# FEEDING ECOLOGY OF MANGROVE CRABS IN CAMEROON

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**Abstract**. The feeding ecology of several species of mangrove crabs was studied in Cameroon mangrove forest through tethering experiments and gut analyses from September 2010 to March 2011. Field observations were two-fold: to investigate mangrove propagules predation and feeding preferences of mangrove leaves. Feeding preference was determined on fresh and senescent leaves of Laguncularia racemosa, Avicennia germinans and Rhizophora species. Propagule predation was investigated on Rhizophora mangle, Rhizophora harrisonii and Rhizophora racemosa. In the laboratory, gut content analysis was done on Metagrapsus curvatus, Sesarma huzardi, Sesarma elegans, Sesarma alberti, Goniopsis pelii and Grapsus grapsus to assess their natural diets. The field observations suggest that 65.9% of the propagules studied was predated, 71.3% of the leaves was damaged. Mangrove material was the main component of crabs diet, it constituted 45.4% of Metagrapsus curvatus diet, 55% Sesarma elegans diet, 62.5% Sesarma alberti, 65.9% Goniopsis pelii diet, 47.8% Sesarma huzardi diet and 37.3% Grapsus grapsus diet. Damage on young mangrove trees was highly correlated to the number of crabs on trees ($r2 = 0.75$). The high damage rate of mangrove materials indicate that crabs play a significant ecological role in the functioning of the mangrove ecosystem, by affecting mangrove recruitment and biogeochemical functioning.
**Keywords**: *Feeding Behaviour, Mangrove leaf species, Mangrove Crabs, Cameroon*

## Introduction

Mangrove crabs are among the most common and abundant faunal groups in mangrove forests (Smith et al. 1991). They play a vital ecological role in these ecosystems (Lee 1998). However, they are often viewed as threats to the successful regeneration or restoration of mangrove forests through their predation of propagules (Dahdouh-Guebas et al. 1997, Islam et al. 2010). In Cameroon, intense human development within mangrove ecosystems, coupled with the rapid urbanization of adjacent towns and the excessive utilization of trees for the production of fuelwood, charcoal and clearing for agricultural purposes, has further gradually degraded these ecosystems (Karen 2000). This degradation is expected to worsen in future years, largely as a result of climate-change induced sea level rise and salt water intrusion (Karen 2000).

Mangrove propagules or seedlings are an important food source for crabs. Majority of propagules are damaged within days of their release from the tree (Hogarth 1999). Crabs show distinct preference for different propagule species. *Avicennia* propagules are the most preferred because they contain simple sugars, low tannin, fibre and protein (Smith 1987). Propagule predation might also affect its mode of dispersal. Many mangrove species exhibit viviparity, a phenomenon where juvenile plants further develop after fertilization while attached to parent trees. When a propagule falls from a


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tree at low tide, it might establish itself upright in the mud; a phenomenon termed the planting strategy (Van Spreybroeck 1992, Dahdouh-Guebas et al. 2011). Alternatively, if the propagule falls during high tide, it might float in water and develop in another site, usually lying horizontally, a phenomenon termed the stranding strategy (loc. cit.). Stranding propagules are more predated, and this may play a critical role in limiting seedling establishment and subsequent recruitment (Van Spreybroeck 1992, Bosire 2005)

Propagule predation is an important source of mangrove mortality (Osborne and Smith 1990, Mckee 1995), suggesting a possibility of predator-controlled recruitment. Earlier studies of predation on mangrove propagules have focused on predation in relation to tree dominance. In reference to the dominance-predation hypothesis proposed by Smith (1987), tested on the Australian north coast (McGuinness 1997), in Malaysia (Smith et al. 1989), and in Belize (McKee, 1995). All these studies provided partial support for this hypothesis, although other studies have supported the hypothesis (Smith et al. 1989, Dahdouh-Guebas et al. 2011).

Leaf-eating mangrove crabs are extremely dependent on the mangrove litter. Leaf materials however, are an inadequate diet given that, irrespective of their stage of senescence and decomposition, the nitrogen content is low. Therefore, leaf-eating crabs must supplement their diet with nitrogen from other resources (Skov 2002). These include algae, bacteria, ingestion of their own faeces colonized by microorganisms, or grazing on surface sediments (Andersen 2002). Previous studies have suggested that crabs show food selective preferences depending on the food nutritional values, varieties and accessibility (Meziane et al. 2002, Dahdouh-Guebas et al. 2011). The critical value of 17: 1 for the C:N ratio has often been used as a point of comparison to determine the nutritional value of food resources ( Russell-Hunter 1970). Dietary C:N ratios above 17:1 are considered to be under the nutritional requirement. However, crabs were reported to consume plant litter with C:N ratios ranging from 25 : 1 to 183.5 : 1 ( Linton et al. 2007). Therefore, crab choice in the consumption of mangrove litter is unclear.

Although a great deal is known about the biology, behaviour and ecology of mangrove crabs in the past in a variety of geographic locations, very little is known about their feeding ecology in the west coast of Africa.

The goal of the present study is to improve understanding of the feeding ecology of mangrove crabs in West Africa. The objectives are to quantify (1) the propagule consumption rates and preference, (2) the leaf consumption rates and preference, (3) the diet of Sesarmidae and Grapsidae under natural conditions.

