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Meristic and morphological characterization of the freshwater prawn, *Macrobrachium macrobrachion* (Herklots, 1851) from the Mono River – Coastal Lagoon system, Southern Benin (West Africa): Implications for species conservation

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The freshwater prawn, *Macrobrachium macrobrachion* is one of the shrimp's species that contribute to the fisheries in the Mono River – Coastal Lagoon water system of the Southern Benin, where major causes of environmental degradation that affect species integrity and survival, are hydro electrical dam, bridges, mangrove destruction, water hyacinth invasion, dumping of domestic wastes from a public market, use of detrimental fishing gears and overfishing. A total of 780 specimens of *M. macrobrachion* were sampled from two locations to investigate the morphological and taxonomic characterization of the species and to detect whether the population is morphologically and taxonomically separable in order to ascertain possible genetic diversity. The population exhibited significant ($P \leq 0.01$) morphological relationships with positive slopes varying between 0.28 and 2.80 and coefficients of correlation "r" between 0.70 and 0.96. The positive slopes "b"<3 (2.80 for Heve location; 2.71 for Onkuiwe location) from the total length - body weight relationships suggest that *M. macrobrachion* exhibited an allometric growth in the Mono River – Coastal Lagoon system. The results indicated that the morphometric features across the two sub-populations of *M. macrobrachion* were not significantly different ($0.00001 \leq F_{1,778} \leq 0.205$, $P \geq 0.05$). Computed body proportions revealed that the prawn was twice as long as its cepholothorax and twice as long as its abdomen. Also, the cephalothorax was as long as the dorsal rostrum and twice as long as its height. The total length was 4.9-8.69 times the uropod length and 5.17-9.45 times the telson length, and the cephalothorax length was 6-8.83 times the eye diameter. Also, the meristic counts from the two sub-populations of *M. macrobrachion* were not significantly different ($0.000001 \leq F_{1,778} \leq 0.000003$, $P \geq 0.05$). *M. macrobrachion* had 12-15 rostral spines at the dorsal side of the rostrum and 3-5 rostral spines at the ventral side. As a results the morphometric measurements and the meristic traits of *M. macrobrachion* from the two (2) locations did not differ significantly ($P \geq 0.05$), indicating that the population of *M. macrobrachion* in the Mono River – Coastal Lagoon system of Benin is morphologically and taxonomically inseparable and, consequently, may not be genetically diversified. Hence, search in genetic diversification requires molecular characterization to detect eventual variation among the population. Also, for species conservation and habitat protection purpose, the output generated from this study will form documentation for this prawn and serve as reference for species follow-up pending any further changes in the ecosystem.

Key words: Degradation, genetic diversification, *Macrobrachium macrobrachion*, morphological characterization, Mono River, species conservation, sympatric speciation.

INTRODUCTION

The freshwater prawns of the genus *Macrobrachium* are distributed throughout the tropical and subtropical regions of the world, and over two hundred species make up the genus (New and Singholka, 1985; Jimoh et al., 2009). Many species of this prawn, such as *Macrobrachium vollenhooveini*, *Macrobrachium macrobrachion* etc. occur in the West African region and are of high economic importance, both in artisanal fisheries and for aquaculture diversification (Jimoh et al., 2005; Agadjihouèdé, 2006; Gbaguidi, 2012).

The freshwater shrimps of the genus *Macrobrachium* is an arthropod belonging to the family of the Palaemonidae; Suborder, Natantia; Order, Decapoda; Subclass, Malacostraca and Class, Crustacea (Powell, 1980; Goore Bi, 1998; Meye and Arimoro, 2005). Habitats of *Macrobrachium* species are freshwater and brackish water areas including rivers, streams, creeks, lakes, lagoons and estuarine areas (Powell, 1980). However, most species of the freshwater shrimps require brackish waters to complete their life cycle (Powell, 1982; 1985).

Biology and aspects of morphological traits of large species such as *M. macrobrachion* has been documented by recent studies in the brackish waters in Southwest Nigeria and in Luubara creek, Niger Delta (Deekae and Abowei, 2010; Lawal-Are and Owolabi, 2012; Jimoh et al., 2012). *M. macrobrachion* is recognizable by its large second cheliped which usually end in strong pincers. This prawn is abundant during the rainy and flooding periods and reproduces actively during these two seasons. Sex-ratio approximated 1: 3.7 in the Badagry Creek (Southwest Nigeria) and length-weight relationships showed an allometric growth pattern (Jimoh et al., 2012; Lawal-Are and Owolabi, 2012). As in most crustaceans, the life cycle of *M. macrobrachion* comprises four (4) main stages namely egg, larva, post-larva (juvenile) and adult including molting cycle (Lawal-Are and Owolabi, 2012; Yamasaki-Granados et al., 2012). *M. macrobrachion* exhibit an amphidromous life history pattern, characterized by a female hatching migration from rivers to estuaries, larval development in saltwater, and a return upriver migration by postlarvae (juveniles) (Bauer and Delahoussaye, 2008).

