# AUTHOR ACCEPTED MANUSCRIPT

FINAL PUBLICATION INFORMATION

Composition of Macrobenthos in the Wouri River Estuary Mangrove, Douala, Cameroon

The definitive version of the text was subsequently published in

African Journal of Marine Science, 34(3), 2012-10-25

Published by Taylor and Francis

**THE FINAL PUBLISHED VERSION OF THIS ARTICLE IS AVAILABLE ON THE PUBLISHER'S PLATFORM**

# COMPOSITION OF MACROBENTHOS IN THE WOURI RIVER ESTUARY MANGROVE, DOUALA CAMEROON.

Vanessa Maxemilie Ngo-Massou[1], Guillaume Léopold Essome Koum[1], Emmanuel Ngollo Dina[2], and Ndongo DIN [1†]

1Department of Botany, Faculty of Science, the University of Douala. P.O. Box 8948 Douala Cameroon.

2World Bank, 9903 Good Luck Road, Apt. 101, Lanham, MD 20706 (USA); Tel: (301)794-7363; e-mail: ngollodina@yahoo.com.

† Corresponding author: ndongodin@yahoo.com

## ABSTRACT

The macrobenthos of mangroves is dominated by crabs and molluscs that have a significant ecological role in terms of structure and performance. This research aims at determining the abundance and biological diversity of these invertebrates. Three methods of crabs capture (excavation, sight harvest and visual count) have been used in $10 \times 10$ m² plots for the crabs. One by one square meter quadrats were delimited for mollusc counts. Twenty four species evenly distributed between the two groups were collected. Five families of crabs and six families of molluscs have been identified. Sesarmidae (eight species) and Pachymelaniidae (four species) are best represented in terms of species richness, whereas the Sesarmidae (94.6%) and the Potamididae (45.6%) are the most abundant taxa. The mangroves' macrobenthos in Cameroon now contain 60 species including nine (three crabs and six of molluscs) from this study.

**Keys words**: abundance, crabs, diversity, inventory, mangroves, molluscs.

## INTRODUCTION

Mangroves form a complex ecosystem comprising several interconnected elements at the land - sea interface which are in turn connected with adjacent coastal ecosystems such as coral reefs, seagrass beds and terrestrial vegetation. Mangrove forests prevent coastal erosion, contribute to the progression of the land towards the sea and react as buffer in areas prone to cyclones or other ocean surges (Mazda et al. 1997, 2002, Koedam and Dahdouh-Guebas 2006, Dahdouh-Guebas and Koedam 2008, Din and Baltzer 2008, Gilman et al. 2008). Debris (leaves) break down under the action of bacteria and fungi and the resulting product maintains large populations of vertebrate and invertebrate food webs. Invertebrates are probably the most significant biotic components except for trees that share mangrove species richness and their ecological role (Macintosh 1984, Hartnoll et al. 2002).

Crabs and molluscs are two major predominant invertebrates groups in mangroves (Ellison 2008, Nagelkerken 2008). Their ecological roles in terms of structure and function in this ecosystem are multiple (Lee 1998, 1999). They represent the links between primary detritus at the bottom of the food chain (Bosire et al. 2005a), consumers in higher trophic levels (Macintosh 1984, Dahdouh-Guebas et al. 2002), and predators at the highest levels (Cannicci et al. 1996, 1999), given their abundance and biomass (secondary production). They aerate soil by digging (Micheli et al. 1991) and reduce the soil salinity which affects productivity and development of mangroves (Stieglitz et al. 2000, Smith et al. 2009). They also affect forest structure in both natural and afforested conditions by propagule predation (Steele et al. 1999, Bosire et al. 2005b, Dahdouh-Guebas et al. 2010).

In total, approximately 10,500 species of crabs have been discovered in the world among which 6,793 names of valid species enclosed in 1,271 genera, 93 families and 38 sub-families (Ng et al. 2008). Six of these families are mostly represented in and around mangrove forests; they are: Gecarcinidae, Portunidae, Ocypodidae, Xanthidae Sesarmidae, Grapsidae

(Lee 1998). Fiddler crabs (*Uca* spp.) are recognized to be the most abundant in mangroves (Smith et al. 2009). They influence or regulate productivity in mangroves (Kristensen 2008).

Molluscs perform periodic vertical migrations on trees depending on the tide's oscillations (Vannini et al. 2006). These migrations help them avoid immersion and exposure to marine predators, which is the case for *Cerithidea decollata* (Linné 1758) in the Kenyan mangroves (Vannini et al. 2006, 2008b). This species climbs on trees to relax during high tide and descends to feed on the mud as soon as the waters recede. It is most active during the daylight than night time, during bright water tides than dead waters (Vannini et al. 2006, 2008b). Unlike *C. decollata*, *Terebralia palustris* L. is typically amphibious; it is active during both low tide and high tide (Pape et al. 2008).

Information on the macrobenthos of West-African mangroves is limited (Binder 1968, Zabi and Le Lœuff 1993, Seck 1996), as opposed to research conducted in East Africa (Cannicci et al. 2001, 2008, 2009, Dahdouh-Guebas et al. 2000, Hartnoll et al. 2002, Dahdouh-Guebas et al. 2004, Pape et al. 2008, Vannini et al. 2008a, 2008b). In Cameroon, crab and mollusc inventories have been carried out by Plaziat (1974), Boyé et al. (1975), Bandel and Kowalke (1999), and Longonje (2008). *Nerita*, *Neritina* and *Neritilia* (molluscs) genera were separated from each other based on the anatomy of their radula and their ecology. Likewise, *Pachymelania* and *Angiola, Littorina, Assiminea, Potamopyrgus* (*Thai*s), *Melampus*, *Onchidium* and *Tympanotonos* genera were found. The lamellibranches are found on silty substrates and the mangrove roots. The most common species found in both brackish and fresh waters are *Corbula trigona* (Hinds 1843), *Gryphea gasar* (Philippi 1847), *Iphigenia rostrata* (Römer 1869), *Cyrenoides* sp. and *Egeria radiata* (Lamarck 1804). Crabs are dominated by *Uca* and *Sesarma* genera.

The city of Douala, like similar metropolis in other developing countries is characterized by an uncontrolled urbanization due to a strong demographic pressure causing deforestation of riparian ecosystems (Mohamed et al. 2009, Nfotabong Atheull et al. 2009). Mangrove forests in Cameroon do not benefit from the Biological Diversity Conservation laws even when they happen to be located in a natural reserve. The disappearance of mangroves around cities leads to the degradation of macrobenthos (Bartolini et al. 2010), which in Douala consists mainly of individuals that hardly migrate. There is currently little knowledge on mangrove crabs and molluscs of the Wouri River estuary. Relevant data on the density, diversity, and distribution of these invertebrates do not exist or are insufficient and often fragmented. The crab and mollusc inventory in this research is designed to make necessary improvements and to retain information about this ecosystem for which the chaotic management will inevitably lead to its total disappearance.

## MATERIALS AND METHODS

### STUDY SITE

The study was carried out in the mangrove of the Wouri River estuary (Figure1). The climate of the region belongs to the Equatorial regime of a particular type or Cameroonian (Din et al. 2008). It is characterized by a long rainy season (March – November) and a short dry season (December - February). Heavy rainfall (approximately 4000 mm per year) with high and stable temperatures (around 26.7°C), and a high humidity throughout the year approaching 100% are typical to this region. Monsoon watering this region has a low wind gust with the exception of its phases of onset (April – May) and withdrawal (September – October) accompanied by relative violent storms (Din and Baltzer 2008). The tide rhythm is semi-diurnal with average amplitude of 2.5 m. Soils are grey or black vases, of silty texture, sand or clay, formed of fluvial sediments relatively rich in organic matter. These are young clay soils, characterized by a high carbon/nitrogen (C/N) ratio due to the slowdown in biological activity resulting from the anoxia. The annual variation in salinity in the region is between 0 and 20‰. During the long rainy season, the salinity of waters watering twice the mangrove is always less than 10‰. During the dry season, measurements show that it varies between 4 and 20‰ (Din and Baltzer 2008). Less than 30 km away from the ocean, salinity in Douala mangroves is zero during the rainy season (Din et al. 2002).

The flora consists essentially of tree species. The herbaceous stratum represents less than 1% of all vegetation. However, the flora remains poor with *Rhizophora racemosa* GF Meyer being largely the dominant vegetation. The fauna includes vertebrates such as birds, reptiles and fish, but especially a wide range of invertebrates namely the crabs and molluscs which constitute the bulk of immerged and epibenthic wildlife in the region. *Periophthalmus papilio* (Bloch and Schneider 1801), characteristic fish of mangroves is present and abundant. This fish moves and swims on the water surface and is the main predator of small invertebrates in the mangroves. Its presence often marks the actual limits of the mangrove forests; it is a useful biological indicator that differentiates the mangrove forests from other hydromorphic forests.

## SAMPLING METHOD

The study extended over six sites selected on each side of the Wouri River Bridge and in relation with the anthropogenic pressure on the mangrove forest. In each site, a transect was opened perpendicularly to the main channel, from land to water. One plot of $10 \times 10$ m² was established on each transect where light facilitated the observation of small and dark invertebrates. Overall, six plots have been delineated. Sampling was carried out for four months and specimen sampling was performed during low tide corresponding to the intense activity of the macrobenthos species. This increase in activity is explained by the absence of competition, predators (fish and other crabs), and availability of organic matter essential for their feeding (Silva et al. 2009). Each plot was inspected for 30 minutes using binoculars at an approximate distance of 5 m. All individual crabs observed (visual count) were counted and described (Ashton et al. 2003a, Cannicci et al. 2009). Description concerns the differentiating criteria such as color, the presence of antennae, hair, chelae, the eye cavity and the body shape features, etc.

Crabs are caught by hands on the trees, dead wood and detritus of all kinds on the plot surface (Bouchet et al. 2006) or excavated up to 50 cm of depth for the purpose of identification (Joana et al. 2003). Two quadrats of $1 \times 1\ m^2$ were established at the left bottom and the right upper limit of the plot on the transect direction for the collection of molluscs. Molluscs being less mobile and totally exposed, their collection required less effort. All comments and findings from the field were recorded in log books.

