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Length-weight relationship and condition factor for 18 fish species from Ono, Kodjoboué and Hébé lagoons, Southeast of Ivory Coast

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Abstract
The length-weight relationship (LWR) and condition factor for18 fishes of three small lagoons of Ivory Coast were studied for fisheries management. Samples were monthly collected using traps, gillnets, harpoons and hawks between September 2015 and August 2016. Standard length of individuals was taken to the nearest 1 mm and body weight to the nearest 0.01 g. A total of 1886, 1825 and 1483specimens belonging to 18 species and 11 families were collected respectively in Ono, Kodjoboué and Hébé lagoons. All LWR were significant with a coefficient of determination (r^2) varying from 0.731 (*Chrysichthys nigrodigitatus*) to 0.999 (*Hepsetus odoe*). The coefficient of allometry (*b*) ranged from 2.01 for *Heterotis niloticus* to 3.78 for *Labeo courbie* in Ono lagoon, from 2.03 for *Chrysichthys nigrodigitatus* to 3.03 for *Clarias ebriensis* in Kodjoboué lagoon and from 2.01 for *Tilapia guineensis* to 3.17 for *Clarias ebriensis* and *Hemichromis fasciatus* in Hébé lagoon. The K values varied from 0.79 ± 0.12to 2.89 ± 0.73 in Ono lagoon, from 0.70 ± 0.10 to 2.94 ± 0.30 in Kodjoboué lagoon and from 0.96 ± 0.27 to 2.86 ± 0.16 in Hébé lagoon. The value of both parameters indicates a good well-being of fishes in these lagoons.

Keywords: Allometry, condition factor, fish species, growth, isometry, small lagoons

1. Introduction
Fish is highly important for the development of the Ivory Coast because it is a source of protein with low cholesterol levels and other essential nutrients required by the human body. Knowledge of some quantitative aspects such as length weight relationship (LWR) and condition factor (K) of fishes is an important tool for the study of fishing biology. The LWR is of great importance in fishery assessments [1]and in fish biology [2, 3]. Indeed, Length and weight measurements can give information on the stock composition, life span, mortality, growth and production [4, 5, 6]. For production models, this key is used to predict the biomass of the stock using fish lengths[7].

On the other hand, the condition factor is a parameter of the state of well-being of fish based on the hypothesis that heavier fish of a particular length is in a better physiological condition [8]. The K factor can also be used as an index for the monitoring of feeding intensity in fish [9] or to access the status of the aquatic ecosystem [10]. However, it is strongly influenced by both biotic and abiotic environmental conditions. Numerous works on fish fauna were carried out on the bio-ecology of species with aquaculture potential in the main lagoon systems of Ivory Coast [11, 12]. However, information on LWRs and condition factor are very scarce for fish species of small lagoons that are very sensitive to different types of pollution.

This study aimed to estimate the LWR parameters and condition factor of fish species useful to provide information for fisheries management of Ono, Kodjoboué and Hébé lagoons in the Southeast of Ivory Coast.

2. Materials and methods
2.1. Study area
Ono lagoon (5°22'22"N and 3°33'53"W), Kodjoboué lagoon (5°14'11 "N and 3°35'9" W) and Hébé lagoon (5°12'14" N and 3°33'15" W) are three small lagoons of the Southeast of Ivory Coast (Figure 1). Their surfaces are respectively 400 ha, 423 ha and 244 ha.

Because Ono lagoon is invaded by several floating macrophytes, the exploitable surface is 296 ha. In the other lagoons, only the banks are occupied by the floating macrophytes, with a pronounced degree of invasion in Kodjoboué lagoon. These lagoons, permanently connected to the Comoé river have an equatorial climate, including two rainy seasons (April-July and October-November) and two dry seasons (December-March and August-September). The permanent linkage with the Comoé river produces typical freshwater characteristics of these lagoons.

