RACIAL STUDY AND CHELIPED FLUCTUATING ASYMMETRY OF BLUE CRABS FROM OLIGOHALINE AND MESOHALINE ESTUARIES OF NIGER DELTA, NIGERIA

[*1]UDOH, J.P. & [2] A.A. NLEWADIM

1. Department of Fisheries and Aquaculture, University of Uyo, P.M.B. 1017, Uyo - 520003, Nigeria
2. Department of Fisheries and Aquatic Resources Management, Michael Okpara University of Agriculture, Umudike, Nigeria

*Corresponding Author: jjamesphilip@gmail.com + 234- 802-3197-962.

ABSTRACT

A racial study of Callinectes amnicola was conducted in Imo and Qua Iboe River estuaries, Niger Delta, Nigeria, using morphometry, colour morphotype and cheliped characters to determine variations in its populations. Carapace lengths showed no significant population difference (t-Test, P > 0.05) while total weight and carapace width were greater (P < 0.05) in crabs of the Qua Iboe River estuary. Intersexual and interpopulation variations in body dimensions and condition factor of specimens were not significantly different (t-Test, P > 0.05). Asymmetry of palm depth was significantly different from zero (P < 0.05) reflecting developmental instability from endogenous genetic or exogenous factors resulting from graded distribution and differential growth during development, in favour of male right-handedness within the populations. Chela robustness, chela size and finger size had positive values and exhibited heterochely of 77 - 80% tendency towards right handedness. Three moult stages were encountered, with higher occurrence of green morphotypes (59 – 61%). Significant (P < 0.05) allometry of the carapace length in relation to total weight, carapace width, cheliped palm depth, palm length, finger length and gape was observed with negative correlation with cheliped finger length and fluctuating asymmetry. The exponent b indicated negative allometry in cheliped dimensions in males, females and combined (P < 0.05). The character which affords high discriminatory values between sexes was cheliped palm depth and hence, serves as a secondary sexual character. Interpopulation differences were phenotypic in nature and attributable to salinity differences; hence C. amnicola from Qua Iboe and Imo River estuaries are of the same stock and could be subjected to similar management and conservation regulations.

Keywords: Moulting, coastal marine habitats, freshwater rivers.

INTRODUCTION

Blue crabs, *Callinectes amnicola,* are demersal crab species. They are usually brown or grayish in color, which allows them to blend in with the muddy and sandy bottom of the inshore shallow estuaries. They exhibit different colour morphotypes/variations of the carapace in relation to environmental variation of their habitat (Mc Gaw and Naylor, 1992; Mc Gaw *et al.,* 1992). They are highly mobile, making it feasible for them to move between areas and to select habitats, from the lower reaches of freshwater rivers and estuaries to coastal marine waters (Micheli and Peterson, 1999; Ryer *et al*., 1997).

Earlier publications on this species in Nigeria deal with their taxonomy and distribution (Powell, 1983, 1985; Jonathan and Powell, 1989), nutritional composition (Fineman-Kalio, 1987; Alfred-Ockiya, 2000; Oduro *et al.,* 2001), ecology (Okafor, 1988; Lawal-Are and Kusemiju, 2000; Arimoro and Idoro, 2007), Akin-Oriola, *et al.,* 2005; Nlewadim *et al*., 2009), and food and feeding (Chinda *et al.,* 2000; Lawal-Are and Kusemiju, 2000; Arimoro and Idoro, 2007) and recently, racial study on the stocks of the Lagos lagoon, Nigeria by Lawal-Are (2009).

Racial studies are often conducted to investigate racial segregation in fish stocks using haemoglobin (Bayagbona, 1966) and protein electrophoresis (Anyanwu, 1993), as well as meristic (Lindsey, 1961; Ikusemiju, 1973) and morphometric characteristics (Goodman, 1973; Ikusemiju, 1975; Lawal-Are, 2009) for the purpose of conservation, genetic selection and management of species. This study employs morphometric characteristics and cheliped asymmetry for the same purpose and is part of a series to understand the ecophysiology and population biology of *Callinectes* species from the Niger Delta zone, Southeastern Nigeria. Its specific objective are to investigate interpopulation differences in *C. amnicola* using linear relationships of morphometric and cheliped characters particularly carapace length (CL)-palm depth (PD), carapace length-palm length (PL), carapace length-gape (G) and carapace length-total weight (TW) relationships; and to assess the characters which afford high discriminatory values between sexes and sampling sites; hence, estimate developmental stability by the degree of fluctuating asymmetry of bilateral traits, chelae handedness and colour morphotypes of the crab.

