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Length-weight relationship and condition factor (K) of thirty (30) commercially valuable fish species landed in the lower basin of the Comoé River (Côte d'Ivoire)

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Abstract
This study was conducted in the lower basin of the Comoé River from June 2014 to May 2017. It provides information on length-weight relationship and condition factor (K) of thirty (30) most consumed fish species. The coefficient b ranged from 2.33 to 3.77 while the condition factor (K) ranged 0.50 ± 0.05 to 4.52 ± 0.74. Except for *Distichodus rostratus* and *Mugil cephalus* (b = 3), the Student's t-test indicated a significant difference between the other values of b and 3 ($p < 0.05$). The growth was not in favour of the body weight but in favour of the length ($b < 3$, negative allometric growth) for the major fish species.

Keywords: length-weight relationship, condition factor, fish species, Comoé River, Côte d'Ivoire.

1. Introduction

Added to the list of Ramsar Wetlands of International Importance (Ramsar, Iran, 1971; Ramsar, 2005) [39, 40], the lower basin of the Comoé River is a site of ecological importance because of the diversity of habitats and the biological diversity it contains. Despite its status as an area to be protected, it is subject to various threats, such as chemical and microbiological pollution, above all, the exploitation of fish resources in order to satisfy the demand for, the use of several types of phytosanitary products. This is of greater concern because the fishery is out of control and the resource is increasingly threatened. In fact, the fishery resources cause conflicting situations at different levels of activity, in both exploitation and management Sylvain & Julien, (2007) [43] indicate that a study of these conflicts suggests reasons related to the use of certain catch gear, and more particularly certain practices. The origins of the clashes are more a result of "behavioural differences and sociological reasons" traditionally developed by each of the communities. The current situation in the lower basin of the Comoé River is that there is an increasing scarcity of the fish species most consumed by the population. This can be seen by their low abundance in catches and by the small sizes of the landed individuals.

Fish are very good indicators of environmental conditions, because they are very sensitive to an increase in the impact of fishing, any environmental degradation including those resulting from diffuse pollution and changes resulting from competition or predation (Monod, 2001; Whitfield & Elliot, 2002) [27, 46]. Over-intensive exploitation of the resource, even irrespective of the adverse effects of industrial and agricultural activities, is responsible for a wide variety of impacts on fish communities that can be assessed by reference to a ''natural'' state of the ecosystem. The presence and distribution of species is always used as an indicator of the level of stability or health in an environment where the decline in biodiversity often reflects an environment crisis (Edwards & Abivardi, 1998) [13]. Thus, fish is an interesting communication vehicle to raise public and decision-makers awareness of the need to preserve the quality of natural environments (Monod, 2001) [27]. Therefore, characterizing stream fish communities is a good tool for environmental decision-making (Angermeier & Schlosser, 1995; Boulton, 1999) [4, 11]. Furthermore, this characterization is an index of the quality of the aquatic environment worldwide (Karr *et al*., 1986; Soto-Galera *et al*., 1998; Kestemont *et al*., 2000; Mcdowall & Taylor, 2000; Oberdorff *et al*., 2001) [20, 42, 21, 25, 29], able to report environmental degradation (Fausch *et al*., 1990; Scott & Hall, 1997; Wichert & Rapport, 1998) [14, 41, 47]. It also identifies successful restoration of aquatic ecosystems (Paller *et al*., 2000) [35]. The length-weight relationship parameters are important in fish biology and can give information on stock condition (Bagenal & Tesch, 1978; Anibeze, 2000) [8, 6]. Length-weight relationship studies of any species is a pre-requisite for assessing its population characteristics (Le Cren, 1951) [23]. In addition, the ponderal index or condition factor or the ''fatness'' (K) indicates the well-being of the population with the assumption that the growth of fish in ideal conditions maintain an equlibrium in length and weight (Hile, 1936; Ambily & Nandan, 2010) [18, 5]. This study focuses on fish fauna and anthropogenic activities in the lower basin of the Comoé River. Due to the lack of scientific monitoring of artisanal fisheries in this part of the river, there is little data on the impacts of fishing pressures on the environment and particularly on fish farming communities. The purpose of this study is to determine the length-weight relationship and condition factor of more consumed fish species in this area. The results of this study will contribute to the application of an ecosystem approach to fisheries as a means of sustainable fisheries management in this part of the Comoé River and can be serve as references for future studies.

