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RESEARCH ARTICLE

FISH BIODIVERSITY AND COMMUNITY STRUCTURE OF THE ECOTONAL ZONE OF THE MONO RIVER IN BENIN AND TOGO (WEST AFRICA)

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ABSTRACT

African rivers and floodplain lakes harbor a high fish biodiversity and support important multi-species fisheries that provide sustainable revenues and protein sources for grassroots. The present study assessed the fish biodiversity and community structure of the lower Mono of Benin and Togo in order to improve fish resource conservation and management. Fish samplings have been accomplished on the main channel and tributaries at four locations from May to December 2011. A total of 53 fish species belonging to 41 genera and 29 families were inventoried during the study period. Among the fish taxon, the most speciose family was Cichlidae with 9 species. Numerically, five families Cichlidae, Cyprinotontidae, Clariidae, Claroteidae, and Eleotridae dominated the fish assemblage and accounted together for 87.04%. The Shannon-Weaver index of species diversity (H') ranged between 1.9 and 3.83 and higher values were recorded in the main channel and in the main tributary. Most dominant fish species showed an unimodal size distribution and higher condition factors were recorded for larger species such as *Protopterus annectens* (K=50.10), *Clarias gariepinnus* (K=17.31) and *Clarias agboyiensis* (K=2.63). Length-weight regression equations showed allometric and isometric growth patterns among dominant species. The lower Mono support an intense multi-species fisheries practiced by more than 13,000 professional fishermen capturing annually about 1,416 tons of fish. The lower Mono is under major ecological threats which greatly affect the fish biodiversity and the fisheries. An integrated community –based approach of ecosystem management is required to restore and to sustainably exploit this ecotonal habitat.

INTRODUCTION

Multi-species fisheries dominate most of the African running waters and provide both sustainable revenues and reliable sources of proteins to millions of low-income people, mostly in rural communities of developing countries (Welcomme, 1975; 1976; FAO, 1971; Adite *et al*., 2006). In the western region of Africa, and especially in Benin, rivers and streams, mainly Niger, Oueme, Zou, Penjari, Couffo, Mono, etc. including other associated tributaries, floodplains and lakes, dominate inland waters and produce yearly 33,000 tons of fish (Gbaguidi andPfeifer, 1998) estimated at about US$52,400,000. However, the Mono River underwent major environmental degradations such as the construction of a hydro electric dam, the destruction of mangrove forests at the estuarine habitats, the invasion of the water hyacinth, *Eichhornia crassipes*, the accidental introduction of alien fish species from aquaculture, and the overfishing due to grassroots poverty, the increasing fishermen population, and the use of detrimental fishing gears (Winemiller, 1995, Adite, 2013). For example, in Benin, an exotic species (*Oreochromis niloticus*) has colonized many floodplains lakes (e.g. Lake Toho) of the Mono river and competes with native species (e.g. *Sarotherodon melanotheron*) with high niche overlap (Adite, 2005). Also, alien species may dilute genetic integrity and bring diseases to the ecosystem (Leveque, 1997), and consequently, stand for real threat (Winemiller and Anderson, 1997). Likewise, running waters are being polluted with toxic contaminants originating from industrial and sewage treatment plants, urban and agricultural runoff, organic chemical and pesticides causing alteration of water quality. Water hyacinth (*Eichhornia crassipes*) invasion coupled with the destruction of marginal aquatic vegetation lead to sedimentation and to a progressive reduction of water superficies. All these ecological disasters profoundly modify aquatic habitats conditions and the structure of the fish community. As reported by Leveque (1997), fish diversity is an indicator of ecosystem health, and the well-being of human populations depends on the availability of a variety of renewable resources including freshwater fish which must be utilized sustainably at rates that permit harvest over a long times. Thus, the major environmental concerns should be the conservation of biodiversity in the context of sustainable exploitation and development (Leveque, 1997). However, the success of biodiversity conservation will depend on how well the aquatic environments are managed to minimize the loss of

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biological diversity. Thus, the sustainable management of tropical fisheries in the degrading aquatic habitats (e.g. Mono River) requires a better understanding of the fish biodiversity, community structure and the functional dynamics that contribute to the higher fish productivity of these aquatic ecosystems. Despite the multi-utilization of the Mono River and its high importance in fisheries, knowledge on the fish biodiversity and community structure in the degrading environment is scant (Fahrig andMerriam, 1994). Particularly, little is known about the fish assemblages of the lower Mono, an ecotonal and trans-boundary zone between the two neighbor countries, Togo and Benin. The current study was undertaken in the lower Mono of Benin and Togo to assess the fish biodiversity and community structure in order to improve fish resource management and conservation. Specifically the study (1) assessed the fish assemblages, distribution and community structure; (2) evaluated size structure, length-weight relationships and conditions of fishes; (3) investigated relationships between environment features and biological attributes; (4) evaluated fisheries traits and degradation sources, and finally suggested community-based key actions for resource conservation and management plan.

MATERIAL AND METHODS

Study area

The study area is the lower Mono, around Grand-Popo town, a region where the Mono River serves as frontier between the two coastal countries, Benin and Togo (Figure 1), and stands as a transitional zone between the running freshwater and the brackish coastal lagoon. Indeed, from this ecotonal region, a sensible modification in the water salinity is initiated, and the Mono River shifts from typical freshwater to coastal brackish water. Located South-West, the Mono River (527 Km – length) originated from the mountain of Aledjo in the Atacora Region (North-Benin).