Depending on their size, collected specimens were placed in buckets, boxes or small tubes, then put in the ice water for several minutes for sedation, then washed and stored in labeled tablet jars containing 70% alcohol for later identification. Each species was observed under a binocular microscope and identified using the guides and standards key related to taxonomic groups of crabs (Raymond and Holthuis 1981, Cannicci et al. 2001, Ng et al. 2008) and molluscs (Plaziat 1974, Bandel and Kowalke 1999). A check is now performed by laboratories of the Universities of Yaounde (Cameroon) and Florence (Italy).

## DATA ANALYSIS

In each sampling site, the absolute and relative densities of crabs and molluscs were calculated. Stand faunal diversity was assessed by calculating the Shannon - Weaver index of diversity. This index weighs the number of species in a stand by their relative abundance (Frontier and Picho - Viale 1993). In order to assess the distribution of crabs and molluscs within each sampling site, the Non-Multidimensional Scaling (nMDS) was implemented in PRIMER *v.6* (Clarke and Gorley 2001). Prior to computation of resemblance matrix, the raw data were subjected to pre-treatment (Log (X+1) transform). This allowed a standardization of abundance data. Afterwards, the Bray-Curtis similarity was used to assess the abundance of crabs and molluscs across the sampling sites (Clarke and Green 1988, Kruskal and Wish 1978). To evaluate diversity in each site (based on the specific composition), hierarchical ascending classification was used, based on the measurement of the Euclidean distance determined according to the aggregation procedure and to determine the similarity index (SI). To observe the difference between different sites, swap ANOSIM test was used (Clarke 1993).

## RESULTS

### CRABS INVENTORY

We identified 2,046 individuals, divided into 12 species belonging to five families in this study. The Sesarmidae family is both the most species-rich (eight species) and the most abundant (94.6% of individuals). The other four families have a single species each. The Grapsidae represent 5%, the Gecarcinidae and Ocypodidae (0.15%) and finally the Portunidae are less abundant with 0.1% of the inventoried individuals (Table 1).

*Chiromantes angolense* (Brito Capello 1864) and *Metagrapsus curvatus* (Milne 1837) were found in five out of six sites with the exception of the Bois des Singes (BS) site. *Chiromantes angolense* and *Perisesarma huzardi* (Desmarest 1925) are the most abundant species with respectively 483 and 364 individuals. *Portunus validus* (Herklots 1851) and *Uca tangeri (*Eydoux 1835*)* were found only at Mboussa Essengue (EG). Similarly, *Cardisoma armatum* (Herklots 1951) was harvested only at the Wouri River Bridge (WB). These three species are the less abundant in the study area (Table 2).

*Pachygrapsus transversus* (Gibbes 1850) with 54 individuals is dominant in BS. *Chiromantes angolense* (257 individuals) dominates Bonangang (BG). *Chiromantes* *buettikoferi* (De Man 1883) dominates the Bonamouang (BM) and Bon'Ewonda (BW) sites with respectively 32 and 75 individuals. *Perisesarma huzardi* with 316 individuals dominates at EG site and *Arimase elegans* (Herklots 1951) with 58 individuals dominates the WB site.

The greatest densities of crabs (Figure 2a) have been recorded in the sites of EG, BG and BW (7.64, 4.12 and 3.39 individuals. $m^{-2}$ respectively). The lowest density was recorded in the BM (1.43 individuals. $m^{-2}$). *Chiromantes angolense*, *Chiromantes buettikoferi* and *Perisesarma huzardi* possess large densities (4.83, 3.64 and 3.34 individuals. $m^{-2}$, respectively). The lowest densities (0.03, 0.03 and 0.02 individuals.$m^{-2}$) were observed, respectively for *Uca tangeri, Cardisoma armatum* and *Portunus validus* (Figure 2b).

Crabs species composition is very distinct between sites. Each site presents a particular species richness. BW and WB sites have a substantially similar species composition with an SI of approximately 60% (Figure 3). Low stress value obtained in the nMDS indicates that different populations are well represented and the combination is meaningful. BW and EG sites are very closer in terms of abundance (Figure 4). ANOSIM test indicates that the overall difference in abundance of crabs between sites is $R= 0.46$ ($P < 0.001$).

## MOLLUSCS INVENTORY

In the present study we identified 14,405 individuals, divided into 12 species belonging to five families. The Pachymelaniidae family with four species is the most diverse and that of the Potamididae (45.4% of individuals) is the most abundant. The Melanopsidae are represented by three species and the Potamididae have two. The other two families (Neritidae and Onchidiidae) are represented by a single species. The Pachymelaniidae represents 28%, Melanopsidae (18.5%), the Neritidae (5.2%), the unidentified family (2.8%) and the Onchidiidae, 0.06% of the inventoried (Table 3).

The genus *Pachymelania* is more prevalent (Table 4). *Melanoides pergracilis* (Von Martens 1897), *M. tuberculata* (Müller 1774) and *Theodoxus niloticus* (Reeve 1856) were found only in BW, BM and BG respectively. *Tympanotonus fuscatus* (Linné 1758) with 5,492 individuals and *Pachymelania* spp. (2,076 individuals) are the most abundant species. *Acatina acatina* is the least abundant with only 8 individuals.

*Tympanotonus fuscatus* dominates in BS and EG with 2,878 and 2,614 individuals, respectively. The bivalves dominate at BM with 380 individuals. *Melanoides pergracilis* (1,224 individuals) dominates at BW while *Tympanotonus radula* (Brown 1980) with 835 individuals dominates at BG; and finally *Pachymelania fusca* (Gmelin 1791) with 1,368 individuals dominates the WB site. The highest densities of molluscs have been observed in BS (1,824 individuals. $m^{-2}$), EG (1,695 individuals. $m^{-2}$) and BW (1,583 individuals. $m^{-2}$). The lowest density (745 individuals. $m^{-2}$) was obtained in BG (Figure 5a). *Tympanotonus fuscatus* possesses large densities (≈2,700 individuals. $m^{-2}$). Lowest densities (≈0.04 individuals. $m^{-2}$) are observed in *Acatina acatina* (Figure 5b).

The molluscs species composition in the different sites shows similarities. BS is completely identical to EG (SI: 100%). BG and BW are very close (SI ≈75%). Similarly, SI between WB and BM sites are close to 60% (Figure 6). The zero value of stress obtained in the nMDS indicates that the population representation in different sites is perfect with appropriate data transformation. BS and EG sites are close in terms of abundance (Figure 7). ANOSIM test indicates an overall significant difference in the abundance of molluscs between the sites with $R = 0.32$ ($P < 0.001$).

## DISCUSSION

### CENSUS

The census of macroscopic invertebrates in the Wouri River mangrove resulted in the collection of 16,451 individuals (2,046 crabs and 14,405 molluscs). These individuals have been grouped into 24 species evenly divided between the two taxa, 16 genera (nine crabs and seven molluscs) and 11 families (five crabs and six molluscs). As in most mangrove forests in the world, these two groups of invertebrates dominate the macrobenthos (Bosire et al. 2004; Nagelkerken 2008; Lee 2008).

Five species have particularly high relative abundances. The abundances of *Pachygrapsus transversus*, *Metagrapsus curvatus, Arimase elegans*, *Perisesarma huzardi* and *Perisesarma alberti* (Rathbun 1921) are three to eight times higher than those reported in a previous study (Longonje 2008). However, three other species appear to display an opposite trend. *Portunus validus*, *Cardisoma armatum* and *Uca tangeri* showed extremely low abundances in our sites that may be more than 200 times less than the above mentioned research. In more northern sites along the West-African coasts, Dahdouh-Guebas and Koedam (2001) reported even higher abundances for *Uca tangeri* (up to > 50 individuals. $m^{-2}$).

The majority of the dominant species showed a preference for muddy substrates. Several representatives of the Sesarmidae family crabs are known for a diet rich in leaves and young *Rhizophora* spp. propagules (Dahdouh-Guebas et al.1997, 1998, Lee 1998, Dahdouh-Guebas et al. 1999, Ashton et al. 2003a, Dahdouh-Guebas et al. 2010). The mangroves of the Wouri River estuary being dominated by *Rhizophora* spp., one can understand that this family is the most abundant in the region.

Taxonomic diversity varies in different levels. Species diversity calculated from Shannon – Weaver diversity indices gives H' = 2.98 for crabs and H '= 2.79 for molluscs with $H'_{max}$ = 3.585 identical since both groups have the same number of species. Specific diversity measures the degree of complexity of the stand: the more there are species and their respective neighboring abundances, the higher is the diversity (Frontier and Picho-Viale 1993).

## CRAB DIVERSITY

Most crab species observed in this study are identical to those already described in studies on mangrove forests of Cameroon more than 35 years ago, which indicates the relative stability of the macrobenthic fauna. Boyé et al. (1975) surveyed seven species belonging to four families: Portunidae, Grapsidae, Sesarmidae and Ocypodidae in the Limbe rocky substrates and the estuaries of Mabeta and Sanaga. Longonje (2008) improved the previous inventory by adding ten other species. These latter species belong to five families comprising of the four above-mentioned families and the Gecarcinidae family with a single species *Cardisoma armatum*. The twelve species of crabs surveyed in this work belong to the five identified families mentioned above. However, three distinct monospecific genera and thus three species new to the area, all belonging to the Sesarmidae family (*Perisesarma kamermani* (De Man 1883), *Chiromantes buettikoferi* (De Man 1883), and *Sesarma* sp. have been found in the mangrove forests of the Wouri River estuary (Table 5). This family, with eight species appears always as the most diverse in the mangrove forests of Cameroon, or elsewhere in the world (Lee 1998, Ashton et al. 2003a, Lee 2008, Cannicci et al. 2008, Nagelkerken et al. 2008).

Species in this family are part of the key organic components of the mangrove because they play a major role in the structure and functioning of this ecosystem (Smith et al. 1991). The present study complements the brachyuran fauna list in the mangroves of Cameroon with three species. The species composition of mangrove crabs in Cameroon from now consists of 20 species grouped in 13 genera and five families (Table 6).

