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Population structure, fecundity and morphological characteristics of *M. vollenhovenii* (Herklots, 1857) on lower volta river basin channel, Ghana

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Abstract

Population structure, fecundity and morphological characteristics of *M. vollenhovenii* were studied around Lower Volta River, Ghana subject to dirt of information on this prawn species around the study location. The most prominent morphological characteristics already documented for identification of this species was rostrum bearing 13-15 continuous teeth dorsally and 4-5 teeth on its ventral part. These morphological traits formed the principal components for identification in this study. Results showed that morphological traits on second pereiopods such as presence of spines, spinules, teeth borne within the fingers, and dense projections of setae-like features on telson and uropod were observed relevant for identification purposes. Other results revealed that maximum total length recorded in this study (150-155mm) was higher than total length ranges (≤125mm) documented for this species in earlier studies. Consequently, two adult's classes of prawns were identified (old adult class 81-120mm; and young adults 31-80mm) and older class was observed to be more in catches than the younger prawns. Absolute fecundity revealed that oocytes estimation varied with respect to seasons, ages of prawns and body sizes of specimens examined. In conclusion, this study observed that *M. vollenhovenii* fishery is operating in a sustainable manner at the time of this study around the study location.

Keywords: *Lower Volta River, M. vollenhovenii, Population structures, Absolute fecundity, Morphometric Characters*

1. Introduction

Volta River is the main water sourse in Ghana that drains directly into the Gulf of Guinea. It support prawn fisheries and diversities of other shell and fin fishes (FAO-AQUASTAT, 2005). Eniade et al. *(*2018) observed that some parts of lower Volta River are indeed sanctuaries for exclusively fresh water populations

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of *M. vollenhovenii.* This population reproduces and completes their entire life cycle within freshwater ecosystem and this adaptive quality makes the stock potent and easy for captive rearing. In West Africa, fresh water prawn aquaculture is non-existent. However, it has been considerably developed into commercial farming operations in Europe, Asia and America. The social and economic derivatives reported from fresh water prawn aquaculture in these afore-mentioned regions are products of huge investment priority into research and development activities on this organism over the years. Rutherford (1971) expressed concern about the availability and depth of scientific information on freshwater prawns during his taxonomic exploration of specimens collected in the area of Cape Coast, Ghana and advocated a more rigorous research approach on this organism. Lawal-Are and Owolabi (2012) also reiterated that the inadequacy of applicable scientific knowledge serves as major bane for successful culture of Macrobrachium species across their distribution hot spots in West Africa and suggested a more rigorous research approach with respect to their biology and hatchery propagation of seeds**.** Consequently, this study is designed to explore some aspects of biology which revolved around population structures, fecundity and morphometric characteristics of specimens of *M. vollenhovenii* on designated sections of Lower Volta River, Ghana. This is expected to enhance the volume and quality of scientific information available on this species and enhance knowledge on the status of fresh water prawn fisheries within this study location.

2. Materials and Methods

2.1. Description of Study Location

The study location is a section of lower Volta River, around the Eastern Region of Ghana. The study sections of the river have average elevations of 84 m above sea level. The water course is bounded by hills on both sides with dense vegetation of emergent trees growing around the hills. The river surface is partly covered by *Eichhornia crassippes* and other species of macrophytes with the river substratum basically sandy and having rocky intrusions. This river, the main water course in Ghana, drains directly into the Gulf of Guinea (FAO-AQUASTAT, 2005). Specimen collection activities were carried out around Kotokukope section of Lake Volta ($6^0$17’37.53’’N $0^0$3’43.20’’E), Atimpoku section of Volta River ($6^0$13’36.91’’N $0^0$5’30.56’’E) and Akuse Dam section of Volta River ($6^0$6’57.50’’N 008’0.13’’E).

2.2. Specimen Collection and Identification

Three hundred and fifty two (352) specimens of *M. vollenhovenii* were collected from designated sections of Lower Volta River with the assistance of fishermen fishing around this location between May, 2015 and April, 2017. Prawn basket traps used for sampling were usually set on river substratum beneath the water macrophytes, tied to stakes and left for minimum of about 72 hours or more before being hulled up to collect / harvest the catches. Collected specimens were transported life to ARDEC Laboratory (Aquaculture Research and Development Centre), a unit under Water Research Institute, located at Akosombo, where the specimens were identified to species level using the descriptions of Rutherford (1971) and Powell (1982). Specimens were preserved in labeled sample bottles containing 10% formaldehyde solution for other morphological and fecundity analysis which was done at the Department of Animal and Environmental Biology (Fisheries and Aquaculture Research Laboratory), Adekunle Ajasin University, Akungba-Akoko, Ondo State, Nigeria.