STUDY AREA

Sampling was carried out in the mesohaline swamps of Qua Iboe River (7°33′ W - 8 °20′ W; 4° 30′ - 5° 30′ N) and in the oligohaline swamps of Imo River estuary (6° 50′ E - 7° 25′ E; 4° 45’ - 7°

15' N), East of the Niger Delta, Nigeria (Fig. 1). The climate of the area is typically the equatorial hot-humid type with year-round precipitation. Two seasons are discernible: the dry season (November – March with a peak in January and the wet season (April to October). The area comprises tidal creeks, small brackish water lagoons and fringing mangrove swamps as detailed by Eyenihi *et al*. (1988) and Enplan Study Group (1974).

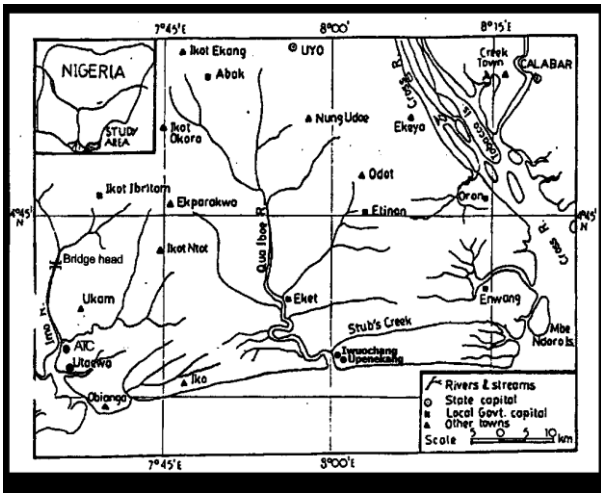

Fig. 1: The coastal zone of southeastern Nigeria showing sampling points (●) along the Imo and Qua Iboe River estuaries
(Inset: Map of Nigeria showing the study area; ATC represents
African Trading Company)

MATERIALS AND METHODS

Specimens of *Callinectes* species were collected bi-monthly for twelve months (June 2008 to May, 2009) from artisanal fishers at Upenekang and Iwouachang fish landing beaches (about 1.5 km apart) in Ibeno along the Qua Iboe River Estuary and at the African Trading Company (ATC) and Uta Ewa fishing settlements (about 3 km apart) along the Imo River estuary. Fishers used a combination of about 100 yd gill nets of 3.5 inches (10 cm) stretched mesh size and circular crab nets of 1.7 inches (6.2 cm) stretched mesh size. After collection, samples were preserved in 10% formalin. The sex, colour morphotype, development stage and moult stage were noted for each crab (Nlewadim *et al.*, 2009). Males were also classified as immature when the abdomen is sealed and firmly attached to the ventral surface of the shell, and as mature when the abdomen is free.

The crab carapace length with spines CL mm (from tip of frontal spine to margin of carapace) and carapace width with spine CW mm (from the tip of one lateral spine to the tip of the other) were measured to 0.1mm, using sliding jaw vernier calipers, and body total weights (TW) taken, after draining out excess water from the body, to 1.0 g using electronic balance. Cheliped morphometry such as the palm length (PL), palm depth (PD), finger length (FL) and gape (G) were measured to 1.0 mm using vernier calipers (Fig. 2). Heterochely or handedness (position of the major chelae) was observed in both sexes and both locations, and their percentage occurrence calculated.

Data analysis was performed using the Statistical Package for Social Scientists (SPSS) software. The mean, standard deviations and least square regression analysis (with carapace length after logarithm transformation) of each morphometric and meristic feature were determined and established for male, female and both sexes in both locations. The intersexual and interpopulation differences in cheliped morphometry were determined using the t-Test. The regression equation was of the form:

$$W = a + b\,L$$

where

W = log total weight in grammes

L = log carapace length (CL) or width (CW) in mm

a = constant

b = exponent of carapace width or length.

The use of regression analysis to explain relationships between various morphometric characters are found to be most suitable (Vijayakumar *et al.,* 2000). The exponents of the regression analysis *b* obtained were tested for departure from isometry using t –statistics as given in Sachs (1974):

$$t = \frac{[S\,x\,|b-3|\sqrt{n-2}]}{[S\,y\sqrt{1-r^2}]}$$

where S_x, S_y are standard deviations of CL or CW and TW, respectively; r^2 is the coefficient of determination of the relationship.