Six species of crabs (*Callinectes amnicola*, *C. pallidus*, *Grapsus grapsus*, *Ocypode africana*, *O. ippeus* and *Pachygrapsus gracilis*) identified by previous research were not recovered in this study. This can be due to the limited mangrove area surveyed by this work, but could also be attributed specifically to the nature of substrates (they prefer the Limbe rocky substrates above to the muddy substrates of the Wouri River estuary). Twenty species of crabs currently reported in Cameroon are found in the inventory of Cumberlidge (2006) which reports a total of 36 crab species for Central Africa. Given the similarities in biological composition of Atlantic mangroves, it is likely that all species surveyed above are also found in mangrove forests of Cameroon.

The low relative diversity amongst mangrove crabs in the Wouri River estuary can currently be attributed to the nature of the substrate. The genus *Uca* for example, type in Cameroon represented by a single species, as elsewhere, could contain several species often distinguished by the nature of the substrate. Some species prefer muddy substrates (e.g. *U. vocans*), while others (e.g. *U. annulipes*) are found in sandy soils (Lim and Wong 2010). Low species diversity may also be explained according to Alfaro (2006) by sampling of invertebrates in contiguous habitats of difficult access such as mud. Lee (2008) believes that physical environmental stress (hypersaltiness, hypoxia, hypercapnia) and poor litter nutritional quality due to pollution of all kinds must also contribute to the proliferation of species decline in mangroves for the assemblage to be dominated by a population of some species which can adapt.

The low similarity observed between specific composition and abundances can be explained by the predominance of Sesarmids crabs. At least 50% of species of this family have been found on different sites but only BW and WB seem to be closer with SI= 60%. Sesarmidae are the most diversified and abundant among mangroves crabs (Lee 2008). These species constituted the key functioning elements of this ecosystem (Smith et al. 1991, Lee 1997, Boon et al. 2008). The nMDS shows that EG and BW sites are close in terms of abundance (*cf.* Figure 4). This result could be explained by the low abundances of the three different species (*Perisesarma kamermani, Portunus validus* and *Uca tangeri*) between both sites.

MOLLUSC DIVERSITY

Several species of molluscs collected from this work are similar to those described in previous studies in mangrove forests of Cameroon. Boyé et al. (1975) tracks 23 species of molluscs including 13 of gastropods and 10 bivalves. Species of gastropods belong to seven families: Ellobiidae (*Melampus liberianus*), Fissurellidae (*Fissurela* spp.), Littorinidae (*Scabra scabra, S. angulifera, Tectarius granosus*), Muricidae (*Purpura collifera*, *P. yetus*), Neritidae (*Neritina glabrata*, *N. senegalensis*), Pachymelaniidae (*Pachymelania aurita*, *P. fusca*), Potamididae (*Tympanotonus fuscatus*) and Thaididae (*Thais callifera*). Encountered lamellibranches are: *Arca* sp., *Corbula trigona*, *Crassostrea gasar, C. rufa, Cyrenoida rosea, Egeria radiata*, *Iphigenia rostrata, Ostrea tulipa, Sepia officinalis* and *Siphonaria mouret*.
Bandel and Kowalke (1999) improve the previous inventory by adding nine new species of gastropods. Three of these species belong to three new families: Assimineidae (*Assiminea hessei*), Planaxidae (*Angola lineata*) and Onchidiidae (*Onchidium* sp.). The remaining six species belong to some above-mentioned families: the Pachymelaniidae (*Pachymelania byronensis*), the Neritidae (*Neritina afra, N. rubricata, Neritilia rubida, N. manoeli*), and the Potamididae (*Tympanotonus radula*).

Twelve species of molluscs harvested by the current study enrich inventory in mangrove forests in Cameroon with a new family (Melanopsidae) and six new species (Table 7). Three of these species belong to the new family (*Melanoides pergracilis, M. tuberculata Potadoma lirincta*). The other species are: *Acatina acatina* (Onchidiidae), *Theodoxus niloticus* (Neritidae) and the undetermined bivalve. The species composition of molluscs of mangrove forests in Cameroon is now incorporated in the stemming from this study, of 40 species, 27 genera and 20 families. These are subdivided into 29 species of gastropods (snails) and 11 species of lamellibranches. Gastropods are made of seventeen genera grouped in 12 families. Bivalves contain 10 genera grouped in eight families (Table 8). With seven species, the family of the Neritidae appears today as the most diversified in the mangrove forests of Cameroon.

As reported above for crabs, the low diversity of molluscs in general can also be explained by the nature of the substrate, the identification issues, the difficult access in the workplace and the physical environmental stress. Generally, the species richness of macrobenthos in the mangroves is low, but high in absolute abundance (Lee 2008). In addition, estuarine wetlands are recognized as being relatively poor of mollusc species (Zabi and Le Loeuff 1993).

Species composition shows affinities between BS and EG (SI = 100%), BG and BW (75%) and WB and BM (60%) sites. In terms of abundances, BS and EG sites are also the most close (Figure 7). This similarity can be explained by low diversity of molluscs (only two species) on these sites accompanied by great abundance (the highest densities). The spatial location favors for similarity of environmental factors (Din et al. 2002). The distribution of Invertebrates in mangroves is influenced by vegetation and some abiotic characteristics (Nobbs 2003). Mangrove species richness patterns of molluscs strongly followed plant diversity evolution (Ellison 1999). Both sites are submitted to a harsh demographic pressure that affects biologic composition by progressive reduction of less resilient species.

Apart from two species (*Melampus liberianus* (H. and A.Adams1854) and *Neritina rubricata* (Morelet 1858)) previously reported in mangrove forests close to Douala airport, all other species mentioned by previous studies in this area were collected. The species absent in this inventory but reported as Cameroonian species have been recorded in other mangrove sites. *Assiminea hessei* (Boettger 1887) and *Thais* sp. were found in the mangrove forests of Tiko and Sandy estuary of the Sanaga River. *Neritina glabrata* (Sowerby 1843) lives among organic debris on the wet sand leaf in Limbe and the Northern volcanic coastline at the base of Mount Cameroon in association with *Angiola lineata* (Da costa 1778), *Nerita* sp. and *Scabra scabra* (Linné 1758). *S. angulifera* (Rehder 1981) is usually present in the mangrove forests by the sea shore accompanied by *Neritilia manoeli* (Dohrn 1866) and *Neritina afra* (Sowerby 1843). These species live on aquatic plants, dead wood, rocks and stones. Large densities of *Neritina rubricata* and *N. glabrata* were reported near Limbe and Tiko.

Molluscs (gasteropods and bivalves) have very different habitats and life styles. Most bivalves are microphages; they feed either on plankton or organic particles in suspension in water (suspension feeders), or on food collected on the bottom (deposit feeders). Some have however developed special diets, carnivorous or xylophagous (Ashton et al. 2003a).

According to Zabi and Le Loeuff (1993), Cameroon estuary houses high densities of herbivorous detritus feeders, especially Potamididae (*Tympanotonus* spp.) and Pachymelaniidae (*Pachymelania* spp.). The species that disappear first when one is progressing far into the estuary are *Melampus* spp. (bivalves), *Littorina* spp. and *Thais* spp. (gasteropods) which are less tolerant to decreasing salinity. *Ostrea* and *Tympanotonus* genera are less demanding because they clearly descend below the value of 5‰. However, *Pachymelania fusca* and *Neritina glabrata* show the most resistance. These results are consistent with those of the present work.

## CONCLUSION

The inventory of the macrobenthos (crabs and molluscs) in the mangrove forests of the Wouri River estuary allowed the collection of 24 species almost evenly divided between these two groups. The current study contributed to complementing the crab and mollusc species list of mangrove forests in Cameroon with nine other species (*Acatina acatina, Chiromantes buettikoferi, Melanoides pergracilis, M. tuberculata, Perisesarma kamermani, Potadoma* *lirincta*, *Sesarma* sp. and *Theodoxus niloticus*) grouped into seven genera and five families. This last census of macrobenthos in the mangrove forests of the Wouri River estuary has now taken the crab and mollusc inventory in the mangroves of Cameroon from 51 species to 60. The Sesarmidae family and that of the Pachymelaniidae appear to be the most diverse and *Sesarma angolense* and *Tympanotonus fuscatus* the most abundant species in the mangrove forests of the Wouri River estuary. However, the inaccessibility of muddy habitats, pollution and environmental factors such as the hypersaltiness, hypoxia, hypercapnia and the vegetation variability all have an influence on the diversity and abundance of macrobenthos in the mangroves. Mangrove forests of the Wouri River undergo many pressures that alter them, reduce their biodiversity and prevent them from fully performing their multiple services. Based on the rapid deterioration suffered by this ecosystem in the southern part of the study area, this research provides a relevant ecological database.

## BIBLIOGRAPHY

Alfaro AC. 2006. Benthic macro-invertebrate community composition within a mangrove sea grass estuary in northern New Zealand. *Estuarine Coastal and Shelf Science* 66: 97–110.

Ashton EC, Hogarth PJ, Macintosh DJ. 2003a. A baseline study of the diversity and community ecology of crab and molluscan macrofauna inthe Semantan Mangrove forest, Sarawak, Ma1aysia. *Journal tropical of Ecology* 19: 127-142.

Bandel K, Kowalke T. 1999. Gastropod fauna of the Cameroonian coasts. *Helgol Marine Research* 53: 129-140.

Bartolini F, Cimò F, Dahdouh-Guebas F, Fusi M, Penha Lopes G, Cannicci S. 2010. The effect of sewage discharge on the ecosystem engineering activities of two East African fiddler crab species: Consequences for mangrove ecosystem functioning. *Marine Environmental Research* doi:10.1016/j.marenvres.2010.10.002.

Boon PY, Yeo DCJ, Todd PA. 2008. Feeding ecology of two species of *Perisesarma* (Crustacea: Decapoda: Brachyura: Sesarmidae) in Mandai mangroves, Singapore. *Journal of Crustacean Biology* 28(3): 480–484.