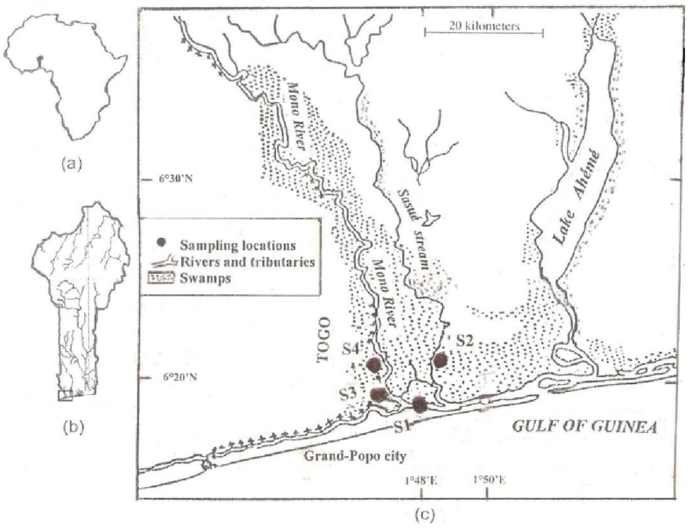

Figure 1. Map showing (a) Benin in Africa, (b) Benin and (c) the study area at the Mono River. Sampling sites are S1 (Onkouihoue), S2 (Houndjohoudji), S3 (Agbannakin1) and S4 (Agbannakin2).

From Aplahoue town, the lower Mono serves as frontier between Benin and Togo Republics on about100 Km (Pliya, 1980) and withdraw its waters in the Atlantic Ocean through a large delta called the "Boca del Rio" or the "Mouth of the King". From Agbannakin village in Togo, the Mono River is connected to Grand-Popo lagoon (15 km-length) through which water withdrawal in the ocean occurs (Pliya, 1980 ; Capo-chichi, 2006). Some of its tributaries are the Sazue stream, the largest one, Agogo, Adanwadonmè etc. Flooding at the Mono River is seasonal and takes place between August and November, withdrawing water in the coastal lagoons and other associated floodplain lakes such as lakes Toho, Aheme, Doukonta, etc. The climate is sub equatorial with two (2) wet seasons (April to July; mid-September to October) and two (2) dry seasons (December to March; mid-August to mid-September). Ambient temperature around Grand-Popo town varied between 23°C and 34°C and annual mean rainfall ranged between 730 mm – 1145 mm (Mean : 900 mm). Relative humidity ranged between 70% and 90%. 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* are common and dominated brackish water habitats. Fish, shrimp and oyster resources are intensively exploited in the lower Mono which presently undergoes multiple environmental degradations that affect the water quality and the structure of the fish community.

Sampling Sites

Sampling locations (Table I) were selected not only according to the importance of fisheries, but also according to the accessibility to the sites. Two sampling sites around villages Onkuihoue and Houndjohoundji were selected in the Benin side of the Mono River and two others, Agbannankin1 and Agbannankin2 around the village Agbannakin in the Togo side of the River. Onkuiwe and Agbannankin1 are located on the main channel of the River, Houndjohoundji located on Sazue stream, a main tributary of the Mono River and Agbannankin2, a tributary flowing through Agbannankin village. At each site, samplings were made in the open water and in adjacent aquatic vegetation.

Table I. Geographic coordinates of the sampling sites at the lower Mono (South-Benin and Togo)

Sampling locations	Location name	Country	Geographic coordinates: Longitude	Latitude
Site1	Onkuihoue village	Benin	06° 17' 11.4" N	001° 48' 39.7" E
Site2	Houndjohoundji village	Benin	06° 18' 19.5" N	001° 49' 52.9" E
Site3	Agbannakin1	Togo	06° 17' 13.7" N	001° 48' 30.1" E
Site4	Agbannakin2	Togo	06° 17' 30.9" N	001° 48' 11.0" E

Evaluation of habitats characteristics

The water quality was evaluated for each sampling site. Temperature and dissolved oxygen were respectively measured to the nearest 0.1 °C and 0.1 $mg.l^{-1}$, with a digital oxythermometer. Water depth and transparency were measured to the nearest millimeter using a graduated rope and a secchi disk, respectively. pH was measured to the nearest 0.1 with a model 3150 waterproof pH meter and salinity was measured to the nearest 1‰ with a model VISTA refractometer. In addition, habitat condition was evaluated for water type, utilization of adjacent lands, aquatic vegetation, mangrove degradation, substrate, and pollution. Data was collected once a month to encompass dry, wet and transitional season.

Fish Collection

At the four locations, fish samplings have been done from fishermen captures. At each sampling site, one third of each fishermen capture was sampled, including all uncommon species (Okpeicha, 2011). In addition, experimental fishing have been accomplished at each sampling site with 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 in marginal aquatic vegetation and shallow sites were made by setting the seine stationary, and kicking the vegetation to drive the fish in to the net before lifting it (Adite, 2013). Five to ten rounds of seining were done at each location. Gill nets were attached to the sticks and were set for 12 hours. Samples from fishermen captures, seining and gill net were gathered to assess the whole fish assemblages of this ecotonal region of the Mono River. After samplings, the fish samples were identified, measured, weighted and preserved in 10% formalin and latter in 70% ethanol to facilitate laboratory observation (Schreck, 1990; Murphy and Willis, 1996). Species identification was based on references such as Needham and Needham (1962), Reed *et al*. (1967). Van Thielen *et al*. (1987), Leveque *et al*. (1990a, 1990b), Taphorn (1992), Skelton (1993), Lowe McConnell (1975, 1987) and Lopez-Fernandez and al. (2003).

Survey on human dimension of fisheries and ecosystem degradation

In collaboration with grass-roots and using a questionnaire, a survey was implemented in fishermen villages to investigate on fishing techniques and gears, socio-economic aspects of fisheries, ecosystem degradation sources and effects on the fish biodiversity, fisheries and the overall 'ecological health' of the lower Mono.

