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Population characteristics of the swimming crab *Callinectes amnicola* De Rocheburne, 1883 (Crustacea, Brachyura, Portunidae) in the Qua Iboe River estuary, Nigeria

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Abstract. Aspects of the biology of *Callinectes amnicola,* from the Qua Iboe River estuary, south-eastern Nigeria, was investigated for twelve months from June 2008 to May 2009, with respect to its size composition and population characteristics. A total of 1,193 specimens were obtained comprising 508 males and 685 females with overall (1:1.35, χ^2 = 26.26, 1 df, $p < 0.05$) and rainy season (1:1.2; χ^2 = 2.17, I df, $p < 0.001$) sex ratios in favour of females, while the dry season ratio of 1:0.84 was male-biased (χ^2 = 11.44, 1 df, $p < 0.05$). Carapace length (CL), carapace width (CW) and total weight (TW) of crabs were significantly ($p < 0.05$) influenced by sex, moult stage, colour morphotypes, and development stage. The crabs sampled were 26.6 to 87.0 mm CL (Mean ± S.E: 62.48 ± 0.23), 53.7 to 187.0 mm CW (124.5 ± 0.51) and 9 to 323 g (126.39 ± 1.43) and exhibited a high composition (80 - 90%) of adults. Males ranged from 14 to 323g and 78 to 175 mm CW, and females 9 to 293g and 54 – 187 mm CW, indicating sexual dimorphism in which males attain larger sizes than females ($p < 0.05$). The crabs were further classified as juvenile or adult based on abdominal morphometry. The reproductive indices (gonadosomatic index and hepatosomatic index) were significantly higher ($p < 0.05$) in adult than in juvenile crabs. Crabs of the green morphotype were larger in proportion (59.31 %) and were significantly longer and heavier than other colour morphotypes ($p < 0.05$). Crab total weight and carapace length/width were higher ($p < 0.05$) in the dry months (November to March) than in the wet (April to October). The study reveals high internal variabilities in the size composition and population characteristics of *C. amnicola* inhabiting the lower reaches of the Qua Iboe River estuary, Nigeria.
Key Words: Blue crabs, *Callinectes*, population, sex ratio, growth, colour morphotypes.

Introduction. Blue crabs *Callinectes amnicola* are inshore, demersal estuarine crab species. They occupy a variety of estuarine habitats from the lower reaches of freshwater rivers, estuaries and coastal marine waters and are highly mobile, making it feasible for them to move between areas and to select habitats (Micheli & Peterson 1999; Ryer et al 1997). They are abundant and support commercial and recreational fisheries, seaward from Cape Verde islands and Mauritania to Angola in Africa along the east Atlantic Coast (Fischer et al 1981) and in the Gulf of Mexico, Australia, Canada, Japan, Philippines, Southeast Asia and the Chesapeake Bay/tributaries of the United States of America (Prager et al 1990).

Blue crabs are usually brown or grayish in color, which allows them to blend in with the muddy and sandy bottom of the shallow estuaries. They exhibit different colour morphotypes/variations of the carapace in relation to environmental variation of their habitat (Mc Gaw & Naylor 1992; Mc Gaw et al 1992). These habitats provide food, shelter, refuge and are important nurseries for juvenile blue crabs and molting areas for all crabs (Hovel & Lipcius 2001; Perkins-Visser et al 1996).

Little is known of the behaviour, ecology and fisheries of *C. amnicola* crabs in Africa, particularly Nigeria. Earlier publications deal with their taxonomy and distribution (Powell 1983, 1985; Jonathan & Powell 1989), nutritional composition (Fineman-Kalio

1987; Idoniboye-Obu & Ayinla 1991; Alfred-Okiya 2000; Oduro et al 2001), ecology (Okafor 1988; Lawal-Are & Kusemiju 2000; Arimoro & Idoro 2007), morphometrics (Akin-Oriola et al 2005), and food and feeding (Chinda et al 2000; Lawal-Are & Kusemiju 2000; Arimoro & Idoro 2007). There is no report on its occurrence, colour morphotype and biology in the present study area. The objective of this study is therefore, to establish and report on the size and population characteristics of *Callinectes amnicola* inter alia: composition, abundance and occurrence.

