.0038

Abstract

The Ivory Coast has economically and ecologically important rivers that contain various fish and shellfish resources. Thus, the present study aims to assess the length-weight relationships and the condition factor of fish stocks in selected sites on the Bandama River from July 2013 to June 2014. The growth pattern of each species was identified at the using a regression model calculated for the length-weight relationship. The condition factor (K) was analyzed for each species. There were six species of fish (*Chrysichthys nigrodigitatus, Synodontis bastiani, Synodontis schall, Marcusenius senegalensis, Coptodon zillii* and *Labeo coubie*). The length-weight relationship determined for the above six species showed a negative allometric growth pattern (b<3) indicating faster length increase relative to weight for five of them. They are *Chrysichthys nigrodigitatus, Coptodon zillii, Synodontis bastiani, Synodontis schall* and *Marcusenius senegalensis*, Only the species *Labeo coubie* presented a positive allometric growth (b>3) showing that this species put on weight faster than it grows.

The habitat qualities of the majority of fish species were therefore in optimal environmental conditions. The results of the present study constitute a reference, which taken into account would be useful for the implementation of a plan for the sustainable management of fishery resources in Ivory Coast.

Keywords: Lenght-weight relationship; Allometric growth model; Condition factor; Fisheries management; Bandama River

1. Introduction

Fisheries and aquaculture have an important role in achieving the strategic objectives of the FAO (Food and Agriculture Organization of the United Nations) relating to the eradication of hunger, food insecurity, malnutrition and poverty (FAO, 2012). According to this international organization, deliveries of fish for food, from fisheries (sea and inland) and aquaculture, accounted for more than 15% of the total supply of animal protein. World fish production in 2014 was estimated at 167.2 million tonnes, of which 73.8 million were for aquaculture and 93.4 million for fisheries. The share of marine fishing is 81.5 million tonnes and that of inland fishing is 11.9 million tonnes. Inland fishery production has increased since 2009, rising from 10.5 to 11.9 tonnes in 2014 (FAO, 2016).

In Côte d'Ivoire, the rulers rely on its large hydrographic network to carry out multiple development programs, making available to rural populations huge expanses of water suitable for fishing. The fall in coffee and cocoa prices in the 1990s forced the rulers to definitively integrate the fishing sector into the Ivorian economy. Today, the increase in the Ivorian population has resulted in a strong demand for fishery proteins. This strong demand has given rise to significant

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economic challenges and led to the emergence of new markets around the various Ivorian rivers (Boguhé, 2015). This situation has oriented Ivorians to fishing activity and attracted many foreigners to the fishing areas (Kien *et al.,* 2021). Thus, fishing in the Ivorian inland waters, long considered an artisanal and subsistence sector for the inhabitants, has undergone significant changes with the improvement of fishing means and a better valuation of products (FAO, 2016).

This situation has led to an intensification of fishing pressures which have led to a decrease in fish production (Koudou, 2012) and even to their depletion (Kien *et al.,* 2021).

In search of solutions to this threat, studies on the knowledge of fishery resources, fishing gear and actors have been carried out for the establishment of a management system (Lae and Levêque, 1999 ; Tah, 2012 ; Kien *et al.,* 2018). However, very few researchers have addressed the effects of environmental disturbances on the growth and condition of fish in river watersheds. This information deficit constitutes a handicap in the preparation and conduct of development and management plans for any socio-economic sector. The purpose of this study is to provide the information necessary for the establishment of a rational management plan for fish stocks. It is based on the length-weight relationship and the condition factor. According to Hossain *et al.* (2012) and Bolognini *et al.* (2013), the length-weight relationship is an important tool in biology, physiology, ecology and stock assessment for the management and conservation of natural fish populations. Indeed, it is a critically important key used in fisheries assessment and in fish biology (Da Costa and Araujo, 2003). Furthermore, these biometric relationships are essential for estimating different factors and indices such as growth parameters that act as direct indicators in the dynamics of populations of aquatic organisms (Gamage *et al.,* 2021). As for the condition factor, it provides information on the overweight condition of a fish (Levêque *et al.,* 1990). It is an instrument often used to compare the overall physiological state of populations over a seasonal cycle or between ponds with similar or different ecological conditions (Le Cren, 1951). For Baby (2011), the condition factor can be used as an index to assess the level of disturbance in an aquatic ecosystem strongly influenced by environmental parameters. The present study aims to set up a biological database of the ichthyological fauna of rivers and the effect of environmental disturbances on the growth and condition of the 6 species of fish cited by Kien (2016) as the most present in the catches on the Bandama River for appropriate management of their stock.