Data Analysis

Mean values of water physical and chemical parameters have been computed using SPSS (Morgan *et al*., 2001) computer software. Species richness was considered as the number of species in the sample. Species relative abundance was computed to indicate the numerical importance of each species in the sample. Species diversity (H') was determined following Shannon andWeaver (1963) index of diversity (Krebs, 1989):

$$H' = -\sum(pi) * \log10\ (pi)$$

Where H' is the index of species diversity, pi = ni/N, the proportion of total sample belonging to ith species, ni 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 of Shannon-Weaver (E) function was computed following the formula (Krebs, 1989):

$$E = H'/\log S$$

Where H' is the Shannon andWeaver index of diversity, S is the number of species in the sample. The relationships between the fish community attributes and the physico-chemical parameters were evaluated through linear regression analysis and F-test. The frequency histograms of fish size intervals (sizes structures) were constructed for dominant species. Length-weight relationships were examined for different species according to the model:

$W = a\ TL^b$ (Le Cren,1951) 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 a constant, and *b* is the allometry coefficient (Le Cren,1951). One-way analysis of variance was used to test significance of the regression. The conditions of the dominant fish species have been evaluated following Tesch (1971):

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

W = total weight (g) of the fish individual;
TL = Total length (cm) ;
b = Allometry coefficient

RESULTS

Habitat Characteristics

The ecotonal zone of the lower Mono, located in Southern Benin and Togo, is a mild brackish water habitat of low salinities (0-6 g/l) and receiving the salty water from Atlantic Ocean. Overall, recorded water parameters significantly ($P<0.05$) varied among sampling locations. Depths ranged between 10 and 410 cm (mean: 95.53 cm), and higher values were recorded at Onkuihoue location, the main channel and at Houndjohoundji, the main tributary. Transparencies were relatively low and varied from 10 and 52 cm (mean: 23.53 cm). Water temperatures ranged between 26.1°C and 31°C (mean: 28.1°C), the pH between 5.9 and 7.5 (mean: 6.5) and the dissolved oxygen varied from 2.1 to 7.0 mg/l (mean: 3.8 mg/l) (Table II). During flooding period (transitional season), salinities were reduced to 0 g/l. Deeper sites (Onkuihoue, Houndjohoundji) showed sandy-muddy bottoms whereas shallower locations (Agbannakin1, Agbannakin2) exhibited muddy bottoms. Floating plants recorded were dominated by the water hyacinth (*Echhornia crassipes)*, *Pistia stratiotes*, and *Nymphea* sp., *Azolla Africana* and some immerged plants were *Ceratophyllum demersum* and *Utricularia inflexa*. Mangrove trees, *mainly Avicennia Africana*, *Rizophora racemosa* and the grasses *Cyperus sp*, *Paspalum vaginatum* were common in the plant communities.

Fish community composition and diversity Indices

A total of 2731 individual fishes distributed among 53 species belonging to 41 genera and 29 families were collected during the study period (Table III). The main channel, (Onkuihoue) and the main tributary, Sazue stream (Houndjohoundji), were more speciose with 29 and 41species, respectively whereas the two shallower sites, Agbannankin1 and Agbannankin2 comprised only 16 and 10 species, respectively. Among the fish taxon, the most speciose families were Cichlidae (9 species), Alestidae (4 species), and Eleotridae, Cyprinidae, Gobiidae with 3, 3 and 3 species, respectively. Numerically, five families Cichlidae, Cyprinotontidae, Clariidae,

Table II: Mean values and ranges of the water features measured in the four sampling sites of the lower Mono (Mono River, South-Benin and Togo) from May to December 2011

	Onkuiwe		Houndjohoundji		Agbannakin1		Agbannakin2	
Water parameters	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Depth (cm)	165.6	42-410	131.5	10 – 315	50	42-58	35	20-47
Transparency (cm)	38.7	32-51	24.4	10 - 52	21	20.5-21.5	10	6.5-15.3
Temperature (°C)	27.3	26.2-29.1	27.9	27.6 –28.3	28.3	26.1-30.5	28.8	27.1-31
Ph	6.7	6-7.5	6.3	6.2 – 6.4	6.2	5.9-6.4	6.6	6.1-6.9
Dissolved oxygen (mg/l)	5.2	4.2-5.8	3.4	2.8 - 7	3.5	2.1-4.8	3.1	2.5-4.5
Salinity (g/l)	2	0-6	1	0-3	1	0-2	1	0-2

Table III. Ichtyofaunal composition, abundance, size and weight of the lower Mono (Mono River, South-Benin and Togo) fishes collected from May to December 2011