Material and Method. Sampling was carried out in the estuarine swamps of Qua Iboe River ($7^0$33′W - 8 ^{0} 20′ W; 4 ^{0} 30′ - 5^0 30′ N), East of the Niger Delta, Nigeria (Fig. 1). The area as described by Eyenihi et al. (1988) is typically of the equatorial hot-humid climate with year-round precipitation and two discernible seasons: the dry season (November to March with a peak in January; characterized by the prevalence of the north-east winds blowing from the Sahara) and the rainy season (April to October with peaks in July/August; characterized by the prevalence of the rain-bearing south-west wind blowing on-shore from the Gulf of Guinea).

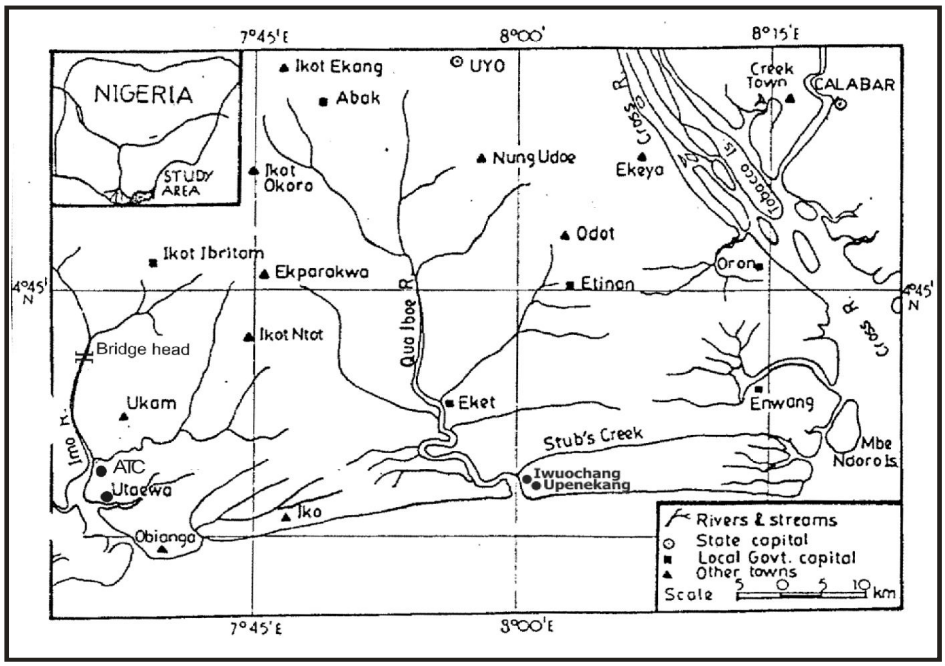

Fig. 1. The coastal zone of southeastern Nigeria showing sampling points (●) along the Qua Iboe River estuary (Inset: Map of Nigeria showing the study area; ATC represents African Trading Company)

A total of 1,193 specimens of *Callinectes amnicola* species were purchased bi-monthly for twelve months (June 2008 to May, 2009) from artisanal fishers at fish landing beaches in Ibeno at Upenekang and Iwuoachang (about 1.5km apart) along the Qua Iboe River Estuary. Fishers used a combination of about 100 yd gill nets of 3.5 inches (10cm) stretched mesh size. After collection, samples were preserved in 10% formalin. The sex, gonads, reproductive and moult conditions, colour morphotype (brown, olive green, olive brown and orange green) and moult sign were noted for each crab. Males were 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 (Nlewadim et al 2009; Milikin & Williams 1984; Campbell & Eagle 1983; Haefner 1976; Van Engel 1958). 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. Salinity was also recorded for each site.

Analysis of variance (ANOVA) was performed on the data obtained. The χ^2 test was used to investigate the sex ratio (Sokal & Rohlf 1981) and inferences derived at 5% significance level.

Results. *Callinectes amnicola* was encountered throughout the year and comprised 508 (42.58 %) males and 685 (57.42%) females, giving a sex ratio of 1:1.35, which was highly and significantly female-biased (χ^2 = 26.26, 1 df, $p < 0.05$). The monthly variation in sex ratio was not significantly different from unity in the months of July to September, however, males out-numbered females in the months of July and January to March while females out- numbered males in April to June and August to December ($p > 0.05$). The pooled rainy season (May to October) samples (n = 697), showed sex ratios of 1:1.2 (χ^2 = 2.17, 1 df, $p < 0.001$) in favour of females; whereas, the dry season (November to April) samples (n = 398) showed ratios of 1:0.84 in favour males (χ^2 = 11.44, 1 df, $p < 0.05$).