## Materials and methods

### *Study area*

This study was carried out from September 2010 to March 2011 in the Cameroon Estuary mangrove (*Figure 1*), located in the South–Western part of Cameroon between latitudes 3$^{o}$ 83' - 4 $^{o}$ 10' N and longitudes 9$^{o}$25' – 10$^{o}$ 00' E. It is estimated that mangrove forest covers 1,750 km$^2$ in this estuary. The area has an equatorial climate characterised by two main seasons: the rainy season from March to October (8 months) and the dry season from November to February (4 months). It has an annual average precipitation of 1,500mm to 3,000mm and high temperatures ranging from 24$^{o}$C to 27$^{o}$C (Letouzey1985). Strong tidal influences on rivers (Wouri, Dibanda and Sanaga) and


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freshwater influxes enable mangroves to growth as far as 100 kilometres inland (UNEP 2007, Nfotabong et al. 2009).

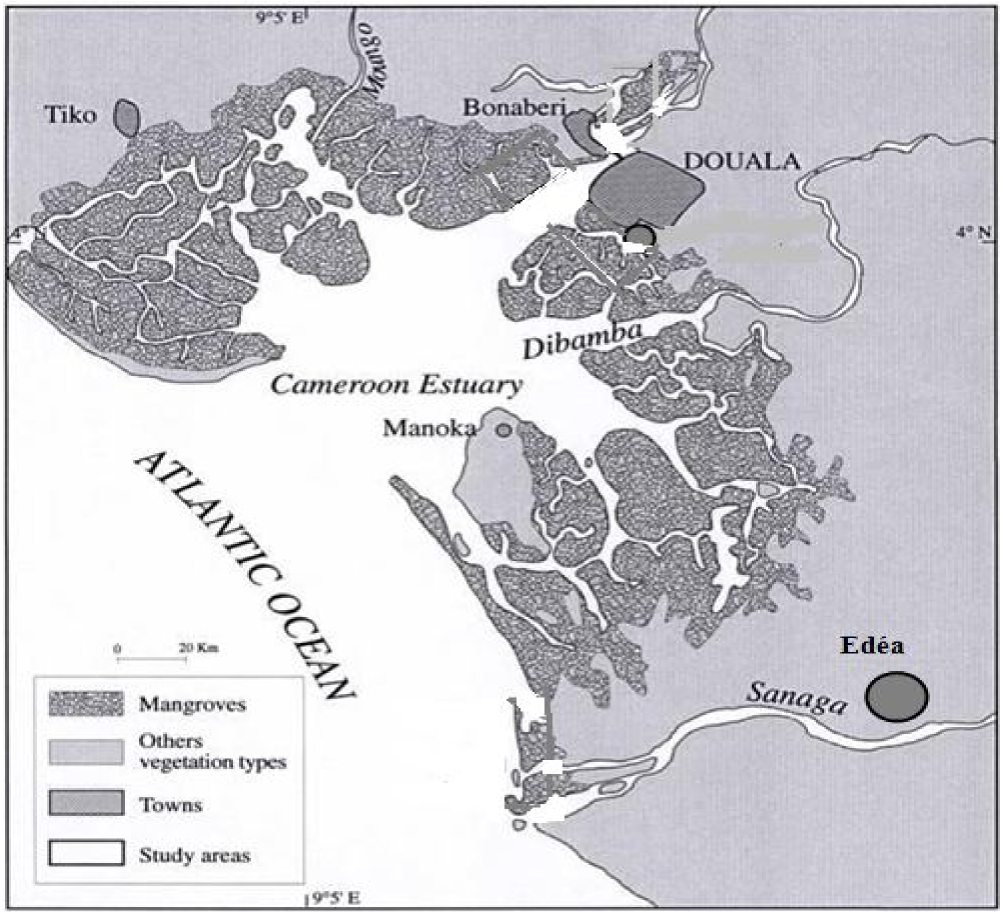


***Figure 1:*** *Mangrove of the Cameroon Estuary (Adapted from Nfotabong et al. 2009)*

The floristic composition of Cameroon mangrove is characteristic of the Atlantic mangroves of West Africa. It is dominated by *Rhizophora mangle, Rhizophora harrisonii and Rhizophora racemosa.* Other species include *Avicennia germinans, Laguncularia racemosa, Conocarpus erectus, Acrostichum aureum, Pandanus candelabrum and Nypa fruticans* (Spalding et al. 1997).

***Propagule predation***

This experiment was carried out in an extensive gap within the forest. A transect of 100 m was established, and 5 evenly dispersed plots of 5m x 5m were set. Each plot was placed 15 m apart, they were located on opposite sides along the transect. The vegetation in each plot was recorded. *Rhizophora* (*R. mangle, R. harrisonii* and *R. racemosa*) were the dominant species in the plots, and only *Rhizophora* species were used in this study because of their elongated propagule. Thirty fresh, mature, similar-sized propagules were collected, ten from each mangrove species and planted either vertically (50%) or laid horizontally (50%) on the forest floor haphazardly. Six propagules were planted in each plot. The vertical planting represents a dispersal


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strategy when the propagule plants itself into the mud when dropping from the adult tree, whilst the horizontal represents the circumstance where the propagule is dispersed by floating on the water at high tide (Dahdouh-Guedas et al. 1999). Each propagule was tethered independently with a 50 cm length of nylon twine, the other end of which was tied to a piece of wood on the forest floor. The propagules were spaced far apart so that the tethers could not get tangled. The length of each propagule was measured and propagules individually tagged. The propagules were checked from a distance using binoculars over a 6 hour period, after which they were checked once a day for one week. All observations were carried out during low tide when the crabs are very active.