In Benin, *Macrobrachium* is common in freshwaters, brackish waters and in estuarine areas of the coastal zone of Southern Benin. Artisanal fisheries occur in the Oueme River, Mono River and their floodplains, Lake Nokoue, Lagoon of Porto-Novo, Lake Aheme and the coastal lagoons, where these prawns are intensively exploited for sale because of their high market demand and commercial value (Pliya, 1980; Kakpo, 2010; Adite and Gbaguidi, 2012). Though underestimated, yearly production of *Macrobrachium* in Benin exceeds 200 tons (Gbaguidi and Pfeiffer, 1996; 1998), and estimated annual revenues reached US$1000, 000. The study region is the Mono River – Coastal Lagoon system of the Kouton (2004) gave preliminary information on the presence of the freshwater prawn, *Macrobrachium* of the Oueme River. In Grand-Popo Lagoon, at the coastal zone of Southern Benin, Agadjihouede (2006) reported six (6) species of *Macrobrachium* namely *Macrobrachium raridens, Macrobrachium dux, Macrobrachium felicinum, Macrobrachium vollenhovenni, Macrobrachium macrobrachion* and *Macrobrachium* sp. Among them, two dominant species, the African river prawns*, M. vollenhovenni* and the brackish water prawn*, M. macrobrachion* are of high importance in the inland fisheries at the Benin costal zone and relative abundances reached 44.75 and 51.50%, respectively (Agadjihouèdé, 2006; Gbaguidi, 2012).

Despite the economic and commercial importance of *Macrobrachium* in fishery in Benin, and the multiple degradation sources which could affect species integrity and survival, knowledge on taxonomy and morphological characterization of the populations is scanty. Presently, the degradation of aquatic ecosystems lead to threatened species and reduction of natural fishable stocks (Lowe-McConnell, 1975, 1987; Van Thielen et al., 1987; Hurtado et al., 2013; Laleye et al., 2003). Therefore, information on morphological and meristic character variations is urgently needed to ascertain genetic diversity and to contribute to implement management plan including habitat protection, species conservation and aquaculture valorization of *Macrobrachium* species (Hurtado et al., 2013; Fagnon et al., 2013).

From evolutionary ecology view point, though geographic isolation of a population is the usual cause of allopatric speciation (Smith, 1992; Coyne and Orr, 2004), however, the combined effects of multiple environmental degradations within an ecosystem, like that occurring in the Mono River – coastal lagoons system, could lead to sympatric speciation with difference in morphological variations. Moreover, the multiple degradations occurring in “Onkuiwe” location as compared to “Heve” location, less degraded, could have caused morphological differences in *M. macrobrachion* from the two locations.”

The aim of the present study was (1) to investigate the morphological and taxonomic variations among the *M. macrobrachion* population at the Benin coastal zone and (2) to detect whether the two sub-populations sampled, are separable morphologically in order to search for genetic diversity. Finally, the output obtained will serve as documentation for this prawn and for species follow-up pending any further changes in the ecosystem, and will contribute to implementing habitat protection and species conservation program.

MATERIALS AND METHODS

Study area

The study region is the Mono River – Coastal Lagoon system of the

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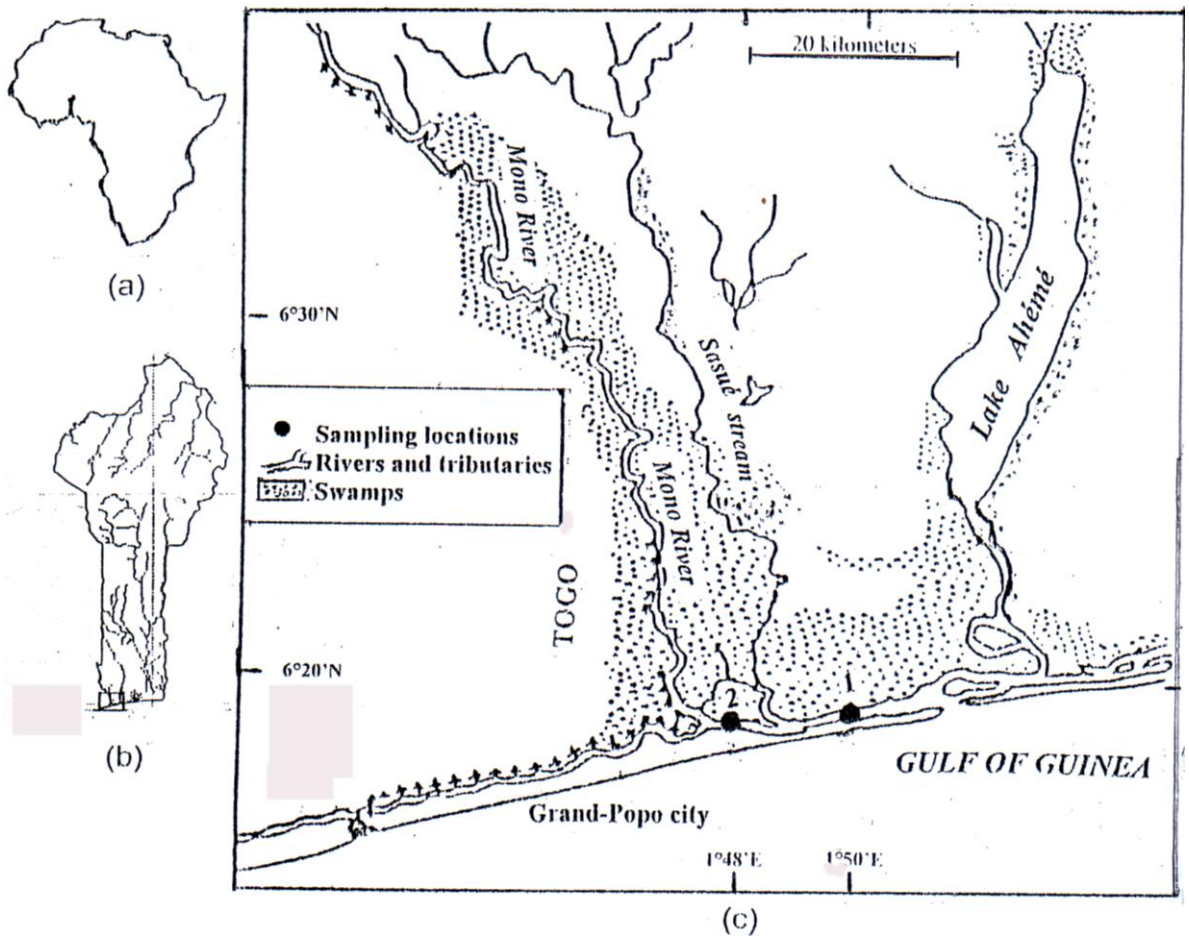