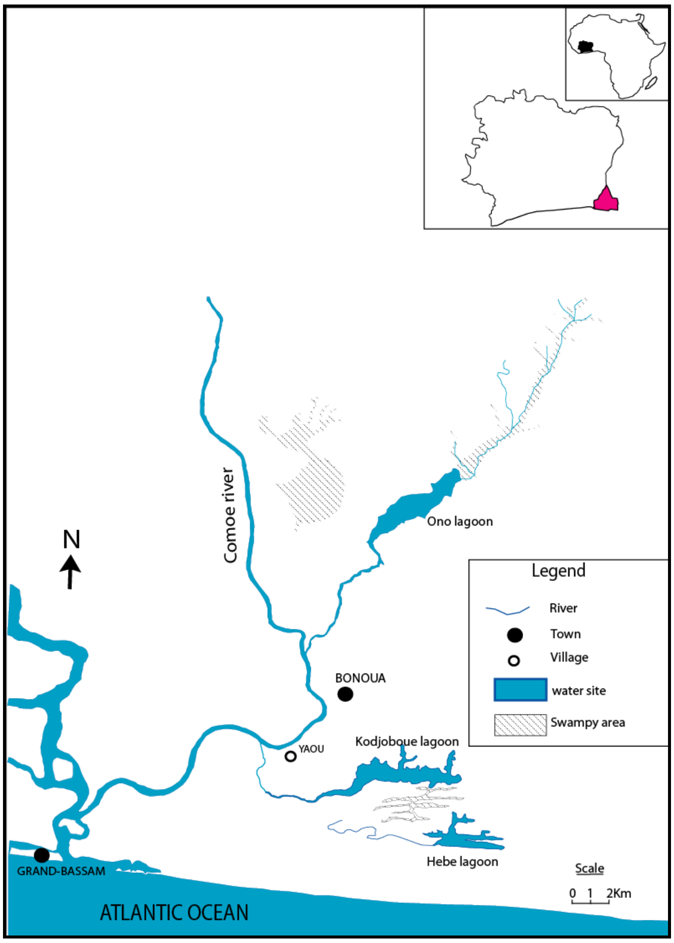

Fig 1: Map of sampling localities

2.2. Sample collection

Fish were monthly sampled from September 2015 to August 2016 using traps, gill nets, harpoons and hawks. All specimens were systematically identified using the identification key of Teugels *et al.* [13] and Paugy *et al.* [14]. Standard length of individuals was taken to the nearest 1 mm and body weight to the nearest 0.01 g using a Sartorius A200 S-F1 electronic balance. Only species whose presence were noted in all areas throughout the sampling period were used in this study.

2.3. Length-weight relationship

The Length-weight relationship (LWR) were separately evaluated for all individuals and grouped by sex (females and males). This relationship was computed to determine the growth patterns of fishes according to species by the application of the equation of Ricker [15] as follows:

$W = aL^b$

Where W = fish weight (g), L = standard length (cm), "*a*" = the intercept and "*b*" = the slope or the growth constant and represents the growth pattern of fish.

Fish can exhibit isometric growth, negative allometric or positive allometric growth patterns. The coefficient *b* is between 2 to 4, but it is more often close to 3. When *b* = 3, there is isometric growth whereas there are negative allometric and positive allometric growth when *b*> 3 and *b*<3 respectively [16, 17]. The coefficient of determination (r^2) for each equation was computed to determine the relationship between length and weight.

2.4. Condition factor

The condition factor is used for comparing the condition, fatness, or well-being of fish [18], based on the assumption that heavier fish of a given length are in better condition. The relative condition factor (Kn) being 1 or closer to 1 indicates, the good condition of fish. The Kn was calculated following Le Cren [19] as:

Kn= W /w

Where W = observed weight of the fish (g) and w = calculated weight (g) derived from length weight relationship.

2.5. Statistical analysis

All statistical analyses were considered at significance level of 5% ($p<0.05$). To check if the b value was significantly different from the isometric value, the t-Student test was performed ($H_0 = 3$), with a confidence level of 95%.

3. Results

3.1. Length-weight relationships

A total of 5194 individuals belonging to 18 fish species and 11 families were used in the study. The number of specimens used was 1886 for Ono lagoon, 1825 for Kodjoboué lagoon and 1483 for Hébé lagoon. The number of specimens, the length ranges (minimum and maximum), parameters of LWRs (*a* and *b*), the coefficient of determination (r^2) and the condition factor are given in Tables 1, 2 and 3. The standard length ranged from 3.9 to 47.5 cm and the weight from 14.05 to 680.18 g with the smallest fish was represented by *Hemichromis bimaculatus* and the biggest fish, by *Papyrocranus afer* and *Parachanna obscura* respectively. All LWR were significant with a coefficient of determination (r^2) varying from 0.731 (*Chrysichthys nigrodigitatus*) to 0.999 (*Hepsetus odoe*). The mean *b* value for all species was 2.01-3.01 (mean = 2.75 ± 0.43), 2.03-3.03 (mean = 2.80 ± 0.27) and 2.51-3.17 (mean = 2.96 ± 0.15) respectively in Ono, Kodjoboué and Hébé lagoons. The *b* values ranged from 2.01 for *Heterotis niloticus* to 3.01 for *Labeo courbie* in Ono lagoon, from 2.03 for *C. nigrodigitatus* to 3.03 for *C. ebriensis* in Kodjoboué lagoon and from 2.51 for *Tilapia guineensis* to 3.17 for *C. ebriensis* and *H. fasciatus* in Hébé lagoon. The t-Student test indicated anisometric growth (*b* = 3) for six species in Ono lagoon, seven species in Kodjoboué lagoon and10 species in Hébé lagoon. Among these species, *P. afer*, *L. courbie* and *M. anguilloides* exhibited this isometric growth in all lagoons. The *b* values of *H. fasciatus* indicated negative allometric growth (b < 3) in Ono and Kodjoboué lagoons and positive allometric growth (*b* > 3) in Hébé lagoon. For *C. ebriensis* and *H. odoe*, growth was isometric in Ono and Kodjoboué lagoons and positive allometric in Hébé lagoon. No positive allometric growth was recorded for the species in Ono and Kodjoboué lagoon. Other species on the list presented negative allometric growth whereas.