Palm length, palm depth and finger length are the standardized values of the major chela and can be used to define the shape aspects or secondary sexual characteristics. Consequently cheliped dimensions such as chela size, chela robustness and finger size were also calculated as follows (William *et al.,* 1980):

Chela size is represented by

$$(PL \times FL \times PD)^{\frac{1}{3}}$$

Chela robustness is represented by

$$PD/PL$$

Finger size is represented by

$$FL/(PL \times PD)^{\frac{1}{2}}$$

where, PL is the palm length, PD is the palm depth and FL is the finger length

Cheliped fluctuating asymmetry (FA) and Fulton's condition factor (K) of whole crabs were calculated as:

$$FA = \left[(|L - R|)\,100\right] \Big/ \left[\frac{(L+R)}{2}\right],$$

where, |L-R| is the absolute value of the difference in the left and right measurements and (L+R)/2 is the mean of these measurements (Palmer and Strobeck, 1986).

$$K = 100\,TW/CL^{a}$$

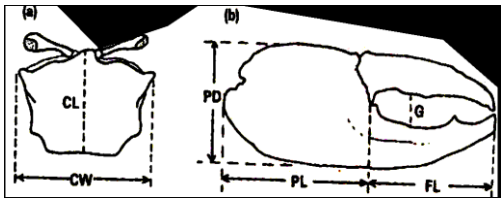

Fig. 2: Characters measured on (a) dorsal carapace, (b) major chela [see text for explanation]

RESULTS

Carapace length of *C. amnicola* from both rivers showed no significant difference (t-Test, P > 0.05). Total weight and carapace width were greater in *C. amnicola* from the Qua Iboe River estuary than those of the Imo River estuary (P < 0.05). The chela palm depth, palm length, finger length and gape of male and female *C. amnicola* from within and between both estuaries were not significantly different (t-Test, P > 0.05). Chela robustness, chela size and finger size had positive values, but no significant difference between both estuaries (t-Test, P > 0.05). Intersexual variations in body morphometry of specimens from both estuaries are listed in Tables 1 and 2.

Fluctuating asymmetry (FA) of the palm depth (chela diameter) was calculated and the mean asymmetry value was significantly different from zero (P < 0.05) in both estuaries, indicating FA within the populations. The variance of total counts (right + left) showed significant intersexual (Table 1) but no significant interpopulation differences (Table 2). The allometric values of FA were generally low and significantly different from zero (P < 0.05) in both estuaries (Table 3). *C. amnicola* exhibited heterochely with 77 to 80% tendency towards right handedness. The heterochely (with one chela larger than the other) was exhibited more in females than the males (Table 1). The condition factor (K) showed no significant difference (t-Test, P > 0.05) between males and females, within and between, both estuaries.

C. amnicola crabs of early pre-moult, inter moult and post moult were encountered during the survey. Only post-moult crabs exhibited significant differences in occurrence: 12.16% in the oligohaline Imo River estuary [at lower mean salinity of 0.53‰] compared to 8.21% occurrence in the mesohaline Qua Iboe River estuary [at a higher mean salinity of 17.4‰]. *C. amnicola* crabs encountered exhibited brown, olive green, olive brown and orange green colour morphotypes. The proportion of green crabs was 60.7% and 59.2% in the Qua Iboe and Imo River estuaries, respectively (Table 2; P > 0.05). However, the proportion of juvenile crabs was higher in the Imo (11.71%) than in the Qua Iboe River estuary (7.12%).

There was significant (P < 0.05) allometry of the carapace length in relation to total weight and carapace width and in relation to cheliped palm depth, palm length, finger length and gape. The regression analyses of body dimensions in relation to carapace length as the independent variable are shown in Table 3. Regression analyses showed a negative correlation between the carapace length in relation to cheliped finger length and fluctuating asymmetry. The exponent *b* was significantly lower than three in males, females and combined sexes, (p < 0.05), indicating negative allometry in morphometry.