2. Material and methods

2.1 Study zone and sampling sites

The study area largely belongs to the Grand Bassam wetland located less than 20 km from Abidjan. For this study, the choice of stations was made taking into account their accessibility and the importance of fishing and other anthropogenic activities (industrial discharges, discharge of domestic waste, presence of plantations, farms). A total of ten (10) sites have been identified in the lower Comoé River basin (Figure 1) namely: Motobé, Konian, Kodjran, Yaou, Palm-CI, Adjékro, Moossou, Delanoi, Adiaho and Kodjoboué, because of their accessibility and the fishing and agricultural activities that take place there.

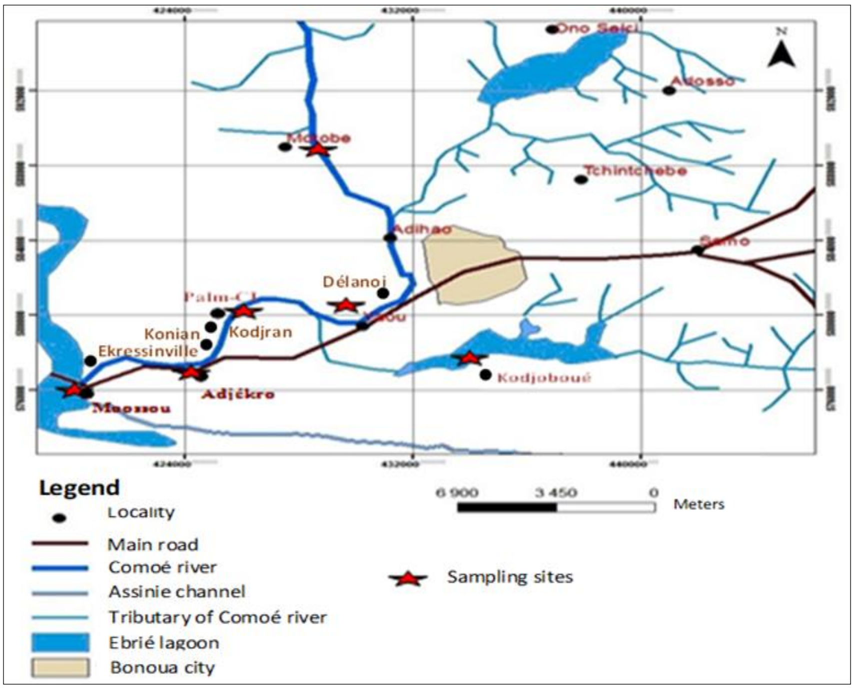

Fig 1: Location of the lower basin of the Comoé River and sampling stations

2.2 Methods

2.2.1 Data collection

Fish sampling for the experimental fishery was carried out using two sets of gillnets, 6, 10, 13 15, 18, 20, 25, 30, 40 and 60 mm apart. Each of these nets is 25 to 30 m long and has a drop height of 1.5 to 2m. The gill nets consist of a monofilament nylon netting web mounted on an upper headline with floats and a leaded lower head rope.

Artisanal fishing was carried out using gillnets, traps, longlines, traps and handlines. The equipment used for the collection of ichthyological data is:

- A record of the details of the species caught during each fishing trip.
- A fish ichtyometer was used to measure the collected fish and two electronic scales of the Kitchen Scale (model WH-B05) and EKS Electronic (precision + 1 g) were used to determine the fish mass (Figure 2).

Fig 2: Fish measuring and weighing equipment: A = ichtyometer; B = EKS Electronic scale and C = WH-B05 Series Electronic Kitchen Scale User's Manual scale)

For the purpose of this study, to gain a broader understanding of environmental species, two type of two-years seasonal sampling were selected and conducted over eight (8) campaigns: 4 of which were in the dry season and 4 in the rainy season from June 2014 to May 2017. These are as follows:

- Prospecting sampling using experimental fisheries;
- Sampling to assess diversities exploited (targeted) by artisanal fishing.

