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Biodiversity, length-weight patterns and condition factors of cichlid fishes (Perciformes: Cichlidae) in brackish water and freshwater lakes of the Mono River, Southern Benin, West Africa

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Abstract
Cichlids are the major components of the ichthyodiversity and fisheries in tropical Africa. In Southern Benin, cichlids is of great importance and made about half (49.82%) of the inland fisheries. This study assessed diversities, length-weight models and condition factors of cichlids in South-Benin in order to contribute to species conservation and management. Six (6) cichlids dominated by *Sarotherodon melanotheron* (72.92%), a native species and *Oreochromis niloticus* (20.83%), an invasive alien species were recorded in Lake Toho. Likewise, the coastal zone comprised nine (9) cichlids dominated by *S. melanotheron* (74.49%) and *Tilapia guineensis* (20.06%). In both habitats, dominant species showed isometric growth patterns. The results showed significant ($p \leq 0.0001$) variations in the condition factors across both habitats. In Benin, cichlids have a high potential in fisheries and in aquaculture. Further studies are required and should focus on bioecology, dynamics, fisheries and aquaculture in order to implement a sound community-based approach of habitat protection, conservation and valorization scheme of cichlids species.

Keywords: Alien cichlid, Cichlidae, Condition factors, Conservation/Fisheries, Degradation, Isometric growth

1. Introduction
In inland waters of tropical Africa, cichlids are the major components of fish biodiversity and fisheries (FAO, 1995) [1]. As reported by Leveque (1997) [2], about 870 cichlid species belonging to 143 genera were recorded for the whole African continent. Almost all of these cichlids are concentrated in the Great Lakes of East Africa namely Lake Malawi comprising 600 cichlids, Lake Victoria with 250, and Lake Tanganyika with 185 (Fryer and Iles, 1972; Lowe McConnell, 1987; Snoeks, 2000) [3-5]. According to Moyle and Cech (1988) [6], the major cause of cichlid speciation is that not only most species have a strong trends to forage in lake bottoms that comprise a large variety of foods, but also because of the presence of pharyngeal jaws that confer to cichlids a high ability for trophic specialization.
In Southern Benin, of a total of 126 fish species known for the whole region, only nine (9) cichlid species are currently recorded. Though less speciose, cichlids consistently remain numerically the dominant species in freshwater and brackish water fisheries. Indeed, of a total annual fish production of 23,067.2 metric tons estimated for South-Benin inland waters, almost half (49.82%) were cichlids, evidencing its great fisheries and commercial importance in the Benin aquatic ecosystems (Gbaguidi *et al*.,1998) [7].
However, despite its potentials in fisheries and its socio-economic importance, knowledge on diversity, abundance and condition factors of cichlid fish community in the degrading environment are scant. Particularly, in the ecotonal coastal brackish water, and in Lake Toho, a freshwater floodplain lake both linked to the Mono River, very little documented research works are available on the diversity, population structure and growth models of cichlid fish fauna in these degrading aquatic habitats. However, difference in salinities, primary production, and environmental degradations of both habitats could affect the abundance and well-being of the fishes, leading to a decline of fisheries production, actually estimated at 2,506 tons and 905 tons, respectively for the coastal zone and Lake Toho.
Knowledge on cichlid biodiversity and structure are badly needed for habitat protection, species conservation and valorization.

Condition factors and length-weight relationships of fishes are important tool for fishery management (Abowei, 2010a, Abowei, 2010b) [8-9]. Particularly, length-weight regression equations assess the plumpness or well-being of the fish resources and hence, are response of physiological conditions of fishes which in turn depend on habitat conditions (Tesch, 1971) [10]. Consequently, length-weight relationships could be used to evaluate the productivity and the "ecological health" of the aquatic ecosystems. Likewise, as reported by Deekae and Abowei (2010) [11], condition factors can be used as indicators to assess overall ecosystem status. More importantly, condition factors consistently affect the spawning cycle and are robust predictors of fecundity, reproduction, growth and mortality in fishes, and have been widely used as a measure of feeding intensity (Abowei, 2009) [12]. As results, length-weight models and condition factors of fishes are valuable community structure tool for management decision in fisheries.

The present study was carried out to assess the diversity, abundance, trends of length – weight relationships and the condition factors of cichlids species from the ecotonal coastal zone, a brackish water, and Lake Toho, a freshwater floodplain lake of the Mono River in Southern Benin.

2. Material and Method

2.1. Study area

Lake Toho: Lake Toho (6°36'0" N ; 1°46'60" E) (Fig. 1c) is a freshwater floodplain lake of the Mono River located in Southeast Benin and covers about 10 km^2 during the dry season and 15 km^2 during the high-water season. This floodplain lake receives water from the Mono River (also from Adiko & Akpatohoun streams), and withdraws its water in Sazoé River during the flooding period (Adite, 2002) **[13]**.

The climate of the Southern Benin is sub-equatorial with two (2) wet seasons (April to July; mid-September to October) with a peak usually recorded in June, and two (2) dry seasons (December to March; August to mid-September). Annual mean rainfall reached 1307.3 mm and ambient temperatures varied between 20.74°C and 33.6°C (Akoegninou *et al*., 1993) **[14]**.