2. Material and methods

2.1. Study area

The survey and sampling stations (Figure 1) were selected based on their proximity to the Bandama River where fishing is a very important activity; the existence of a commercial fish exploitation, their easy accessibility in all seasons by road and the density of their population. The three (3) stations selected are: Tiassalé (5 ° 53 N and 4 ° 49 W), N'Zianouan (6 ° 00 N and 4 ° 49 W) and Singrobo (6 ° 05 N and 4 ° 55 W).

2.2. Data collection

2.2.1. Landings survey

Surveys on fish landings took place in all stations from July 2013 to June 2014. During these various missions, we examined the daily catches of fishermen. The fishermen are chosen at random.

The identification of fish was done using the dichotomous key of Paugy (2003a) and Paugy (2003b). The specimens thus sampled were individually measured to the nearest mm (standard lengths [LS]) using an ichthyometer and weighed to the nearest g using a balance.

2.2.2. Data processing

For this study, we considered the most frequent species in the captures, i.e. present at all stations throughout the collection period and represented by at least 10 specimens as recommended by Batiabo *et al.* (2019) and Ibala *et al.* (2020).

Length-weight relationship

For each species studied, the length-weight relationship is determined. The variations make it possible to specify the type of allometry (Koné, 2012). The length-weight correlation is established according to the formula of Riker (1975):

$P = aLSb$

With P = weight of the fish in g; LS = standard length of the fish in cm; a = constant and b = coefficient of allometry.

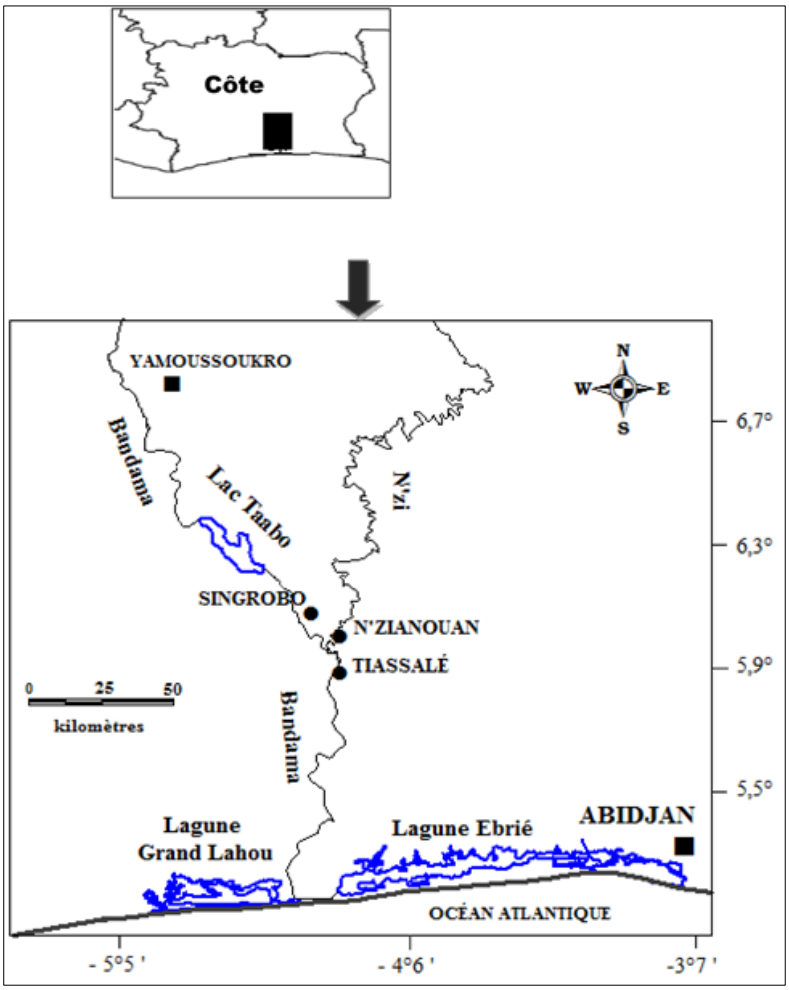

Figure 1 Geographical location of the survey and sampling stations (●) on the Bandama River

The parameters a and b were estimated after transforming the previous linear function into a logarithmic function of formula:

log10 P = log10 a + b log10 LS.