Families	Species	Abundance	Relative abundance (%)	Mean SL (mm)	Range SL (mm)	Mean weight (g)	Range weight (g)
	Alestes sp.	2	0.07	95	49-140	29	2.04-55
Alestidae	*Brycinus sp.*	7	0.26	33	30-35	0.54	0.45-0.69
	Brycinus longipinnis	1	0.04	46	46-46	1.61	-
	Micralestes sp.	31	1.14	31	27-40	0.43	0.35-0.94
Anabantidae	*Ctenopoma petherici*	2	0.07	108	97-118	50	37-62
Aplocheilidae	*Epiplatys lamottei*	1	0.04	27	27-27	0.28	-
Carangidae	*Caranx crysos*	4	0.15	80	33-100	20	0.75-30
Channidae	*Parachanna africana*	18	0.66	211	150-273	120	43-292
	Parachanna obscura	18	0.66	203	127-265	128	33-258
Cichlidae	*Hemichromis bimaculatus*	1	0.04	42	-	2.64	-
	Hemichromis fasciatus	10	0.37	52	24-142	12	0.18-57
	Oreochromis niloticus	6	0.22	76	37-235	67	1.77-385
	Sarotherodon galilaeus	13	0.48	112	65-245	74	10-424
	Sarotherodon heudoletii	1	0.04	444	-	3.37	-
	Sarotherodon melanotheron	698	25.56	28	10-178	7.42	0.04-212
	Tilapia dageti	17	0.62	30	24-46	1.14	0.45-3.8
	Tilapia guineensis	188	6.88	38	13-140	3.98	0.06-103
	Tilapia mariae	3	0.11	22	21-23	0.33	0.19-0.56
Clariidae	*Clarias agboyiensis*	113	4.14	179	107-263	66	15-165
	Clarias gariepinus	60	2.20	246	95-460	242	36-1058
Claroteidae	*Chrysichtys auratus*	26	0.95	110	85-144	29	11-60
	Chrysichtys nigrodigitatus	211	7.73	139	94-265	54	13-394
Clupeidae	*Ethmalosa fimbriata*	2	0.07	86	71-101	19	8-30
Cynoglossidae	*Cynoglossus senegalensis*	1	0.04	305	-	98	-
Cyprinidae	*Labeo senegalensis*	3	0.11	141	57-184	133	3.65-207
	Barbus callipterus	2	0.07	36	36-36	0.7	0.64-0.77
	Barbus sp.	2	0.07	33	29-37	0.75	0.5-1
Eleotridae	*Dormitator lebretonis*	292	10.69	27	13-58	0.45	0.01-3.05
	Eleotris senegalensis	53	1.94	39	16-130	3	0.08-51
	Eleotris vittata	6	0.22	50	30-62	3	0.46-4.83
Gerreidae	*Eucinostomus melanopterus*	10	0.37	28	21-42	0.36	0.17-1.18
Gobiidae	*Awaous sp.*	40	1.46	36	23-70	0.8	0.05-5.3
	Periophthalmus barbarus	2	0.07	44	43-45	1.28	1.12-1.44
	Porogobius sp.	23	0.84	33	27-43	0.6	0.22-1.14
Gymnarchidae	*Gymnarchus niloticus*	1	0.04	679	679-679	954	-
Haemulidae	*Pomadasys jubelini*	1	0.04	89	-	22	-
Hepsetidae	*Hepsetus odoe*	4	0.15	160	88-200	60	8.3-84
Lutjanidae	*Lutjanus dentatus*	2	0.07	67	59-75	8	4.26-12
Mochokidae	*Synodontis obesus*	5	0.18	206	110-618	76	37-229
	Synodontis schall	3	0.11	115	74-141	50	31-65
Monodactylidae	*Psettus sebae*	1	0.04	135	-	68	-
Moronidae	*Dicenthracus sp.*	13	0.48	96	22-27	34	0.11-0.2
Mugilidae	*Mugil cephalus*	1	0.04	214	-	268	-
	Liza falcipinnis	22	0.81	136	78-215	59	10-174
Osteoglossidae	*Heterotis niloticus*	4	0.15	502	410-595	1601	854-2437
Paralichthydae	*Citharichtys stampflii*	2	0.07	53	26-80	4	0.18-8
Poeciliidae	*Aplocheilichtys spilauchen*	273	10.00	26	18-36	0.4	0.09-0.89
	Rhexipanchax lamberti	437	16.00	23	14-39	0.26	0.03-1.36
Polypteridae	*Polypterus senegalus senegalus*	7	0.26	206	183-227	74	47-94
Protopteridae	*Protopterus annectens*	21	0.77	313	194-431	162	97-382
Schilbeidae	*Schilbe intermedius*	40	1.46	102	80-154	13	6-30.96
Syngnathidae	*Enneacampus kaupi*	1	0.04	94	-	0.26	-
	Microphis brachyurus aculeatus	26	0.95	111	95-123	0.43	0.22-0.72
Total weight	:61733.44 g						
Total number of individuals	:2731						
Total number of families	:29						
Total number of genera	:41						
Total number of species	:53						

Claroteidae, and Eleotridae dominated the sample and accounted together for 87.04%. Likewise, ten species, namely *Sarotherodon melanotheron, Tilapia guineensis, Aplocheilichthys spilauchen, Rhexipanchax lamberti, Dormitator lebretonis*, *Eleotris senegalensis, Chrysichtys nigrodigitatus, Clarias agboyiensis, Clarias gariepinus and Awaous sp.* dominated the sample and accounted together for 73.31%. *S. melanotheron,* alone, constituted 25.56% of the total sample followed by *R. lamberti* (16%), *D. lebretonis* (10.69%), *A. spilauchen* (10%), *C. nigrodigitatus* (7.73%), *T. guineensis* (6.88%), *E. senegalensis* (1.94%) *and Awaous sp* (1.46%). The remaining (26.69%) was shared by 43 species and none of them had individually a relative abundance more than 1.46%. With regard to biomass, ten species *S. melanotheron, Sarotherodon galilaeus*, *C. nigrodigitatus, C. agboyiensis, C. gariepinus, Parachanna qfricana, Parachanna obscura, Liza falcipinnis, Protopterus annectens and Heterotis niloticus* constituted together for about 89.25% of the total biomass. Especially, *C. gariepinus,*though numerically less abundant, constituted alone 23.52% of the total biomass. The remaining (10.75%) is shared by 43 species and none of them had individually a biomass more than 1.23%. The Shannon-Weaver index of species diversity (H') computed for aggregated location samples ranged between 1.9 and 3.83 and higher indices were recorded for Onkuihoue (H'=3.83), the main channel and for Houndjohoundji (H'=3.29), the main tributary. The evenness (E) varied between 0.53 and 0.79 (Table IV). The species diversity index (H') computed for the fishing gears ranged between 1.90 (trap) and 3.87 (cast net) and the evenness index (E) varied between 0.57 for trap and 0.82 for cast net (Table IV).

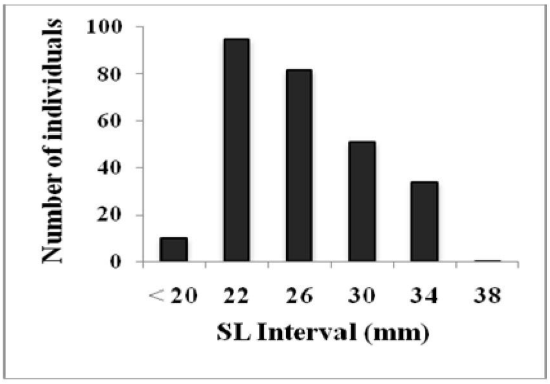

Figure 2. Size structure of *Aplocheilichtys spilauchen* (N= 273) captured in the Mono River (South-Benin, Togo).

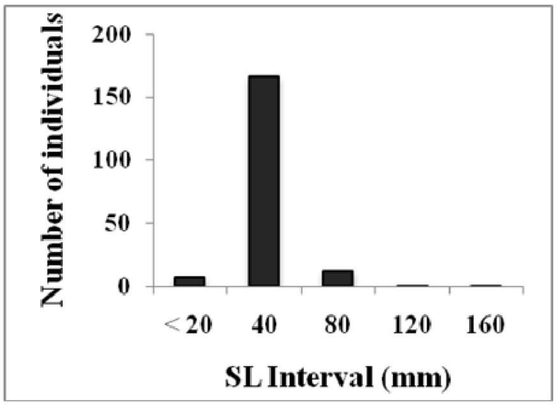

Figure 3. Size structure of *Tilapia guineensis* (N= 188) captured in the Mono River (South-Benin, Togo).