The plant community at Lake Toho is composed of floating species such as *Nympheae lotus*, *Ipomoea aquatica*, *Brachiaria mutica* and *Echinochloa pyramidalis*, *Pistia stratiotes*, *Ceratophyllum demersum* and *Azolla africana* which were sometimes mixed with *Cyperus papyrus* and *Typha australis*. Plant species such as *Adansonia digitata, Saccharum officinalis, Elaeis guineensis*, *Tectona grandis*, *Imperata cylindrica* are common in the adjacent terrestrial habitats (Adite, 2002) [13].

Intense artisanal fisheries activities targeted to all fish family such as Cichlidae, Clariidae, Gymnarchidae, Cyprinidae, Anabantidae, Hepsetidae, Mormyridae, Notopteridae, Polypteridae, Protopteridae and Osteoglossidae occured in this floodplain lake.

Coastal lagoon: The coastal lagoon extended on 130 km and covers about 30 km^2 (Akoegninou *et al*., 1993) [14]. The area investigated is a transitional region around Grand-popo city, where a sensible modification in the water salinity is recorded (Fig. 1a). As brackish coastal water, the hydrological regime depends on the Mono River (527 km-length). During flooding, the coastal lagoon receives freshwater from the Mono River located South-West, and salty water from Atlantic Ocean (Pliya, 1980; Capo-chichi, 2006) [15-16]. Flooding at the Mono River is seasonal, takes place between August and November and withdraws in the coastal lagoons.

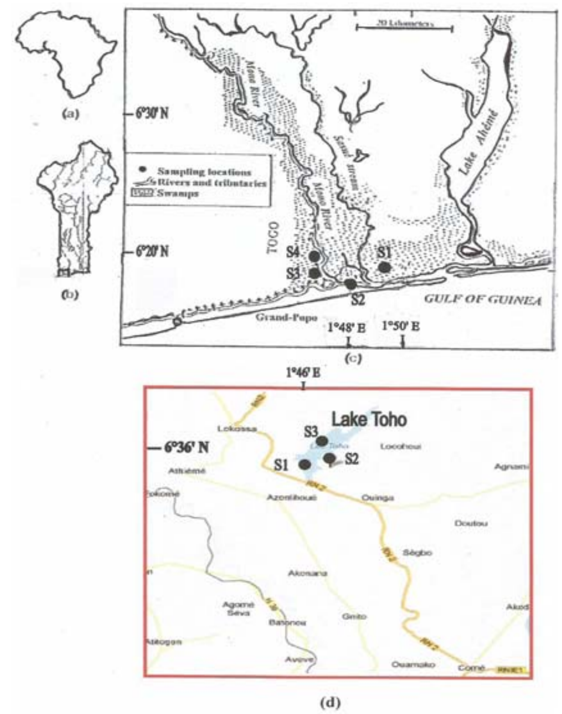

Fig. 1: Map showing (a) Benin in Africa, (b) study location in South-Benin and (c) the coastal lagoon with the four sampling sites (S1, S2, S3, S4) and (d) Lake Toho with the three sampling sites (S1, S2, S3)

The climate is sub equatorial with two wet seasons (April to July; mid-September to October) and two dry seasons (December to March; mid-August to mid-September). Ambient temperature ranged between 23°C and 34°C and annual mean rainfall and varied between 730 mm – 1145 mm. Dominant adjacent plant species were *Cocos nucifera*, *Elæis guineensis*, *Borasus aethiopium*, *Mitragyna inermis, Adonsonia digitata*, *Ceiba pentandra*, and *Milicia excels*. Two mangrove species, *Avicennia Africana*, and *Rizophora racemosa* were common and dominated the brackish water habitats. Like Lake Toho, intense multi-species fisheries activities targeted to fish, shrimp, crabs and oyster occurred at the coastal zone (Adite & Winemiller, 1997) [17].

2.2. Sampling Sites

Sampling sites has been selected according to the importance of fisheries and the accessibility to the sampling locations. In Lake Toho, there (3) sites were selected for the fish samplings (Fig. 1d): (S1) Tohonou village, (S2) Kpinnou village and (S3) at lake center. At these sampling sites, water salinity was nearly 0.2g/l. Depths ranged between 210 - 395 cm and transparencies varied from 46 - 90 cm. Water temperatures ranged between 23.2°C - 29.6 °C, pHs between 4.3 - 7.4 and dissolved oxygen concentrations varied from 3.2 mg/l - 7.4 mg/l.

At the costal lagoon, four sampling locations were selected: villages Onkuiwe (S1), Houndjohoundji (S2), with Agbanankin1 (S3) and Agbanankin2 (S4) from the Togo part of the Mono River, at the transitional zone of the coastal lagoon (Fig. 1c). At each sampling site, mangrove, aquatic vegetation and open water were sampled. The ecotonal zone is a mild brackish water of low salinities (0-6%o) with depths ranging between 10 and 410 cm (mean: 95.53 cm) and low transparencies varying between 10-52 cm (mean: 23.53 cm). Water temperatures ranged between 26.1°C and 31°C (mean: 28.1°C), pHs between 5.9 and 7.5 (mean: 6.5) and dissolved oxygen concentrations varied between 2.1 - 7.0 mg/l (mean: 3.8 mg/l). During flooding period, salinities were reduced to 0%o. Deeper sites showed sandy-muddy bottoms whereas shallower locations exhibited muddy bottoms.