Bosire JO, Dahdouh-Guebas F, Kairo JG, Cannicci S, Koedam N. 2004. Spatial variations in macrobenthic fauna recolonisation in a tropical mangrove bay. *Biodiversity and Conservation* 13(6): 1059-1074.

Bosire JO, Dahdouh-Guebas F, Kairo JG, Cannicci S, Kazungu J, Dehairs F, Koedam N. 2005a. Litter degradation and CN dynamics in reforested mangrove plantations at Gazi Bay, Kenya. *Biological Conservation* 126: 287-296.

Bosire JO, Kazungu J, Koedam N, Dahdouh-Guebas F. 2005b. Predation on propagules regulates regeneration in a high-density reforested mangrove plantation. *Marine Ecology Progress Series* 299:149-155.

Bouchet P, Olivier P, Le Guyader H. 2006. Des voyages de Cook à l'expédition Santo: un renouveau des explorations naturalistes des îles du Pacifique. *Journal de la société des Océanistes*: 126-127.

Boyé M, Baltzer F, Caratini C, Hampartzoumian A, Olivry JC, Paziat JC, Viliiers JF. 1975. Mangrove of the Estuary, Cameroon. In: Walsh GE, Snedaker SC, Teas HJ (eds) Biology and Management of Mangroves. Proceedings of International Symposium, Honolulu, October 8-11th, 1974. I.F.A.S. Univ. Florida, Gainesville (USA), pp 431-455.

Cannicci S, Dahdouh-Guebas F Anyona D, Vannini M. 1996. Natural diet and feeding habits of *Thalamita crenata* (Decapoda: Portunidae). *Journal of Crustacean Biology* 16(4): 678-683.

Cannicci S, Fratini S,Vannini M. 1999. Short range homing in fiddler crabs (Ocypodidae, genus *Uca*): a homing mechanism not based on local visual landmarks. *Ethology* 105(10): 867-880.

Cannicci S, Dahdouh-Guebas F, Montemagno L. 2001. Field keys for Kenyan mangrove crabs. La Specola. University of Florence.

Cannicci S, Burrows D, Fratini S, Lee SY, Smith III TJ, Offenberg J, Dahdouh Guebas F. 2008. Faunistic impact on vegetation structure and ecosystem function in mangrove forests: a review. *Aquatic Botany* 89: 186–200.

Cannicci S, Bartolini F, Dahdouh-Guebas F, Fratini S, Litulo C, Macia A, Elisha Mrabu J, Penha-Lopes G, Jose P. 2009. Effects of urban waste water on crab and Subtropical mangroves of East Africa. *Estuarine Coastal and Shelf Science* 30: 1-14.

Clarke KR. 1993. Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology* 18: 117-143.

Clarke KR, Green RH. 1988. Statistical design and analysis for a biological effects study. *Marine Ecology* 46: 21-226.

Clarke KR, Gorley RN. 2001. PRIMER v6: User manual/tutorial. PRIMER-E Ltd, Plymouth, UK.

Cumberlidge N. 2006. Rapid survey of the decapods crustaceans of the Boké Prefecture Guinea. In: Rapid biological assessment of Boké Préfecture, Northwestern Guinea. RAP Bulletin of biological Assessment 41. Distributed for conservationinternational, 192p.

Dahdouh-Guebas F, Verneirt M, Tack JF, Koedam N. 1997. Food preferences of *Neosarmatium meinerti* de Man (Decapoda: Sesarminae) and its possible effect on the regeneration of mangroves. *Hydrobiologia* 347: 83-89.

Dahdouh-Guebas F, Verneirt M, Tack JF, Van Speybroeck D, Koedam N. 1998. Propagule predators in Kenyan mangroves and their possible effect on regeneration. *Marine and Freshwater Research* 49(4): 345-350.

Dahdouh-Guebas F, Giuggioli M, Oluoch A, Vannini M,Cannicci S. 1999. Feeding habits of non-ocypodid mangrove crabs from Kenya. *Bulletin of Marine Science* 64(2): 291-297.

Dahdouh-Guebas F, Mathenge C, Kairo JG, Koedam N. 2000.Utilization of mangrove wood products around Mida Creek (Kenya) amongst subsistence and commercial users. *Economy Botany* 54(4): 513-527.

Dahdouh-Guebas F, Koedam N. 2001. Are the northernmost mangroves of West Africa viable? A case study in Banc d'Arguin National Park, Mauritania. *Hydrobiologia* 458: 241-253.

Dahdouh-Guebas F, Verneirt M, Cannicci S, Kairo JG, Tack JF, Koedam N. 2002. An exploratory study on grapsid crab zonation in Kenyan mangroves. *Wetlands Ecology and Management* 10: 179-187.

Dahdouh-Guebas F, Van Pottelbergh I, Kairo JG, Cannicci S, Koedam N. 2004. Human-impacted mangroves in Gazi (Kenya): predicting future vegetation based on retrospective remote sensing, social surveys, and distribution of trees. *Marine Ecology Progress Series* 272: 77-92.

Dahdouh-Guebas F, Koedam N. 2006. Coastal vegetation and the Asian tsunami. *Science* 311: 37-38.

Dahdouh-Guebas F, Koedam N. 2008. Long-term retrospection on mangrove development using transdisciplinary approaches: a review. *Aquatic Botany* 89(2): 80-92.

Dahdouh-Guebas F, Koedam N, Satyanarayana B, Cannicci S. 2010. Human hydrographical changes interact with propagule predation behaviour in Sri Lankan mangrove forests. *Journal of Experimental Marine Biology and Ecology* doi:10.1016/j.jembe.2010.11.012.

Din N, Priso RJ, Kenne M, Ngollo DE, Blasco F. 2002. Early growth stages and natural regeneration of *Avicennnia germinans* (L.) Stearn in the Wouri estuarine mangroves (Douala- Cameroun). *Wetlands Ecology and Management* 10: 461-472.

Din N, Baltzer F. 2008. Richesse Floristique et évolution des mangroves de l'estuaire du Cameroun. *African Geosciences Review* 2: 119-130.

Din N, Saenger P, Priso RJ, Dibong DS, Blasco F. 2008.Logging activities in mangrove forests: A case study of Douala Cameroon. *African Journal Environmental Science and Technology* 2 (2): 022-030.

Ellis J, Nicholls P, Craggs R, Hofstra D, Hewitt J. 2004. Effects of terrigenous sedimentation on mangrove physiology and associated macrobenthic communities. *Marine Ecology Progress Series* 270: 71–82.

Ellison AM. 2008. Managing mangroves with benthic biodiversity in mind: moving beyond roving banditry. *Journal of Sea Research* 59: 2-15.

Ellison AM, Farnsworth EJ, Merkt RE. 1999. Origins of mangrove ecosystems and the mangrove biodiversity anomaly. *Global Ecology and Biogeography* 8: 95–115.

Frontier S, Picho-Viale D. 1993. Ecosystèmes: structure, fonctionnement, évolution. Masson, Paris.

Gilman E, Ellison J, Duke NC, Field C. 2008. Threats to mangroves from climate change and adaptation options: a review. *Aquatic Botany* 89(2): 237-250.

Hartnoll RG, Cannicci S, Emmerson WD, Fratini S, Macia A, Mgaya Y, Porri F, Ruwa RK, Shunnula JP, Skov MW, Vannini M. 2002. Geographic trends in mangrove crab abundance in East Africa. *Wetlands Ecology and Management* 10: 203–213.

Joana M, Jordan O, Oliveira RF. 2003. Comparison of non-invasive methods for quantifying population density of the Fiddler crab *Uca tangeri*. *Journal of the Marine Biological Association* 83: 981-982.

Kristensen E. 2008. Mangrove crabs as ecosystem engineers; with emphasis on sediment processes. *Journal Sea Research* 59: 30-43.

Kruskal JB, Wish M. 1978. Multidimensional scaling. Sage Publications, Beverly Hills. 93p

Lee SY. 1997. Potential trophic importance of the faecal material of the mangrove crab *Sesarma messa*. *Marine Ecology* 159: 275-284.

Lee SY. 1998. Ecological role of Grapsid crabs in mangrove ecosystems: a review. *Marine Freshwater Research* 49: 335-343.

Lee SY.1999.The effect of mangrove leaf litter enrichment on macrobenthic colonization of defaunated sandy substrates. *Estuarine Coastal and Shelf Science* 49: 703-712.

Lee SY. 2008. Mangrove macrobenthos: Assemblages, services and Linkages. *Journal Sea Research* 59: 16-29.

Longonje S. 2008. Distribution, Diversity and Abundance of Crabs in Cameroon Mangroves. Ph.D Thesis, University of York.

Lim SSL, Wong JAC. 2010. Burrow residency and re-emergence rate in a droving species, *Uca vocans* (Linnaeus, 1758) and its sympatric associate, *U. annulipes* (H. Milne Edwards, 1837) (Brachyura, Ocypodidae). *Crustaceana* 83 (6): 677-693.

Lui TH, Lee SY, Sadovy Y. 2002. Macrobenthos of a tidal impoundment at the Mai Po marshes nature reserve, Hong Kong. *Hydrobiologia* 468: 193–212.

Macintosh DJ. 1984. Ecology and productivity of Malaysian mangrove crab populations (Decapoda: Branchyura). In: Soepadimo E, Rao AN, Macintosh DJ (eds) Proceedings of the Asian Symposium on Mangrove Environment, Research and Management.

Mazda Y, Magi M, Kogo M, Hong PN. 1997. Mangroves as a coastal protection from waves in the Tong King Delta, Vietnam. *Mangroves and Salt Marshes* 1: 127-135.

Mazda Y, Magi M., Nanao H, Kogo M, Miyagi T, Kanazawa N, Kobashi D. 2002. Coastal erosion due to long-term human impact on mangrove forests. *Wetlands Ecology and Management* 10: 1–9.

Micheli F, Gherardi F, Vannini M. 1991. Feeding and burrowing ecology of two East African mangrove crabs. *Marine biology* 111: 247-254.

Mohamed MOS, Neukermans G, Kairo JG, Dahdouh-Guebas F, Koedam N. 2009. Mangrove forests in a peri-urban setting: the case of Mombasa (Kenya). *Wetlands Ecology and Management* 17: 243-255.