2.3. Morphological and Morphometric Characterization

Morphological characters were classified into non-parametric and parametric features according to Jimoh et al. (2012). Non- parametric features such as body coloration, egg coloration, shape of rostrum, dorsal and ventral spine counts on rostrum and number of abdominal somites were examined under a Vista vision stereoscopic microscope (Model number 0608340) and results obtained were presented in Table and pictorial (Jpeg) format.

Parametric features such as:

- Total length (from tip of rostrum to the tip of telson) was measured to sensitivity of 1 mm using a Mitutoyo A Digital vernier caliper;
- Standard length (from tip of rostrum to the tip of 6^{th} abdominal somite);
- Carapace length (from eye socket to mid dorsal margin of carapace); and
- Rostral length (from the tip to posterior margin of the orbit) were measured to the nearest 1 mm using vernier caliper.

Also, the body weight was measured to the nearest 0.01 g with a top loading Mettler balance (Sartorius Model E12000). Data obtained from measurements of lengths (TL, SL CL, and RL) and weight were transformed to their natural logarithm equivalents before used to model growth patterns subject to various X ; Y regression relationships as expressed below: Relationships between;

- Total length-Body weight (TL-to-BW);
- Standard length- Body weight (SL-to-BW);
- Total length- Carapace length (TL-to-CL); and
- Total length-Rostral length (TL-RL); were obtained based on sex groupings.

Non-linear regression graphs were obtained using Microsoft Excel (2010) software package to establish values of constants (*a*), (*b*), (*r*) and (R^2) from corresponding regression equation;

$$W = a L^b$$

$$\text{Ln } W = \text{Ln } a + b \text{ Ln } L$$

where W = the weight of the prawn in grams;

L = the standard length of the prawn in millimeters.

The pattern of growth was therefore deduced from the value of slope (*b*) from the regression graph and the corresponding values of (*a*), (*b*), (*r*), and (R^2) were presented in table format.

2.4. Determination of Population Structure

Population structure of *M. vollenhovenii* collected from designated study sections of Lower Volta River, Ghana was studied by examining the population total length-frequency distributions. The total length (TL) is the metric measurement (millimeter or centimeter standard international unit) of a prawn specimen from tip of rostrum to the tip of telson using venire caliper. These total length-frequency distributions was then used to separate specimens collected into different age groups according to previous works of Rutherford (1971); Powel (1982); Marioghae (1982); Edokpayi (1989); and Abohweyere (2008), where;

a. Prawn of size range of 10-30 mm is classified as juveniles;
b. Prawn of size range of 31-80 mm is classified as young adults; and
c. Prawn of size range of 81-120 mm is classified as old adults.

Also, length-frequency distribution graphs were obtained to establish size and age structures based on sex delineation using Microsoft excel (2010) software package.

2.5. Determination of Absolute Fecundity

Absolute fecundity of specimens collected in this study was evaluated by gravimetric method. The eggs were carefully removed from the ovarian tissues and put inside labelled specimen bottles. The specimen bottles containing the eggs were corked and then chilled in a refrigerator for an hour. These were transferred into a freeze-dryer machine (Labfreez with model number FD-12-MR) operated at a temperature of -45^0C for 2 hours. The samples were then exposed to dry air in the specimen bottle for 24 hours. The total weight of eggs in each specimen bottles was obtained using a Mettler weighing balance (Sartorius Model Number E12000). Random sampling of about 500 eggs were done for samples in each specimen bottle and weighed. The total numbers of eggs in the ovaries were then evaluated with the equation;

$$F = nG/g$$

where F = Absolute fecundity, n = Number of eggs in the subsample, G = Total weight of the ovaries, g = Weight of the subsample.

Absolute fecundity was then obtained for two age classes of berried females identified at both rainy and dry seasons throughout the study period.