2.3. Fish collections

Fish samplings in both water bodies has been done at each habitat and sampling site using a seine (4.20 m-length, 2 m – width, 5 mm-mesh) and an experimental gill net (50 m x 1.30 m, 50 mm-mesh; 50 m x 1.30 m, 25 mm-mesh). Samplings with seine in the aquatic vegetation and shallow sites were done by setting the seine stationary, and by kicking the vegetation and mud to drive the fish in to the net before lifting it (Winemiller, 1992a) [18]. At each sampling site, five to ten rounds of seining were performed. Samplings with gill nets were made by attaching the net to the sticks and left it for 12 hours. In addition, fish were sampled from fishermen captures. At each sampling site, one third of each fishermen capture was collected and uncommon species were systematically included in the sample (Okpeicha, 2011) [19]. For each lake, aggregated samples from seining, gill nets and those from fishermen captures were gathered to assess the whole fish assemblages of Lake Toho and the ecotonal zone.
The fish samples were then identified, measured, weighted and preserved in 10% formalin and latter in 70% ethanol to make easier laboratory observation (Murphy and Willis, 1996) [20]. Species identification was based on references such as Needham and Needham (1962) [21], Reed *et al*. (1967) [22], Van Thielen *et al*. (1987) [23], Leveque *et al*. (1990, 1992) [24-25], Skelton (1993) [26], Lowe McConnell (1975) [27] and Lopez-Fernandez and al. (2003) [28].

2.4. Data Analysis

Cichlid fish sub-community data were recorded in SPSS (Morgan *et al*., 2001) [29] computer software spreadsheet. Means and ranges of fish standard length (SL) and weight (W) were computed and community structure indices were calculated. Species abundance and relative abundance were computed to indicate the numerical importance of each cichlid species in the sample. Species richness (d) was determined following Margalef index (1968) [30].

$$d= S-1/LnN$$

where S is the number of species, and N the number of individuals in the sample. Species diversity (H') was computed following Shannon & Weaver index of diversity (1963)[31]:

$$H' = -\sum(p_i) (\log_2 p_i)$$

where H' is the index of species diversity, $p_i = n_i/N$, the proportion of total sample belonging to ith species, n_i the number of individuals of each species in the sample, N the total number of individuals of all species in the sample. The evenness measure (J') of Shannon & Weaver (1963) [31] was computed following the formula:

$$J' = H'/\log_2 S$$

where H' is the Shannon &Weaver index of diversity, S is the number of species in the sample.
We evaluated the trophic structure of the fish community by grouping fishes in five trophic categories, (1) detritivores, (2) planktinovores/ microcarnivores, (3) herbivores, (4) intermediate carnivores and (5) top-carnivores. The importance of each trophic category was appreciated using the relative abundance of fish species Halliday &Young (1996) [32], Adite & Winemiller [17]. For dominant species, the frequency histograms of fish size intervals (sizes structures) were constructed and length-weight relationships were examined according to Le Cren (1951) [33] model:

$$W = a\,TL^b$$

and its log-linear form

$$\text{Log } W = \text{Log } a + b \text{ Log } TL$$

where TL is the total length, W is the individual weight, *a* is the intercept, and *b*, the slope, is the allometry coefficient (Le Cren, 1951) [33]. One-way analysis of variance was used to test significance of the regression. The conditions of the dominant cichlids have been evaluated following Tesch (1971) [10] condition factor:

$$K = (W / LT^b) \times 100$$

where K is the condition factor, W, the total weight (g) of the fish individual, TL the total length (cm), and b the allometry coefficient.

3. Results

3.1. Cichlid biodiversity and relative abundance

Lake Toho: In this floodplain lake, the fish assemblage indicated that Cichlidae is the most speciose family. Indeed, of twenty (20) fish species inventoried in this lake, six (6) species, namely, *Sarotherodon melanotheron, Oreochromis niloticus, Tilapia guineensis, Chromidotilapia guntheri, Hemichromis fasciatus, and Hemichromis bimaculatus* were cichlids, and none of the ten (10) remaining families comprised more than two (2) species (Table 1). Also, with regards to abundance, of a total of 8962 fish individuals collected in Lake Toho, cichlids dominated the sample and numerically made 93.89% that corresponded to 78.90% of the total biomass of Lake Toho fish community. Specifically, the native tilapia (Fig. 2), *S. melanotheron*, dominated the fish community and accounted numerically for 68.46% (72.92% of cichlids sub-community) (Table 1), while the invasive introduced cichlid, *O. niloticus*, with a relative abundance of 19.56% (20.83% of cichlid sub-community) (Table 1), was the second most important cichlids, followed by *T. guineensis* (5.22%), a highly commercial common species that was always present in the catches. The remaining cichlids, *C. guntheri* (0.62%), *H. fasciatus* (0.26%), and *H. bimaculatus* (0.15%) were trivial and less represented in the fish community. Also, with six (6) cichlid species, Lake Toho showed a low Margalef species richness (d=0.55) and reduced Shannon & Weaver diversity index and evenness that were H'=1.108 and J'=0.43, respectively.