Nagelkerken I. 2008. The habitat function of mangroves for terrestrial and marine fauna: A review. *Aquatic Botanic* 89: 155-185.

Nfotabong Atheull A, Din N, Longonje SN, Koedam N, Dahdouh-Guebas F. 2009. Commercial activities and subsistence utilization of mangrove forests around the Wouri estuary and the Douala-Edea reserve (Cameroon). *Journal of Ethnobiology and Ethnomedicine* 5: 35.

Nfotabong Atheull A. 2011. Impact of anthropogenic activities on the vegetation structure of mangrove forests in Kribi, the Nyong river mouth and Cameroon Estuary. Ph.D Thesis, Université Libre de Bruxelles-ULB, Brussels, Belgium / The University of Douala, Cameroon, 196 pages + appendices.

Ng PKL, Daniele G, Peter JFD. 2008. Systema Brachyuroran: part I. An annotated checklist of extant Brachyuran crabs of the world. *Raffles bulletin of Zoology* 17: 1-286.

Pape E, Muthumbi A, Kamanu CP, Vanreusel A. 2008. Size-dependent distribution and feeding habits of *Terebralia palustris* in mangrove habitats of Gazi Bay, Kenya. *Estuarine Coastal and Shelf Science* 76: 797-808.

Plaziat JC. 1974. Répartition des mollusques amphibies de quelques littoraux et estuaires à mangroves (Nouvelle Calédonie et Cameroun). *Haliotis* 4: 17-167.

Raymond BM, Holthuis LB. 1981.West African Brachyuran Crabs (Crustacea:Decapoda). Smithsonian contributions to Zoology, number 306. City of Washington

Seck AA. 1996. Le peuplement des mollusques et des polychètes du Littoral de Dakar (Baies de Hann et de Soumbedioune): Impact et conséquences des perturbations du milieu sur la structure. Thèse, Université Cheikh Anta Diop, Dakar.

Silva ACF, Brazão S, Hawkins SJ, Thompson RC, Bonaventura DM. 2009. Abundance, population structure and claw morphology of the semi-terrestrial crab *Pachygrapsus marmoratus* (Fabricius, 1787) on shores of differing wave exposure. *Marine Biology* 156: 2591–2599.

Skilleter GA, Warren S. 2000. Effects of habitat modification in mangroves on the structure of mollusc and crab assemblages. *Journal of Experimental Marine Biology and Ecology* 244:107-129.

Smith TJ, Boto KG, Fruscher SD, Giddens RL. 1991. Keystone Species and Mangrove forest dynamics: the influence of burrowing by crabs on soil nutriment status and forest productivity. *Estuarine Coastal and Shelf Science* 33: 419-432.

Smith FN, Wilcox C, Lessmann JM. 2009. Fiddler crab burrowing affects growth and production of the white mangrove (*Laguncularia racemosa*) in a restored Florida coastal marsh. *Marine Biology* 156: 2255–2266.

Steele OC, Ewel KC, Goldstein G. 1999. The importance of propagule predation in a forest of non-indigenous mangrove trees. *Wetlands* 19(3): 705-708.

Stieglitz T, Ridd P, Müller P. 2000. Passive irrigation and functional morphology of crustacean burrows in a tropical mangrove swamp. *Hydrobiologia* 421: 69-76.

Vannini M, Rorandelli R, Lahteenoja O, Mrabu E, Fratini S. 2006. Tree-climbing behaviour of *Cerithidea decollata*, a western Indian Ocean mangrove gastropod (Mollusca: Potamididae). *Journal of the Marine Biological Association UK* 86:1429-1436

Vannini M, Lori E, Coffa C, Fratini S. 2008a. *Cerithidea decollata*: a snail that can foresee the future? *Animal Behaviour* 76: 983-992.

Vannini M, Coffa C, Lori E, Fratini S. 2008b.Vertical migrations of the mangrove snail *Cerithidea decollata* (L.) (Potamididae) through a synodic month. *Estuarine Coastal and Shelf Science* 78: 644–648.

Zabi GSF, Le Lœuff P. 1993. Revue des connaissances sur la faune benthique des milieux margino-littoraux d’Afrique de l’Ouest. Deuxième partie: Peuplement et biotopes. *Review Hydrobiology Tropical* 26 (1): 19- 51.

Table 1: Habitats and burrows of twelve species of crab surveyed in the mangrove forests of the Wouri River estuary

| **Families** | **Species** | **Microhabitat and burrows** |
|---|---|---|
| Gecarcinidae | *Cardisoma armatum* | Burrow very deep in the sand |
| Grapsidae | *Pachygrapsus transversus* | Muddy burrows |
| Ocypodidae | *Portunus validus* | Sandy burrows |
| Portunidae | *Uca tangeri* | Muddy burrows, on dead wood |
| | *Arimase elegans* | On plant roots and trunks, in *Pandanus* spp. leaf axils |
| Sesarmidae | *Chiromantes buettikoferi = Sesarma buettikoferi* | Dead wood, in *Pandanus* spp. leaf axils, on plant trunks |
| | *Metagrapsus curvatus* | Muddy burrows, on dead wood |
| | *Perisesarma alberti = Sesarma alberti* | Muddy burrows, on dead wood, in *Pandanus* spp leaf axils |
| | *Perisesarma huzardi* | Muddy burrows, on dead wood |
| | *Perisesarma kamermani* | Deep burrows in the mud |
| | *Chiromantes angolense= Sesarma angolense* | Muddy burrows, on dead wood |
| | *Sesarma* sp. | On dead wood, on the sand surface |

Table 2: Crab species diversity in the mangrove forest of the Wouri River estuary.

Ni, Number of individuals of species i; N, Total Number of individuals;

H', Shannon-Weaver diversity index.

| Species | Sites | | | | | | Total | Ni/N | $Log_2$ (Ni/N) | H' |
|---|---|---|---|---|---|---|---|---|---|---|
| | BS | BG | BM | BW | EG | WB | | | | |
| *Arimase elegans* | 24 | 0 | 0 | 53 | 25 | 58 | 160 | 0.0782 | -3.6767 | 0.2875 |
| *Cardisoma armatum* | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 0.0015 | -9.4136 | 0.0138 |
| *Chiromantes angolense* | 0 | 257 | 31 | 62 | 97 | 36 | 483 | 0.2361 | -2.0827 | 0.4917 |
| *Chiromantes buettikoferi* | 0 | 76 | 32 | 75 | 132 | 19 | 334 | 0.1632 | -2.6149 | 0.4269 |
| *Metagrapsus curvatus* | 6 | 57 | 1 | 12 | 69 | 0 | 145 | 0.0709 | -3.8187 | 0.2706 |
| *Pachygrapsus transversus* | 54 | 0 | 22 | 0 | 27 | 0 | 103 | 0.0503 | -4.3121 | 0.2171 |
| *Perisesarma alberti* | 49 | 22 | 27 | 60 | 23 | 53 | 234 | 0.1144 | -3.1282 | 0.3578 |
| *Perisesarma huzardi* | 20 | 0 | 0 | 14 | 316 | 14 | 364 | 0.1779 | -2.4908 | 0.4431 |
| *Perisesarma kamermani* | 8 | 0 | 30 | 0 | 41 | 34 | 113 | 0.0552 | -4.1784 | 0.2308 |
| *Portunus validus* | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 0.0010 | -9.9986 | 0.0098 |
| *Sesarma* sp. | 10 | 0 | 0 | 63 | 29 | 0 | 102 | 0.0499 | -4.3262 | 0.2157 |
| *Uca tangeri* | 0 | 0 | 0 | 0 | 3 | 0 | 3 | 0.0015 | -9.4136 | 0.0138 |
| **Total** | **171** | **412** | **143** | **339** | **764** | **217** | **2046** | / | / | **2.9785** |

Table 3: Habitats of twelve species of mollusc surveyed in the mangrove forests of the Wouri river estuary

| Families | Species | Habitat |
|---|---|---|
| Melanopsidae | *Melanoides pergracilis* | On the mud, on plant roots and trunks |
| | *Melanoides tuberculata* | On the mud, on plant roots and trunks |
| | *Potadoma lirincta* | On the mud, on plant roots and trunks, on the propagules |
| Neritidae | *Theodoxus niloticus* | On the mud, on plant roots and trunks |
| Onchidiidae | *Acatina acatina* | On the mud, on plant roots and trunks |
| | *Pachymelania aurita* | On the mud |
| Pachymelaniidae | *Pachymelania fusca* | On the mud, on plant roots and trunks |
| | *Pachymelania granifera* | On the sand, on dead wood |
| | *Pachymelania* sp. | On plant roots and trunks |
| | *Tympanotonus fuscatus* | On the mud, on plant roots and trunks, on the propagules |
| Potamididae | *Tympanotonus radula* | On the mud, on the propagules |
| - | Unknown species | On the mud, on plant roots and trunks |

Table 4: Mollusc species diversity in the mangrove forests of the Wouri river estuary. Ni, Number of individuals of species i; N, Total Number of individuals; H’, Shannon-Weaver diversity index.