Figure 1. Map showing (a) Benin in Africa, (b) Benin Republic and (c) the study area with the two sampling locations (1 and 2) at the Mono River - Coastal Lagoon system.

Southern Benin (Figure 1). The coastal lagoon is a brackish water covering about 30 km^2 and extended to 130 km. Swamps cover about 60 km^2 and flooding at the coastal zone depends on the hydrological regime of the Mono River (527 km-length). This river supports a hydro electrical dam which greatly affects the flooding regime of the coastal waters and the biological resources. 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). Annual mean rainfall is about 1307.3 mm (Akoegninou et al., 1993). During the study period, ambient temperatures at the study locations varied between 25 and 32°C. The two locations had sandy-muddy bottom and depths, transparencies and water temperatures ranging between 238-360 cm, 32-124 cm and 26.20-30.30°C, respectively. The pH varied from 6.1 to 7.6, the dissolved oxygen from 2.9 to 7.5 mg/l and the salinities from 0 to 18‰.

Though very diverse, the plant communities at the coastal zone are dominated by mangrove species such as *Rizophora racemosa* and *Avicennia africana*. The mangroves are being intensively degraded for domestic use such as firewood and house constructions. At some sites, a seagrass*, Cyperus articulatus* is well established in the water and habitats where mangroves were destroyed are mostly colonized by a grass, *Paspalum vaginatum*. Along the coastal zone, there is a vast plantation of *Coco nucifera* (coconut-tree) and *Elaeis guineensis* (palm-tree) which were exploited for industry use, oil and food.

Dominant and commercial fish species in the coastal lagoon are *Chrysichthys nigrodigitatus*, *Dormitator lebretonis, Ethmalosa fimbriata, Liza falcipinnis*, *Mugil curema*, *Mugil cephalus, Sarotherodon melanotheron*, *Tilapia guineensis, Tilapia zillii, Hemichromis fasciatus, Aplocheilichthys spilauchen*, *Gerres melanopterus*, *Caranx hippos*, *Clarias gariepinus*, *Cynoglossus senegalensis*, *Elops lacerta*, *Pomadasys jubelini*, *Protopterus annectens*, *Progobius schlegeli*, *Eleotris senegalensis*, *Eleotris vitatta*, *Lutjanus agennes*, *Lutjanus goriensis*, *Parachana obscura*, (Kakpo, 2010). Dominant and commercial shrimps belonged to family Penaeidae and the freshwater prawn to genus *Macrobrachim.* Multi-species fisheries including oyster (*Crassostrea* sp. mainly*)* collection and traditional oyster farming dominated the coastal lagoon.

Sampling sites

Two locations of the Mono River – Coastal Lagoon system were selected for the shrimp collection (Figure 1). Selection was based on accessibility, importance in fishing activities and difference in habitat features. The first location, around Heve village (06° 17' 03.2" N; 001° 50' 24.8" E), had a more vegetated fringe with salinities (5-18%0) relatively higher than those of Onkuiwe village, and less degradation sources. The second location, around Onkuiwe village (06° 17' 14.4" N; 001° 48' 38.0" E), was less