Crab size - structure

The size composition by sampling site, sex, moult condition, colour morphotype, gonad stage, and seasonal variations are summarized in Tables 1, 2 and Figure 2.

Table 1

Population and demographic traits of *C. amnicola* in Qua Iboe River estuary, Nigeria (mean ± std. error)

Population characteristics	Iwuochang	Upenekang	Qua Iboe
Total Weight, g	123.92 ± 1.94 (9 - 282.0)	129.78 ± 2.10 (9.0 – 323.0)	126.89 ± 1.43 (9.0 – 323.0)
Carapace Length, mm	61.51 ± 0.30 (26.6 – 82.4)	63.41 ± 0.33 (28.0 – 87.0)	62.48 ± 0.23 (26.6 – 87.0)
Carapace Width, mm	122.07 ± 0.71 (53.7 – 174.9)	126.95 ± 0.66 (58.0 – 187.0)	124.54 ± 0.51 (53.7 – 187.0)
% Females	57.99	56.86	57.42
% Males	42.01	43.14	42.58
Sex Ratio	1:1.38	1:1.33	1:1.33
% Early Pre-Moult	4.93	5.12	5.03
% Intermoult	87.93	85.62	86.76
% Post-Moult	7.14	9.26**	8.21
% Immature	5.27	6.78	6.04
% Pubertal	1.87	0.33	1.09
% Adult	91.84	92.89	92.37
% Juvenile	7.14	7.11	7.12
% Adult	91.84	92.89	92.37
% Brown	0.00	0.17	0.08
% Olive Brown	38.27	40.00	39.15
% Olive Green	50.68	50.58	50.63
% Orange Green	11.05*	9.26	10.14
Dry Season, %	39.29	37.69	38.47
Wet Season, %	60.71	62.31	61.53
% Undeveloped Gonad (O)	15.65	14.05	14.84
% Immature Gonad (I,II,III)	33.16	36.03	34.62
% Mature gonad (IV,V)	8.67	6.78	7.71

* The Iwuochang values are significantly higher than those of Upenekang
** The Upenekang values are significantly higher than those of Iwuochang
Values in parentheses represent range (min – max)

Table 2

Growth pattern of *C. amnicola* in Qua Iboe River estuary, Nigeria in relation to population characteristics [mean ± s.e (min – max)]

Population Characteristics*	Mean Total Weight, g	Mean Carapace Length, mm	Mean Carapace Width, mm
Sex			
Females (685)	104.83±1.28 (9 - 293)	61.09 ± 0.298 (26.6 – 87.0)	122.61 ± 0.66 (53.7 – 187.0)
Males (548)	156.65±2.30 (14 - 323)	64.35± 0.33 (34.2 – 80.3)	127.15± 0.78 (78.0 – 174.9)
Moult Stage			
Early Pre Moult (60)	109.37±2.7 (73 - 164)	61.77 ± 0.91 (38.9 – 79.9)	122.46 ± 1.82 (80.0 – 145.0)
Intermoult (1035)	131.31±1.52 (29 - 323)	62.89± 0.23 (32.0 – 87.0)	125.12 ± 0.53 (53.7 -187.0)
Post Moult (98)	90.18±5.13 (9 – 282)	58.52 ±1.16 (26.6 – 75.0)	119.76 ± 2.30 (57.2 – 152.0)
Devt. Stage			
Immature (72)	53.13±3.20 (9 – 141)	46.60± 0.93 (26.6 – 63.0)	91.02 ± 1.70 (53.7 – 120.0)
Pubertal (13)	64.38±3.91 (38 – 92)	50.05 ±1.62 (40.7 – 62.9)	99.11 ± 2.97 (83.4 – 125.0)
Adult (1101)	132.39±1.40 (39 – 323)	63.67±0.19 (32.0 – 87.0)	127.04±0.45 (58.0 – 187.0)
Color Morphotype			
Brown	121	580	1083
Olive Brown (467)	124.46±2.51 (9 - 271)	61.68±0.40 (26.6 – 77.2)	125.22±0.85 (57.2 – 187.0)
Olive Green (604)	129.60±1.86 (14 - 323)	62.84±0.29 (32.0 – 80.3)	125.19±0.66 (53.7 – 162.0)
Orange Green (121)	123.04±4.44 (49 - 293)	63.75±0.74 (45.1 – 87.0)	118.85±1.81 (83.6 – 174.9)
Season			
Dry Season (459)	131.00±2.47 (9 – 323)	62.91±0.39 (26.6 – 80.3)	128.10±0.85 (57.2 – 162.0)
Wet Season (734)	124.21±1.74 (34 - 293)	62.21±0.27 (38.9 – 87.0)	123.78±0.63 (53.7 – 187.0)
Gonad Devt.			
Undeveloped (177)	89.72±2.47 (9 – 189)	59.31±0.67 (26.6 – 81.0)	118.28±1.48 (57.2 – 187.0)
Immature (413)	108.86±1.56 (29 – 293)	61.49±0.36 (32.0 – 86.0)	123.68±0.77 (53.7 – 158.0)
Mature (90)	116.70±3.49 (48 - 229)	62.89±0.74 (46.0 – 87.0)	126.58±1.81 (58.0 – 187.0)