Table 1: Intersexual variation in morphometric features of *Callinectes amnicola* in Qua Iboe and Imo River estuaries, Nigeria (mean ± standard deviation)

Variable	Qua Iboe River estuary			Imo River estuary		
	Male	Female	Both sexes	Male	Female	Both sexes
Carapace length (mm)	64.35 ± 7.45	61.09 ± 7.79	62.48 ± 7.81	60.27 ± 4.10	57.21 ± 3.57	58.83±2.78
Total weight (g)	156.65 ±51.86	104.83± 33.51	126.89 ± 49.45	127.54 ± 2.12	89.89 ± 1.20	109.85 ± 1.36
Carapace width (mm)	127.15 ±17.51	122.61± 17.25	124.5 ± 17.50	118.18 ± 8.55	115.67 ± 7.13	117.00 ± 5.65
Palm depth(mm)	25.4 ± 4.78	19.0 ± 2.65	22.9 ± 5.12	22.5 ± 4.94	18.7 ± 3.86	21.7 ± 4.96
Palm length(mm)	51.1 ± 55.35	33.1 ± 3.80	44.0 ± 44.01	39.9 ± 6.04	30.6 ± 4.81	38.0 ± 6.89
Finger length (mm)	32.9 ± 3.85	26.5 ± 3.08	30.4 ± 4.75	27.6 ± 5.35	24.7 ± 2.93	27.0 ± 5.07
Gape (mm)	7.1 ± 2.10	5.4 ± 154	6.4 ± 2.07	7.0 ± 3.16	6.4 ± 1.83	6.9 ± 2.94
Condition factor	64.82 ± 150.11	55.41 ± 20.82	61.46± 110.61	59.51 ± 22.25	43.67 ± 8.77	57.44 ± 8.78
Fluctuating Asymmetry	22.46 ± 14.16	37.76 ± 42.64	28.44 ± 29.56	25.85 ± 22.03	28.80 ± 13.09	26.45 ± 20.49

Table 2: Morphometric and meristic features of *C. amnicola* from Qua Iboe and Imo River estuaries, Nigeria

	Qua Iboe estuary	Imo River estuary
Total weight (g)	126.89 ± 49.45	109.85 ± 1.36
Carapace length (mm)	62.48 ± 7.81	58.83 ± 2.78
Carapace width (mm)	124.50 ± 17.50	117.00 ± 5.65
Right chela diameter (mm)	22.54 ± 5.20	20.94 ± 5.18
Left chela diameter (mm)	18.74 ± 5.16	18.53 ± 4.14
Chela robustness	0.58 ± 0.11	0.57 ± 0.10
Chela size	30.47 ± 6.83	7.93 ± 5.0
Finger size	1.02 ± 0.15	0.98 ± 0.30
Fluctuating Asymmetry	28.44 ± 29.55	26.45 ± 20.49
Heterochely		
% Crabs with bigger left chelae	20	23
% Crabs with bigger right chelae	80	77
% Crabs with one chela cut off	40	31
Sex Ratio	1:1.94	1: 0.89
%Early Pre-Moult	5.03	1.95
% Intermoult	86.76	85.89
% Post-Moult	8.21	12.16
% Immature	6.04	6.56
% Pre-Pubertal	0.00	5.07
% Pubertal	1.09	0.08
% Adult	92.37	88.29
% Juvenile	7.12	11.71
% Brown	0.08	0.23
% Olive Brown	39.15	40.45
% Olive Green	50.63	46.84
% Orange Green	10.14	12.47
Sample Number	1283	1193

Table 3: Regression analysis of morphometric characters of *Callinectes amnicola* based on the carapace length with spine (CL) as independent variable in Qua Iboe and Imo River estuaries, Nigeria