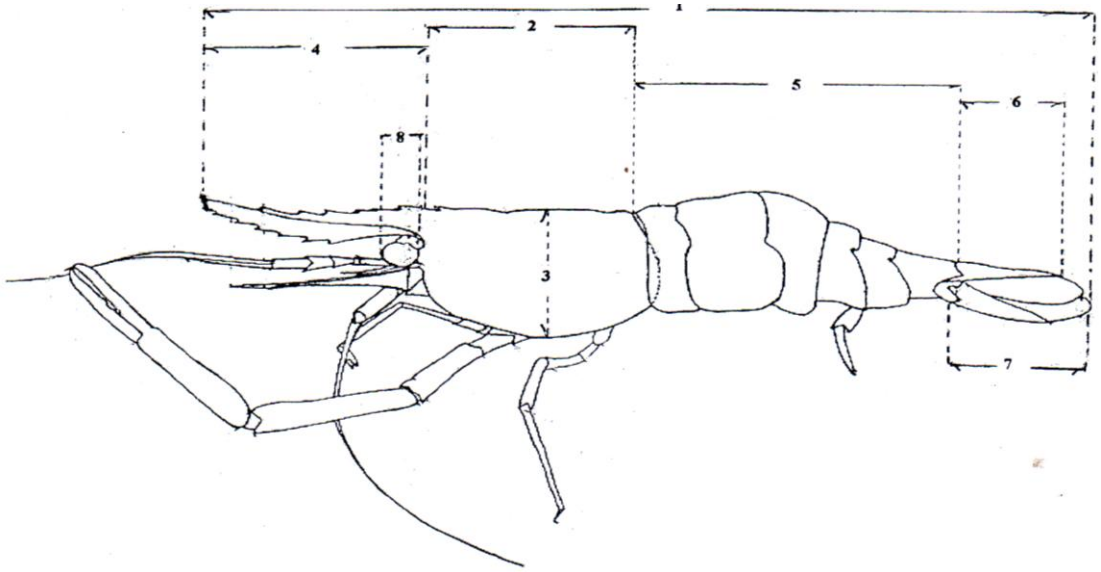

Figure 2. Morphometric measurements used in describing *M.macrobrachion* in the Mono River - Coastal Lagoon system of Benin: 1 = total length, 2 = dorsal cephalothorax length, 3 = cephalothorax height, 4 = dorsal rostral length, 5 = abdomen length, 6 = telson length, 7 = uropod length, 8 = eye diameter.

vegetated at the fringe, with relatively lower salinities (0-10‰) and more degradation sources. Indeed, at Onkuiwe site, mangrove was more degraded, 3 bridges were constructed, a public market was constructed near the river, and more frequent water hyacinth invasion occurred.

Prawns collections

From September 2011 - August 2012, *Macrobrachium* samples were collected fortnightly from the two locations to obtain the sample of the two sub-populations. The collecting fishing gear, locally called “Nukukuidja”, is a cylindrical trap (height: 55-83 cm; opening: 20-25 cm) possessing a non-return valve system (Marioghae, 1990). The “Nukukuidja” is a woven trap made of palm branches. Every evening (around 7:30 - 8:00 pm), baited traps were set at each site among aquatic vegetation, against the water current and left overnight. Baits were a mixture of rotten meat and grounded coconut. In the following morning, after about twelve hours, the traps were retrieved and the prawns were collected and preserved immediately in a cooler (Jimoh et al., 2012), and then transported to the laboratory of the Department of Zoology of the Faculty of Sciences for identification, measurements and taxonomic examinations.

Laboratory analysis

In the laboratory, the prawns were identified up to species level following Powell (1980, 1982) and Holthius (1980). The sexes of individual *M. macrobrachion* were differentiated visually based on morphological features (Deekae and Abowei, 2010). Male prawns possess appendix masculina on the second pleopod while females have none. Also, the berried females were identified and counted. Morphometric measurements (Figure 2) follow Carrillo (1968) and Jimoh et al. (2002), and were (1) total length (TL), (2) dorsal cephalothorax length (DCL), (3) cephalothorax height (CH), (4) dorsal rostral length (DRL), (5) abdomen length (AL), (6) telson length (TsL), (7) uropod length (UL), (8) eye diameter (ED) and (9) body weight (BW). Measurements were done to the nearest 1.0 mm with a Vernier calipers. Body weight was measured to the nearest 0.1 g with an electronic scale Camry (Model EHA1)). Meristic counts were (1) number of spines on the upper face of the rostrum (DRS) and number of spines on the lower face of the rostrum (VRS). Data on morphometric measurements and meristic counts from the two locations served to compare the two sub-populations.

Data analysis

The data on morphometric measurements and meristic counts were recorded in Excel software spreadsheet and mean values, ranges and standard deviation (±SE) of each feature were computed for each sub-population. All computed values were from combined sexes. Length - weight relationships of the prawns from the two locations were evaluated using linear regression. The total length – body weight relationships of *M. macrobrachion* were obtained from the relationship (Le Cren, 1951):

$W = aL^b$

Where, W = body weight (g); L = total length (mm); a = intercept; b = slope.

The linear regressions were obtained by a logarithm transformation according to the following formula (Le Cren, 1951; Enin, 1994, 1995):

$Log_{10} W = log\ a + b log_{10} L$

In this equation, the slope b determines the plumpness or the well-being of the prawns (Le Cren, 1951).

Furthermore, seven (7) ratios, TL/DCL, TL/UL, TL/TsL, TL/AL, DCL/DRL, DCL/CH and DCL/ED were computed using morpho-metric measurements data. Ratios are efficient tool to characterize and to identify shrimps and fish species (Jimoh et al., 2005,

Table 1. Morphometric measurements and meristic counts of *Macrobrachium macrobrachion* from two locations (Hêve village, Onkuiwé village) of the Mono River – Coastal Lagoon system, Benin.