3.2. Condition factor

The results on the relative condition factor (Kn) of the 18 species are shown in Tables 1, 2 and 3. The Kn ranged from0.79 ± 0.12 (*H. bimaculatus*) to 2.89 ± 0.73(*H. odoe*) in Ono lagoon, from 0.70 ± 0.10 (*Barbus ablabes*) to 2.94 ± 0.30 (*Tylochromis jentinki*) in Kodjoboué lagoon and from 0.96 ± 0. 37 (*T. jentinki*) to 2.86 ± 0.16 (*C. ebriensis*) in Hébé lagoon. The Kn values of species was 1 or closer to 1, except for *C. ebriensis*, *H. bimaculatus* and *H. niloticus* in Ono lagoon and for *B. ablabes*, *H. bimaculatus* and *O. niloticus* in Kodjoboué lagoon.

Table 1: Length-weight relationship parameters and condition factor (K) of fish species from Ono Lagoon. N = Number of fish; r² = Coefficient of determination; *a* = Intercept of regression; *b* = Slope of regression; se (b); K= Condition factor; I= Isometric growth; A- = Negative allometric growth, A+ = Positive allometric growth

		Standard length (cm)		**Parameters of the relationship**					
Species	**N**	**Min**	**Max**	**a**	**b**	**se (b)**	**r^2**	**Growth**	**K**
Clarias ebriensis	32	15.9	21.3	0.036	2.99	0.302	0.993	I	0.82±0.23
Chrysichthys nigrodigitatus	351	14.0	24.4	0.114	2.96	0.305	0.992	A-	2.72±0,46
Hepsetus odoe	28	15.9	27.0	0.055	3.00	0.280	0.999	I	2.89±0.73
Brycinus macrolepidotus	41	7.2	13.5	0.013	2.96	0.284	0.923	A-	1.93±0.54
Barbus ablabes	19	5.9	8.1	0.062	2.76	0.301	0.828	A-	1.70±0.23
Labeo courbie	41	15.6	34.2	0.002	3.01	0.317	0.998	I	2.77±0.60
Parachanna obscura	87	16.2	42.8	0.145	2.10	0.256	0.972	A-	1.15±0.24
Hemichromis bimaculatus	33	3.9	7.0	0.177	2.09	0.244	0.825	A-	0.79±0.12
Hemichromis fasciatus	48	9.5	15.7	0.062	2.20	0.190	0.945	A-	1.95±0.14
Oreochromis niloticus	51	9.4	17.6	0.031	2.96	0.193	0.965	A-	1.42±0.08
Sarotherodon melanotheron	361	7.9	29.6	0.017	2.70	0.204	0.777	A-	1.93±0.31
Tilapia guineensis	161	8.4	23.5	0.167	2.64	0.223	0.885	A-	1.60±0.18
Tylochromis jentinki	107	10.5	20.5	0.051	2.99	0.239	0.998	I	2.88±0.52
Hybrid Tilapia	283	7.2	30.1	0.016	2.69	0.277	0.768	A-	2.55±0.49
Ctenopoma petherici	27	5.8	9.9	0.109	2.66	0.363	0.986	A-	1.52±0.22
Papyrocranus afer	98	20.0	45.5	0.012	2.99	0.485	0.996	I	1.96±0.75
Mormyrops anguilloides	96	16.2	33.4	0.015	2.98	0.301	0.999	I	1.64±0.51
Heterotis niloticus	22	21.2	45.2	0.174	2.01	0.405	0.998	A-	0.92±0.13