*values in parentheses represent sample number

Both sexes exhibited two modes: males - 64.55 mm and 67.55 mm CL; 127.55 mm CW and females - 61.55 to 65.55 mm CL; 112.55 mm and 127.55 mm CW. Females were absent in 42.55 to 47.55 mm CW and 67.55 to 72.55 mm CL, and males in 42.55 to 72.55 mm CL size classes. Crabs of both sexes exhibited high composition (about 90 %)

of adults and ranged from 26.6 to 87.0 mm CL (mean ± standard error: 62.48 ± 0.23), 53.7 to 187.0 mm CW (124.54 ± 0.51) and had total weights of 9 to 323 g; 126.89 ± 1.43 (Fig. 2) with highly significant temporal changes ($p < 0.05$; Fig. 3). The crabs were heavier and longer in the dry months (November to March; $p < 0.05$) than in the wet months (April to October). Mean carapace width of male crab rose from 110.43 - 115.44mm in April/May to 132.42 - 133.04mm between October and December. The number of crabs sampled was also significantly higher ($p < 0.05$) in the dry months (November to March; $p < 0.05$) than in the wet months (April to October).

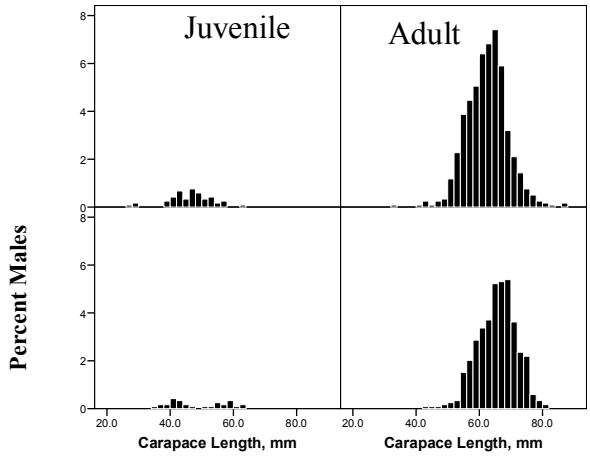

Figure 2. Size compositions of female and male *Callinectes amnicola* collected in Qua Iboe River estuary, Nigeria (2008 - 2009)