Costal lagoon: Like Lake Toho, and mostly during the flooding season, the coastal lagoon received the freshwater from the Mono River. The habitat sampled is an ecotonal (transitional) zone, a mild brackish water that were weakly influenced by the marine habitat. Of the 53 fish species identified in this ecotonal zone, nine (9) species belonged to Cichlidae, the most speciose family in the fish assemblage, and none of the twenty eight (28) remaining families contained more than four (4) species (Table 2). Like Lake Toho *S. melanotheron* dominated the coastal lagoon and made 25.56% of the fish community (74.49% of cichlids sub-community) followed by *T. guineensis* (20.06%), *T. dageti* (1.81%), *S. galilaeus* (1.64%), *H. fasciatus* (1.07%), *O. niloticus* (0.64%), *T. mariae* (0.32%), *S. heudoletii* (0.11%) and *H. bimaculatus* (0.11%). (Table 2). As a result, like Lake Toho, cichlids dominated the coastal lagoon with aggregated numeric abundance of 34.32%. At the coastal lagoon, Margalef species richness (d=1.17) and Shannon & Weaver diversity index (H'=1.137) were higher than those of Lake Toho for its relative high number of cichlid species. However, evenness measure (J'=0.36) was lower than that of Lake Toho.

Sarotherodon melanotheron **(**Rüppell, 1852**)**

Tilapia guineensis **(Gunther, 1852)**

Sarotherodon galilaeus **(**Linné, 1758**)**

Oreochromis niloticus **(**Linné, 1758**)**

Fig. 2: Dominant and common cichlids recorded. *Sarotherodon melanotheron, Tilapia guineensis* and *Sarotherodon galilaeus* are native cichlids, *Oreochromis niloticus* is an invasive exotic cichlids.

Table 1: Species composition, relative abundance, size and weight of cichlid fishes collected at Lake Toho (South-Benin).

Cichlid species	Abundance	Relative abundance (%)	Mean SL (mm)	Range SL (mm)	Mean weight (g)	Range weight (g)	Total Weight (g)
Chromidotilapia guntheri	52	0.62	70	39-95	14.23	2-30	739.96
Hemichromis bimaculatus	13	0.15	67	27-175	14.77	13-78	192.01
Hemichromis fasciatus	22	0.26	72	55-91	13.82	5-24	304.04
Oreochromis niloticus	1753	20.83	61	09-330	37.60	0.06-1321	65912.8
Sarotherodon melanotheron	6135	72.92	62	12-185	15.16	0.06-291	93006.6
Tilapia guineensis	439	5.22	93	22-300	57.49	0.97-1040	25238.11
Total	8414	100					185393.5

Table 2: Species composition, relative abundance, size and weight of cichlid fishes collected at the coastal lagoon (ecotonal zone), Southern Benin.

Cichlid species	Abundance	Relative abundance (%)	Mean SL (mm)	Range SL (mm)	Mean weight (g)	Range weight (g)	Total Weight (g)
Hemichromis bimaculatus	1	0.11	42	-	2.64	-	2.64
Hemichromis fasciatus	10	1.07	52	24-142	12	0.18-57	120
Oreochromis niloticus	6	0.64	76	37-235	67	1.77-385	402
Sarotherodon galilaeus	13	1.39	112	65-245	74	10-424	962
Sarotherodon heudoletii	1	0.11	44	-	3.37	-	3.37
Sarotherodon melanotheron	698	74.49	28	10-178	7.42	0.04-212	5179.2
Tilapia dageti	17	1.81	30	24-46	1.14	0.45-3.8	19.38
Tilapia guineensis	188	20.06	38	13-140	3.98	0.06-103	748.24
Tilapia mariae	3	0.32	22	21-23	0.33	0.19-0.6	0.99
Total	937	100					7437.8

3.2. Size structure

Means and range sizes of cichlids species of Lake Toho and of the ecotonal zone of the coastal lagoon are shown in Tables 1&2. Overall, in Lake Toho, the standard length (SL) of cichlids varied from 9mm (*O. niloticus*) to 330mm (*O. niloticus*). However, higher mean sizes were found in *T. guineensis* (mean SL: 93 mm). In the coastal waters, cichlids sizes (SL) ranged between 10mm (*S. melanotheron*) and 245mm (*S. galilaeus*) and smaller sizes were found in *S. melanotheron* (mean SL: 28 mm).