		Qua Iboe River estuary					Imo River estuary				
Variable	**Sex**	**a**	**b**	**r**	**r^2 (%)**	**t_b**	**a**	**b**	**r**	**r^2 (%)**	**t_b**
Total weight	♂	-6.600	3.17	0.872	75.69	2.02*	-5.83	2.840	0.749	56.102	4.67*
	♀	-4.040	2.17	0.812	65.93	11.13*	-2.600	1.65	0.768	59.298	0.53
	♀♂	-5.503	2.711	0.820	67.24	49.48*	-4.820	2.470	0.883	77.443	4.02*
Carapace width	♂	0.475	0.902	0.577	33.30	11.39*	1.506	0.321	0.308	9.514	19.68*
	♀	1.673	0.230	0.215	4.61	14.50*	0.105	1.103	0.913	83.41	13.36*
	♀♂	1.410	0.385	0.340	11.55	21.97*	1.339	0.414	0.389	15.132	21.58*
Palm Depth	♂	-1.358	1.513	0.553	30.55	4.52*	-0.653	1.118	0.402	16.149	5.38*
	♀	0.762	0.290	0.491	24.13	28.90*	-0.409	0.938	0.416	17.283	3.48*
	♀♂	0.088	0.700	0.493	24.26	16.64*	-0.600	1.080	0.390	15.215	6.16*
Palm Length	♂	-0.856	1.379	0.332	11.00	2.86*	0.516	0.608	0.501	25.089	16.57*
	♀	1.349	0.095	0.187	3.48	31.88*	-0.442	1.081	0.710	50.415	6.20*
	♀♂	0.570	0.572	0.301	9.07	11.99*	0.434	0.641	0.430	18.482	14.35*
Finger Length	♂	-0.344	1.021	0.677	45.88	12.37*	0.432	0.563	0.382	14.575	13.01*
	♀	1.244	0.099	0.197	3.88	32.25*	-0.236	0.914	0.797	63.547	10.44*
	♀♂	0.703	0.430	0.446	19.85	26.60*	0.364	0.597	0.406	16.504	14.66*
Gape	♂	-0.733	0.857	0.193	3.71	3.40*	1.547	-0.423	-0.111	1.24	6.60*
	♀	0.686	0.012	0.008	0.01	10.47*	-0.079	0.489	0.199	3.97	3.61*
	♀♂	0.069	0.395	0.170	2.89	10.17*	1.351	-0.313	-0.085	0.73	7.44*
Chela Robustness	♂	-0.502	0.134	0.030	0.09	22.53*	-1.168	0.510	0.217	4.72	12.37*
	♀	-0.587	0.195	0.306	9.34	9.84*	0.034	-0.143	-0.080	0.64	7.98*
	♀♂	-0.482	0.128	0.070	0.49	28.38*	-1.035	0.439	0.191	3.63	13.53*
Chela Size	♂	-0.853	1.304	0.644	41.43	15.04*	-1.168	0.763	0.508	25.829	8.05*
	♀	1.118	0.161	0.377	14.19	4.28*	-0.362	0.978	0.715	51.067	5.61*
	♀♂	0.454	0.567	0.485	23.53	29.82*	0.066	0.772	0.489	23.953	9.07*
Finger Size	♂	0.764	-0.425	-0.162	2.63	26.09*	0.501	-0.300	-0.179	3.20	14.57*
	♀	0.189	-0.093	-0.234	5.45	8.52*	0.190	-0.095	-0.063	0.40	7.13*
	♀♂	0.374	-0.206	-0.116	1.36	44.98*	0.447	-0.264	-0.156	2.43	15.97*
Fluctuating Asymmetry	♂	1.726	-0.278	-0.025	0.06	5.33*	3.943	-1.481	-0.236	5.55	5.73*
	♀	1.955	-0.318	-0.083	0.69	2.25*	-1.555	1.698	0.531	28.156	1.61
	♀♂	2.459	-0.651	-0.116	1.36	1.84	3.153	-1.019	-0.168	2.83	5.82*

♀ = female ♂= male ♀♂= both

DISCUSSION

Several studies on morphology, anatomy and chelal bio-mechanics in crabs and other decapods such as lobsters, indicate that the cheliped often comprise a high percentage of total body weight or a high size ratio with respect to overall body dimensions (Lee and Seed, 1992; Brown *et al.,* 1979; Vermeij, 1977; Hamilton *et al.*, 1976). Allometric values for cheliped palm depth, finger length, palm length and gape of *C. amnicola* from Qua Iboe and Imo River estuaries were low but *C. amnicola* from Imo River estuary had a negative *b* value for gape and an isometric value of total weight. Similar observations by William *et al.* (1980), showed that allometric values of body dimensions of *Uca* species were generally near zero.

Intersexual and interpopulation variations in cheliped palm depth, palm length, finger length and gape of *C. amnicola* in this study were not significantly different (t-Test, $p > 0.05$), though male values were higher. This is at variance with other authors (Akin-Oriola *et al*., 2005 and Haefner, 1990), probably due to species, ecological and sampling differences. Akin-Oriola *et al*. (2005), recorded significant differences (t-Test, $p < 0.05$) in the body weight, chelae diameter and condition factor between males of the land crab *Cardiosoma armatum* and the swimming crab *Callinectes pallidus* and of their female counterparts in the Badagry Lagoon of Lagos, Nigeria (Akin-Oriola *et al*., 2005). Haefner (1990) also recorded highly significant intersexual differences between right and left chelipeds for all

chelae dimensions in *C. ornatus* in Bermuda and demonstrated that cheliped laterality and frequency of right handedness decreases with increase in size and age. Williams *et al.* (1980) also observed marked asymmetries in the male chelae of *Uca* species.