Morphometric measurements and meristic features*	Hêvè (N = 519)			Onkuiwé (N= 261)		
	Mean	± SE	Range	Mean	± SE	Range
BW	15.74	4.90	8.60-26.66	15.87	4.82	8.63-26.69
TL	103.00	9.76	89-123	102.80	9.55	88-126
DCL	43.58	4.31	36-53	43.54	4.11	36-53
CH	20.06	2.94	12-27	20.18	3.26	11-28
DRL	34.50	4.16	29-45	34.42	3.98	28-46
AL	42.36	4.35	35-52	42.16	4.40	34-53
TsL	14.14	1.37	11-17	14.02	1.52	11-18
UL	17.06	2.01	13-21	17.10	2.52	12-21
ED	5.74	0.44	5-6	5.75	0.44	5-6
DRS	13.81	0.70	12 – 15	13.84	1.08	12 – 15
VRS	4.06	0.70	3 – 5	4.02	0.71	3 – 5

*Values ofmales and females indiscriminately. SE = Standard error, BW = body weight (g), TL= total length (mm), DCL = dorsal cephalothorax length (mm), CH = cephalothorax height, TsL = telson length, DRL = dorsal rostral length (mm), AL = abdomen length (mm), UL= uropod length (mm), ED = eye diameter (mm), DRS = dorsal rostral spines, VRS = ventral rostral spines.

2012). Indeed, morphometric measurements and meristic counts when expressed as proportion of the total body length and cephalothorax length are very useful tool in the identification of shrimps because body structures expressed as percentage of total length generate similar ratio in same species (Anetekhai, 1989; 1997). Using locality as factor, one-way Anova was run using the Statistical Package for Social Sciences (SPSS version 9.0) (Morgan et al., 2001) to determine if there were any morphological and meristic variations among the population of *M. macrobrachion* from the two locations.

RESULTS

Aspects of population structure

From September 2011 to August 2012, a total of 780 *M. macrobrachion* (249 males, 531 females) were collected from the two sites, 519 (34.3% males, 65.7% females) from “Heve village” and 261 (27.2% males, 72.8% females) from “Onkuiwe village”. The “Heve” sample comprised 32.95% juveniles, 67.05% adults whereas the “Onkuiwe” sample was composed of 37.93% juveniles, 62.07% adults. A total of 96 and 48 berried females were recorded in “Heve” sample and “Onkuiwe” sample, respectively.

Morphometric measurements

Table 1 shows the morphological features of *M. macrobrachion* captured from the Mono River – Coastal Lagoon system. In general, morphometric measurements varied between and within locations. Body weights of *M. macrobrachion* varied from 8.60-26.69 g and mean values were 15.74±4.90 and 15.87±4.82 g, respectively for Heve and Onkuiwe (Table 1). Body total length varied from 88-126mm; dorsal cephalothorax length, 36-53mm; cephalothorax height, 11-28mm; dorsal rostral length, 28-46mm; abdomen length, 34-53mm; telson length, 11-18mm; uropod length, 12-21mm; eye diameter, 5-6mm; For most measurements, the higher values were recorded in Onkuiwe location.

One-way analyses of variance on the morphometric features of *M. macrobrachion* from the two locations indicated that the variations of morphometric measurements across these two sites were not significantly different ($P \geq 0.05$). Indeed, the computed *F*-values, along with degrees of freedom and *p*-values were $F_{1,778} = 0.007$, $p = 0.93$ for body total length, $F_{1,778} = 0.019$, $p = 0.89$ for cephalothorax dorsal length, $F_{1,778} = 0.044$, $p = 0.84$ for cephalothorax height, $F_{1,778} = 0.024$, $p = 0.88$ for dorsal rostral length, $F_{1,778} = 0.018$, $p = 0.89$ for abdomen length, $F_{1,778} = 0.205$, $p = 0.65$ for telson length, $F_{1,778} = 0.026$, $p = 0.87$ for uropod length, $F_{1,778} = 0.00001$, $p = 0.99$ for eye diameter.

Body ratios

The morphometric measurements were used to generate the body proportions presented in Table 2. The ratio of dorsal cephalothorax length to total length ranged from 2.14-2.51 and the mean values of 2.37±0.06 and 2.36±0.08 were recorded at Heve and Onkuiwe location, respectively. The uropod length to total length ratio ranged from 4.9-8.69 and mean values of 6.07±0.55 and 6.10±0.79 were recorded at Heve and Onkuiwe,

Table 2. Body ratios (proportions) of *M. macrobrachion* from two locations (Hêve village, Onkuiwé village) of the Mono River – Coastal Lagoon system, Benin.

Body ratios	Hêvè (N = 519)			Onkuiwé (N = 261)		
	Mean	± SE	Range	Mean	± SE	Range
TL/DCL	2.37	0.06	2.17-2.49	2.36	0.08	2.14-2.51
TL/UL	6.07	0.55	5.21-8	6.10	0.79	4.9-8.69
TL/TsL	7.31	0.61	5.41-8.75	7.38	0.76	5.17-9.45
TL/AL	2.43	0.07	2.15-2.57	2.44	0.08	2.13-2.61
DCL/DRL	1.26	0.10	0.93-1.48	1.27	0.10	0.93-1.47
DCL/CH	2.20	0.22	1.68-3.17	2.22	0.30	1.81-3.55
DCL/ED	7.61	0.62	6.17-8.83	7.60	0.64	6-8.83

*Values of males and females indiscriminately.

respectively. Telson length : total length ratio showed mean values of 7.31±0.61 and 7.38±0.76, respectively, for Heve and Onkuiwe. The ratio of abdomen length to total length showed mean values of 2.43±0.07 and 2.44±0.08, respectively, for Heve and Onkuiwe and the mean ratios of the dorsal rostral length to the dorsal cephalothorax length were 1.26±0.12 and 1.27±0.10 at Heve and Onkuiwe, respectively. Cephalothorax height : dorsal cephalothorax length ratio varied from 1.68-3.55 and the mean values were 2.20±0.22 and 2.22±0.30, respectively, for Heve and Onkuiwe locations. The ratio of eye diameter to cephalothorax dorsal length varied from 6-8.83 and gave mean values of 7.61±0.62 for Heve and 7.60±0.64 for Onkuiwe.