For experimental fishing, nets were set only once per season at each site in the afternoon between 16 and 17 o'clock and set the following day between 7 and 8 o'clock. In addition, seals numbered in accordance with the mesh of the nets were used to collect the fish caught during the removal of the nets. Artisanal fishing was carried out using gillnets, baited and baited longlines, traps and traps with or without bait. The nets are usually set before 6 pm and are raised the next day between 3 am and 5 am by the fishermen. Fish caught were identified using keys from Paugy *et al.* (2003a; 2003b) [36, 37] and FishBase (2018). Morphometric measurements were made using an ichthyometer on each of the specimens. Fish were measured for total length (horizontal distance in mm from tip of snout to hinge tip of caudal fin) and for standard length (horizontal distance in mm from tip of snout to base or articulation of caudal fin) to the nearest 1 mm, the total weight was measured to nearest 1 g (W in g) as shown in Figures 3 and 4.

Fig 3: Fish sorting (A) and measuring (B) session

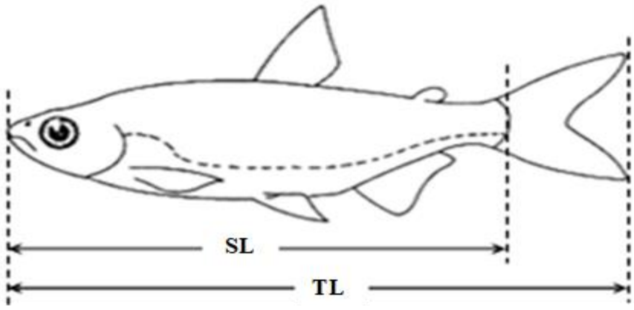

Fig 4: Length measurements made on fish: Total length (TL) and Standard length (SL) (Ahouansou, 2011) [3]

2.2.2 Data analysis

Length-weight relationship of the target species

In fish, growth is manifested by variations in weight and length and there is also a close relationship between these two variables (Le Cren, 1951; Baijot *et al*., 1994; Pauly & Moreau, 1997; Lévêque, 1999 and Frota *et al*., 2004) [23, 9, 38, 24, 15].

The relationship between fish length and weight is represented by the formula (Le Cren, 1951) [23]:

$$W = a\,L^{b}$$

where W is the total weight of the fish in g and L is the standard length of the fish in mm; a and b are characteristic factors of the environment and species.

Type linear logarithmic transformation:

$$\text{LogW} = \text{Log a} + \text{bLog L}$$

Reduces variability and homogenizes both variables (W and L). Knowledge of the parameters ‘‘a’’ and ‘‘b’’ of the length-weight relationship, particularly the value of ‘‘b’’, has many applications in fisheries biology (Odat, 2003; Gonzalez-Gandara *et al*., 2003; Abdurahiman *et al*., 2004; Frota *et al.*, 2004) [30, 17, 1, 15]. The value of b = 3 indicates that the growth is isometric. A value of b less than or greater than 3 indicates allometric growth (Bayhan & Kara, 2011) [10]). Indeed, b 3 indicates negative allometry while b > 3 translates positive allometry (Morey *et al*., 2003; Konan *et al*., 2007; Minos *et al*., 2008; Chérif *et al*., 2008; Ahouansou *et al.*, 2009; Tah *et al*., 2012) [28, 22, 26, 12, 2, 44]. For each species, regression was used to estimate the original ordinate (a) and the regression or slope coefficient (b) using Microsoft R (Abdurahiman *et al*., 2004; Frota *et al*., 2004; Ambily & Nandan, 2010) [1, 15, 5]. Student’s t-test was applied to verify whether the declivity of regression (constant ‘‘b’’) presented a significant difference of 3.0, indicating the type of growth (Chérif *et al*., 2008) [12]. This Student’s t-test was made using Microsoft R.

Condition factor (K)

The condition coefficient or factor (K) is determined from the length and weight. The formula used to calculate this factor as defined by Le Cren (1951) [23] is the ratio:

$$K = \frac{(W \times 10^{5})}{SL^{3}}$$

With (W) the fresh weight expressed in grams and (SL) the standard length expressed in millimeter.

The condition coefficient (K) study is intended to assess the adaptation of populations to their environment (Le Cren, 1951) [23]. This adaptation may vary with size and season. The factor (K) gives a good indication of the overweight of the fish, in other words the relative importance of its body weight relative to its length. It also reflects the physiological and nutritional status of fish in its environment (Avit *et al*., 1996) [7].