| Species | Sites | | | | | | Total | Ni/N | $Log_2$ (Ni/N) | H' |
|---|---|---|---|---|---|---|---|---|---|---|
| | BS | BG | BM | BW | EG | WB | | | | |
| *Acatina acatina* | 0 | 3 | 2 | 3 | 0 | 0 | 8 | 0.0006 | -10.8143 | 0.0060 |
| *Bivalve* (unknown) | 0 | 0 | 380 | 0 | 0 | 22 | 402 | 0.0279 | -5.1632 | 0.1441 |
| *Melanoides pergracilis* | 0 | 0 | 0 | 1224 | 0 | 0 | 1224 | 0.0850 | -3.5569 | 0.3022 |
| *Melanoides tuberculata* | 0 | 0 | 219 | 0 | 0 | 0 | 219 | 0.0152 | -6.0395 | 0.0918 |
| *Pachymelania aurita* | 0 | 112 | 243 | 487 | 0 | 0 | 842 | 0.0585 | -4.0966 | 0.2395 |
| *Pachymelania fusca* | 0 | 88 | 26 | 135 | 0 | 1368 | 1617 | 0.1123 | -3.1552 | 0.3542 |
| *Pachymelania granifera* | 0 | 240 | 0 | 580 | 0 | 0 | 820 | 0.0569 | -4.1348 | 0.2354 |
| *Pachymelania* sp. | 770 | 40 | 0 | 491 | 775 | 0 | 2076 | 0.1441 | -2.7947 | 0.4028 |
| *Potadoma lirincta* | 0 | 149 | 247 | 245 | 0 | 0 | 641 | 0.0445 | -4.4901 | 0.1998 |
| *Theodoxus niloticus* | 0 | 17 | 0 | 0 | 0 | 0 | 17 | 0.0012 | -9.7268 | 0.0115 |
| *Tympanotonus fuscatus* | 2878 | 0 | 0 | 0 | 2614 | 0 | 5492 | 0.3813 | -1.3912 | 0.5304 |
| *Tympanotonus radula* | 0 | 835 | 0 | 0 | 0 | 212 | 1047 | 0.0727 | -3.7822 | 0.2749 |
| **Total** | **3648** | **1484** | **1117** | **3165** | **3389** | **1602** | **14405** | / | / | **2.7925** |

Table 5: Review of the crab species composition of the mangrove forests of Cameroon as reported by three authors. Boyé et al. (1975) reported seven species; Longonje (2008) added ten more species and the present study improved this inventory with three other species.

| **Boye et al. (1975)** | **Longonje (2008)** | **Present study** |
|---|---|---|
| *Callinectes amnicola* | *Arimase elegans* | *Chiromantes buettikoferi* |
| *Callinectes pallidus* | *Cardisoma armatum* | *Perisesarma kamermani* |
| *Chiromantes angolense* | *Grapsus grapsus* | *Sesarma* sp. |
| *Goniopsis pelii* | *Metagrapsus curvatus* | |
| *Ocypoda ippeus* | *Ocypode africana* | |
| *Pachygrapsus gracilis* | *Pachygrapsus transversus* | |
| *Uca tangeri* | *Pachygrapsus* sp. | |
| | *Perisesarma alberti* | |
| | *Perisesarma huzardi* | |
| | *Portunus validus* | |

Table 6: Crab species surveyed in different locations within the mangrove forests of Cameroon.

| Families | Species | Location |
|---|---|---|
| Gecarcinidae | *Cardisoma armatum* | Tiko, Limbe, Wouri |
| Grapsidae | *Gonopsis pelii* | Limbe, Tiko, Mabeta |
| | *Grapsus grapsus* | Limbe, Kribi, Sanaga |
| | *Pachygrapsus gracilis* | Tiko, Limbe, |
| | *Pachygrapsus transversus* | Tiko, Limbe, Wouri |
| | *Pachygrapsus* sp. | Tiko, Limbe, |
| Ocypodidae | *Ocypoda africana* | Limbe |
| | *Ocypoda. ippeus* | Limbe, Mabeta, Sanaga |
| | *Uca tangeri* | Tiko, Limbe, Wouri Mabeta, Sanaga |
| Portunidae | *Callinectes amniocola* | Tiko, Limbe, Mabeta, Sanaga |
| | *Callinectes pallidus* | Tiko, Limbe, Mabeta, Sanaga |
| | *Portunus validus* | Tiko, Limbe, Wouri |
| Sesarmidae | *Arimase elegans* | Tiko, Limbe, Wouri |
| | *Chiromantes buettikoferi* | Wouri |
| | *Metagrapsus curvatus* | Limbe |
| | *Perisesarma alberti* | Tiko, Limbe, Wouri |
| | *Perisesarma huzardi* | Tiko, Limbe, Wouri |
| | *Perisesarma kamermani* | Wouri |
| | *Sesarma angolense* | Tiko, Limbe, Wouri Mabeta, Sanaga |
| | *Sesarma* sp. | Wouri |

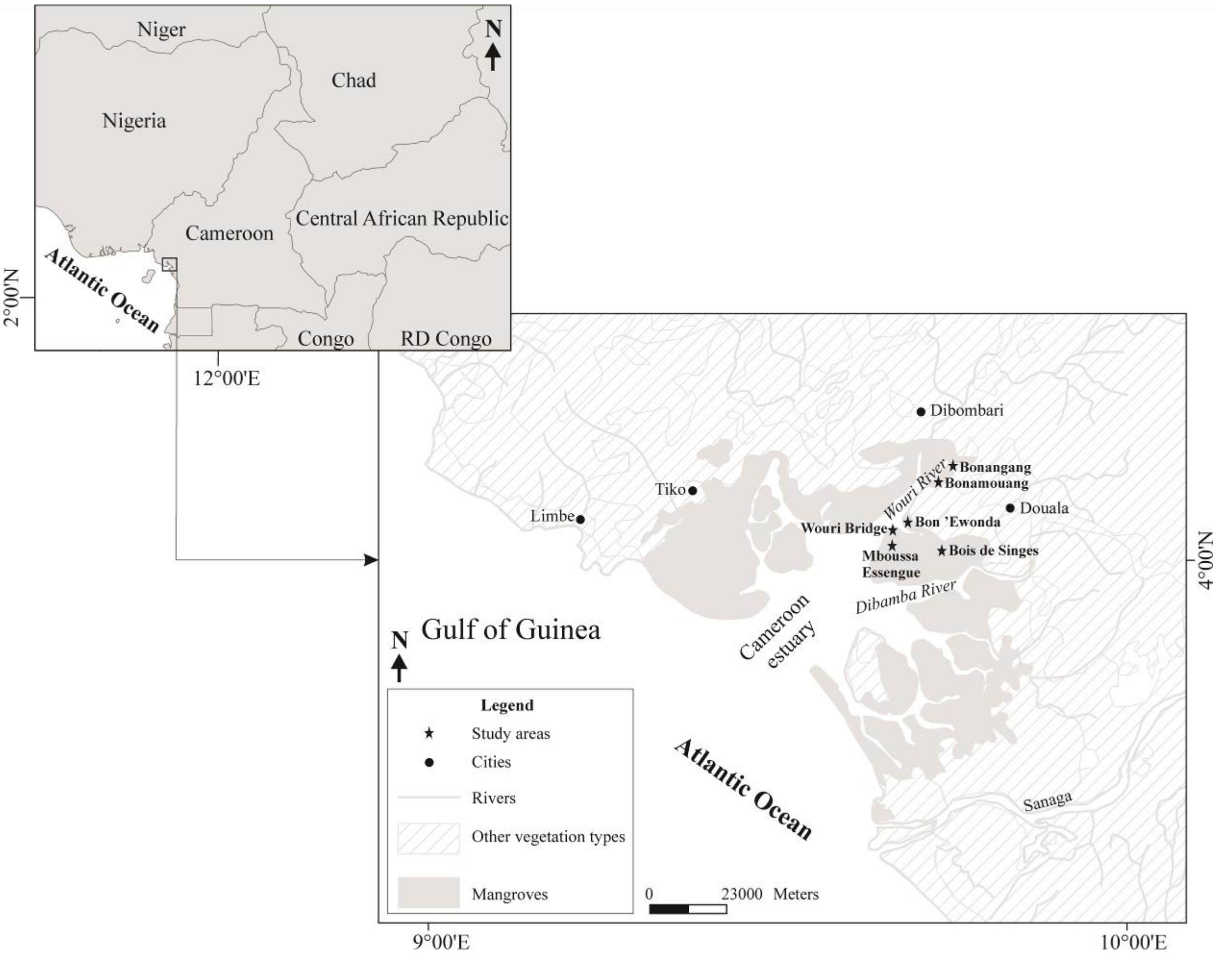
Table 7: Review of the mollusc species composition of the mangrove forests of Cameroon as reported by three authors: Boyé et al. (1975) reported eleven species; Bandel (1999) added six more species and the present study improved this inventory with five other species.

| Boye et al. (1975) | Bandel (1999) | Present study |
|---|---|---|
| *Fissurela* sp. | *Angiola lineata* | *Acatina acatina* |
| *Melampus liberianus* | *Assiminea hessei* | *Melanoides pergracilis* |
| *Neritina glabrata* | *Neritina afra* | *Melanoides tuberculata* |
| *Neritinasenegalensis* | *Neritina rubricata* | *Potadoma lirincta* |
| *Onchidium* sp. | *Neritilia rubida* | *Theodoxus niloticus* |
| *Pachymelania byronensis* | *Neritilia manoeli* | |
| *Scabra angulifera* | | |
| *Scabra scabra* | | |
| *Semifusus moris* | | |
| *Tectarius granosus* | | |
| *Thais callifera* | | |

Table 8: Molluscs species surveyed in and around different locations in the mangrove forests of Cameroon.