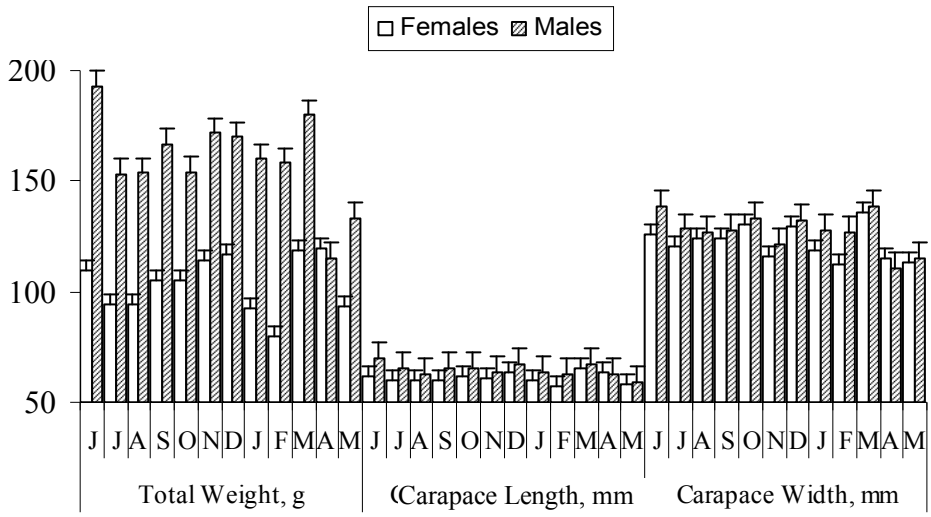

Figure 3. Sexual and temporal variation in mean total weight, carapace length and width of *Callinectes amnicola* at Qua Iboe River Estuary, Nigeria (Error bars represent standard error of mean)

Sexual dimorphism in weight and length of crabs

Intersexual and temporal variations indicate significant mean differences ($p < 0.05$) between total weights of males and females all year round except in the month of April (Fig. 3). Males averaged 64.35mm CL and 127.15mm CW and were about 3.26mm CL

and 4.54mm CW longer than females (61.09mm CL and 122.61mm CW); the mean weight of males (156.73g) was also 52g greater than females (104.82g).

Variation in moult, developmental stage and colour morphotype

Moult stage, development stage, colour morphotype and sex significantly ($p < 0.05$) influenced the morphometry and population structure of blue crabs in the estuary ($F_{season} = 45.125$ $p < 0.000$; $F_{developmental.\ stage} = 0.995$, $p < 0.370$ and $F_{sex} = 0.803$, $p < 0.371$). Figure 4 shows the proportion of crabs sampled by sex, moult and development stage. Pre-pubertal crabs did not occur. Pubertal crabs were all males in inter moult and post moult stages. Early pre-moult crabs were also all males in the immature and adult stages of development. The mean weights and lengths of crabs indicate two significantly heterogeneous groups ($p < 0.05$; Fig. 6a) on moult basis:

- Intermoult > early pre-moult Ξ post moult crabs in TW
- Intermoult Ξ early pre-moult > post moult crabs in CL
- Intermoult Ξ early pre-moult Ξ post moult crabs in CW

Mature males weighed more than similarly-sized immature males; in contrast, mature females weighed less than immature females of equal size. Based on maturity stage the mean weights and carapace length/width were in three and two significant categories, respectively ($p < 0.05$; Fig. 6c) as follows:

- adult > pubertal > immature in TW
- adult > pubertal Ξ immature in CL
- adult > pubertal Ξ immature in CW.

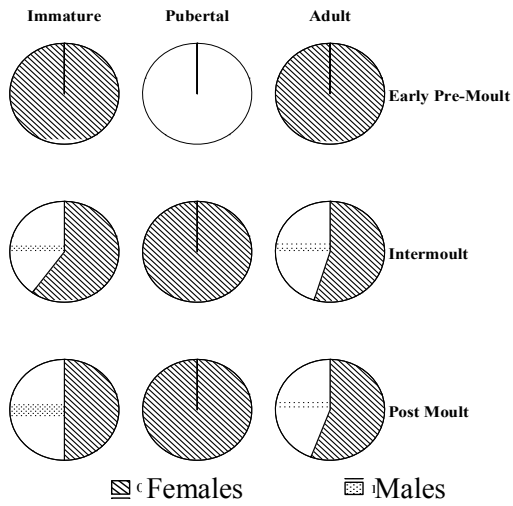

Figure 4. Occurrence of *C. amnicola* by sex, moult and developmental stages along the Qua Iboe estuary, Nigeria