Table IV. Species richness, diversity indices and evenness of the fish community of the lower Mono (Mono River, South-Benin and Togo)

Habitat	Species richness (Number of species)	Shannon-Weaver diversity indice (H')	Evenness (E)
Onkouihoue (Main channel)	29	3.83	0.79
Houndjohoundji (Sazue tributary)	41	3.29	0.61
Agbannakin1	16	3	0.75
Agbannakin2	10	1.9	0.53

Table V. Species richness, diversity indices and evenness of the fish community of the lower Mono according to fishing gears type

Fishing gears	Species richness (Number of species)	Shannon-Weaver diversity indice (H')	Evenness (E)
Cast net	26	3.87	0.82
Acadja*	15	2.99	0.77
Seine	24	2.73	0.59
Longline	12	2.18	0.61
Trap	10	1.90	0.57

*Park of branches installed in the shallow water bodies to attract fishes

Size distribution

Table III shows the standard length (SL) means and ranges of the fish community of the lower Mono. In general, the SL ranged from 10 mm (*S. melanotheron*) to 679 mm (*G. niloticus*) and their respective corresponding weights were 0.04 g and 954 g. Larger fish such as *H. niloticus*, *G. niloticus, C. gariepinus, P. annectens, P. obscura, P. Africana, E. senegalensis, E. vitatta C. nigrodigitatus, H. odoe,* were recorded in the main channel and in the main tributary (Sazue stream). On the contrary, smaller fish, such as *A. spilauchen*, *D. lebretonis*, *Epyplatys sp etc.* were mostly recorded in the shallower locations. SL frequency histograms (**Figures 2-7**) established for the 6 dominant species showed a unimodal size distribution.

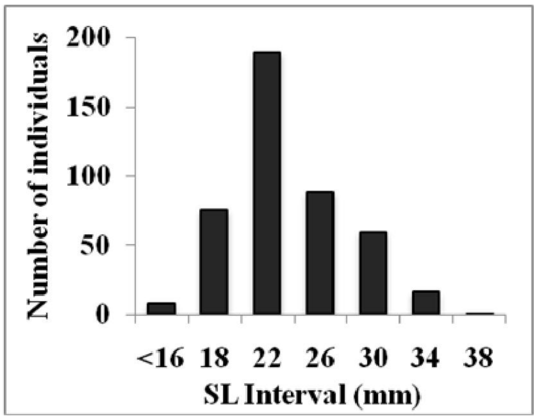

Figure 4. Size structure of *Rhexipanchax lamberti* (N= 437) captured in the Mono River (South-Benin, Togo).

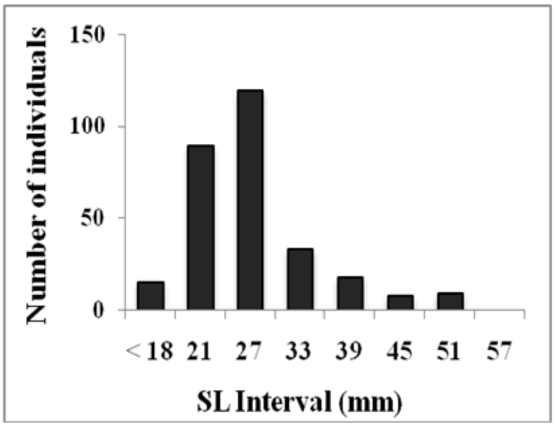

Figure 5. Size structure of *Dormitator lebretonis* (N= 292) captured in the Mono River (South-Benin, Togo).

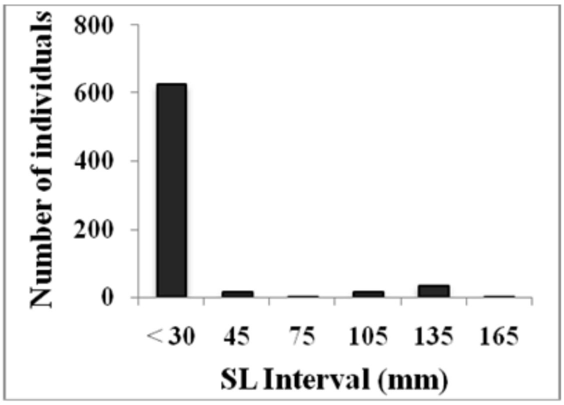

Figure 6. Size structure of *Sarotherodon melanotheron* (N= 698) captured in the Mono River (South-Benin, Togo).

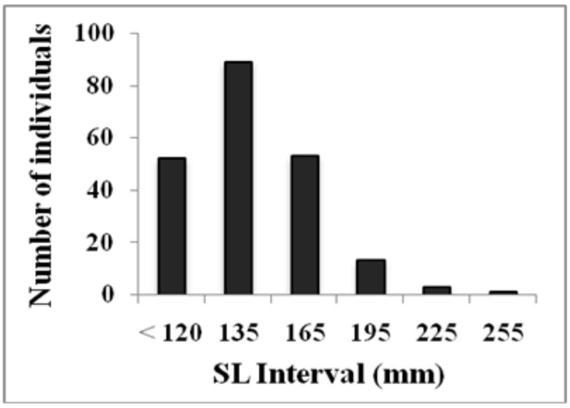

Figure 7. Size structure of *Chrysichthys nigrodigitatus* (N= 211) captured in the Mono River (South-Benin, Togo).