Predation status was recorded following Smith (1987b): (1) when the epicotyl was eaten (2) when 50 % of the hypocotyl was lost (3) when the propagule was pulled into the burrow of the crab. Each propagule was classified as viable (capable of growth, i.e. ≤ 50% of propagule eaten), non-viable (incapable of growth, i.e. >50% of propagule eaten) and missing (when lost). Signs of snail predation were also recorded.

### *Leaf predation*

This study was conducted in 10m x10m quadrats. The vegetation of the quadrat was a mixture of *Laguncularia racemosa*, *Avicennia germinans* and *Rhizophora* (*R. mangle, R. harrisonii* and *R. racemosa*) the main species in Cameroon mangroves. Leaves of *Laguncularia racemosa*, *Avicennia germinans* and *Rhizophora* species were used; both fresh and senescent leaves were gathered. Fresh leaves were harvested from trees, while senescent leaves (yellow and easily abscised) were either picked from the forest floor or harvested from the tree. Ten replicate leaves (fresh and senescent) of each species were spread across the quadrat, each tethered with a nylon string 50cm in length with the other end tied to a piece of wood on the forest floor and tagged. The leaves were tied randomly and far apart to avoid tangling. The leaf surface was measured by tracing the edge on graph paper. The Leaves were checked after 24 hours, and percentage predation damage and leaf position was recorded (whether the leaves were found on the surface or in a crab burrow). Leaves that were in crab burrows were removed by gently pulling on the attached string. The experimental quadrat was not isolated from falling leaves. The forest floor was clean, probably due to the fact that the fallen leaves were swept by tidal movements.

Additional data on leaf predation were gathered from crabs predating within the canopy. Crabs were seen residing on tree trunks, branches and prop roots. They were observed climbing mangrove trees; usually early in the morning to feed on leaves and by midday they descended, and climbed again at twilight then descended by night fall. An average of 5 crabs was found on a single tree. Two young trees (1.5m to 2m tall, dbh 2.3cm to 5cm) of each species *Laguncularia racemosa*, *Avicennia germinans* and *Rhizophora* species were observed from a close distance for about 5 hours and crab feeding activities and leaf damage recorded.

### *Gut contents analysis*

Adult grapsid [*Metagrapsus curvatus*, *Sesarma (Perisesarma) huzardi*, *Sesarma (Chiromanthes) elegans*, *Sesarma (Perisesarma) alberti*] and sesarmid[*Goniopsis pelii*, *Grapsus grapsus* ] crabs of similar size 20-35mm carapace width were sampled for gut content analysis. They were collected during the most active period, at low and receding tides, when the foregut would be most likely to be full and the contents most easily


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recognised. The crabs were sedated in ice for a few minutes, washed and placed in 70% alcohol for later analysis. The crabs were dissected, stomaches removed and the contents stirred with 10-15ml of distilled water in a petri dish and examined under a light microscope at X20 magnification. The percentage composition of different items within each gut was determined over 10 cells within a 100 cell grid. The degree of fullness of the stomach was estimated as follows: 0 for an empty stomach, 1 for a half-full stomach, 2 for a full stomach. The contribution of each food item to the total diet was expressed in terms of the percentage of the field occupied by the different items. The items were classed as plant material (not identified to mangrove species level), animal material, algae, sand, detritus and unidentified debris.

### *Data analyses*

Descriptive statistics were used to analyze gut contents, propagules and leaves predation. To test whether or not there was a significant difference between propagule predation amongst plots, the non parametric Kruskal-Wallis ANOVA was performed. Differences in leaf damage among mangrove species were also compared using parametric ANOVA test.

Non parametric tests (Friedman, Tukey) were employed to test for differences in propagules planting strategies, propagules viability (viable and non-viable) and leaf consumption preference (fresh and senescent). Correlation between tree leaf damage and the number of crabs on trees was analysed. All of the above analyses were performed using SPSS.

## Results

### *Propagule predation*

Propagule predation by crabs occurred in all of the five plots, ranging from 34% to 80%. An average of 69.8% of *Rhizophora racemosa* , 66.3% of *Rhizophora mangle*, 61.6% of *Rhizophora harrisonii* was predated. The effect of crab predation on propagules did not differ amongst mangrove species in all the plots, except for plot 4 where *Rhizophora harrisonii* was substantially reduced (*Figure 2*). There were no significant differences of propagule predation between mangrove species in all plots ($F=0.16$, $df=2$, $P=0.86$) .Majority of the propagules were found to be non-viable after predation and some were lost by being washed away by high tide (*Figure 3*). There was a significant difference between the number of non viable and viable propagule ($T= 2.13$, $df = 4$, $P = 0.002$) with majority being non viable. In general, crabs prefer horizontally laid propagules, irrespective of mangrove species or plot position (*Figure 4*). Crabs were aggregated around horizontal propagules, whereas vertical propagules close by were neglected, and only horizontally planted propagules were dragged to crab burrows ($F = 7.11$, $df = 2$, $P = 0.05$). Some propagules were predated by gastropods, but the extent of this was minimal.

### *Leaf Predation*

The percentage of leaves consumed by crabs varied amongst mangrove species (*Figure 5*). *Rhizophora* species was the most consumed and *Avicennia* was the least, although this was not significant between species (ANOVA, $F = 2.3$, $P = 0.24$).