Table 2: Length-weight relationship parameters and condition factor (K) of fish species from Kodjoboué Lagoon. N= Number of fish; r² = Coefficient of determination; *a*= Intercept of regression; *b* = Slope of regression; se (b); K= Condition factor; I= Isometric growth; A-= Negative allometric growth, A+ = Positive allometric growth

		Standard length (cm)		**Parameters of the relationship**					
Species	**N**	**Min**	**Max**	**a**	**b**	**se (b)**	**r^2**	**Growth**	**K**
Clarias ebriensis	35	15.9	24.5	0.029	3.03	0.286	0.991	I	2.08±0.35
Chrysichthys nigrodigitatus	128	12.2	20.5	0.037	2.03	0.284	0.915	A-	1.71±0.33
Hepsetus odoe	34	13.4	22.3	0.013	2.98	0.248	0.997	I	1.02±0.01
Brycinus macrolepidotus	13	7.3	13.3	0.097	2.94	0.254	0.918	A-	1.79±0.49
Barbus ablabes	18	9.2	11.2	0.050	2.96	0.225	0.860	A-	0.70±0.10
Labeo courbie	47	15.0	20.5	0.003	2.99	0.227	0.997	I	1.38±0.38
Parachanna obscura	134	20.3	47.5	0.195	2.76	0.242	0.996	A-	1.38±0.23
Hemichromis bimaculatus	51	4.6	7.1	0.100	2.77	0.259	0.832	A-	0.92±0.03
Hemichromis fasciatus	94	9.4	14.0	0.099	2.37	0.245	0.991	A-	2.78±0.14
Oreochromis niloticus	36	9.6	19.0	0.038	2.72	0.261	0.967	A-	0.89±0.07
Sarotherodon melanotheron	153	8.4	29.5	0.200	2.51	0.251	0.781	A-	1.38±0.22
Tilapia guineensis	389	7.6	28.7	0.081	2.97	0.224	0.823	I	1.97±0.21
Tylochromis jentinki	123	9.4	13.4	0.011	2.94	0.266	0.971	A-	2.94±0.30
Hybrid Tilapia	283	7.2	29.6	0.028	2.85	0.092	0.737	A-	1.60±0.67
Ctenopoma petherici	43	5.8	9.9	0.041	2.65	0.009	0.987	A-	2.31±0.41
Papyrocranus afer	97	19.3	47.5	0.112	2.99	0.010	0.996	I	1.84±0.75
Mormyrops anguilloides	126	19.2	36.0	0.031	2.99	0.078	0.999	I	2.35±0.82
Heterotis niloticus	21	19.0	35.1	0.023	2.99	0.243	0.999	I	1.69±0.65

Table 3: Length-weight relationship parameters and condition factor (K) of fish species from Hébé Lagoon. N = Number of fish; r² = Coefficient of determination; *a* = Intercept of regression; *b* = Slope of regression; se (b); K= Condition factor; I= Isometric growth; A- = Negative allometric growth, A+ = Positive allometric growth

		Standard length (cm)		Parameters of the relationship					
Species	**N**	**Min**	**Max**	**a**	**b**	**se (b)**	**r^2**	**Growth**	**K**
Clarias ebriensis	38	19.8	22.2	0.023	3.17	0.158	0.959	A+	2.86±0.16
Chrysichthys nigrodigitatus	136	12.2	26.6	0.022	2.99	0.162	0.731	I	1.67±0.43
Hepsetus odoe	22	12.2	23.9	0.015	3.07	0.170	0.991	A+	0.99±0.37
Brycinus macrolepidotus	18	7.3	13.6	0.069	3.00	0.175	0.959	I	1.17±0.38
Barbus ablabes	12	6.1	9.5	0.085	2.99	0.204	0.946	I	1.36±0.43
Labeo courbie	36	13.2	18.9	0.057	3.01	0.215	0.998	I	1.30±0.27
Parachanna obscura	158	15.3	25.8	0.021	2.99	0.240	0.999	I	1.61±0.36
Hemichromis bimaculatus	12	3.9	7.4	0.028	2.92	0.254	0.992	A-	1.17±0.32
Hemichromis fasciatus	19	9.1	15.7	0.058	3.17	0.274	0.944	A+	2.07±0.57
Oreochromis niloticus	29	10.2	17.0	0.088	3.01	0.278	0.993	I	1.76±0.61
Sarotherodon melanotheron	338	8.5	29.5	0.041	2.97	0.249	0.801	I	1.00±0.25
Tilapia guineensis	318	8.5	26.6	0.099	2.51	0.072	0.832	A-	2.07±0.43
Tylochromis jentinki	51	10.5	20.5	0.056	2.96	0.083	0.987	A-	0.96±0.27
Hybrid Tilapia	28	9.0	22.1	0.028	2.85	0.104	0.826	A-	2.26±0.54
Ctenopoma petherici	23	5.2	9.9	0.072	2.72	0.008	0.912	A-	1.48±0.43
Papyrocranus afer	98	18.4	45.7	0.110	2.99	0.010	0.999	I	1.49±0.63
Mormyrops anguilloides	121	16.3	35.8	0.033	2.99	0.065	0.999	I	2.46±0.56
Heterotis niloticus	26	19.0	45.2	0.018	3.01	0.277	0.999	I	1.93±0.94