In particular, the two dominant native species of both habitats *S. melanotheron* and *T. guineensis* exhibited variation in size according to habitats. Indeed, one-way ANOVA on the standard lengths (SL) of these two cichlids revealed that the sizes across the two habitats were significantly different ($p \leq 0.0001$). The computed *F*-values, along with degrees of freedom and *p*-values were $F_{1,\,6832} = 1010.525$, $p = 0.0001$ for *S. melanotheron*, $F_{1,\,626} = 413.856$, $p = 0.0001$ for *T. guineensis*. However, the introduced invasive species, *O. niloticus,* more abundant in Lake Toho showed similar SL in both habitats ($F_{1,\,1758} = 0.471$, $p = 0.493$). Also, the standard length frequency histograms established for the thre dominant cichlids, *S. melanotheron* and *O. niloticus* in Lake Toho and *S. melanotheron* and *T. guineensis* at the coastal lagoon showed unimodal size distribution (Fig. 3-6).

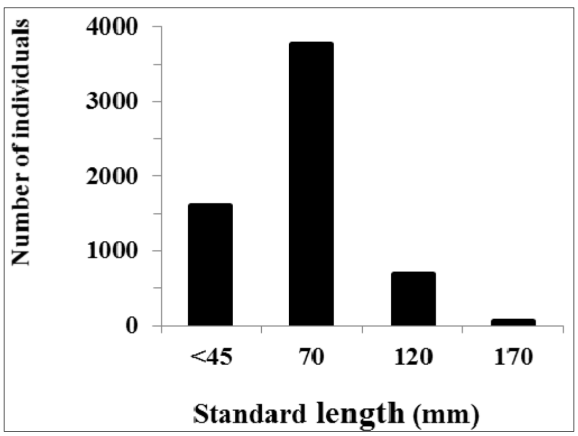

Fig 3: Size structures of *Sarotherodon melanotheron* (n= 6135) from Lake Toho, Southern Benin.

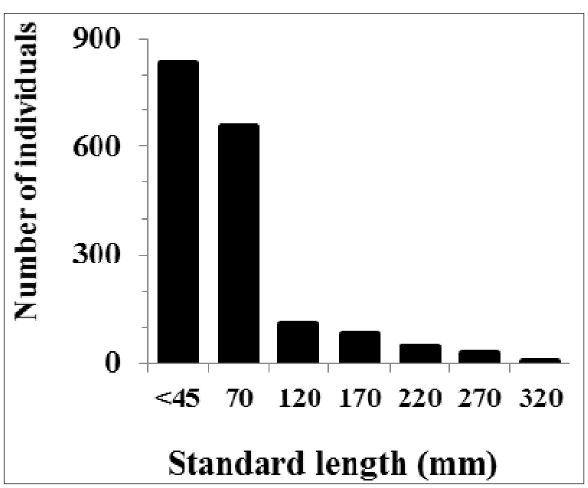

Fig 4: Size structures of *Oreochromis niloticus* (n= 1753) from Lake Toho, Southern Benin.

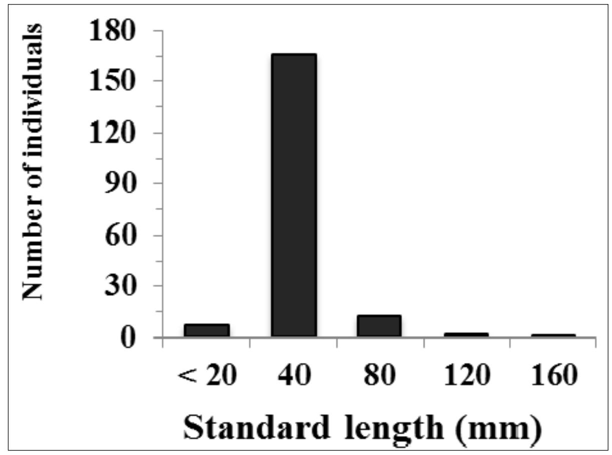

Fig 5: Size structures of *Tilapia guineensis* (n= 188) from the ecotonal zone of the coastal lagoon, Southern Benin.

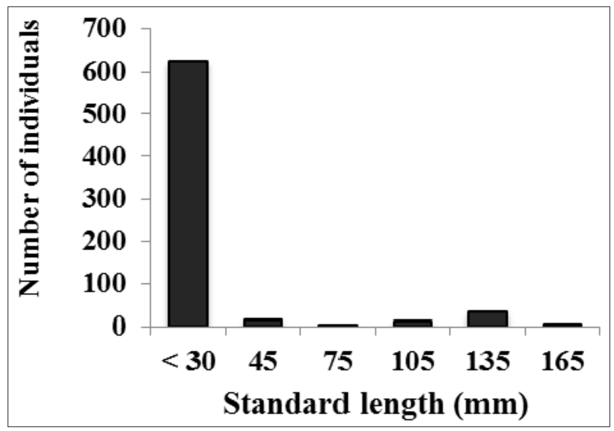

Fig 6: Size structures of *Sarotherodon melanotheron* (n= 698) from the ecotonal zone of the coastal lagoon, Southern Benin.

3.3. Length-weight relationships

The matrix of slopes, intercepts and correlation coefficients obtained from cichlid length-weight regression equations of Lake Toho and the coastal lagoon are shown on Tables 3-4. Plots were done for dominant cichlid species (Figures 7-10).