Length-Weight Relationships

Length-weight relationships were established for the 14 dominant fish species (out of which 4 were represented) (Figures 8-11) to examine the growth patterns of the fishes in the lower Mono. All the computed slopes were positives and ranged between 1.842 (*P. annectens*) and 3.81 (*R. lamberti*), and the coefficients of correlation varied from 0.77 (*P. annectens*) to 0.98 (*S. melanotheron, L. falcipinus*) (Table VI). One-way analysis of variance performed on the regression equations revealed that all the computed correlations were significant ($p<0.05$). Among the dominant species, six, namely *S. melanotheron, T. guineensis, A. spilauchen, C. nigrodigitatus, S. intermedius, L. falcipinus* exhibited an isometric growth patterns whereas the eight remaining showed an allometric growth (**Table VI**) in the lower Mono with *R. lamberti* (Poeciliidae) showing the highest positive allometric growth

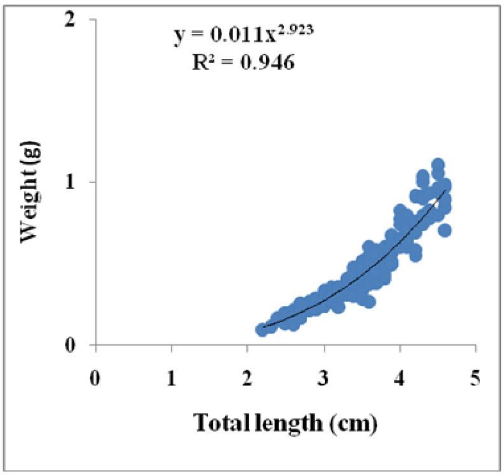

Figure 8. Length–Weight relationships of *Aplocheilichtys spilauchen* (N=273) captured in the Mono River (South-Benin, Togo) from May to December 2011.

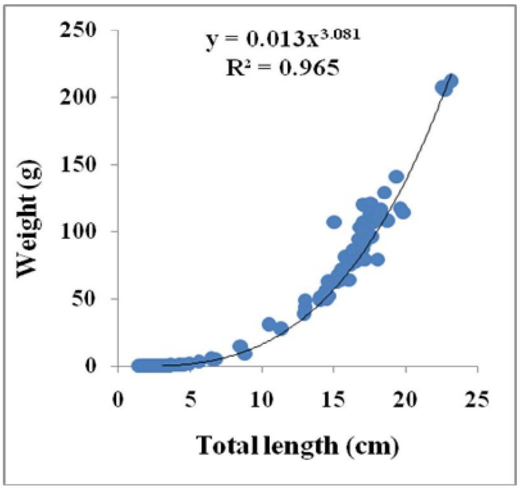

Figure 9. Length–Weight relationships of *Sarotherodon melanotheron* (N=698) captured in the Mono River (South-Benin, Togo) from May to December 2011.

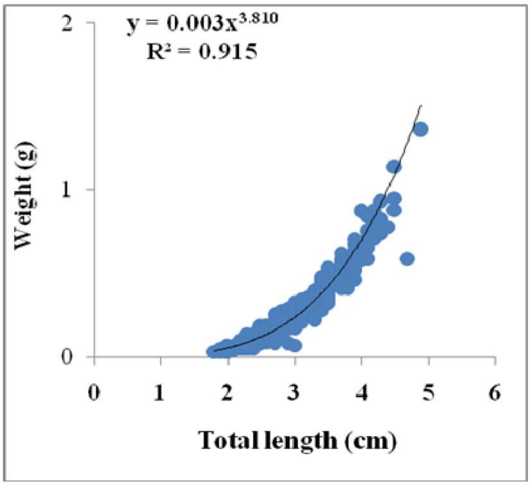

Figure 10. Length–Weight relationships of *Rhexipanchax lamberti* (N=437) captured in the Mono River (South-Benin, Togo) from May to December 2011.

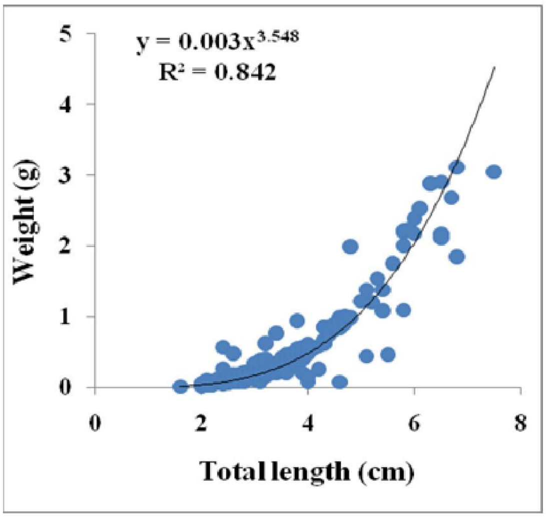

Figure 11. Length–Weight relationships of *Dormitator lebretonis* (N= 292) captured in the Mono River (South-Benin, Togo) from May to December 2011.

Condition factors of fishes

The means and ranges of the indices of condition or well-being (K) for the dominant fish species are shown on Table VII. The results revealed that computed K ranged between 0.004 recorded for *L. falcipinnis* (Mugilidae) and 50.10 for *P. annectens* (Protopteridae). One-way analysis of variance performed on calculated K revealed significant ($p<0.05$) variation among the condition factors of the fish assemblages. In general, larger species such as *P. annectens, C. gariepinnus* and *C. agboyiensis* exhibited higher condition factors.

Environnemental Correlates

Table VIII shows the matrix of correlation coefficients (r) generated from the regressions between the water quality parameters and the fish community attributes. Overall, "r" ranged between 0.003 and 0.84. Particularly, the results indicated that the species richness and the diversity indices (H') significantly ($P\leq0.05$) increased with dissolved oxygen

Table VI: Linear regression equations (Log SL – Log W) of the dominant fish species captured in the lower Mono River (South-Benin, Togo) from May to December 2011