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Senescent leaves were preferred more than fresh leaves for all species (*Figure 6*), and there was a significant difference in the percentage consumed of fresh and senescent leaves (T = 4.3, df = 2, P = 0.02). The majority of leaves were taken into burrows *Laguncularia racemosa* 60% *Avicennia germinans* 55%*Rhizophora* species 75%, and they were substantially eaten when recovered from the burrows. No leaf breakage was identified during the recovering process.

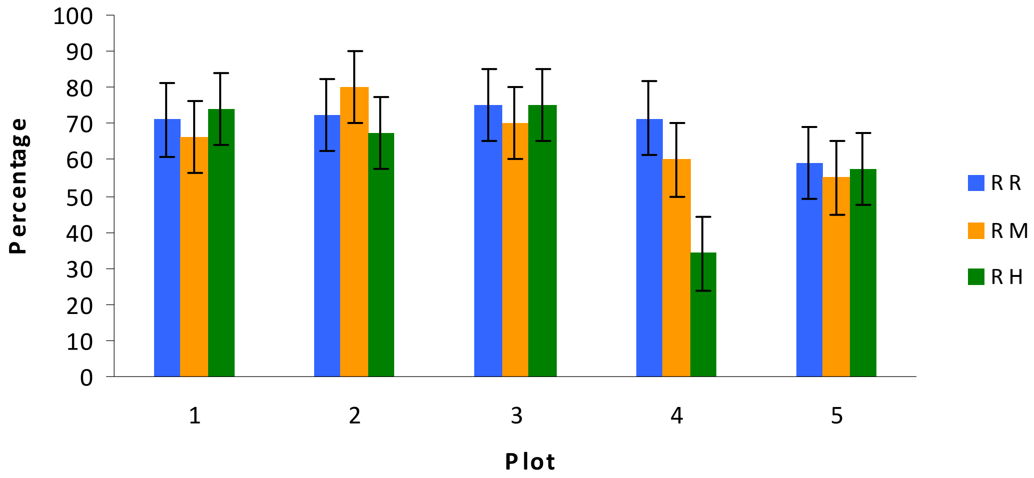


***Figure 2.*** *Percentage of propagule predation within each plot. RR= Rhizophora racemosa, RM= Rhizophora mangle, RH = Rhizophora harrisonii (Error bars represent standard errors)*

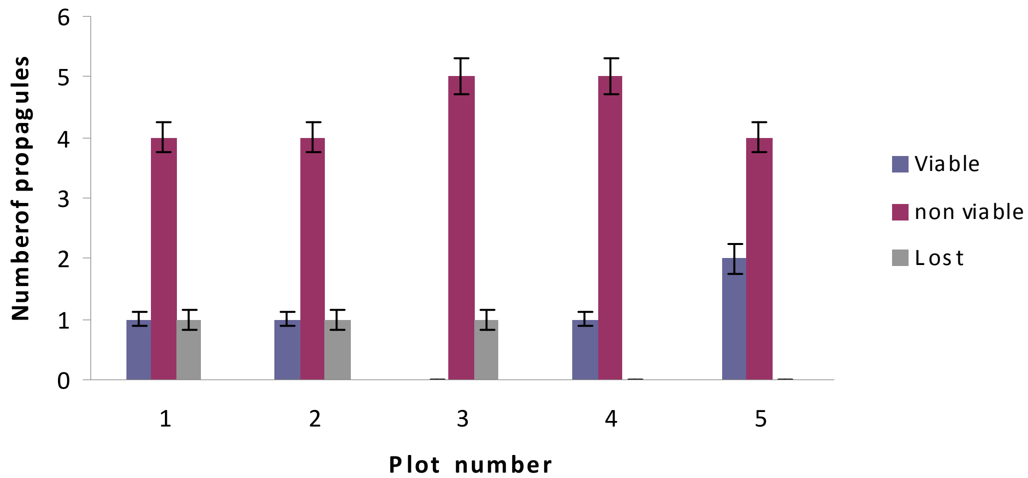


***Figure 3:*** *Number of propagules per plot killed by crabs, lost or still viable after predation (Error bars represent standard errors)*

A total of 195 attached leaves were examined in 6 young trees for the presence of crab damage. Thirty four leaves were found damaged on the sampled trees, fifty three leaves were examined in *Laguncularia racemosa* species, 4(7.6%) were damaged, sixty four leaves were examined in *Avicennia germinans* species, 7(10.9%) were damaged