3. Results

A total of 30 fish species were selected because of their relative abundance for the analysis. The minimum number is 11 (*Sphyraena afra*) and the maximum is 655 (*Chrysichthys nigrodigitatus*). The sample size, length range, type of growth, parameters ‘a’ and ‘b’, and coefficient of determination (r^2) ranging from 0.7702 to 0.9929, are presented in table 2. It appears that the values of the allometry coefficients are between 2.33 (*Chrysichthys maurus*) and 3.77 (*Cynoglossus senegalensis* and *Schilbe mandibularis*). The different values of b subjected to the t-Student test, allow to distinguish in the species concerned three types of growth. Thus, we distinguish 2 species that have an isometric growth, 9 having a negative allometry and 19 having a positive allometry. The Chi-deux test ($\chi^2 = 14.6$; df = 2; p-value = 0.0006755 < 0.05) confirms that there is a significant difference between the three proportions of fish species.

The values of the condition factor ranged from 0.50 ± 0.05 (*Papyrocranus afer*) to 4.52 ± 0.74 (*Pelmatolapia mariae*) are indicated in table 1. Six species *Hemichromis fasciatus* (3.46 ± 1.33), *Sarotherodon melanotheron* (3.53 ± 0.63), *Ctenopoma petherici* (3.90 ± 0.70), *Coptodon guineensis* (3.94 ± 0.69), *C. zillii* x *C. guineensis* (4.12 ± 0.65) and *Pelmatolapia mariae* (4.52 ± 0.74) have a relatively high K value. These values show a good adaptation of these fish, compared to others, to their environment, a good physiological and nutritional state. In contrast, the other species have their condition coefficients between 0.50 ± 0.05 and 2.82 ± 0.56. This implies a poor physiological and nutritional condition; they are not overweight.

Table 1: Average values of condition factors (K) of fish species caught in the lower basin of Comoé River: N = Specimen numbers

Species	Number	K (average)
Brycinus macrolepidotus	150	2.03 ± 0.76
Chrysichthys maurus	65	1.49 ± 0.61
Chrysichthys nigrodigitatus	655	1.45 ± 0.52
Clarias anguillaris	96	1.07 ± 0.40
Clarias gariepinus	121	1.05 ± 0.18
Ctenopoma petherici	71	3.90 ± 0.70
Cynoglossus senegalensis	31	0.58 ± 0.15
Distichodus rostratus	345	2.11 ± 0.33
Elops lacerta	34	1.08 ± 0.11
Hemichromis fasciatus	62	3.46 ± 1.33
Hepsetus odoe	71	1.32 ± 0.14
Kribia kribensis	55	2.13 ± 0.43
Labeo coubie	159	2.42 ± 0.46
Marcusenius furcidens	20	1.11 ± 0.13
Marcusenius senegalensis	27	1.31 ± 0.62
Marcusenius ussheri	74	1.19 ± 0.32
Mormyrops anguilloides	19	0.66 ± 0.06
Mugil cephalus	34	1.57 ± 0.21
Papyrocranus afer	68	0.50 ± 0.05
Parachanna obscura	18	1.27 ± 0.09
Polydactylus quadrifilis	21	1.72 ± 0.39
Sarotherodon melanotheron	358	3.53 ± 0.63
Schilbe intermedius	119	1.12 ± 0.13
Schilbe mandibularis	148	0.96 ± 0.31
Sphyraena afra	11	0.68 ± 0.06
Coptodon guineensis	74	3.94 ± 0.69
C. zillii x *C. guineensis*	89	4.12 ± 0.65
Pelmatolapia mariae	68	4.52 ± 0.74
Tylochromis intermedius	37	2.79 ± 0.87
Tylochromis jentinki	32	2.82 ± 0.56

Table 2: Regression values for various morphometric characteristics of fish species in the lower basin of Comoé River as a function of standard length.