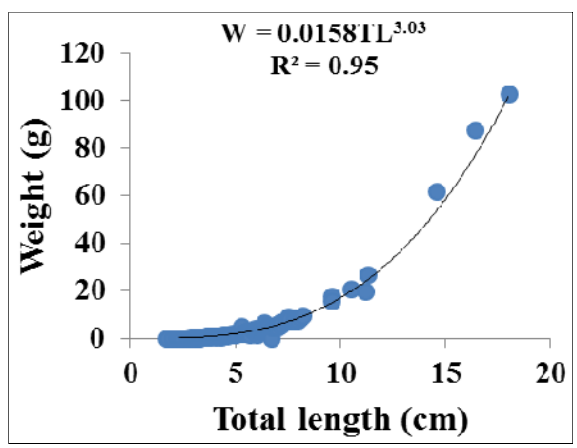

Fig 7: Length-weight relationship of *Tilapia guineensis* (n= 188) from the the coastal lagoon, Southern Benin.

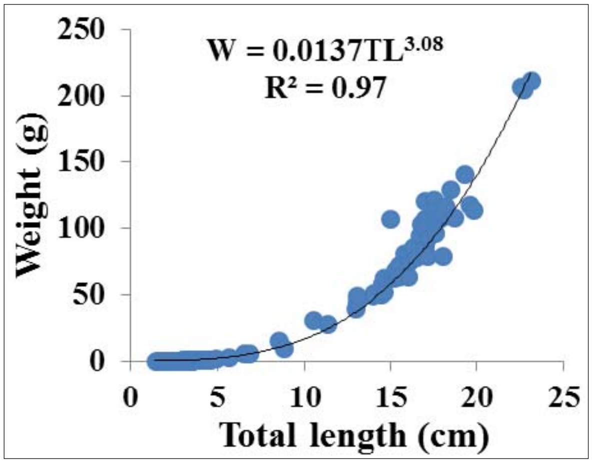

Fig 8: Length-weight relationship of *Sarotherodon melanotheron* (n= 698) from the coastal lagoon, South-Benin.

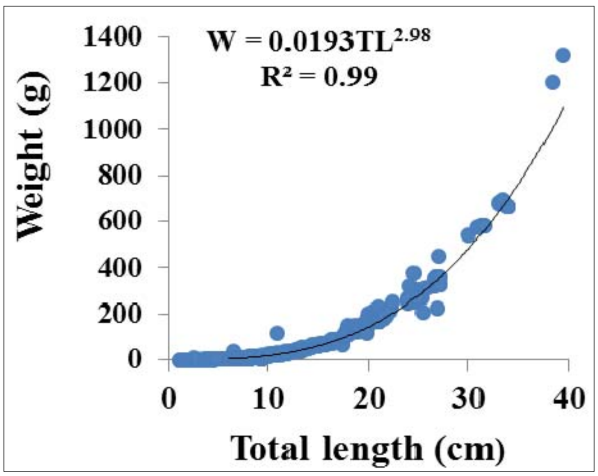

Fig 9: Length-weight relationship of *Oreochromis niloticus* (n= 1753) from Lake Toho, Southern Benin.

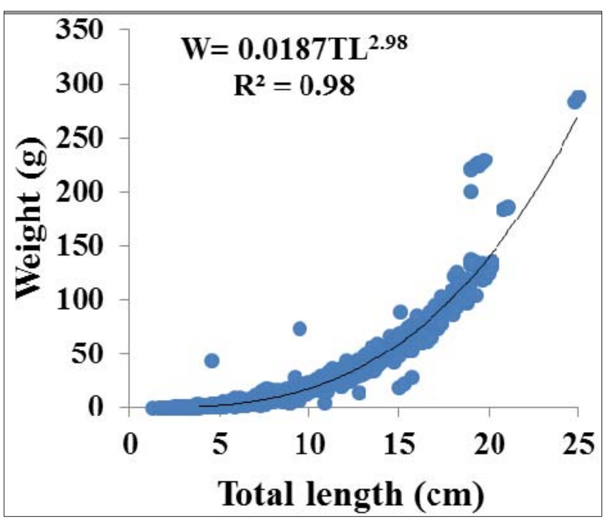

Fig 10: Length-weight relationship of *Sarotherodon melanotheron* (n= 6135) from Lake Toho, Southern Benin.

In Lake Toho, the slopes were positive for all cichlids and ranged between 2.578 (*H. bimaculatus*) and 3.398 (*H. fasciatus*), and all the correlation coefficients were significant ($p < 0.001$) and varied between 0.97 for *H. bimaculatus* and 0.99 for *O. niloticus.*

At the coastal lagoon, to avoid bias in results, regression equations for species like *S. heudoletii*, *H. bimaculatus* and *T. mariae* with fewer individuals (Table 4) were not established. For the remaining cichlids, the slopes were positive for all species and ranged between 2.831 (*S. galilaeus*) and 3.188 (*T. dageti*), and the correlation coefficients were all significant ($p<0.001$) and varied between 0.98 for *H. fasciatus* and 0.99 for *T. dageti.*

Table 3: Linear regression equations (Log SL – Log W) of cichlid fishes captured at Lake Toho, Southern Benin.