Species	Abundance	Slope (*b*)	*r**	*a**
Sarotherodon melanotheron	698	3.081	0.98	-1.89
Tilapia guineensis	188	3.034	0.97	-1.82
Aplocheilichthys spilauchen	273	2.923	0.97	-1.96
Rhexipanchax lamberti	437	3.810	0.96	-2.52
Chrysichthys nigrodigitatus	211	3.023	0.96	-2.22
Chrysichtys auratus	26	3.163	0.95	-2.30
Dormitator lebretonis	292	3.548	0.92	-2.52
Eleotris senegalensis	53	3.484	0.96	-2.52
Clarias agboyiensis	113	2.595	0.96	-1.59
Clarias gariepinus	60	2.112	0.92	-0.78
Awaous lateristriga	40	3.358	0.96	-2.52
Schilbe intermedius	40	2.976	0.97	-2.16
Protopterus annectens	21	1.842	0.77	-0.57
Liza falcipinus	22	2.953	0.98	-2.00

* r = Correlation Coefficient, a = Constant.
P<0.01 for all regression slopes, except *P. annectens.*

Table VII : Mean condition factors (K) of the dominant fish species captured in the lower Mono (Mono River, South-Benin, Togo) from May to December 2011

Species	Abundance	Mean Condition Factor (K)	Range (K)	± SE*
Sarotherodon melanotheron	698	1.44	0.35-8.38	0.51
Aplocheilichthys spilauchen	273	1.11	0.62-1.45	0.13
Rhexipanchax lamberti	437	0.37	0.10-0.59	0.07
Chrysichthys nigrodigitatus	211	0.68	0.48-1.11	0.12
Dormitator lebretonis	292	0.38	0.03-2.51	0.19
Tilapia guineensis	188	1.75	0.11-3.81	0.34
Clarias agboyiensis	113	2.63	1.85-3.79	0.27
Clarias gariepinus	60	17.31	9.81-28.96	5.14
Awaous lateristriga	40	0.37	0.19-0.73	0.13
Eleotris senegalensis	53	0.37	0.16-1.83	0.29
Schilbe intermedius	40	0.70	0.66-0.95	0.07
Chrysichtys auratus	26	0.55	0.45-0.91	0.09
Protopterus annectens	21	27.62	20.27-50.10	7.79
Liza falcipinus	22	0.19	0.004-1.11	0.29

***SE** = Standard error

Table VIII : Matrix of correlation coefficients (r) obtained from the regression equations between water parameters and the community attributes of the fishes species captured in the lower Mono (Mono River, South-Benin, Togo) from May to December 2011.

Water parameters	Species richness (Number of species)	Relative abundance (%)	Shannon-Weaver diversity indices (H')
Depth (cm)	0.51	0.01	0.35
Transparency (cm)	0.33	0.17	0.33
Temperature (°C)	0.14	0.003	0.17
pH	0.05	0.03	0.39
Dissolved oxygen (mg/l)	0.71	0.33	0.84

with r=0.71 and r=0.84, respectively. Likewise, species richness and H' increased with depth, transparency, Ph and temperature, but not significant (P≥0.05). Though not significant (P≥0.05), the fish relative abundance was positively correlated with transparency (r=0.17) and dissolved oxygen (r=0.33).

Fisheries and habitats degradation in the lower Mono

The ecotonal region of the lower Mono support an intense multi-species fisheries practiced by more than 13,000 professional fishermen acquiring some sustainable revenues and reliable sources of proteins. Annual fish production reached 1,416 tons (Gbaguidi and Pfeifer, 1998) corresponding to an estimated revenue of US$ 2,548,800. The main fishing gears used were mostly cast net, gill net, traps, and "acadja" (park of branches installed in the shallower location), that contributed to about 91% of the total catches. Seine, longlines contributed less to the total catches (Figure 12). Though not widespread, fish farming (aquaculture) is present in the lower Mono and reared species included the nile tilapia, *Oreochromis niloticus* and at a lower scale, the indigenous species, such as *S. melanotheron* and *C. gariepinus*. Despite its importance in fisheries, the lower Mono is under severe degradations and ecological disasters which greatly affect the fish biodiversity and the fisheries. Some of these major degradation sources are (a) the overfishing caused by grassroots poverty, the increasing grass-root population and the use of various detrimental fishing gears and fishing methods, (b) the destruction of the coastal mangrove, (c) the construction of a hydro electrical dam on the Mono River to provide electrical power for Benin and Togo, (d) the invasion of floating plants, mainly the water hyacinth, *Eichhornia crassipes*, and (e) the construction of a public market at the fringe of the Mono River with a daily dumping of domestic wastes.

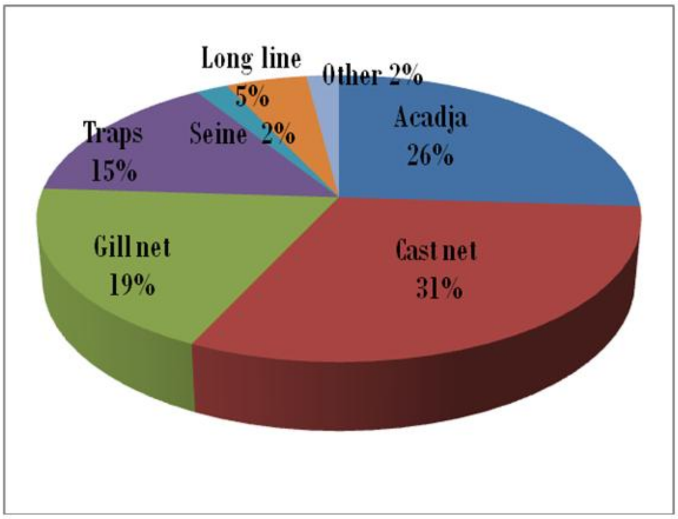

Figure 12. Contribution of the different fishing gears in the total fish catches of the lower Mono (Mono River, South-Benin, Togo) during the study period, May - December 2011.