3. Results

Strong rostrum with dorsal part lacking prolonged toothless portion remained the easiest morphological character for identification of *M. vollenhovenii* during field collection (Table 1 and Plate 1). Also, non-parametric traits on second pereiopods such as presence of spines, spinules and teeth borne within the fingers are evident and useful for identification purposes (Table 2 and Plate 2). Presence of pubescence (setae-like projections) on telson and uropod were observed (Plate 3). Results on the population size structure derived from length-frequency distribution graphs (Figure 1) revealed that 3% of the female population grows to attain maximum total length (TL) range of 140-150 mm. However, about 7% of the male population grow to this same maximum size ranges. Consequently, the size range with the highest frequency of occurrence within this population for the two years of study was the 90mm class for both males and females. Male population (21%) within this size class (90 mm class) outnumbered the females (18%). Also, the age classification method adopted in this study revealed that adults sizes of *M. vollenhovenii* belong to two age classes (Young Adults = 31-80 mm and Old Adults = 81 $\geq$ 120 mm). Post larvae or juvenile prawns (0-30 mm size) were excluded in all the catches. Old adult population outnumbered the young adult in all the catches (Figure 2). Other results from computation of growth patterns for this population of *M. vollehovenii* returned positive regression co-efficient values (+ve *r*-values) for various combinations of X: Y regression of natural logarithmic values of TL:BW, SL:BW, TL:CL and TL:RL. The slope (*b*-values) for TL: BW regression for males and females equals 3.01 and 2.23 respectively, while *b*-values for SL:BW equals 2.93 and 2.14. Tables 3 to 6 revealed various X: Y regression relationships for the population of *M. vollenhovenii* in this study. Results on fecundity estimations obtained based on seasonality and ages of prawns revealed that absolute fecundity of young adults varied between 2,908 to 2,900 in the span of rainy and dry seasons while it varied between 12,162 to 9,831 for old adults in the span of rainy and dry seasons.

Table 1: Indices for identification of *M. vollenhovenii* on studied sections of lower volta river

Species nomenclature	Author and description year	Sampling stations for this study	F.A.O name or synonyms at sampling station	Major diagnostic descriptions used	References and catalogue codes
***M. vollenhovenii* (Exist as a solitary population at designated upstream and midstream segmen of the Volta River but exist in mixed population with *Atya gaboniensis* at the downstream segmeent**	Herklots, 1857	Kotoku section (ARDEC STATION - Upstream Volta River Ghana);Atimpoku section (Midstream Volta River Ghana); Akuse Dam site section (Downstream Volta River, Ghana)	African River PrawnNATIVE NAME: Ebor	Male: Rostrum convex with tip lacking prolonged toothless portion. Fingers of 2nd Cheliped dark blue with yellow patch at articulation with palm.Female: Rostrum same as in male. Eggs red or orange in colourBody colour:Number of Abdominal Somites: six (6)	Holthuis, 1980 (Pg. 106-107); Powell, 1982 (Pg. 270) ;Rutherford, 1971(Pg.87-91)Code: PALAEM Macro 49

Table 2: Non-parametric traits indicators used in morphological characterization of *M. vollenhovenii* on the studied sections of lower volta river

Specimen	Sex	Sampling locations	Anatomical features on 2nd pereiopod and other body parts							Palm, merus and carpus
			Type of finger			Presence of non-parametric traits on (spnls and pub) some body parts				
			FF	CF	GF	C	P	CH	TEL	
M. vollenhovenii	M	Volta River Basin Channel, Ghana	×	×	√	×	√	√	√	Short
	F		×	×	√	×	√	√	√	

Note: F.F = Fixed Finger, C.F = Close Finger, G.F = Gaping Finger; SPNLS = Spinules, PUB = Pubescence, C = Carapace, P = Pereiopods; CH = Chela, TEL = Telson; X = Absent, √ = Present.