Cichlid Species	Abundance	Slope (*b*)	r^2*	Intercept (*a*)
Sarotherodon melanotheron	6135	2,976	0,98	-1,74
Oreochromis niloticus	1753	2,977	0,99	-1,72
Tilapia guineensis	439	2,976	0,96	-1,72
Chromidotilapia guntheri	52	2,788	0,96	-1,57
Hemichromis fasciatus	22	3.398	0.95	-2.22
Hemichromis bimaculatus	13	2.578	0.94	-1.41

* r = Correlation Coefficient,
P<0.001 for all regression slopes.

Table 4: Linear regression equations (Log SL – Log W) of cichlid fishes captured in the ecotonal coastal zone (Southern Benin.

Cichlid Species	Abundance	Slope (*b*)	r^2*	Intercept (*a*)
Sarotherodon melanotheron	698	3.081	0.98	-1.89
Sarotherodon galilaeus	13	2.831	0.99	-1.57
Sarotherodon heudoletii	1	-	-	-
Tilapia guineensis	188	3.034	0.98	-1.82
Tilapia dageti	17	3.188	0.99	-1.92
Tilapia mariae	3	-	-	-
Oreochromis niloticus	6	3.007	0.99	-1.82
Hemichromis fasciatus	10	3.150	0.97	-2.10
Hemichromis bimaculatus	1	-	-	-

* r = Correlation Coefficient
P<0.01 for all regression slopes

3.4. Condition factors

Tables 5 - 6 shows means and ranges of the condition factors (K) of cichlids from Lake Toho and the ecotonal zone of the coastal lagoon. In Lake Toho, the computed mean K (±SD) ranged between 0.67±0.083 recorded for *H. fasciatus* and 4.01±0.89 for *H. bimaculatus*. In the coastal zone, the mean condition factors varied from 0.001±0.0004 recorded for *T. mariae* and 2.80±0.12 for *S. galilaeus.*

Particularly, the two dominant cichlid species, *S. melanotheron* and *T. guineensis* exhibited significant ($p \leq 0.0001$) variation in the condition factors of the two habitats. Indeed, the computed *F*-values, along with degrees of freedom and *p*-values were $F_{1,\ 6832} = 333.310$, $p = 0.0001$ for *S. melanotheron* and $F_{1,\ 626} = 145.684$, $p = 0.0001$ for *T. guineensis*. The exotic species, *O. niloticus,* more abundant in Lake Toho exhibited similar condition factors in both habitats ($F_{1,\ 1758} = 0.690$, $p = 0.406$). For *S. melanotheron* and *T. guineensis*, higher conditions indices were recorded in Lake Toho, a typically freshwater habitat.

Table 5: Mean condition factors (K) of cichlid fish species captured in Lake Toho (South-Benin) from May to December 2011.

Species	Abundance (Number of individuals)	Mean Condition Factor (K)	Range (K)	± SD*
Sarotherodon melanotheron	6135	1.90	0.39-45.82	0.21
Tilapia guineensis	439	1.94	0.11-3.56	0.21
Chromidotilapia guntheri	52	2.75	1.62-3.27	0.23
Oreochromis niloticus	1753	2	0.37-54.26	0.29
Hemichromis fasciatus	22	0.67	0.56-0.84	0.083
Hemichromis bimaculatus	13	4.01	2.77-5.44	0.89

*SD = Standard deviation

Table 6: Mean condition factors (K) of cichlid fish species captured in the ecotonal coastal zone, Southern-Benin.

Species	Abundance (Number of individuals)	Mean Condition Factor (K)	Range (K)	± SD*
Sarotherodon melanotheron	698	1.44	0.35-8.38	0.51
Sarotherodon galilaeus	13	2.80	2.60-3.06	0.12
Sarotherodon heudoletii	1	-	-	-
Tilapia guineensis	188	1.75	0.11-3.81	0.34
Tilapia dageti	17	1.26	1.08-1.45	0.08
Tilapia mariae	3	0.001	0.0005-0.001	0.0004
Oreochromis niloticus	6	1.54	1.19-1.84	0.25
Hemichromis fasciatus	10	0.85	0.45-1.28	0.27
Hemichromis bimaculatus	1	-	-	-

*SD = Standard deviation

4. Discussions and Conclusion

4.1. Diversity, relative abundance and growth

Cichlids are worldwide commercially and economically important fish species dominating most tropical inlands water in term of richness and abundance (Fryer and Iles, 1972) [3]. Especially in tropical Africa, Cichlidae is one of the most speciose family in inlands waters and appears to be the main component of most African fisheries.