DISCUSSION AND CONCLUSIONS

In the two neighbor countries, Benin and Togo of West Africa, the Mono River (527 km) is of great importance, economically and socially because of its multiple utilizations namely fisheries, aquaculture, agriculture, transportation, drinking water etc. (Adité, 2002). Also, and for about three decades, the Mono River has been provided electricity to Benin and Togo through the construction of a hydro electrical dam (Pliya, 1980; Adite, 2002). This preliminary ecological study on Mono River assessed habitat conditions, fish assemblages and structure, and fisheries in the degrading lower Mono, an ecotonal habitat of the Mono River. The lower Mono, as transitional zone, is a region of confluence where the main channel of the Mono River and its main tributary, the Sazue stream converge. Also, it is the region where the Mono River, a freshwater, is connected to the coastal lagoons (Lagoon of Grand-popo, Lagoon of Ouidah), a typically brackish water. These hydrological traits may explain the lower salinity (0-6‰) recorded in the lower Mono compared to that of the coastal lagoons (0-35‰), but higher than a typical freshwater of the upstream sites. Consequently, ichtyofaunal composition and structure shifts accordingly (Djodo, 1999; Chikou, 2006). Of a total of 53 species inventoried during the study period, the main tributary (Houndjohoundji), with 41 species was more speciose than the main channel probably because of the presence of various micro-habitats such as "Acadja", mangrove, floating plants, grasses that harbor many species.

Also, the main channel (29 species) with more dynamic water exhibited higher flow causing some species, mainly small fishes to avoid the high current. The other two locations (Agbannakin1, Agbannakin2) in the Togo side, more shallower, showed low species richnesses. This species richness (53 species) recorded in this ecotonal habitat is comparable to that observed (51 species) in the connected coastal lagoon (Adite, 2013). However, ichtyofaunal compositions were quite different between the two habitats because of the difference in habitat condition, mainly the salinity ranging between 0 and 35 ‰ (mean: 20.1‰) for the coastal lagoon dominated by the marine estuarine species (Lowe-McConnell, 1987, 1975 ; Winemiller *et al*., 1990, 1995 ; Winemiller, 1998). Indeed, fish families such as Serranidae, Scombridae, Pomadasydae, Polynemidae, Ophichthyidae, Lutjanidae, Elopidae, Cynoglossidae, Carangidae, Bothidae, and Belonidae, recorded in the coastal lagoon were absent in the lower Mono (Anato *et al*., 2003). Inversely, the fish families Alestidae, Anabantidae, Aplocheilidae, Cichlidae, Gymnarchidae, Mochokidae, Osteoglossidae, Polypteridae, Protopteridae and Schilbeidae recorded in the lower Mono were absent in the coastal lagoon fish assemblages (Adite, 2013). With regard to fish abundance, some wide range salinity-tolerant brackish water fish such *S. melanotheron* (25.56%), *R. lamberti* (16%), *D. lebretonis* (10.69%), *A. spilauchen* (10.0%), *Chrysichthys sp* (8.68%), *T. guineensis* (6.88%) and *Clarias sp* (6.34%) dominated the fish community because of the lower salinity (0-6‰) recorded in the lower Mono whereas typical marine species are uncommon and less abundant in the fish assemblages. Like species richness, the Shannon&Weaver diversity indices (H') were higher in the main channel (3.83) and in the main tributary (Sazue stream) (3.29), habitats of high fish abundance and richness. Also, non selective fishing techniques and gears such as cast net with H'= 3.87, "Acadja" (H'= 2.99), and seine (H'= 2.73) exhibited higher diversity indices (H') and thus, coupled with the non-respect of national fishing regulation, greatly contributed to high fishing effort and overfishing (Adite and Van Thielen, 1995; Williams *et al*., 1998).

As showing by the standard length frequency histograms (Figures 2-7), small size classes dominated the size structure of most fish species population. This size structure pattern may be a result of a high fishing effort due to the use of controversial and non selective fishing gears (3 mm-mesh cast net; 2 mm-mesh seine; 5 mm-mesh gill net etc .) causing overfishing. This overexploitation of fish resources recorded in the lower Mono is common in most coastal lakes of Benin namely Lake Nokoue, Lake Aheme, Lake Toho, coastal lagoons, Lagoon of Porto-Novo etc., permanently exploited with some sophisticated and prohibited fishing gears (Laleye *et al*. 2003; 2004). Nevertheless, in the lower Mono, some large specimens were recorded for some species such as, *C. gariepinus, C. agboyiensis, L. falcipinnis, P. annectens, R. lamberti and A. spilauchen*, but, in low abundance. Length-weight regression equations of dominant fish species were all significant ($p<0.05$) suggesting that the fish size increased with its weight, and this is shown by the isometric and the allometric growth patterns depicted. Significant ($p<0.05$) variation were recorded among the condition factors of the fish community of the lower Mono, and some larger species, such as *P. annectens* (mean K= 27.62), *C. gariepinnus* (mean K= 17.31) and *C. agboyiensis* (mean K= 2.63) exhibited higher condition factors. The opportunistic and omnivore-like feeding habit of these species could have increased their niche breadth and lead these fishes to forage on various food resources to satisfy nutritional needs for a high well-being or condition (Winemiller, 1989a; 1989b; 1990; Adite and Winemiller. 1997; Adite *et al*. 2005). In particular, the rusticity of these fish species could have helped to adapt to this changing and degraded environment of the lower Mono, and hence, to maintain a relatively high growth rate (Winemiller, 1992a ; 1992b; Winemiller, K. O. 2003). With regard to environmental correlates, the species richness and the diversity indices (H') consistently increased with dissolved oxygen. Also, the fish relative abundance increased with dissolved oxygen ($r = 0.33$) and transparency ($r = 0.17$), but not significant ($P\geq0.05$). The lower Mono supports intense multi-species fisheries, a permanent source of proteins for urban and rural communities, and provides sustainable revenues that improve the life of low-income people. However, the use of detrimental fishing gears and fishing methods led to overfishing and the reduction of fish production. More importantly, other ecological threats such as the destruction of mangrove forest, the invasion of the water hyacinth, the construction of hydro electrical dam and the accidental introduction of exotic species (*O. niloticus*) from aquaculture, greatly affect the fish community structure and the fish production of the lower Mono. The present ecological study, though preliminary, provide quantitative and qualitative database and information on the fish biodiversity, community structure and exploitation of the lower Mono. An integrated community –based approach of the lower Mono management including species conservation and valorization plan, mangrove restoration, reinforcement of the fishery regulation, coupled with an extensive ecological study is required to restore and to sustainably exploit this ecotonal habitat.

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