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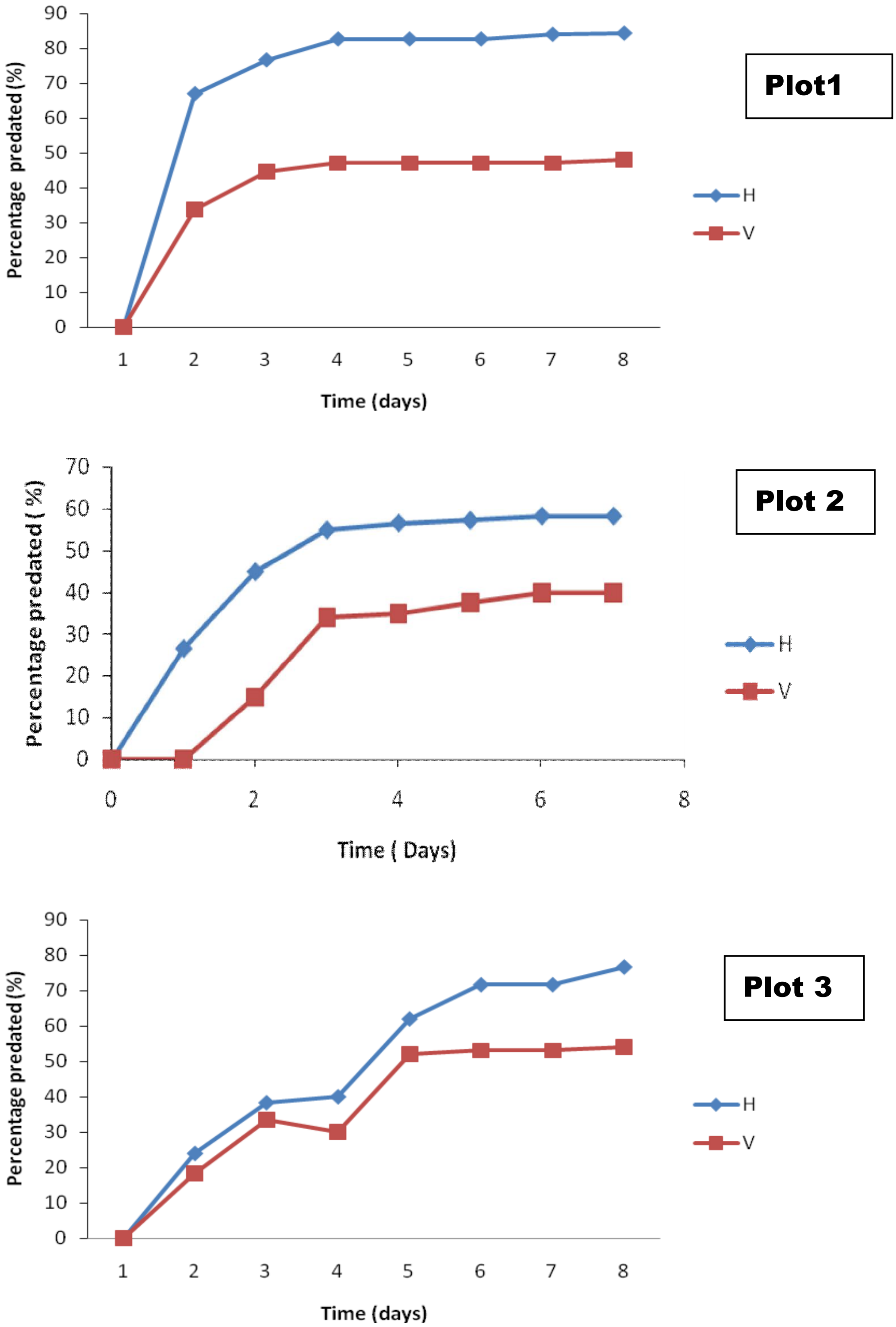
and seventy eight leaves were examined in *Rhizophora* species, 23 (29.5%) were damaged. All the crabs recorded were from family grapsidae; *Goniopsis pelii (G. cruentata)* (37), *Grapsus grapsus* (8) and sesarmidae; *Sesarma* spp (21), *Metagrapsus curvatus* (12). The estimated damaged leaves were highly correlated to the number of crabs on trees ($r^2 = 0.75$) (*Figure 7*).





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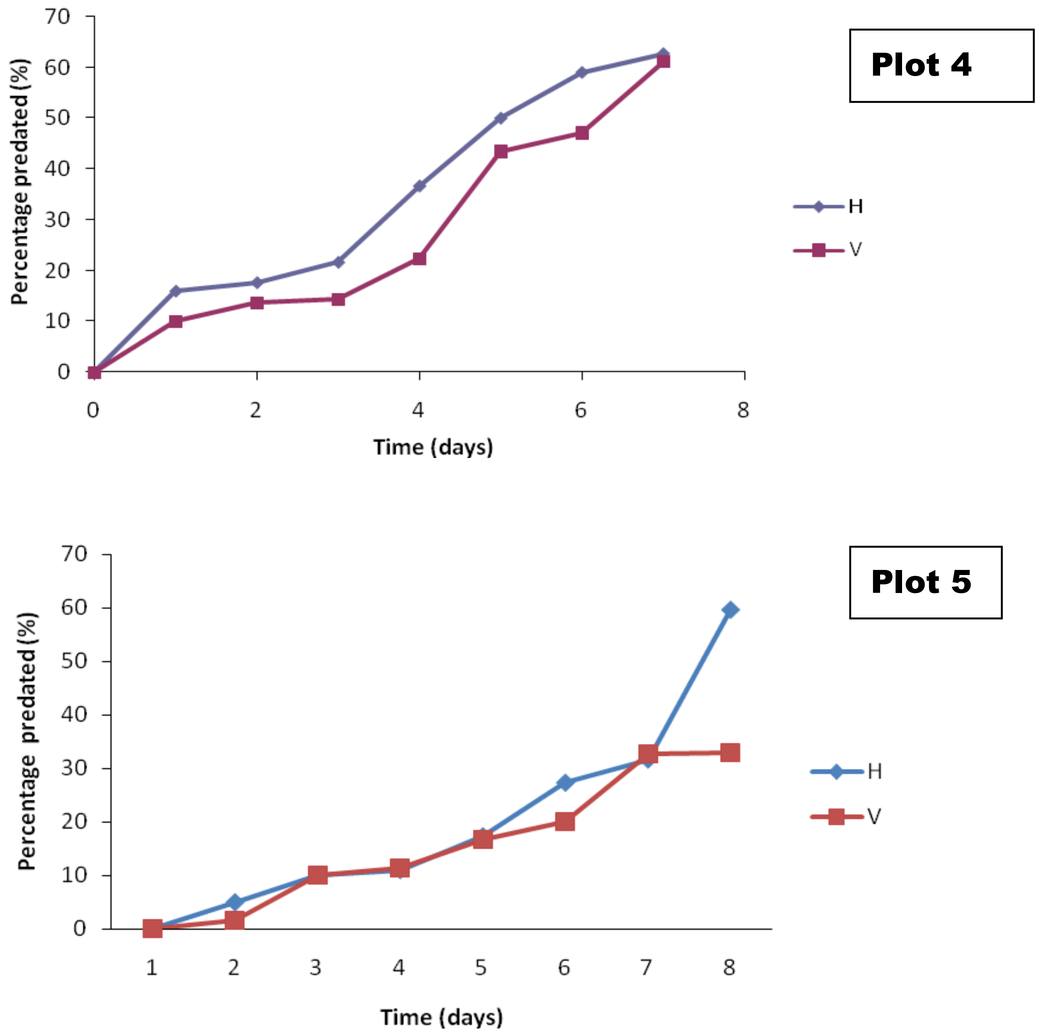