The value of b gives information about the type of growth of the fish. When b=3, the growth is isometric and when b≠3, the growth is allometric. If b<3, the allometry is negative or lower, the fish is growing faster than it put on weight. If b>3, the allometry is positive or major, the fish put on weight than it grows (Levêque, 2006).

In order to check whether the value of b is significantly different from 3, Student's t test was used (p=0.05) (Lae and Levêque, 1999). If ts≥t theoretical (1.96), then the difference is significant.

If ts ≤t theoretical (1.96), then the difference is not significant. The correlation coefficient (r) was used as an indicator of the degree of correlation between length and weight. The closer this coefficient is to unity in absolute value, the greater the strength of the relationship between the two variables (Schwartz and Lazar, 1964).

Condition coefficient (K)

In most fish, after metamorphosis, the body retains its original proportions during growth. The condition factor or condition coefficient (K) is an expression of the length-weight ratio which gives an idea of the overweight of a considered species (Kartas and Quignard, 1984). Condition coefficients are used to compare the overweight of fish.

For the present study, the Fulton condition coefficient (Bagenal, 1978) was used and calculated for each fish according to the formula:

$K = (Pt / LS^3) \times 100$

With: Pt = total weight of the fish (fresh) in g;

LS = standard length of the fish in cm.

3 = exponent of the length-mass relationship or allometric coefficient (b).

3. Results

3.1. Condition coefficient

Table 1 show the different values of the average condition coefficient (K) calculated for the species studied. These values are between 1.36 and 2.54 for *Chrysichthys nigrodigitatus, Synodontis bastiani, Synodontis schall and Marcusenius senegalensis*. They are 4.69 for *Coptodon zillii* and 3.12 for *Labeo coubie*.

Chrysichthys nigrodigitatus: the values of K obtained are 2.23 ± 0.07 at Tiassalé; 2.47 ± 0.16 in N'Zianouan and 2.93 ± 0.63 in Singrbo for an average value equal to 2.54 ± 0.36.

Coptodon zillii shows K values ranging from 4.51 ± 1.01 in N'Zianouan; 4.78 ± 1.11 in Tiassalé to 4.8 ± 0.62 in Singrobo. The average K obtained for this species is 4.69 ± 0.16.

Labeo coubie has a condition in the study environment that ranges from 2.9 ± 0.45 in Tiassalé; 3.18 ± 0.29 in Singrobo to 3.29 ± 0.45 in N'Zianouan with an average of 3.12 ± 0.2. *Synodontis schall* has an estimated condition coefficient of 2.33 ± 0.21 in N'Zianouan; 2.39 ± 0.27 at Tiassalé and 2.4 ± 0.28 at Singrobo with an average value equal to 2.37 ± 0.04.

Marcusenius senegalensis, the values of K obtained are: 1.2 ± 0.07 in Tiassalé, 1.38 ± 0.06 in N'Zianouan and 1.5 ± 0.03 in Singrobo. The mean value of K for this species in the present study is 1.36 ± 0.15.

Synodontis bastiani shows K values between 2.14 ± 0.16 at Singrobo; 2.48 ± 0.12 in N'Zianouan and 2.58 ± 0.24 in Tiassalé. The mean of K calculated for this species is 2.4 ± 0.23.