4. Discussion

Ono lagoon is invaded by several floating macrophytes, limiting the exploitable surface. In Kodjoboué and Hébé lagoons, only the banks are occupied by floating macrophytes, with a pronounced degree of invasion for Kodjoboué lagoon. The LWR parameters and condition factor obtained in this study varied greatly according localities. Growth was isometric for six species in Ono lagoon, seven species in Kodjoboué lagoon and 10 species in Hébé lagoon. This implies that small specimens in the samples under consideration have the same form and condition as large specimens [20]. The type of growth of some species varied greatly according localities, being isometric in one lagoon and positive or negative allometric in other lagoons and vice versa. For example, none of species exhibited positive allometric growth in Ono and Kodjoboué lagoons whereas growth was positive allometric for three species in Hébé lagoon. The *b* value of most of the species in Ono and Kodjoboué lagoons showed a negative allometric growth whereas only three species exhibited this type of growth in Hébé lagoon. However, all *b* values were within the expected range from 2.5 to 3.5 for tropical fish stocks [21], except for *P. obscura*, *H. bimaculatus* and *H. fasciatus* in Ono lagoon and for *C. nigrodigitatus* and *H. fasciatus* in Kodjoboué lagoon. This range of *b* value agrees with those reported by Tah *et al.* [22] for 36 species of two tropical reservoirs in Ivory Coast, by Konan *et al.* [23] for 57 species of small coastal rivers in south-eastern of Ivory Coast and by Ecoutin and Albaret [7] for 52 species of lagoons and estuaries in West Africa. Agboola and Anetekhai [24]noted that if fish must maintain his shape as it grows, their b-values must be equal to 3, but there is no existing theory that says the b-value must be negatively or positively allometric. Numerous authors reported that various factors, including seasons, environmental parameters, the presence of food, feeding ratio, habitat, sex and physiological conditions of fish may be responsible for differences in the observed b value [25, 26, 27 28]. The coefficient of determination (r^2) values of all species indicated strong relationships between length and weight. This agrees with previous studies on different fish species from various water bodies [23, 22, 29].

Condition factor is a morphometric index used to evaluate physiological status of fish based on the principle that those individuals of a given length which have a higher mass are in better ‘condition’. It reflects, information on the physiological state of fish in relation to its welfare and well-being [30, 31]. In this study, the K factor ranged from 0.70 ± 0.10 to 2.94 ± 0.30. Barnham and Baxter [32] noted that if the K value is 1.00, the condition of the fish is poor, long and thin whereas a K value of 1.20 indicates that the fish is of moderate condition and acceptable. According to Telvekar *et al.* [33], the highest values of ‘K’ in a period seem to be the preparation for the reproductive activities. All the fish had condition factors greater than 1 except for *C. ebriensis, H. bimaculatus and H. niloticus* from Ono lagoon, *B. ablabes, H. bimaculatus* and *O. niloticus* from Kodjoboué lagoon and *H. odoe* and *T. jentinki* from Hébé lagoon. Despite these differences observed, Oni *et al.* [9]and Sarkar *et al.* [34] noted that K factor was not constant for a species or population over a time interval and might be influenced by both biotic and abiotic factors such as feeding regime and gonadal development.

5. Conclusion

This study provides the first basic information on length weight parameters and condition factors of fish from small lagoons of Ivory Coast. All the *b* values were within the expected range from 2.5 to 3.5 for most of the species and the K value of most species was greater than 1 which indicated that the well-being of fish was good. This study shows different growth pattern and condition factors of fish. However, more comprehensive studies need to be conducted which would involve the standardisation of the sampling sizes, sampling season as well as understanding the bio-ecology of fish before further inferences could be made for comparisons among these various localities.

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