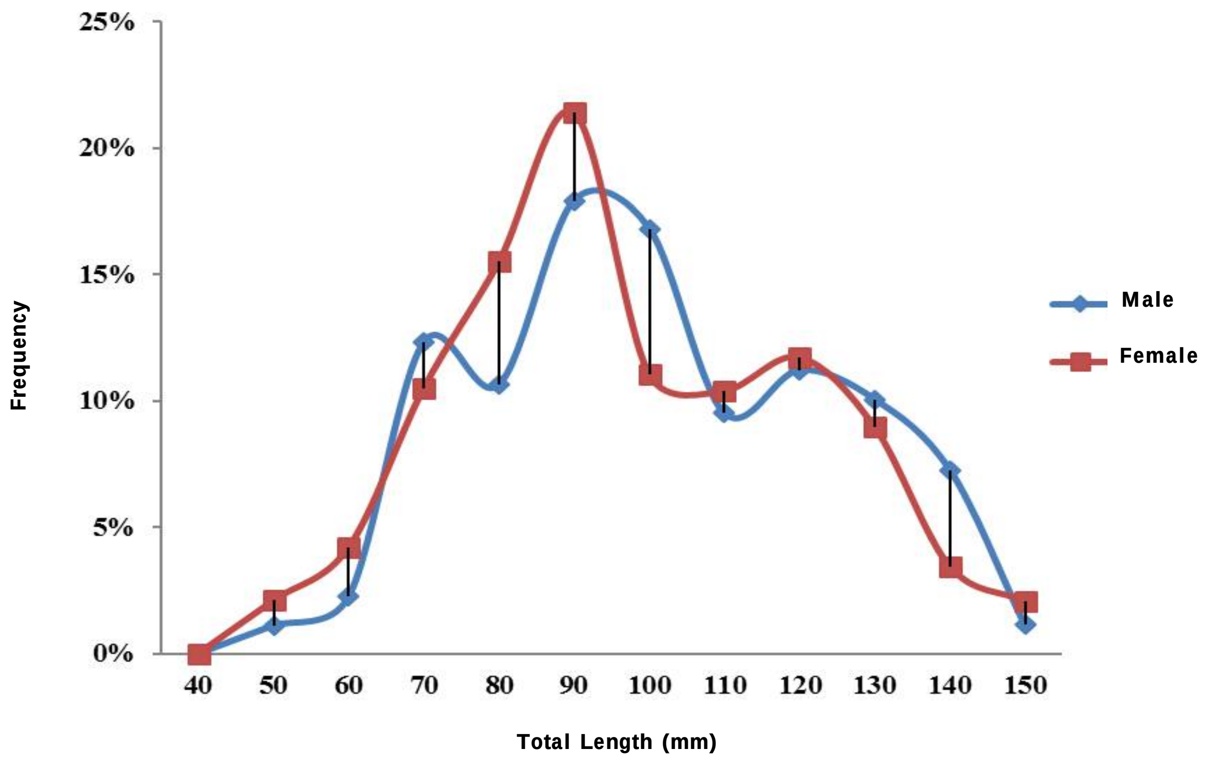

Figure 1: Length frequency distribution and size structure of population of *M. vollenhovenii* collected from Lower Volta River basin channel, Ghana over a period of two years