Table 1 Condition coefficient K of the six main species of fish landed at Tiassalé, Singrobo and N'Zianouan on the Bandama river from July 2013 to June 2014

Species	K Values			K-mean
	Tiassalé	Singrobo	N'Zianouan	
Chrysichthys nigrodigitatus	2.23 ± 0.07	2.93 ± 0.63	2.47 ± 0.16	2.54 ± 0.36
Coptodon zillii	4.78 ± 1.11	4.8 ± 0.62	4.51 ± 1.01	4.69 ± 0.16
Labeo coubie	2.9 ± 0.45	3.18 ± 0.29	3.29 ± 0.45	3.12 ± 0.20
Synodontis bastiani	2.58 ± 0.24	2.14 ± 0.16	2.48 ± 0.12	2.4 ± 0.23
Synodontis schall	2.39 ± 0.27	2.4 ± 0.28	2.33 ± 0.21	2.37 ± 0.04
Marcusenius senegalensis	1.2 ± 0.07	1.5 ± 0.03	1.38 ± 0.06	1.36 ± 0.15

3.2. Length-weight relationship

The lengths of *Chrysichthys nigrodigitatus* are between 7.8 cm and 37 cm for weights varying from 10 g to 2742 g. Regarding *Coptodon zillii*, the lengths are between 6 cm and 26.5 cm and the weights vary from 8 g to 531 g. The lengths of *Labeo coubie* vary between 13.5 cm and 55 cm with weights ranging from 42 g to 5012 g. For the *Synodontis bastiani* species, the lengths are between 8 cm and 28 cm. The weights obtained for this species range from 16 g to 214 g. *Synodontis schall* has lengths ranging from 7 cm to 28 cm with weights of 20 g to 233 g. The minimum values of the

length and the weight of *Marcusenius senegalensis* are respectively 10.5 cm and 17 g for maximum measurements respectively equal to 35 cm and 321 g.