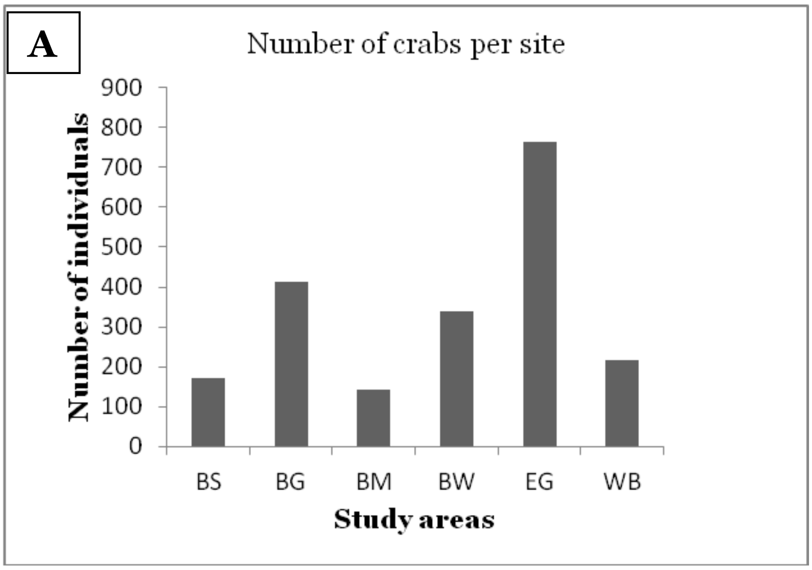
| Families | Species | Locations |
|---|---|---|
| Assimineidae | *Assimenea hessei* | Tiko, Limbe, Mabeta, Sanaga |
| Arcidae | *Arca* sp. | Tiko, Limbe, Mabeta, Sanaga |
| Corbulidae | *Corbula trigona* | Tiko, Limbe, Mabeta, Sanaga |
| Cyrenoididae | *Cyrenoida rosea* | Tiko, Limbe, Mabeta, Sanaga |
| Donacidae | *Egeria radiata* | Tiko, Limbe, Mabeta, Sanaga |
| | *Iphigenia rostrata* | Tiko, Limbe, Mabeta, Sanaga |
| Ellobiidae | *Melampus liberianus* | Douala airport |
| Fissurellidae | *Fissurellida* sp. | Tiko, Limbe, Mabeta, Sanaga |
| Littorinidae | *Scabra scabra* | Tiko, Limbe, Mount Cameroon, Kribi |
| | *Scabra angulifera* | Tiko, Limbe, Mount Cameroon, Kribi |
| | *Tectarius granosus* | Tiko, Limbe, Mabeta, Sanaga |
| Melanopsidae | *Melanoides pergracilis* | Wouri |
| | *Melanoides tuberculata* | Wouri |
| | *Potadoma lirincta* | Wouri |
| Muricinidae | *Purpura collifera* | Tiko, Limbe, Mabeta, Sanaga |
| | *Purpura. yetus* | Tiko, Limbe, Mabeta, Sanaga |
| Neritidae | *Neritina afra* | Tiko, Limbe, Wouri, Mabeta, Sanaga |
| | *Neritina glabrata* | Tiko, Limbe |
| | *Neritina senegalensis* | Tiko, Limbe, Mabeta, Sanaga |
| | *Neritina rubricata* | Douala airport |
| | *Neritilia rubia* | Beaches,Mount Cameroon |
| | *Neritilia manoeli* | Beaches, Mount Cameroon |
| | *Theodoxus niloticus* | Wouri |
| Onchidiidae | *Acatina acatina* | Wouri |
| | *Onchidium* sp. | Tiko, Limbe, Wouri Mabeta, Sanaga |
| Ostreidae | *Cassostrea gasar* | Tiko, Limbe, Wouri Mabeta, Sanaga |
| | *Cassostrea rufa* | Tiko, Limbe, Wouri Mabeta, Sanaga |
| | *Ostrea tulipa* | Tiko, Limbe, Wouri Mabeta, Sanaga |
| Pachymelaniidae | *Pachymelania aurita* | Tiko, Limbe, Wouri Mabeta, Sanaga, Mount Cameroon, Kribi |
| | *Pachymelania byronensis* | Tiko, Limbe, Mabeta, Sanaga |
| | *Pachymelania fusca* | Tiko, Limbe, Wouri Mabeta, Sanaga Tiko, Limbe, Mount Cameroon, Kribi |
| | *Pachymelania granifera* | Tiko, Limbe, Wouri Mabeta, Sanaga, Tiko, Mount Cameroon, Kribi |
| | *Pachymelania* sp. | Tiko, Limbe, Mabeta, Sanaga |
| Planaxidae | *Angola lineata* | Tiko, Limbe, Mount Cameroon, Kribi |
| Potamididae | *Tympanotonus fuscatus* | Tiko, Limbe, Wouri Mabeta, Sanaga, Mount Cameroon, Kribi |
| | *Tympanotonus radula* | Tiko, Limbe, Wouri Mabeta, Sanaga |
| Sepiidae | *Sepia officinalis* | Tiko, Limbe, Wouri Mabeta, Sanaga |
| Siphonariidae | *Siphonaria mouret* | Tiko, Limbe, Wouri Mabeta, Sanaga |
| Thaididae | *Thais callifera* | Tiko, Limbe, Wouri Mabeta, Sanaga |

Figure 1

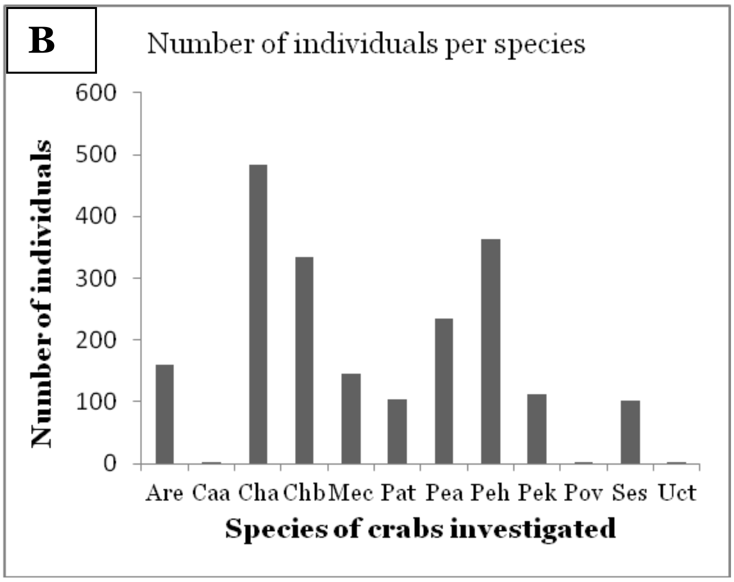


Niger
Chad
Nigeria
Cameroon
Central African Republic
Atlantic Ocean
Congo
RD Congo
2°00'N
12°00'E
N
Dibombari
Bonangang
Bonamouang
Wouri River
Tiko
Douala
Limbe
Wouri Bridge
Bon 'Ewonda
Mboussa Essengue
Bois de Singes
Dibamba River
Cameroon estuary
Gulf of Guinea
Legend
Study areas
Cities
Rivers
Other vegetation types
Mangroves
Atlantic Ocean
Sanaga
0
23000 Meters
9°00'E
10°00'E
4°00'N

Figure 2



A
Number of crabs per site
Number of individuals
900
800
700
600
500
400
300
200
100
0
BS
BG
BM
BW
EG
WB
Study areas

B
Number of individuals per species
Number of individuals
600
500
400
300
200
100
0
Are
Caa
Cha
Chb
Mec
Pat
Pea
Peh
Pek
Pov
Ses
Uct
Species of crabs investigated

Figure 3

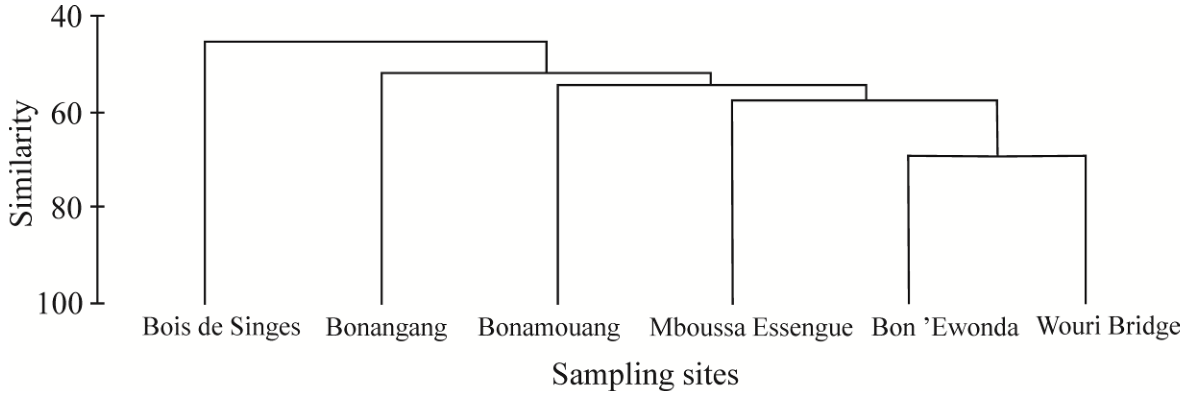

40
60
80
100
Similarity
Bois de Singes
Bonangang
Bonamouang
Mboussa Essengue
Bon ’Ewonda
Wouri Bridge
Sampling sites