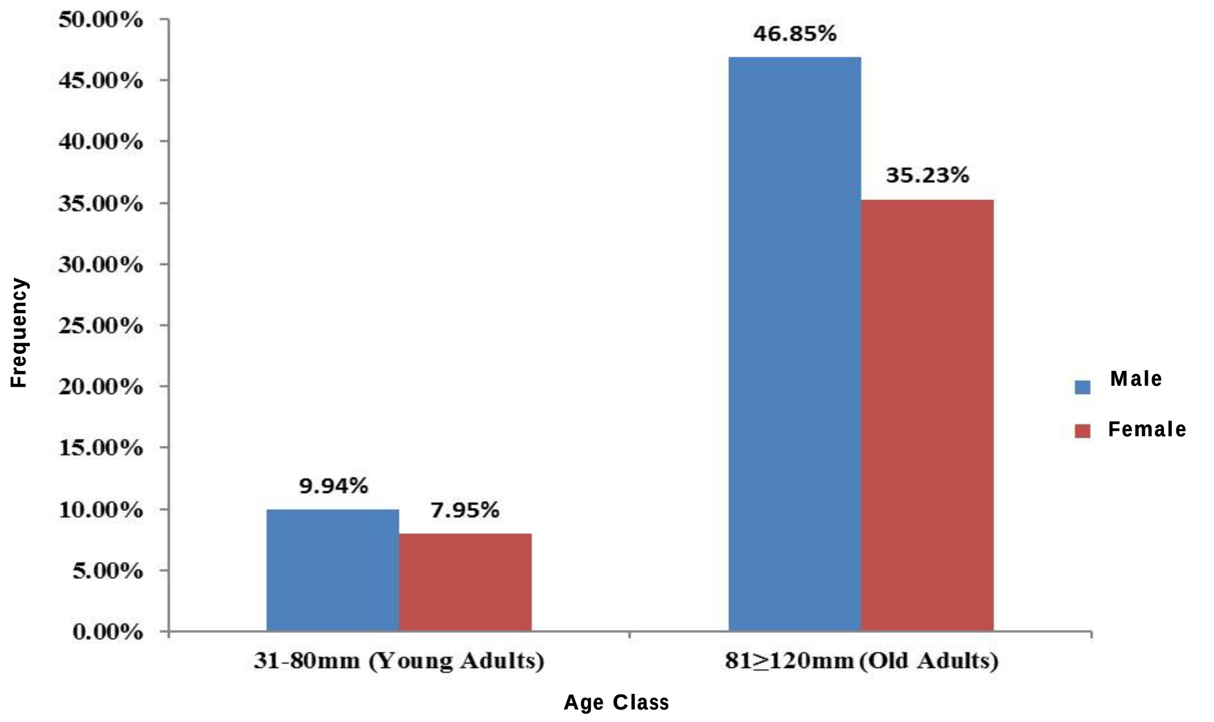

Figure 2: Age class structure of population of *M. vollenhovenii* collected from volta river basin channel, Ghana

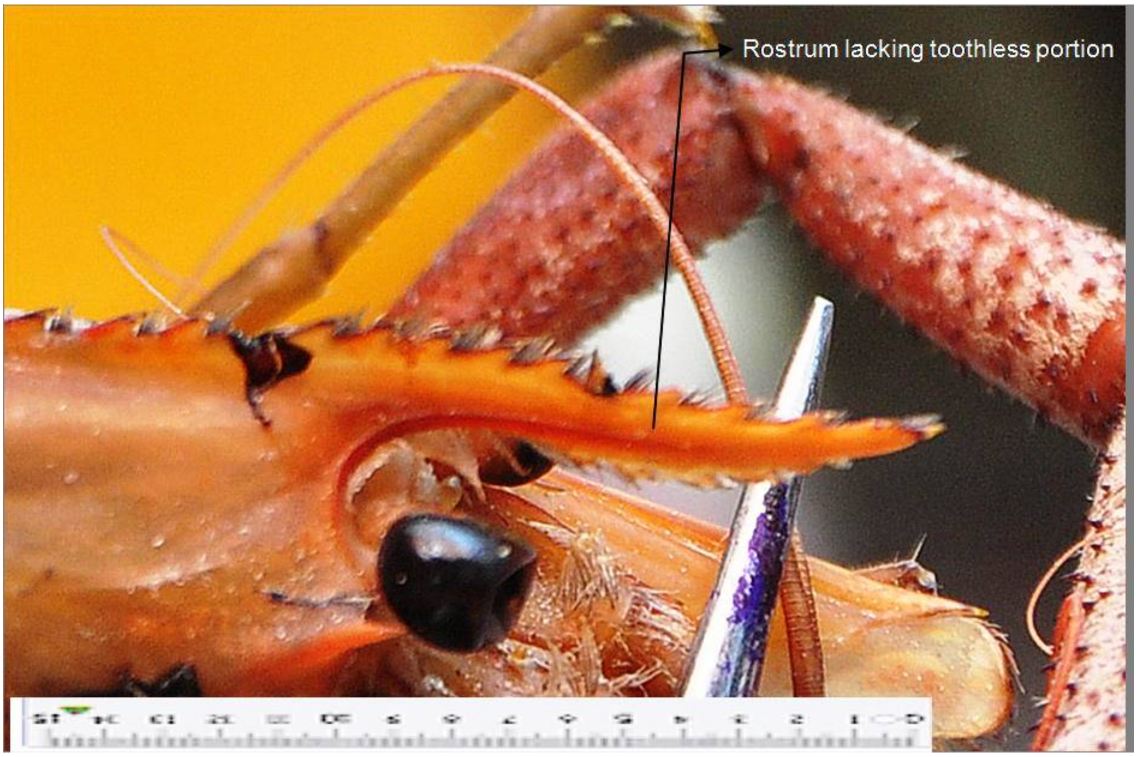

Plate 1: Specimen of *M. vollenhovenii* collected from Volta River Basin Channel, Ghana with rostrum lacking toothless portion – Magnification: X3