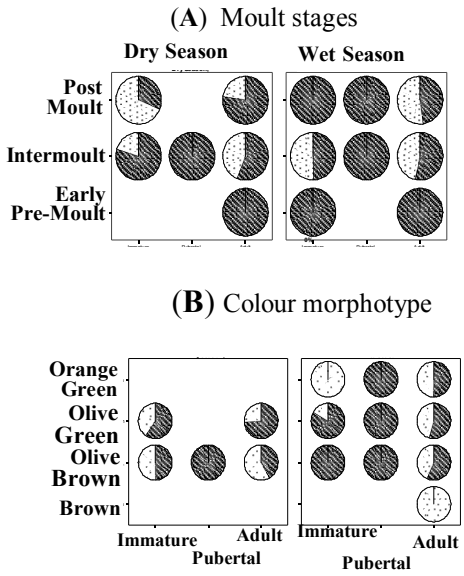

Figure 5. Seasonal occurrence of *C. amnicola* by sex, moult stage (A) and colour morphotype (B) along the Qua Iboe estuary, Nigeria

Females
Males

Figure 5 shows seasonal variation in occurrence of blue crabs by moult (Fig. 5a), colour morphotype (Fig. 5b) and sex with ANOVA of $F_{season} = 3.042$, $p < 0.081$; $F_{developmental.\ stage} = 30.799$, $p < 0.000$ and $F_{sex} = 20.501$, $p < 0.000$. Crabs sampled were of brown, olive green, olive brown and orange green morphotypes. The proportion of green crabs was 59.31%. The green crabs were significantly longer and heavier than other crabs ($p < 0.05$; Fig. 6b):

- olive green > olive brown Ξ orange green > brown crabs in TW
- olive brown > olive green Ξ olive brown > brown in CL
- olive green Ξ olive brown > orange green > brown crabs in CW

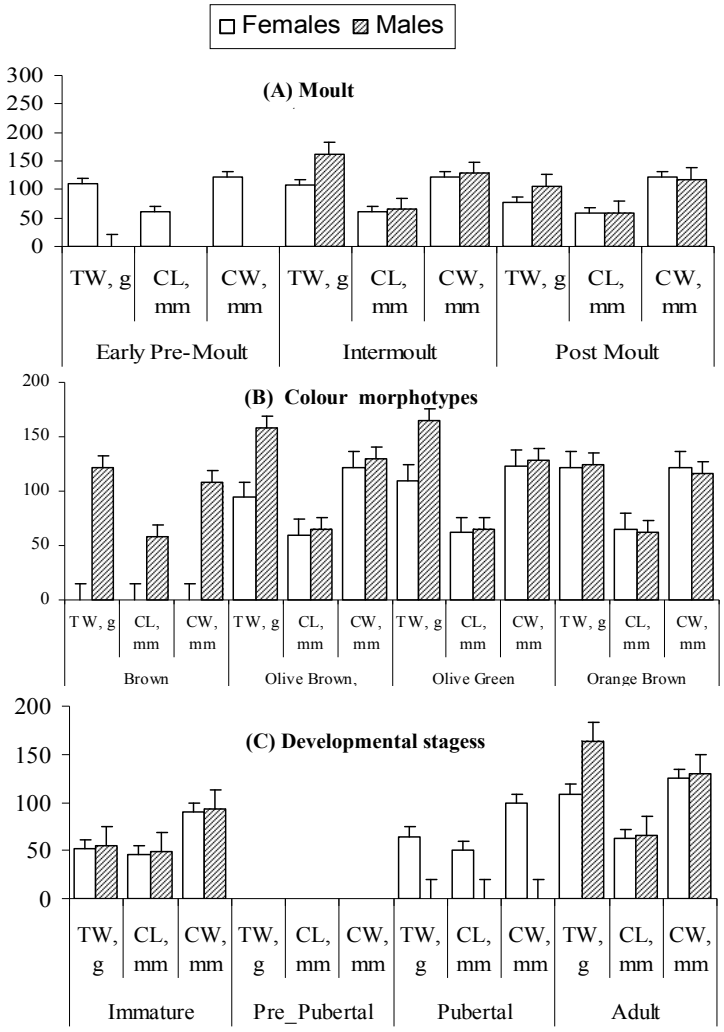

Figure 6. Mean total weight, carapace length and width of crabs by sex, moult (A), colour morphotypes (B) and developmental stages (C) along Qua Iboe River Estuary, Nigeria [error bars represent standard error of means]

Gonad stages and reproductive condition

Crabs of gonad stages 0 – 5 were encountered. Ovigerous females with matured gonads (stages IV and V) constituted 8.67% and 6.78% at Iwuochang and Upenekang, respectively (Table 1). The reproductive indices were significantly higher ($p < 0.05$) in adult than in juvenile crabs (Table 3).