Meristic counts

Rostral spines are the main meristic counts that characterize better the species of *Macrobrachium*. At the dorsal face of the rostrum, *M. macrobrachion* had 12-15 spines in both locations and means were 13.81±0.70 and 13.84±1.08, respectively for Heve and Onkuiwe locations (Table 1). Ventrally, *M. macrobrachion* had between 3 and 5 rostral spines and mean values of 4.06±0.70 and 4.02±0.71 were recorded for Heve and Onkuiwe, respectively.

One-way ANOVA on the meristic traits of *M. macrobrachion* from the two locations, Heve and Onkuiwe, indicated that the variations of the meristic characters across these two sites were not significantly different (*P≥0.05*). Indeed, the computed *F*-values and *p*-values were $F_{1,778}$ = 0.000003, p = 0.98 for the dorsal rostral spines counts (DRS) and $F_{1,778}$ = 0.000001, p = 0.99 for the ventral rostral spines counts (VRS).

Morphological relationships

At Heve location, for the seven regression equations performed, all the slopes were positive and varied between 0.28 and 2.80 (Table 3) with significant (P≤0.01) coefficient of correlation “r” varying between 0.70 and 0.96. This result indicated that total length of *M. macrobrachion* increases with the other seven morphometric measurements (Table 3). Also, at Onkuiwe location, the slopes were positive and varied between 0.54 and 2.71 (Table 4) with significant (P≤0.01) correlation coefficients “r” varying between 0.76 and 0.94. Nevertheless, at this latter site, regression between total length and telson length, and between total length and uropod length showed non-significant (P>0.05) coefficients of correlation (Table 4).

Prawn plumpness

M. macrobrachion conditions were evaluated by the slope of the total length-body weight relationships (Abohweyere, 2008; Abowei and George, 2009; Abowei et al., 2009) and associated regression equations were as follows:

Heve location: Log_{10} W=-4.458 + 2.80 Log_{10} L (N = 519, r = 0.88)

Onkuiwe location: Log_{10} W=-4.26 + 2.71 Log_{10} L (N = 261, r = 0.85)

The Students “t” test performed on the regression equations indicated that the correlations were significant both for “Heve” sub-population (t = 60.76, df = 517, p = 0.001) and for “Onkuiwe” sub-population (t = 35.87, df = 259, p = 0.001). Consequently, the two positive slopes, 2.80 and 2.71, recorded respectively for “Heve” and “Onkuiwe” suggest that *M. macrobrachion* exhibited an allometric growth in the Mono River – Coastal lagoon system.

Ecological threats and habitat degradation

Currently, the Mono River - Coastal lagoons system

Table 3. Relationships between morphological features of *M. macrobrachion* from Heve location, Mono River - Coastal Lagoon system, South-Benin. Morphological measurements are Log_{10} transformed data. Number of specimens = 519.

Regression factor	Slope (b)	Intercept (a)	Coefficient of correlation (r)	Coefficient of determination (r^2)
TL – BW	2.802	-4.458	0.88	0.77
TL – DCL	1.010	-0.395	0.96	0.93
TL – CH	0.275	-1.306	0.81	0.65
TL – TsL	0.705	-0.271	0.70	0.78
TL – DRL	0.820	-0.115	0.75	0.57
TL – AL	1.033	-0.452	0.96	0.92
TL – UL	0.884	-0.550	0.70	0.49

*Values of males and females indiscriminately. *P<0.01* for all regression slopes. BW = body weight (g), TL= total length (mm), DCL = dorsal cephalothorax length (mm), CH = cephalothorax height (mm), TsL = telson length (mm), DRL = dorsal rostral length (mm), AL = abdomen length (mm), UL = uropod length (mm).

Table 4. Relationships between morphological features of *M. macrobrachion* from Onkuiwe location, Mono River – Coastal lagoon system, South-Benin. Morphological measurements are log10 transformed data. Number of specimens = 261.