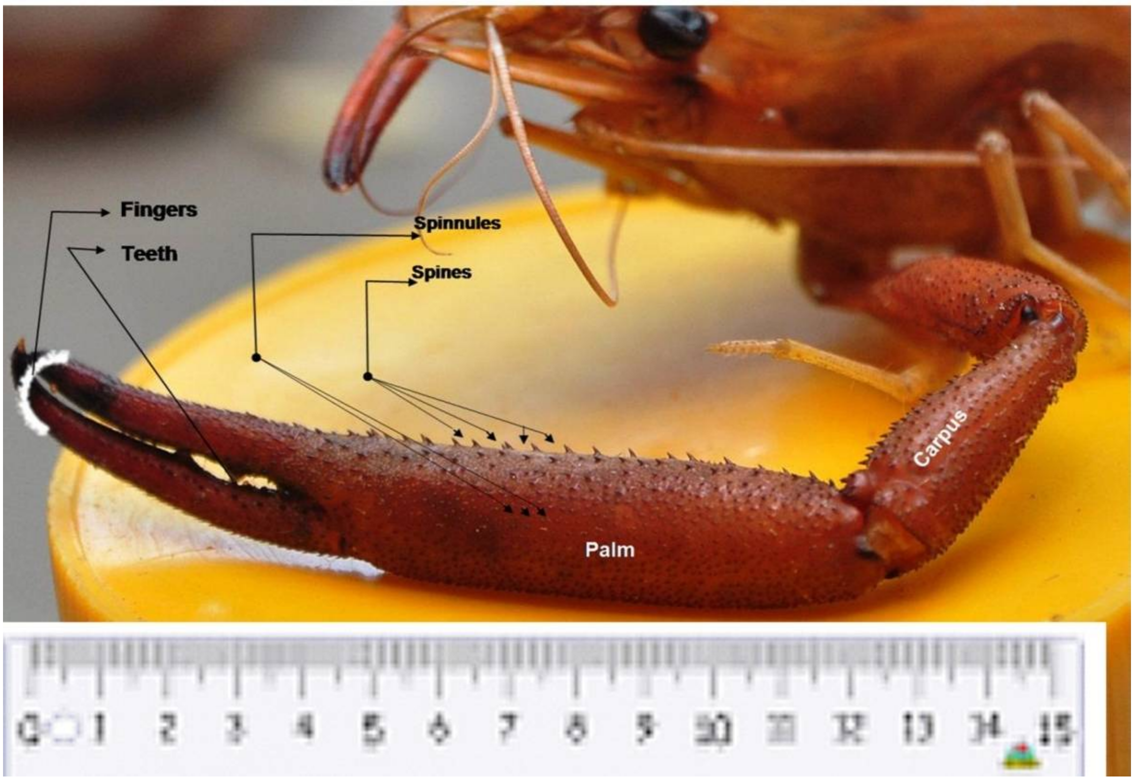

Plate 2: Left chelae of *M. vollenhovenii* showing teeth on the inner part of the finger, presence of spines and spinules on the palm, carpus and merus – Magnification: X3.1

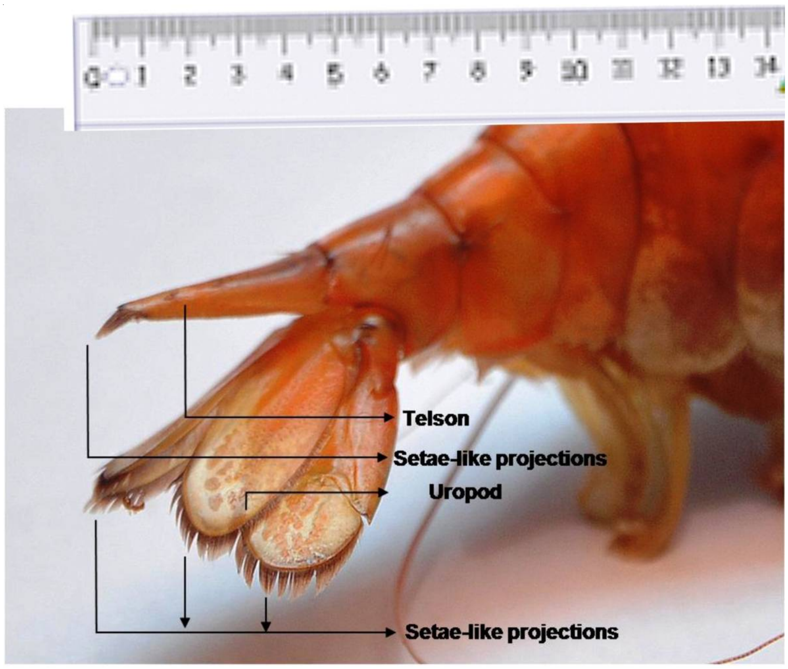

Plate 3: *M. vollenhovenii* with setae-like projections on telson and uropods – Magnification: X2.4

Table 3: Morphometric relationship of *M. vollenhovenii* collected from studied sections of Lower Volta River, Ghana using total length and body weight as regression factors