***Figure 4:*** *Rate of propagule predation V= Vertical, H = Horizontal.*

### *Gut content analysis*

A total of 43 crabs were dissected. Plant material was identified as principally mangrove leaves based on stomatal features and constituted 45.4% of *Metagrapsus curvatus* diet, 55% *Sesarma (Chiromantes) elegans* diet, 62.5% *Sesarma (Perisesarma) alberti*, 65.9% *Goniopsis pelii (G. cruentata)* diet, 47.8% *Sesarma (Perisesarma) huzardi* diet and 37.3% *Grapsus grapsus* diet ( *Figure 8*). It is clear that plant material (mangrove and algae) is a major component of the diet of grapsid and sesarmid crabs in Cameroon mangrove, with animal materials of minor importance.

## Discussion

Numerous species of mangrove macrofauna are known to consume plant materials, including crabs (Smith 1987a, Micheli 1993, Steinke et al. 1993) and snails (Slim et al. 1997) and insects (Robertson and Duke 1987). Amongst these, crabs are thought to be


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major consumers and a key source of leaf and seedling mortality in mangroves (Clarke and Kerrigan 2002). Amongst mangrove macrobenthos, crabs are one of the most significant groups in terms of species numbers and total biomass. It is therefore important to understand their feeding habits and position in the food web (Macintosh 1988, Cannicci et al. 2008). Many species of mangrove crabs are known to consume a large proportion of the annual primary production of mangrove (leaves and propagules) (Lee 1998). For example, in Malaysia *Chiromanthes onychophorum* de Man (Malley 1978), in Sri Lanka *Neosarmatium malabaricum* (Henderson), *N. meinerti* (de Man), *N. smithii* (H. Milne-Edwards) and *Episesarma tetragonum* (Fabricius)(Dahdouh-Guebas et al. 2011), in South Africa and Kenya *Neosarmatium meinerti* (Emmerson and McGwynne 1992, Dahdouh-Guebas et al. 1997, 1998), *Goniopsis cruenata* (Latreille) (Von Hagen 1977).

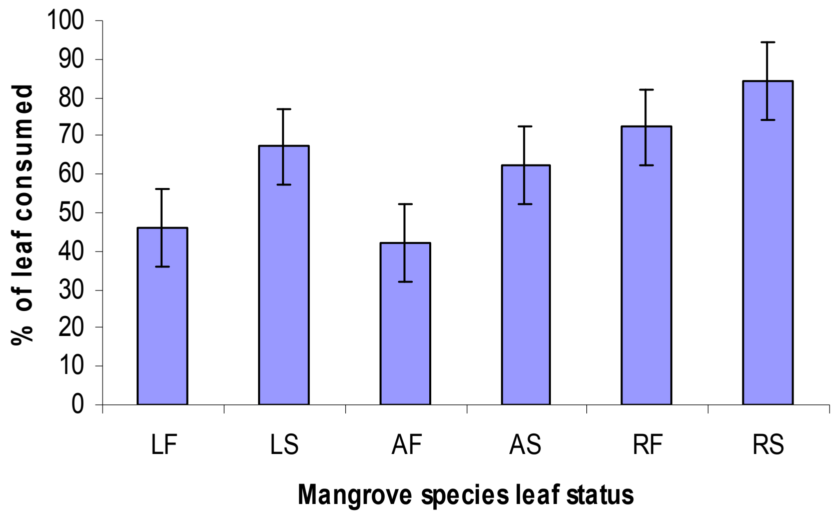


***Figure 5:*** *Percentage of leaf material consumed by crabs for each mangrove species. LF=Laguncularia fresh, LS= Laguncularia senescent, AF = Avicennia fresh, AS = Avicennia senescent, RF = Rhizophora fresh, RS = Rhizophora senescent (Error bars represent standard errors)*

Leaves consumed by herbivorous crabs vary in size, state of composition, physical toughness, nutritional value and palatability (Robertson 1986, Micheli 1993). Fresh mangrove leaves that have fallen from the tree are poor in nitrogen but rich in tannin, but most grapsid crabs have been reported feeding on fresh leaves on the forest floor or take entire leaves into their burrows (caching) ( Robertson 1986, Micheli 1993). According to Giddins et al. (1986), crabs prefer decaying leaves to senescent or fresh leaves when given the choice. They also suggested that crabs allow leaves to decompose inside their burrows for many weeks before eating them, during this time tannins are lost from the leaves through leaching, whilst nitrogen concentration increases through bacterial action, resulting in a higher nutritional content. Other advantages of taking leaves into the burrow is to prevent them from being carried away by the tides (Robertson 1986) It creates a safe environment for crabs to eat without fear of predators, tidal inundation, high temperatures and low humidity (Wolcott and O'Connor 1992).