Figure 4

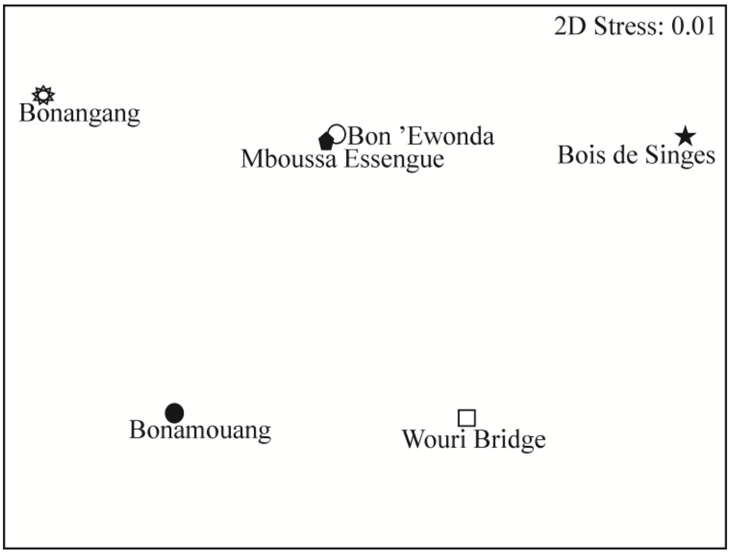
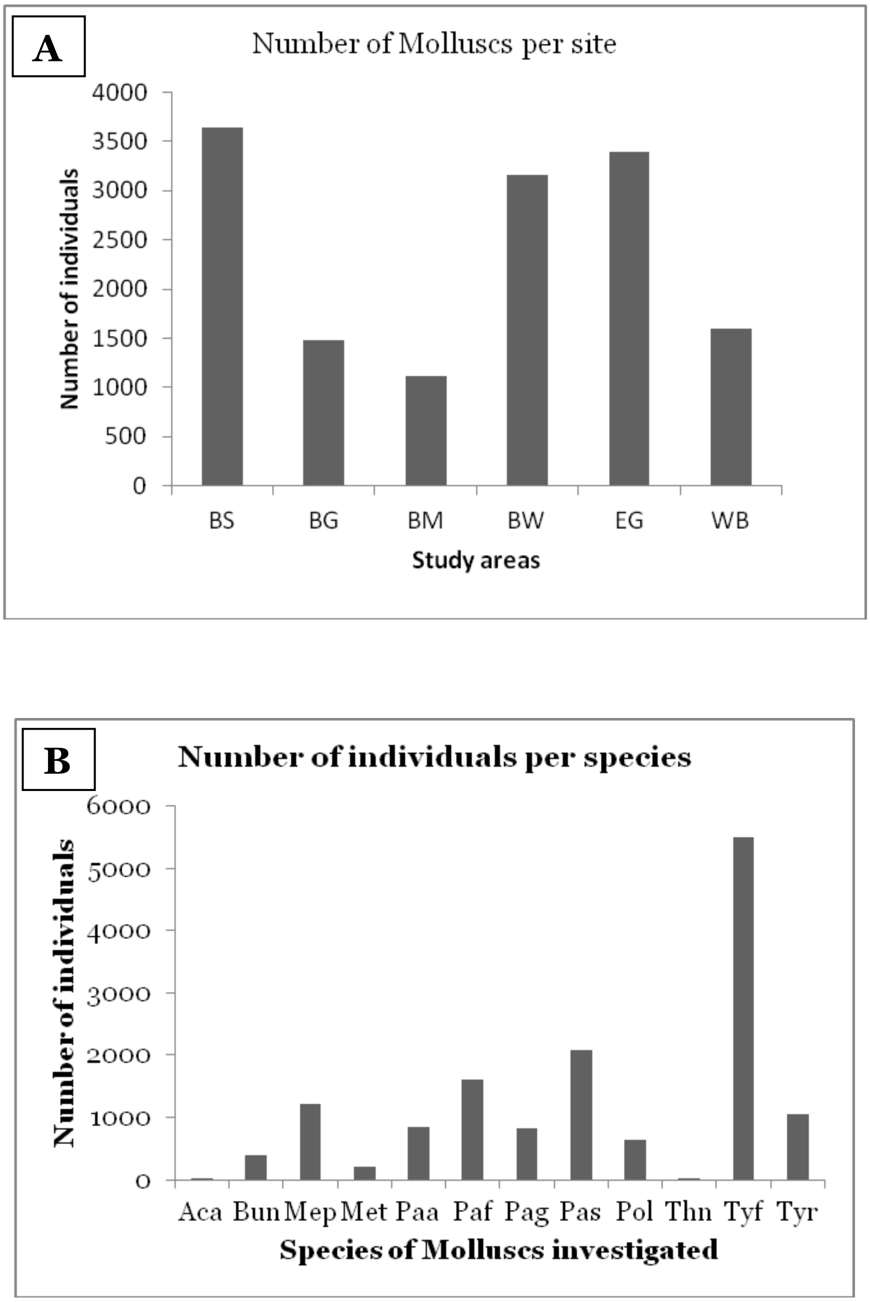

2D Stress: 0.01
Bonangang
Bon 'Ewonda
Mboussa Essengue
Bois de Singes
Bonamouang
Wouri Bridge

Figure 5



A
Number of Molluscs per site
Number of individuals
4000
3500
3000
2500
2000
1500
1000
500
0
BS
BG
BM
BW
EG
WB
Study areas
B
Number of individuals per species
Number of individuals
6000
5000
4000
3000
2000
1000
0
Aca
Bun
Mep
Met
Paa
Paf
Pag
Pas
Pol
Thn
Tyf
Tyr
Species of Molluscs investigated

Figure 6

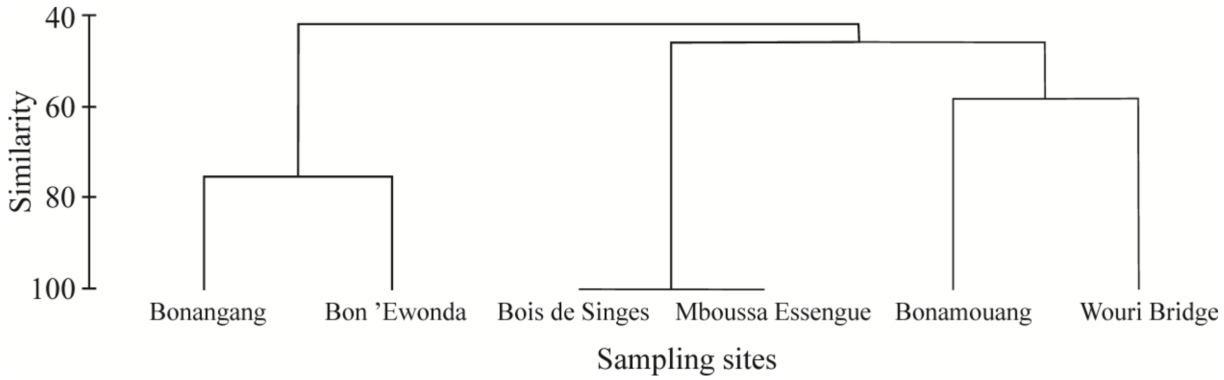
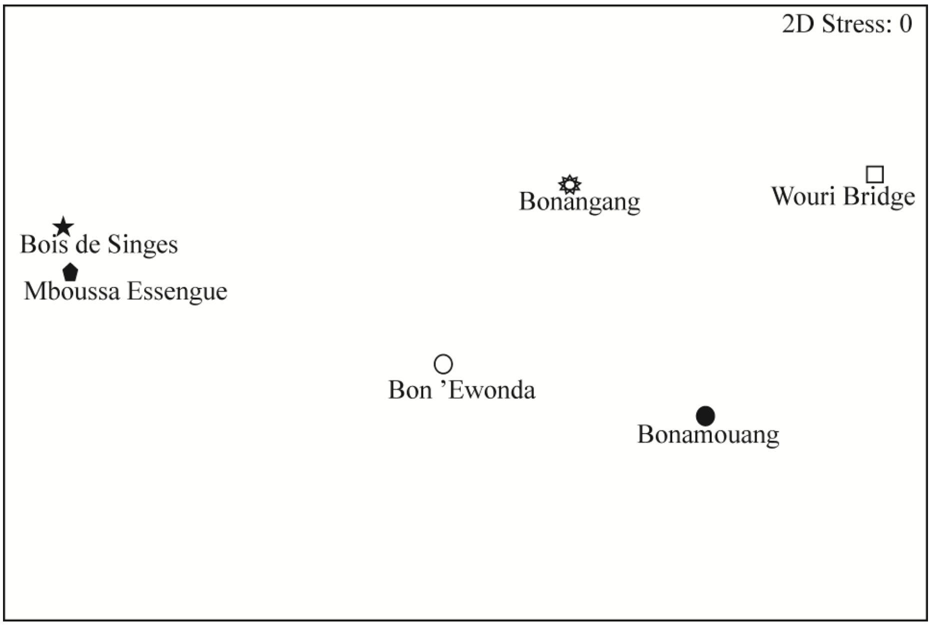

Similarity
40
60
80
100
Bonangang
Bon ’Ewonda
Bois de Singes
Mboussa Essengue
Bonamouang
Wouri Bridge
Sampling sites

Figure **7**


2D Stress: 0
Bonangang
Wouri Bridge
Bois de Singes
Mboussa Essengue
Bon ’Ewonda
Bonamouang

## LEGENDS FOR FIGURES

**Figure 1:** Localization of different study areas (modified from Nfotabong Atheull 2011).

**Figure 2:** Abundance of crabs in the mangrove ecosystem of the Wouri River estuary (Douala, Cameroon).

**A**, Abundance per site and **B**, Abundance per species. BS = Bois de Singes; BG = Bonangang; BM = Bonamouang; BW = Bon'Ewonda; EG = Mboussa Essengue; WB = Wouri Bridge. Are, *Arimase elegans;* Caa, *Cardisoma armatum;* Cha, *Chiromantes angolense;* Chb, *Chiromantes buettikoferi;* Mec, *Metagrapsus curvatus;* Pat, *Pachygrapsus transversus;* Pea, *Perisesarma alberti;* Peh, *Perisesarma huzardi; Pek, Perisesarma kamermani;* Pov, *Portunus validus;* Ses, *Sesarma* sp.*;* Uct, *Uca tangeri.*

**Figure 3:** Hierarchical ascending classification of sites based on specific composition of crabs. Five groups appear under 50% with only Bon'Ewonda and Wouri Bridge seemed to be closed (SI ≈ 60%).

**Figure 4:** Non Multi-Dimensional Scaling (nMDS) plot of crab abundance in the sampling sites. In terms of abundance, Wouri Bridge and Mboussa Essengue are much closer.

**Figure 5:** Abundance of Molluscs in the mangrove ecosystem of the Wouri estuary (Douala, Cameroon).

**A**, Abundance per site and **B**, Abundance per species. BS = Bois de Singes; BG = Bonangang; BM = Bonamouang; BW = Bon'Ewonda; EG = Mboussa Essengue; WB = Wouri Bridge. Aca, *Acatina acatina;* Bun, Bivalve*;* Mep, *Melanoides pergracilis;* Met, *Melanoides tuberculata;* Paa, *Pachymelania aurita;* Paf, *Pachymelania fusca;* Pag, *Pachymelania granifera;* Pas, *Pachymelania sp.;* Pol, *Potadoma lirincta;*, Thn, *Theodoxus niliticus;* Tyf, *Tympanotonus fuscatus;* Tyr, *Tympanotonus radula.*

**Figure 6:** Hierarchical ascending classification of sites based on specific composition of molluscs. There are three distinct groups: Bois de singes and Mboussa Essengue are identical while Bonangang and Bon'Ewonda are much closer (≈ 75%). Bonamouang and the Wouri Bridge constituted the last group.

**Figure 7:** Non Multi-Dimensional Scaling (nMDS) plot of mollusc abundance in the sampling sites (stress = 0). This stress indicates an ideal ordination with appropriate data transformation.