X : Y regression factors	Growth indices	*M. vollenhovenii* (Volta River Basin specimen, Ghana)	
		M	F
(Ln) of TL:BW	*a*	–11.01	–7.57
	b	3.01	2.23
	r	0.84	0.69
	R^2	0.70	0.47

Note: Regression Equation = Ln *W* = Ln *a* + *b* Ln *L* Where: *W*= weight (g); *L*= Length (mm); *a* = intercept, *b* = slope; *r* = co-efficient of regression and R^2 = co-efficient of determination; Ln = Natural Logarithms; *M* = Males; F= Females

Table 4: Morphometric relationship of *M. vollenhovenii* collected from Lower Volta River, Ghana using standard length and body weight as regression factors

X : Y regression factors	Growth indices	*M. vollenhovenii* (Volta River Basin specimen, Ghana)	
		M	F
(Ln) of SL:BW	*a*	–10.18	–6.79
	b	2.93	2.14
	r	0.84	0.69
	R^2	0.70	0.48

Note: Regression Equation = Ln *W* = Ln *a* + *b* Ln *SL* Where: *W*= weight (g); SL= Standard Length (mm); *a*= intercept, *b*= slope; *r* = co-efficient of regression and R2= co-efficient of determination; Ln = Natural Logarithms; M= Males; F= Females.

Table 5: Morphometric relationship of *M. vollenhovenii* collected from Lower Volta River, Ghana using total length and carapace length as regression factors

X : Y regression factors	Growth indices	*M. vollenhovenii* (Volta River Basin specimen, Ghana)	
		M	F
(Ln) of TL:CL	*a*	–1.51	-1.82
	b	1.07	1.12
	r	0.85	0.97
	R^2	0.72	0.93

Note: Regression Equation = Ln *CL* = Ln *a* + *b* Ln *TL* Where: CL= Carapace Length (mm); TL = Total Length (mm); *a* = intercept, *b* = slope; *r* = co-efficient of regression and R^2= co-efficient of determination; Ln = Natural Logarithms; M = Males; F = Females

Table 6: Morphometric relationship of *M. vollenhovenii* collected from Lower Volta River, Ghana using total length and rostral length as regression factors

X : Y regression factors	Growth indices	*M. vollenhovenii* (Volta River Basin specimen, Ghana)	
		M	F
(Ln) of TL:RL	*a*	–0.95	–1.29
	b	0.90	0.97
	r	0.89	0.92
	R^2	0.79	0.85

Note: Regression Equation = Ln RL = Ln a + b Ln TL Where: RL= Rostral length (mm); TL= Total Length (mm); *a*= intercept, *b* = slope; *r* = co-efficient of regression and R^2= co-efficient of determination; Ln = Natural Logarithms; M = Males; F = Females

Table 7: Absolute fecundity estimation for *M. vollenhovenii* specimens collected from Studied Sections of Lower Volta River, Ghana based on their age class distribution and seasonality of sampling

Identified Specimen	Prawn Fecundity Estimation For Macrobrachium Prawn Specimens On Lower Volta River Basin Channel, Ghana			
	Dry SeasonsRainy Seasons			
	Young Adults	Old Adults	Young Adults	Old Adults
M. vollenhovenii (Ghana specimen)	2,900	9,831	2,908	12,162

Note: Young Adult = 31-80 mm; Old Adult = 81 ≥ 120 mm.