Discussion. *Callinectes amnicola* was encountered throughout the year with the absence of other species. Similar observations were made by Abowei & George (2010) in Okpoka creek, Niger Delta, Nwosu (2010) in Cross River estuary, Arimoro & Idoro (2007) in Warri River and Lawal-Are (2003) in the Lagos Lagoon, Badagry lagoon and Lekki lagoon, all in Nigeria. The inability to capture *C. pallidus,* and *C. marginatus* during sampling in the study area may be due to their rarity, low abundance and/or gear inefficiency and may not necessarily mean their non-occurrence in the study area. *C. amnicola* is a delicacy that is highly patronized by all income class groups in the area and is mostly sold fresh.

The deviation from 1:1 sex ratio between males and females of brachyurans are linked to several causative factors. Several authors have recorded crab sex ratios that were male-biased (Snowden et al 1991; Sumpton et al 1994) and female-biased (Devi 1985; White 1999; Lawal-Are & Kusemiju 2000; Wakefield 2002; Meye et al. 2003; Akin-Oriola et al 2005; Arimoro & Idoro 2007; Lawal-Are & Bilewu 2009; Abowei & George 2010). Sex bias could arise from spatial preference of females for deeper waters,

efficiency of fishing gear, selective pressure from fishers and consumer preferences for males, since males are larger and more valued in the market (Mendonça et al. 2010; Murphy et al 2001; Archambault et al 1990) and schooling by sex (Devi 1985). Studies by Archambault et al (1990), Murphy et al (2001), Severino-Rodrigues et al (2001) and Mendonça et al (2010) show that *Callinectes* species usually presents differentiated distribution according to the environmental conditions, leading to male dominance in much lower salinities, while females are present in higher numbers in more saline environments, since they migrate to open seas for spawning. This explains why Qua Iboe River estuary, QIRE (with higher salinity ~ 17.4 ‰) is female-biased while Imo River estuary, east of QIRE is male-biased, having a much lower salinity.

Table 3

Variations in morphometric and reproductive variables of juvenile and adult male and female *C. amnicola* in Qua Iboe River estuary, Nigeria [mean ± std. error (min – max)]

Morphometric and reproductive variables	Male		Female	
	Juveniles (n = 31)	Adults (n = 471)	Juveniles (n = 54)	Adults (n = 631)
Total Weight, g	91 ± 5.95 (14.0-141)	163.44±2.09 (43.0-323.0)	54.81 ± 2.85 (9.0- 93.0)	109.11±1.22 (39.0-293.0)
Carapace Length, mm	48.53±1.62 (34.0–63.0)	65.42 ± 0.28 (43.0– 80.0)	46.34 ± 0.93 (27.0-63.0)	62.35 ± 0.26 (32.0 - 87.0)
Carapace Width, mm	92.78±1.79 (78.0-13.0)	129.48±0.71 (85.0-175.0)	91.96 ± 2.21 (54.0-120.0)	125.24±0.58 (58.0-187.0)
Gonadosomatic Index, %	0.09 ± 0.03 (0.0 – 0.70)	2.07 ± 0.08 (0.0 – 16.4)	2.32 ± 0.67 (0.0 – 23.4)	6.25 ± 0.65 (0.0 – 79.5)
Hepatosomatic Index, %	3.50 ± 0.76 (0.0 – 13.2)	4.28 ± 0.18 (0.0 – 22.7)	4.67 ± 1.61 (0.0 – 76.5)	4.91 ± 0.37 0.0 - 82.4

Seasonal variations in catch and morphometry favouring higher values in the dry months may be attributed to the mass catch of ovigerous crabs in November and December because *C. amnicola* enters the estuary in the dry season, due to higher salinity, for carapace change and copulation. Abowei & George (2010) also reported a mass catch of *C. amnicola* between December and January at the various stations of the Okpoka creek, Niger delta.