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Therefore caching might be frequent in areas with shortage of food supply and greater predator pressure.

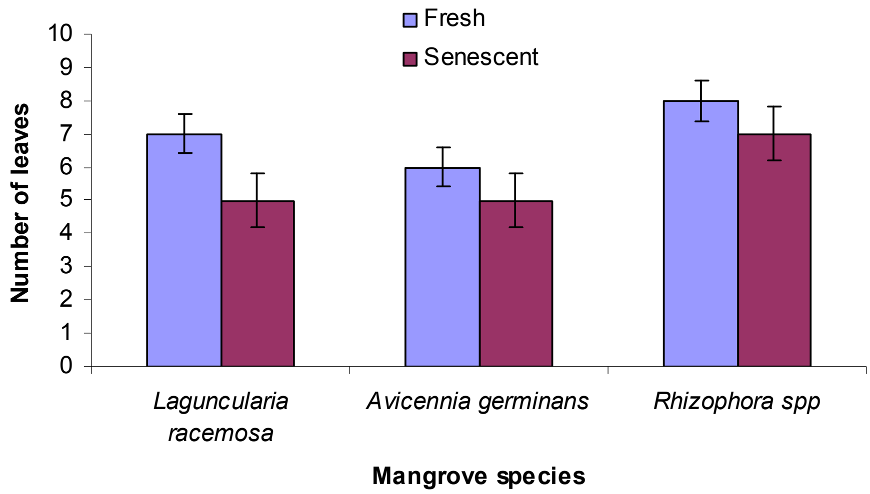


***Figure 6:*** *Number of leaves taken down crab burrows (Error bars represent standard errors)*

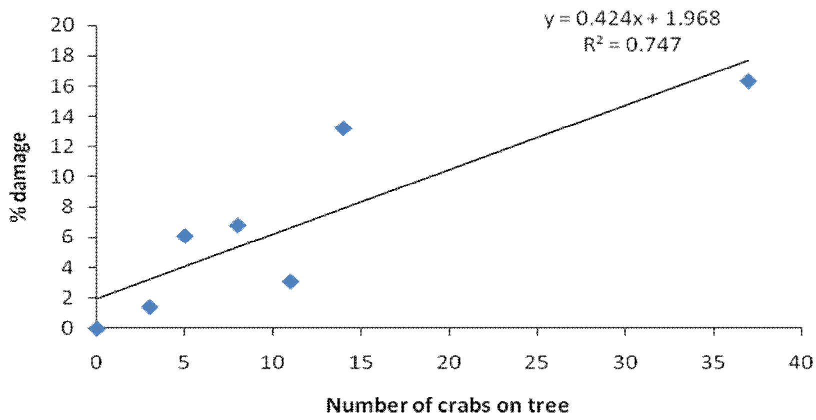


***Figure 7:*** *Relationship between number of crabs and leaf damage*

Many studies have examined gut contents or leaf and propagule damage to determine herbivore diet exclusively. This study is unique in that it might be the first on propagules and leaf feeding on the central Africa mangrove and it is combination of three methods to assess the potential ecological threat to forest health of mangrove ecosystems; gut content analysis, propagule and leaf predation assessment and standing tree assessment. Combination of the results suggested that mangrove crabs damage large amounts of mangrove plant material, both leaves and propagules, and this may have significant ecological consequences for ecosystem structure and function.

### *Propagule predation*

Grapsid and sesarmid crabs are palpable predators of mangrove propagules. *Sesarma* and *Metapograpsus* spp have been reported predating Rhizophoraceae and *Avicennia*


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propagules (Smith et al. 1989, Robertson et al. 1990), and *Aratus pisonii* and *Goniopsis cruentata* in the Caribbean fed on *Rhizophora* propagules (Warner 1967). According to Dahdouh-Guebas et al (1997), in Mida Creek Kenya 50% of propagules were predated within 2 hrs and 85% within 24 hrs. In the present study, 66.7% of the propagules were predated leaving 50% non-viable. This high predation pressure could affect natural restoration of mangrove forest.