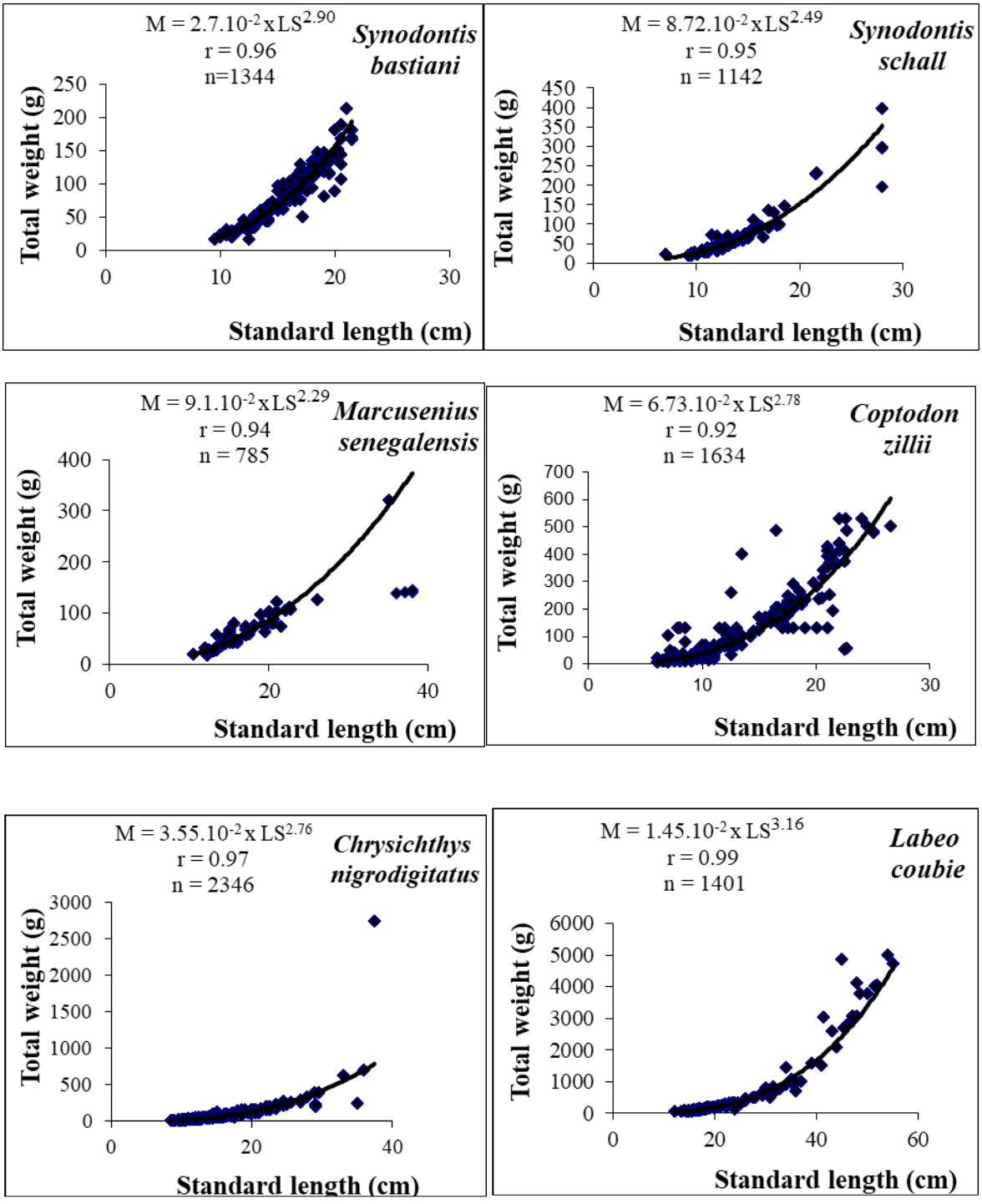

Figure 2 Length-weight relationship of individuals of six species of fish landed at Tiassalé, Singrobo and N'Zianouan on the Bandama river from July 2013 to June 2014 (r = correlation coefficient; LS = standard length, M = total weight and n = number)

The study of the length-weight relationship of these different species gave curves (Figure 2) with the following regression equations:

- *Chrysichthys nigrodigitatus* : $M = 3.55.10^{-2} \times LS^{2.76}$ (r = 0.97)

- *Coptodon zillii* : $M = 6.73.10^{-2} \times LS^{2.78}$ (r = 0.92)
- *Labeo coubie* : $M = 1.45.10^{-2} \times LS^{3.16}$ (r = 0.99)
- *Synodontis bastiani* : $M = 2.7.10^{-2} \times LS^{2.90}$ (r = 0.96).
- *Synodontis schall* : $M = 8.72.10^{-2} \times LS^{2.49}$ (r = 0.95)
- *Marcusenius senegalensis* : $M = 9.1.10^{-2} \times LS^{2.29}$ (r = 0.94)

The correlation coefficient (r) obtained for these different species is close to unity. There is therefore a strong correlation between the length and weight of these different species. The different values of allometric coefficient b obtained vary from 2.29 (*Marcusenius senegalensis*) to 3.16 (*Labeo coubie*). These values are all significantly different from 3 (Student, t>1.96) (Table 2). They are less than 3 for *Chrysichthys nigrodigitatus*, *Coptodon zillii*, *Synodontis bastiani*, *Synodontis schall* and *Marcusenius senegalensis*. These species show negative allometric growth. The allometric growth of *Labeo coubie* is said to be positive.

Table 2 Parameters of the length-weight relationship and type of growth of the six main species of fish landed at Tiassalé, Singrobo and N'Zianouan on the Bandama river from July 2013 to June 2014 (A = constant and B = rate of allometry)

Species	N	Length		Weight		Parameters of the length-weight relationship			Type of growth
		Min	Max	Min	Max	A	B	r	
Chrysichthys nigrodigitatus	2346	7.8	37	10	2742	3.55.10-2	2.76	0.97	A-
Coptodon zillii	1634	6	26.5	8	531	6.73.10-2	2.78	0.92	A-
Labeo coubie	1401	13.5	55	42	5012	1.45.10-2	3.16	0.99	A+
Synodontis bastiani	1344	8	28	16	214	2.7.10-2	2.9	0.96	A-
Synodontis schall	1142	7	28	20	233	8.72.10-2	2.49	0.95	A-
Marcusenius senegalensis	785	10.5	35	17	321	9.1.10-2	2.29	0.94	A-