The significance of heterochely in crabs is unclear. But Daniels (2001) suggested that it may be related to signaling and defense. Large claws and male major chelae play important roles in crab territorial (offence and defense), sexual behaviour and in female may indicate reproductive vigour as well as ability. Descriptions of the major chela, meral lengths, pleopods, chela width and total pereiopod length indicate species differences (Williams *et al.*, 1980). During development, there is a graded distribution of differential growth (otherwise known as *growth gradient*) in other regions of the body. Akin-Oriola *et al.* (2005) posited that heterochely in *Cardiosoma armatum* resulted in a slight tendency towards left handedness (53%), while that of *Callinectes pallidus* was definitely towards right handedness (79%).

Chela robustness, chela size and finger size in this study had positive values, but showed no significant interpopulation variation (t-Test, $p > 0.05$) and increased with size, CL. William *et al.* (1980) recorded similar increases over the whole size range in *Uca polita, U. vocans* and *U. lacteal.* This study also reveals that as the carapace length increases, the body weight and carapace width, and cheliped palm depth, palm length, finger length and gape reduces. Palm length (PL), palm depth (PD) and finger length (FL) are the standardized values of the major chela and can be used to define the shape aspects or secondary sexual characteristics including chela size, chela robustness and finger size (William *et al.,* 1980).

Sex-wise distribution of crabs during the study indicated interpopulation differences in favour of females in the Qua Iboe River estuary and of males in the Imo River estuary (Table 2). This could be linked to differentiated distribution according to environmental conditions, leading to male dominance in much lower salinities [as observed in oligohaline Imo River estuary: 0.54‰], while females are present in higher numbers in more saline environments [as observed in mesohaline Qua Iboe River estuary with higher salinity: 17.4‰], since they migrate to open seas for spawning (Archambault *et al.*, 1990; Murphy *et al*., 2001; Mendonça *et al*., 2010). Moulting also played important role in the interpopulation differences. Moulting was more pronounced at lower salinities, hence post moult crabs were recorded in higher proportion in the oligohaline estuary (which allowed absorption of more water) compared to the mesohaline habitat (Hines *et al.,* 1987).

The carapace length-width relationship of *C. amnicola* was also significantly lower than 3 indicating negative allometry; as the carapace length increases, the width reduces. This is at variance with observation of Lawal-Are (2009) that carapace width increases with carapace length. The variation may be attributed to sampling number and sampling period. Lawal-Are (2009) sampled 30 specimens in one month while this study is based on a 12-month sample of 2,476 crabs. The present study further revealed that as the carapace length increases, the body weight and carapace width, and cheliped palm depth, palm length, finger length and gape reduces. In *C. armatum,* the right chelae diameters of males were significantly bigger ($P < 0.05$) than that of females. On the other hand, the body weight, chelae diameter and condition factors of male *Callinectes pallidus* were significantly higher than those of females.

Fluctuating asymmetry (FA) occurs when the traits of one side of a supposed bilaterally symmetrical organism differ in a random way from those of the other side. It is expressed as a difference in the number, size, shape or other feature of the trait between the left and the right sides (Palmer and Strobeck, 1986). The fluctuating asymmetry of chelipeds from within each estuary showed intersexual differences. When FA is elevated, it is considered to reflect a developmental instability, either by endogenous genetic factors or by exogenous factors such as environmental stress. In this case the cheliped FA results from graded distribution and differential growth during development, in favour of male right-handedness.

CONCLUSION

The results from this study indicate that the interpopulation differences existing between *C. amnicola* from Qua Iboe (mesohaline) and Imo River (oligiohaline) estuaries, are phenotypic in nature and attributable to salinity differences; hence *C. amnicola* from both estuaries are of the same stock and could be subjected to similar management and conservation regulations. In addition, the character which affords high discriminatory values between sexes was cheliped palm depth, which hence, serves as the main secondary sexual character in *C. amnicola* from the Niger Delta zone in Nigeria.

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