Species	N	a	b	r	R^2	t	df	p-value	Y = bX + a	Growth
Brycinus macrolepidotus	150	-4.8141	3.05	0.9883	0.9768	14.559	149	0.000	3.05LS – 4.8141	A^+
Chrysichthys maurus	65	-3.2738	2.33	0.9832	0.9668	-130.198	64	0.000	2.33LS – 3.2738	A^-
Chrysichthys nigrodigitatus	655	-3.8631	2.57	0.9546	0.9114	-186.597	654	0.000	2.57LS – 3.8631	A^-
Clarias anguilaris	96	-4.632	2.86	0.9781	0.9567	-40.087	95	0.000	2.86LS - 4.632	A^-
Clarias gariepinus	121	-4.6384	2.86	0.9639	0.9292	-61.706	120	0.000	2.86LS – 4.6384	A^-
Coptodon guineensis	74	-4.1945	2.89	0.9901	0.9903	-23.517	73	0.000	2.89LS – 4.1945	A^-
Coptodon zillii x *Coptodon guineensis*	89	-4.2333	2.93	0.9392	0.8822	839.1809	88	0.000	2.93LS – 4.2333	A^-
Ctenopoma petherici	71	-3.5361	2.56	0.9035	0.8164	-91.334	70	0.000	2.56LS – 3.5361	A^-
Cynoglossus senegalensis	31	-7.2874	3.77	0.8776	0.7702	104.414	30	0.000	3.77LS – 7.2874	A^+
Distichodus rostratus	345	-4.6778	2.99	0.9942	0.9886	-0.785	344	0.433	2.99LS – 4.6778	I
Elops lacerta	34	-4.7178	2.89	0.9793	0.9591	-31.995	33	0.000	2.89LS – 4.7178	A^-
Hemichromis fasciatus	62	-4.9208	3.23	0.9848	0.9699	32.053	61	0.000	3.23LS – 4.9208	A^+
Hepsetus odoe	71	-5.2931	3.18	0.9931	0.9863	81.473	70	0.000	3.18LS – 5.2931	A^+
Kribia kribensis	55	-5.2072	3.25	0.9822	0.9649	35.512	54	0.000	3.25LS – 5.2072	A^+
Labeo coubie	159	-4.9654	3.14	0.9859	0.9721	52.087	158	0.000	3.14LS – 4.9654	A^+
Marcusenius furcidens	20	-4.9003	2.97	0.9964	0.9929	524.1765	19	0.000	2.97LS – 4.9003	A^-
Marcusenius senegalensis	27	-3.423	2.36	0.8870	0.7869	213.6708	26	0.000	2.36LS – 3.423	A^-
Marcusenius ussheri	74	-4.668	2.88	0.9782	0.957	-24.162	73	0.000	2.88LS – 4.668	A^-
Mormyrops anguilloides	19	-5.1334	2.98	0.9879	0.976	803.2845	18	0.000	2.98LS – 5.1334	A^-
Mugil cephalus	34	-3.8114	2.62	0.9748	0.9503	-115.961	33	0.000	2.62LS – 3.8114	A^-
Papyrocranus afer	68	-5.3141	3.00	0.9856	0.9716	1.913	67	0.059	3.00LS – 5.3141	I
Parachanna obscura	18	-5.1989	3.13	0.9923	0.9847	948.1263	17	0.000	3.13LS – 5.1989	A^+
Pelmatolapia mariae	68	-3.3319	2.52	0.9726	0.9461	772.5485	67	0.000	2.52LS – 3.3319	A^-
Polydactylus quadrifilis	21	-4.6257	2.94	0.9958	0.9917	410.1270	20	0.000	2.94LS – 4.6257	A^-
Sarotherodon melanotheron	358	-3.8995	2.75	0.9705	0.942	-130.299	357	0.000	2.75LS – 3.8995	A^-
Schilbe intermedius	119	-5.2936	3.16	0.9815	0.9634	70.745	118	0.000	3.16LS – 5.2936	A^+
Schilbe mandibularis	148	-6.6333	3.77	0.9815	0.9634	145.419	147	0.000	3.77LS – 6.6333	A^+
Sphyraena afra	11	-4.5186	2.75	0.9956	0.9914	864.8229	10	0.000	2.75LS – 4.5186	A^-
Tylochromis intermedius	37	-4.0842	2.76	0.9765	0.9536	315.0674	36	0.000	2.76LS – 4.0842	A^-
Tylochromis jentinki	32	-4.5264	2.98	0.9845	0.9693	383.3764	31	0.000	2.98LS – 4.5264	A^-

No live specimens are released to the river regardless of their size. All catches are retained. The results of the two indicators which are length-weight relationship and condition factor (K) confirm the landing of juveniles in this part of the river as illustrated in the figure 5.