4. Discussion

According to Bagenal (1978), mature freshwater fish have condition coefficients varying between 2.9 and 4.8. The mean K values in the present study fall within this range of values for *Coptodon zillii* and *Labeo coubie* unlike those for other species. However, all of these values are significantly higher than those determined by Aliko *et al.* (2010) for *Coptodon zillii* (1.32), *Labeo coubie* (1), *Synodontis schall* (1.63) and *Chrysichthys nigrodigitatus* (0.97) on Lake Taabo in the same geographical area. For Koné (2000), the condition coefficient gives an idea of the overweight of a considered species. These fish would present a relatively greater weight on the course of the Bandama river than on the lake. However, it should be noted that this coefficient is not constant for a given specimen, species or population (Kartas and Quignard, 1984 ; Koné, 2000). Its variation was found to be associated with the feeding mechanisms of fish (Kamaruzzaman *et al.,* 2010 ; Ahmed *et al.,* 2018) or with the quantity and / or quality of feed available in the different capture environments (Soedarto and Tembalang, 2019). The presence of plants in all seasons of the river offers food availability to fish unlike the lake (N'Dri *et al.,* 2020) which results in an increase in the condition coefficient (Veronika *et al.,* 2018) on the course of the river. For Ekelemu and Zelibe (2006) and Aydın (2020), food availability is one of the parameters known to influence the condition of fish.

The analysis of the length-weight relationships in the six main species found on the lower course of the Bandama river showed that the values of the coefficient b are all between the limits indicated which are: 2.5 - 3.5 (Moreau, 1979).

The value of b for *Labeo coubie, Chrysichthys nigrodigitatus, Coptodon zillii, Synodontis bastiani, Synodontis schall* and *Marcusenius senegalensis* is significantly different from 3; which means for these species that the development of the body does not take place in the same proportions as its length. Thus, *Labeo coubie* (b>3) is putting on weight faster than he is growing. The other species (b<3) grow more slowly than they put on weight.

In addition, the values of the coefficient b obtained for *Chrysichthys nigrodigitatus* (2.69), *Coptodon zillii* (2.9) and *Synodontis schall* (2.73) on Lake Taabo by [28] show that these three species show the same type of growth as in the

present study. Concerning *Labeo coubie*, these authors note a value of b equal to 2.96. This shows a different growth from that obtained in the present study (b = 3.16).

This difference could be explained by the differences between the numbers of individuals and the size classes analyzed. Indeed, the population of *Labeo coubie* (1401 individuals of sizes between 13.5 cm to 55 cm) analyzed in the present work differs from that examined by Aliko *et al.* (2010) (120 individuals for standard lengths ranging from 15.2 cm to 43 cm).

The work of Aliko *et al.* (2010) based on the analysis of fishermen's catches like the present study, having been carried out in the same geographical region, the differences between the values of b noted for *Labeo coubie* could come mainly from: (1) the numbers analyzed by species, (2) sampled size classes or (3) the combination of the two factors (Ye *et al.,* 2007) as well as (4) climatic conditions and (5) the health of individuals (Herrero-Pérezrul *et al.,* 2008 ; Kamaruzzaman *et al.,* 2010 ; Ahmed *et al.,* 2018).

5. Conclusion

This study examined the length-weight relationships and the condition factors of the most frequent species in the catches of fishermen on the Bandama river. These are *Chrysichthys nigrodigitatus, Synodontis bastiani, Synodontis schall, Marcusenius senegalensis, Coptodon zillii* and *Labeo coubie*. Five of the fish species identified exhibited a strong regression pattern of the length-weight relationship and negative allometric growths. Thus, the Bandama river offers a healthy environment for optimal fish growth. Nevertheless, an in-depth scientific study on environmental parameters would be useful to confirm this suitability of the habitat of the species mentioned above in the Bandama river basin. These results could serve as useful basic data for fisheries managers in their quest for legislation for the sustainable management and conservation of fish resources in Ivorian waters.

Compliance with ethical standards

Acknowledgments

We thank the professional fishermen operating on Bandama river for their help and cooperation. We also thank the departmental directorate of animal and fishery resources for it assistance. We do not forget all those people who provided criticism for the improvement of this manuscript.

Disclosure of conflict of interest

The authors declare that there is no conflict of interest whatsoever among the authors in the cause of executing this research work.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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