Regression factors	Slope (a)	Intercept (b)	Coefficient of correlation (r)	Coefficient of determination(r^2)
TL – BW	2.706	-4.257	0.85	0.73
TL – DCL	0.963	-0.299	0.94	0.88
TL – CH	1.392	-1.500	0.76	0.58
TL – TsL	0.541*	0.054	0.45	0.21
TL – DRL	0.881	-0.241	0.72	0.51
TL – AL	1.057	-0.502	0.94	0.89
TL – UL	0.949*	-0.681	0.58	0.34

*Values of males and females indiscriminately. P<0.01 for all regression slopes except for the regressions TL – TsL and TL – UL.

undergoes several major ecological threats which greatly affect biodiversity and particularly the freshwater prawn. These are (1) the construction of a hydro electrical dam ("Nangbeto") on the Mono River to provide electrical power for Benin and Togo, (2) the construction of three (3) bridges on the Mono River and its Sazue' tributary at the "Onkuiwe" village, (3) the massive destruction of the coastal mangrove, (4) the invasion of floating plants, mainly the water hyacinth, *Eichhornia crassipes*, (5) the construction of a public market at "Onkuiwe" village, at the fringe of the Mono River with a daily dumping of domestic wastes, and (6) the overexploitation of fish and shrimps resources caused by grassroots poverty, the increasing fishermen population and the use of various detrimental fishing gears.

DISCUSSION

M. macrobrachion is one of the large freshwater prawns that occurs abundantly in the Mono River – Coastal Lagoon system of Southern Benin and made numerically 51% of the six *Macrobrachium* species recorded in this ecosystem where it contributed to a sustainable commercial fisheries (Agadjihouèdé, 2006; Adite and Gbaguidi, 2012). The present study gives insight on the morphological and meristic characterization in order to depict whether the population of this species in the Mono River – Coastal Lagoon system is taxonomically separable. Morphological features such as the body total length, cephalothorax length and height, telson length, rostral length, eye diameter, uropod length, abdomen length and appropriated derived body ratios were used by many authors (Jimoh et al., 2005; Powell, 1982; Jimoh et al., 2012; Holthius, 1980; Naiyanetr, 2001) to describe or characterize some *Macrobrachium* species. Also, examination of taxonomical traits such as the number of spines on the dorsal rostrum and on the ventral rostrum was utilized to characterize and differentiate different species belonging to the genus *Macrobrachium* (Powell,

1980, 1985; Bello-Olusoji et al., 2004; Murphy and Austin, 2005).

The results of the present study indicated that the morphometric measurements among the population of *M. macrobrachion* from the two locations, Heve and Onkuiwe did show some variations. But, these variations were not significantly different (*P≥0.05*), suggesting that the two sub-populations of *M. macrobrachion* exhibited similar morphological features.

Computed body ratios indicated that the prawn was twice as long as its cepholothorax and twice as long as its abdomen. Also, the cephalothorax was as long as the dorsal rostrum and twice as long as its height. Proportionally total length measurements were 4.9-8.69 times the uropod length and 5.17-9.45 times the telson length. The cephalothorax lengths were 6-8.83 times the eye diameter. Morphometric measurements (cephalo-thorax length, cephalothorax height, rostrum length etc.) when expressed as the ratio of the total body length or cephalothorax length are very useful tool in the identification of shrimp's species (Jimoh et al., 2005, 2012). As reported by Anetekhai (1997), similar ratios of such body measurements from two sub-populations are, in general, recorded in the same species (Anetekhai, 1997).

Among meristic characters, rostrum, and particularly rostral spines, is one of the main useful taxonomic characters that diagnose prawns species (Naiyanetr, 2001; Murphy and Austin, 2005). At the two locations, Heve and Onkuiwe, *M. macrobrachion* had more spines (12-15) on the dorsal side of the rostrum than on the ventral side (3-5) (Table 1). Similar observations were made by Anetekhai (1997) for *M. macrobrachion* in the Badagry creek of the Southern Nigeria. Dorsally, at Heve, prawns specimens with 12, 13, 14 and 15 spines accounted for 12, 20, 36 and 32%, respectively. Similar trends were observed for Onkuiwe where prawns specimens with 12, 13, 14 and 15 spines accounted for 16, 18, 32 and 34%, respectively. At the Heve location, shrimps specimens with 3, 4 and 5 rostral spines at the ventral face accounted for 20, 52 and 28%, respectively. At Onkuiwe, shrimps specimens with 3, 4 and 5 rostral spines at the ventral face accounted for 24, 50 and 26%, respectively. Dorsally, at the two locations, 14-15 spines occurred the most and accounted for 68 and 66% for Heve and Onkuiwe, respectively, while on the ventral side, 4 spines occurred the most and had the highest frequency occurrence of 52 and 50%, respectively, for Heve and Onkuiwe. These results did show that the rostral spines from the two locations were not significantly different (*P≥0.05*), indicating that the two sub-populations of *M. macrobrachion* exhibited similar meristic features, suggesting that the populations of *M. macrobrachion* from the two locations of the Mono River – Coastal Lagoon system were taxonomically inseparable (Lawson, 2010).

Overall, one-way analysis of variance failed to show any significant variations (*P≥0.05*) for meristic counts among the population of *M. macrobrachion* from the two locations, suggesting that the population of this species in the Mono River – Coastal Lagoon system is taxonomically inseparable (Lawson, 2010).

In both locations, the total length-body weight relationships (Log_{10} W - Log_{10} L) gave some positive slopes "b"<3 (2.80 and 2.71). This result suggests that *M. macrobrachion* exhibited an allometric growth in both locations of the Mono River – Coastal Lagoon system (Tesch, 1971; Prasad, 2001; Enin 1994, 1995). The same trends of positive allometric growth were reported for *M. macrobrachion* from Badagry Creek with a "b" value of 2.58. Anetekhai (1997) and Jimoh et al. (2005) recorded higher b value of 5.8 and 6.32 for *M. vollenhovenii,* respectively, from Asejire Lake and Ologe Lagoon suggesting that *M. vollenhovenii* exhibited a higher condition as compared to *M. macrobrachion*.