Portunid crabs exploited in the Lagos area southwest of Nigeria as reported by Fischer et al. (1981), Lawal-Are & Kusemiju (2000), Lawal-Are (2003), Akin-Oriola et al (2005), Emmanuel (2008) and Lawal-Are & Bilewu (2009) are larger in sizes compared to *C. amnicola* in southeast Nigeria (Udoh et al 2002; Arimoro & Idoro 2007; Abowei & George 2010; this study). However, the crab sizes obtained in this study are higher compared to values reported by Abowei & George (2010). Spatial, environmental, sample number and measurement differences as well as high fishing mortalities may account for these variations in sizes of crabs. Tagatz (1968), Murphy & Kruse (1995) and Guillory (1997) explained that high fishing mortalities impact many juveniles approaching legal size resulting in reduced catch of larger sized crabs.

The size difference between males and females may serve several purposes. Firstly is to protect the females against predators and other male competitors during mating. Secondly, since females spawn once in their lifetime, it is advantageous that they mate with a large, capable male. Studies have suggested that large males store more sperm/ spermatophores and seminal fluid, mate more frequently and deliver larger volume of more potent ejaculate that enhances fertilization of all the egg-mass of the females compared to smaller males (Jivoff 1997, 2003; Kendall et al 2001; Fischer & Wolff 2006). A decline in the male blue crab population may result in a deficit of sperm and thus reduce zoea production. Males can enhance their reproductive success by mating with larger, more fecund females and by mating as many times as possible (Jivoff & Hines 1998). Although females are capable of maintaining normal levels of egg production, females may actually be fertilizing fewer eggs with a reduced quantity of sperm and/or seminal fluid received from fewer and smaller males (Kendall et al 2001). Also, since females are just as likely to initiate mating with a recently mated male with

low sperm volume as with a male that had not recently mated, some females will receive low quantities of sperm (Kendall & Wolcott 1999). Large males require 9-20 days to fully recover all their seminal resources; if males mate again without fully recovering; they deliver lower quantities of sperm (Kendall et al 2001). However, the ability of females to store sperm for at least two spawning during the annual breeding season seems to be advantageous in maximizing reproductive output (Wenner 1989). Therefore, females could enhance their fitness by choosing large, healthy males that have not recently mated so that they receive sufficient sperm to fertilize multiple broods and thus, reduce the population's susceptibility to sperm limitation and reduced reproductive potential (Kendall & Wolcott 1999). The intersexual variation in total weight of crabs, carapace length and carapace width could also be linked to food availability (Pollock 1982; Pollock & Beyer 1981), oxygen depletion in bottom waters (Pollock & Shannon 1987) and female commitment to reproduction after puberty. Hence, males tended to be heavier and longer than their female counterpart, as observed in this and other studies (Olmi & Bishop 1983).

Moulting plays a major role in growth increment and size distribution in crabs. Growth increment through moulting varies between 3 and 44% of premoult carapace width, decreasing as the crab becomes larger (Warner 1997). Blue crabs in this study exhibited about 20.0, 2.0 and 2.0% growth increment in total weight, carapace length and carapace width from early pre-moult to intermoult stages, respectively in the Qua Iboe River estuary. Even though, males in this study were significantly longer (approximately 3mm CL and 4mm CW) than females, the similarity of modes in the size frequency of both sexes suggests low size - definition of moulting, low recruitments and its spread over wide size ranges (Snowden et al 1991). Moulting in reduced salinities ensures the uptake of large quantities of water to expand the exoskeleton immediately after ecdysis. The mechanism for this rapid uptake is unclear in isosmotic, stenohaline crabs but evident in hyperosmotic, euryhaline crabs (Hines et al 1987). It is noted that most crabs in open-water basin are in intermoult and prefer water of higher salinity as they grow. The capture of adult/gravid crabs in the estuary in November/December may be linked to their interruption in downstream migration to water of higher salinity for pairing and spawning.

Portunid crabs of the green morphotype are known to withstand environmental stress (Mc Gaw & Naylor 1992; Mc Gaw et al 1992), oxygen depletion and toxic pollutants (Reid & Aldrich 1989) better than the orange/red crabs. High populations of green crabs in the study sites are therefore indicative of high environmental variability.

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