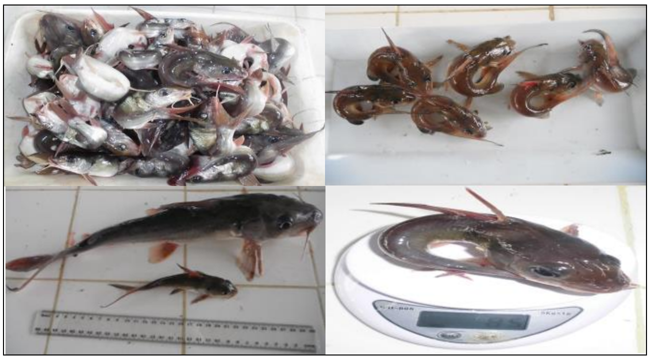

Fig 5: Juveniles of *Chrysichthys nigrodigitatus* of the Comoé River sold at the markets of Bonoua, Yaou and Grand Bassam

4. Discussion

Analysis of the length-weight relationship with 30 commercially valuable fish species consumed by riparian populations reveals that except for *Distichodus rostratus* and *Mugil cephalus* which have isometric growth, 9 species have positive allometry and 19 have negative allometry. The largest proportion of larger fish species have negative allometry. This means that they do not grow but are tapered. Similarly, the condition coefficient (K) calculated for each species gives a general trend of fish that do not grow except for *Ctenopoma petherici, Hemichromis fasciatus, Sarotherodon melanotheron, Coptodon guineensis, C. zillii* x *C. guineensis* and *Pelmatolapia mariae*. By its preferential selection of species of large size and high commercial value and through relationships between species, fishing is changing the specific structure and organisation of the food chain. The situation in the lower basin of the Comoé river is similar to that observed by Katurole & Wadanya (no date) [19] in the Lake Victoria (Uganda). Indeed, the fisheries of this part of the river are declining and fish stock are being threatened with depletion. Commercial fishermen using prohibited fishing gears and methods are landing immature fish. According to Ogutu-Ohwayo *et al*. (1994) [31] and Ogutu-Ohwayo *et al.* (1997) [32], these gears collectively catch relative high proportion of immature fish and are indicative of a declining fishery. Such values suggest immediately and only the effects of intensive fishing pressure. Obviously, fishing cannot be the only explanatory reason. Aquatic resources can be affected by human activities resulting from alteration or destruction of ecosystem habitats and by various sources of over-exploitation. Similar situation have been observed by several researchers such as Cherif *et al.* (2008) [12] in the Gulf of Tunis for 11 fish species, Özaydin & Taskavak (2006) [34] for 47 fish species from Izmir Bay (eastern Aegean Sea, Turkey). According to these authors, the change of b values depends on the shape and fatness of the species, various factors may be responsible for the differences in parameters of the length-weight relationship among seasons and years, such as temperature, food (quantity and quality and size). Bagenal & Tesch (1978) [8] and Gonçalves *et al*. (1997) [16] add that **"**the parameter b, unlike parameter a, may vary seasonally, and even daily, and between habitats. Thus, the length-weight relationship in fish is affected by number of factors including gonad maturity, sex, diet, stomach fullness, health, and preservation techniques as well as season and habitat, none of which were taken into consideration in the present study**"**. Apart from the probable reasons mentioned by the cited authors, the reality of the situation must be taken into account. Indeed, there are several agricultural activities along the river that use different types of phytosanitary products over several decades. These products contain different types of biocidal and toxic active ingredients that could end up in the water through runoff and leaching of leaves and impact plankton that is the basis of fish feed. On the other hand, the riverbank is the site of deposits of household waste that ends up in the river through runoff and leaching, all things that degrade habitats.

Concerning the values of the condition factor, almost the same situation of the Comoé river had been seen in India by Ujjania *et al*. (2012) [45] in the case of Indian major Carps. The authors explained that these values depend on physiological feature of fish namely maturity, spawning, environmental factors and food availability in a water body.

The ideal would be to propose a rational approach based on the protection of breeding stock during the breeding season. For example, Ouattara *et al.* (2006) [33] propose a temporary closure period. According to these authors, such an alternating closure experiment in Lake Kariba in Zimbabwean has led to quite satisfactory conclusions.

5. Conclusion

This study has provided some basic information on the length-weight relationship and the condition factor (K) of 30 fish species from the lower basin of the river Comoé that would be beneficial for fishery researcher and conservationists in order to improve regulations for sustainable fishery management in this area. However, fish species prized by the population such as *Eleotris vittata, Hemichromis bimaculatus, Lates niloticus, Monodactylus sebae, Mormyrus rume, Neochelon falcipinnis, Oreochromis niloticus, Pseudotolithus senegalensis, Sphyraena guachancho, Synodontis bastiani* and *Trachinotus* were not examined for this study because of their low abundance which ranged from 1 to 9. Future studies may provide this missing information for these fish species.

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