The relatively low correlation coefficients, r = 0.45 and r = 0.58 recorded respectively for the TL-TsL and TL-UL regression equations at "Onkuiwe", may be attributed to the combined effects of multiple degradation sources affecting the growth, as compared to "Heve" location. It was also the case of the length – weight regression equations with r = 0.88 ("Heve") and r = 0.85 ("Onkuiwe"), though significant, seemed to slightly deviated from what was commonly reported (nearly r = 0.95), probably because of the stochastic, stressful and poor habitat conditions (Deekae and Abowei, 2010). In Nigeria, Lawal-Are and Owolabi (2012) reported similar trends of lower r = 0.78 and r = 0.71, respectively, for the polluted lagoons of Lagos and Lekki."

As a result, the morphometric measurements, body proportions (ratios) and meristic counts of *M. macrobrachion* from the two locations in the Mono River - Coastal Lagoon water system of Benin did show that the prawn was morphologically and taxonomically inse-parable. The populations among the two locations though showed variations in their morphometric measure-ments, body proportions (ratio) and meristic counts but these did not differ significantly (*P≥0.05*), indicating that the populations may not be genetically diversified. These insignificant variations may be due to habitat and environment, geographic variation and human activities in the study sites (Lawson, 2010; Gbaguidi, 2012).

With the multiple degradations occurring in the first location ("Onkuiwe") as compared to the second location ("Heve"), we should expect depicting morphological differences in *M. macrobrachion* from the two locations. This was not the case. Probably, three combined major causes could have lead to this morphological similarity, (1) the relative proximity (11 km apart) of the two locations, (2) in evolutionary ecology view point, the relative short periods that have lasted the degradations (Smith, 1992; Coyne and Orr, 2004). For example, the three bridges were constructed respectively in 1954 (59 years), 1986 (27 years), 1987 (26 years), the hydro electrical dam in 1987 (26 years), the floating plant inva-

sions in 1975 (38 years), the construction of the market in 1992 (21 years), and (3) a probable degree of rusticity and deve-lopmental/physiological adaptations in *M. macrobrachion*, could have acted to make the species less sensitive to the degradations (Moyle and Check, 1988) and consequently, successful biological functions such as reproduction continued to assure gene flow. For example, the strong hypo-osmoregulatory capacity of the early developmental stages due to ion transport along the inner side of the branchiostegite, the efficient hyper-osmore-gulation in late developmental stages due to the presence of fully functional gills (Boudour-Boucheker, 2013) and the relatively high tolerance of anoxic environment (up to 1mg/l of O_2) (FAO, 1987), are adaptive traits that confirm the relative rusticity of *M. macrobrachion* and probably, help the prawn to cope with the variability of the degraded coastal environment.

In the present study, no taxonomic variations were detected among the populations suggesting that *M. macrobrachion* may probably be the only (unique) species in the Mono River - Coastal Lagoon water system of Benin. However, considering the extent of the Mono river (527 km-length) and that of the coastal zone (130 km), further studies on morphological characterization, diversity and community structures of shrimps should be implemented and must consider samples from downstream, upstream, dam-generated lakes and others sensitive locations of the coastal zone. Also, molecular analysis should be considered because it will provide more precise results on genetic diversification (Lawson, 2010; Hurtado et al., 2013) among the population of *M. macrobrachion* of the coastal zone of Benin.

Management implications and conclusions

The present study provides valuable information and insight on the morphological and meristic characterization of the population of *M. macrobrachion* in the Mono River – Coastal Lagoon system. The species exhibited an allometric growth in the two locations. Also, the research revealed that the population is morphologically and taxonomically inseparable indicating that *M. macrobrachion* may probably be a unique species in this ecosystem. For species conservation and management purpose, the output generated from this study will form documentation for this prawn and may serve as reference for follow-up pending any further modification in the ecosystem.

Also, with regard to current multiple degradations occurring at the prawn habitat, urgent compensatory actions for species conservation targeted to habitat protection are required and must include (1) an extensive ecological, biological, and species morphological characterization studies, encompassing the sensitive sites (downstream, upstream, dam-generated lakes, others sites of the lagoon), should be implemented to species conservation program, (2) supporting and developing the aquaculture of the commercial and large freshwater prawns (e.g., *M. vollenhovenni, M. macrobrachion*) and that of the mangrove oyster, *Crassostrea* sp., to increase grassroots revenue and to reduce fishing pressure, (3) intensifying mangrove restoration (planting) program in a participatory approach with grassroots.

Moreover, the mangrove forest should be classified as protected area, (4) strengthening and re-enforcing fishery regulation, to prevent the use of detrimental fishing gears, overfishing and to protect reproduction and nursery grounds of the freshwater prawns, (5) developing ecological sound ecotourism involving grassroots to reduce pressure on fish and shrimp resources, (6) developing an integrated environmental education program and (7) developing an environment monitoring program as follow-up, to periodically assess the ecological “health” of *M. Macrobrachion* (habitat condition, population structure, status, degradation etc).

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