In the present fish survey, only six (6) and nine (9) cichlid species has been inventoried respectively, in Lake Toho (total : 20 fish species) and in the ecotonal habitat of the coastal zone (total : 53 fish species). Ahouansou (2003) [34] reported the same number of cichlid species for Lake Toho. However, in this floodplain, previous survey implemented by Van Thielen *et al*. (1987) [23] reported four (4) cichlids species (*S. melanotheron*, *Tilapia zilli*, *S. galilaeus*, *H. bimaculatus*), lower than our findings. Probably, this low cichlid species richness may be due to reduced fishing effort or samplings did not encompass all habitats because their collections were done from fishermen catches and not from experimental sampling. The relatively low species richness recorded in both habitats is similar to the finding from other aquatic ecosystems of Southern Benin. Adite (2002) [13] reported five (5) cichlids, *S. melanotheron, T. guineensis, T. zillii, H. fasciatus,* and *H. bimaculatus* for the degraded mangrove ecosystem of the coastal lagoon. Likewise, 6 cichlids were reported by Van Thielen *et al*. (1987) [23] for Lake Nokoue, a brackish water and the largest one in Benin. Lake Nokoue comprises the exotic species, *O. niloticus*, well-established in Lake Toho, and competing with the native species, *S. melanotheron*. Also, Adite and Winemiller (1997) [17] inventoried seven (7) cichlid species for Lagoon Toho-Todougba, a freshwater lake. The same trends of low cichlids richness have been recorded for the Oueme River (7 species), Lagoon of Porto-Novo (7 species), Lake Azilli (5 species), Lake Aheme (4 species) and Lake Doukonta (2 species) of the Southern Benin (Van Thielen *et al*. 1987) [23].

Though the low or moderate cichlids richness could be partially attributed to weak sampling effort, the cichlids diversity in Benin is remarkably low compared to other African region. For the Great Lakes of Africa, Leveque (1997) [2] reported for Lake Malawi 600 endemic cichlid species belonging to 53 genera and about 200 cichlid species await description (Snoeks 2000) [5], 250 cichlids and 21 genera were reported for Lake Victoria, and 185 cichlid species belonging to 50 genera for Lake Tanganyika. As reported by Leveque (1997) [2], this species flock in the Great Lakes of Africa, is the result of adaptive radiation causing an explosive speciation of Cichlids. Such adaptive radiation is the result of morphological adaptations and especially the morphological diversification of the feeding apparatus of cichlids (Leveque, 1997) [2]. Also, combined effects of geographic isolation and habitat degradation could have acted for rapid speciation of cichlids in the Great Lakes of Africa.

Both cichlids assemblages of Lake Toho and the coastal habitat consistently showed a size structure dominated by individuals of small sizes (Tables 1-2; Figures 3-6). In Lake Toho, though *O. niloticus* and *T. guineensis* reached larger sizes of 330 mm-SL and 300 mm-SL, respectively, their mean lengths, 61 mm-SL and 93 mm – SL, respectively, were very low (Table 1. The same trends were recorded for the coastal brackish water with mean of 28 mm -SL and 38 mm -SL, respectively for the dominant species, *S. melanotheron* and *T. guineensis* (Table 2). This size pattern is an indicator of overfishing caused by the increasing grassroots population and the use of detrimental fishing gears (Laleye *et al*., 2003) [35]. Similar results were reported for Lake Nokoue, Lake Aheme, Porto-novo Lagoon and for numerous other floodplain lakes and rivers of Southern Benin under severe overfishing (Laleye *et al*., 2004) [36].

In both habitats, the slope *b* of length-weight regressions of dominant species *S. melanotheron, O. niloticus* and *T. guineensis* indicated that these cichlids exhibited isometric growth patterns. This trends indicated that the fish became more rotund as total length increased (Deekae and Abowei, 2010) [11]. The higher condition factors recorded for *S. melanotheron* and *T. guineensis* in Lake Toho compared to those of the coastal habitat were probably due to the periodic flooding bringing organic and mineral nutrients causing algal blooms and higher primary production available for fishes. The same trends were found for the invasive alien cichlid, *O. niloticus* with higher condition indices (2.00) recorded in

Lake Toho, against 1.54 in the coastal area.

4.2. Cichlid fisheries and aquaculture
As discussed above, despite its low species richness, cichlids have a high potential in fisheries and remain a family of high economic, commercial and social importance for grassroots in Benin. Indeed, in Southern Benin, artisanal fisheries bring about 11492.08 tons of cichlids every year, that correspond to about half (49.82%) of the total fish production (Gbaguidi *et al*.1998) [7]. This cichlid production corresponded to estimated annual revenue of US$ 25,282,576.

In addition to fisheries, the farming of cichlid species is widespread and well-known because most the species meets the required ecological conditions for aquaculture. The introduced species *O. niloticus* and the native tilapia, *S. melanotheron* are well-known for their high potential in aquaculture in the whole African continent and most regions in the world.

This study give preliminary results and database on diversity, abundance and condition factors of cichlids sub-community in these two degrading aquatic habitats, Lake Toho and the ecotonal ecosystem of the coastal zone actually under severe environmental degradation such as overfishing, invasion of water hyacinth, the construction of hydro electrical dam and various type of pollution that modify hydrology and cichlid community structure. Further researches are required on cichlid ecology, biology, fisheries and aquaculture in order to implement an integrated community-based cichlid management plan.

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