4. Discussion

Specimens of *M. vollenhovenii* collected at the designated study locations on Lover Volta River, Ghana were observed to be easily separable from other prawn species such as *Atya gaboniensis* found foraging in mixed population with them around Akuse Dam Section (Down Stream- $6^0$6'57.50''N 008'0.13''E), following the descriptions of earlier authors like Rutherford (1971), Holthuis (1980) and Powel (1982). Rutherford (1971) observed that the major morphological delineation between *M. vollenhovenii* and other prawn species collected from the area of Cape Coast, Ghana is the continuous pattern of spines arrangement on the dorsal part of rostrum lacking toothless portion and that the number of spines on the dorsal and ventral part of rostrum ranged from 13-to-15 and 4-to-5 teeth in adult specimen (Plate 1). Other important morphological features used as field guide are the shortness of carpus and palm lengths. Rutherford's (1971) findings are the major field identification guidelines adopted in this study. Consequently, observations from this study project the importance of other non-parametric features such as the presence of spinules on the palm and dense pubescence on the telson and uropod as useful characters in identification of *M. vollenhovenii*. These traits had not been recognized in the past as major distinguishing characters (Plates 2 and 3). However, these might appear useful as additional evidence for separation of clusters, especially in adult sizes. Computation for regression relationships from measurement of morphometric characters of specimens (Ln Y = Ln a + b Ln X) within this population returned positive regression co-efficient values (+ve r-values) and high values of co-efficient of determination (R^2-values) for various combinations of X:Y regression of natural logarithmic values of TL: BW, SL:BW, TL:CL and TL:RL (Tables 3 to 6). These positive r-values and high R^2-values recorded for the above listed regression models suggest very strong association and fitness between the factors of each model. The slope (b-values) for TL: BW regression for male and female populations of *M. vollenhovenii* equals 3.01 and 2.23 which connote an isometric growth in male (b=3) and a negative allometric growth pattern in female (b< 3). Wootton (1992) explained that an isometric growth pattern is recorded when the weight of fish or invertebrate increases without affecting its body shape (b=3) and that an allometric growth is recorded when fish changes shape as it grows larger. Allometric growth patterns can either be negative (b<3) or positive (b>3). Negative allometric growth occurs when fishes get thinner as they grow and positive allometric growth occurs when fishes get plumber as they grow larger. The total lengths recorded in this study were observed to range between 55 and 55 mm. This inferred that the population under study recorded bigger specimens than observed by Rutherford (1971). It is thus important to mention that Rutherford (1971) recorded a maximum TL of 125 mm for *M. vollenhovenii* in the area of Cape Coast, Ghana. However, this study affirms a record of maximum TL range of between 150 and 155 mm which is a strong indication that there has been lesser fishing pressure and mortality around the study location. In actual sense, this population represents specimens collected within the period of two years. Prawn population within a generation time of a year belongs to one year class. Garcia (1985) explained that a generation time of a prawn is one year. He pointed at the fact that the seasonal reproductive patterns for most populations are usually bi-modal (i.e., when a prawn population is born in the spring, the population will reach its first minor reproductive age in autumn at about 6-7months and will also be able to do another massive but terminal age reproduction at about 1 year during another spring season). So, when a prawn escapes fishing mortality and other anthropogenic and natural sources of death within the first year of life, it will automatically enters into the two years age class with the likelihood of attaining its maximum growth limit. Further observations on size structure of this population showed that 90 mm size class of prawns (Old Adults) was observed to have the highest frequency of occurrence in catches for male and female specimens (Figure 2). The implication is that fishing method and activities around this location showed positive example for fisheries management since the old adults are the most susceptible age class giving room for sustainability of the fishery for as long as young adult class is not under fishing pressure or overfished. Also, catch statistics within this population revealed higher population of males over the females among the two age classes identified. This is unlike in other reported scientific phenomena where females naturally outnumbered the males (Deekae and Abowei, 2010; Jimoh et al., 2012; Oben et al., 2015; and Boguhe et al., 2016). The dynamics experienced within this population in term of male to female percentage ratios might not be out of place because, with pre-mating ecydysis, from young adults class, more females undergoing pre-nuptial molts become prone to attack from rivals or fishing mortality which may gradually impair female population as they grow older (D'Abramo and Brunson, 1996). Absolute fecundity results for this population showed higher values for old adults than young adults and also revealed variations between seasons with comparably higher values for rainy seasons (Table 7). This result connotes that fecundity of a young adult prawn is limited by its body size (Ovie, 1986; and Ang and Law, 1991) and that most berried young adults are likely just reaching their first or minor reproductive phase (Garcia, 1985); and so cannot carry as much eggs as old adults. Also, Marioghae and Ayinla (1995) observed that fecundity and breeding in Macrobrachium species are not strictly seasonal and are not confined to rainy season. Ville (1970) reported fecundity range of 300-1000 eggs for *M. vollenhovenii,* while Marioghae (1987) reported a range of 3,000 to 12,000 oocytes. Using the above results as a benchmark, it is evident that the population of *M. vollenhovenii* foraging around the studied sections of Lower Volta River is operating on a sustainable manner and has the quality of potent aquaculture species.

5. Conclusion

This study revealed that exploitation of *M. vollenhovenii* around the Lower Volta River, Ghana is operating on a sustainable trend at the time of this study. Results also showed that this population exhibits good morphological trait in terms of attainable maximum growth limit (maximum body size); a trait that is most desirable for potential aquaculture species. Therefore, this population is recommended as seeds for trial domestication.

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Conflicts of Interest

The authors confirm that this article content has no conflicts of interest.

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