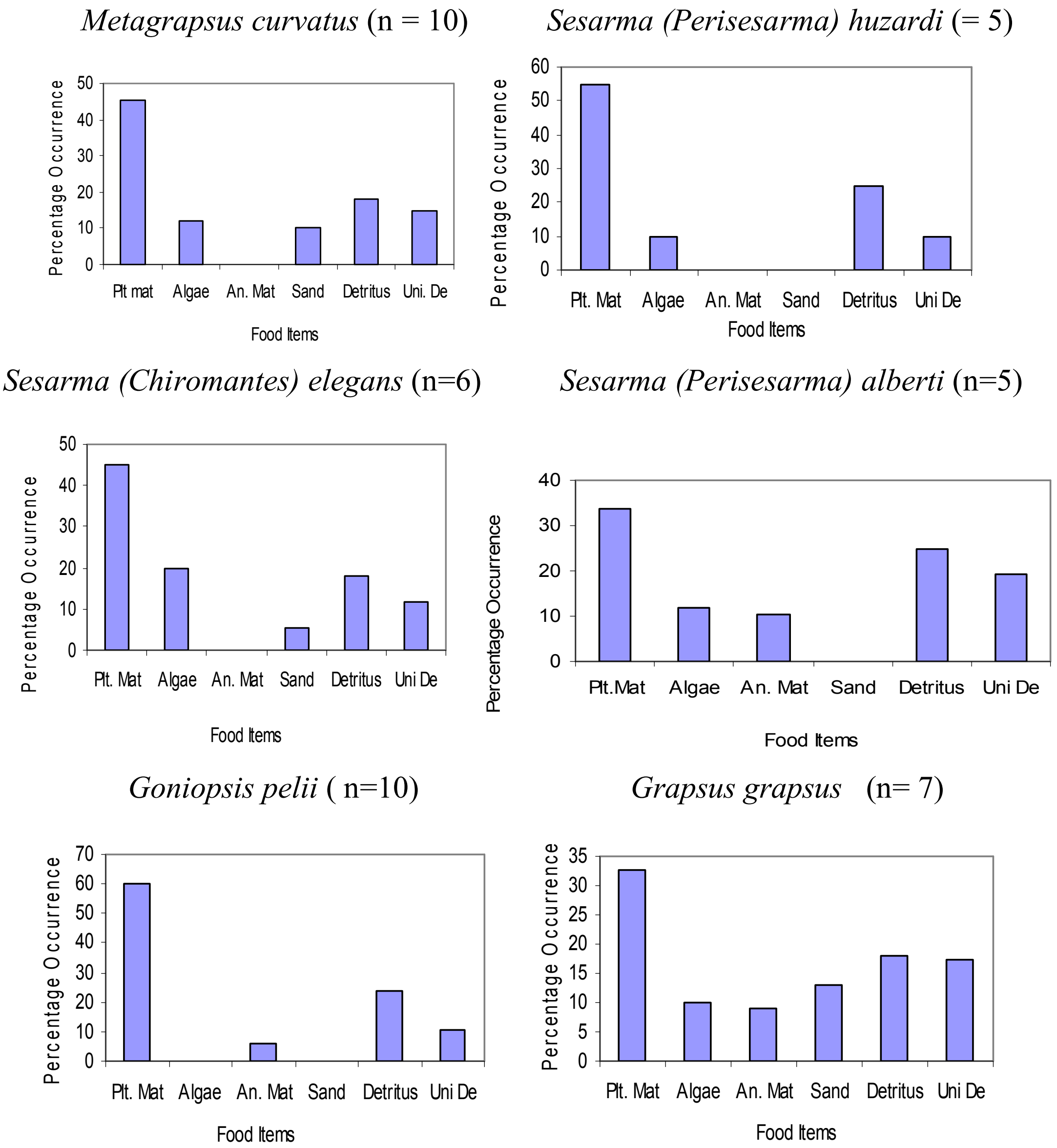


***Figure 8.*** *Percentage occurrence of gut content items. Plt. Mat = Plant material (mangrove leaves), An. Mat = Animal materials (crustaceans, annelids), Uni-De (unidentified debris), n = number of crabs examined.*

Seedling establishment (i.e. type of planting strategy, horizontal or vertical) may also influence predation rate. In Kenya, the crab *Neosarmatium meinerti* preferred horizontally planted propagules (Dahdouh-Guebas et al. 1997), and in the present study,


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horizontally planted propagules were more predated (Figure 4). This might be due to the fact that crabs face difficulties handling vertical propagule because of their size and weight. Although seedling establishment coupled with tidal action might influence mangrove recruitment, selectivity of crabs feeding habit has been reported altering natural restoration of mangrove seedlings in a species-specific way (Lee 1998). In the present study, propagule predation was not significantly different among crab species, though *Goniopsis pelii was* the dominant species foraging on plant material.

### *Leaf predation*

Earlier studies have reported mangrove crab preference for *Rhizophora* species. In Florida *Rhizophora* was preferred to *Avicennia germinans* and *Laguncularia racemosa* (Wilson 1981). The present study similarly indicates preference for *Rhizophora* species to Avicennia *germinans* and *Laguncularia racemosa*.

One of the interesting observations of this study was almost complete lack of fallen leaves on forest floor. Most likely cause might be tidal inundation and high crab activity in the region. High leaf damage rates have been reported in Australia (Robertson 1986; Micheli 1993). The present study similarly indicates high leaf damage by crab (71.3%).

In the present study, there was a significant difference between the amount of fresh and senescent leaves consumed. This result is similar to those of other studies that support the fact that crabs preferred aged leaves (Neilson et al. 1986, Micheli 1993, Kwok and Lee 1995) because of the leaching out of tannins, reduction in leaf toughness and increase of nitrogen content. Mangrove leaf decomposition may affect the leaf quality for herbivores, with decomposed leaves having different tannin concentration and nutritional value compared to fresh leaves, high tannin concentrations inhibiting microbial activity (Neilsons et al. 1986, Steinke et al. 1990).

Physical toughness of leaves will also affect herbivore choice. *Rhizophora* decomposes slowly compared to *Avicennia* and *Laguncularia,* probably due to the thick cuticle and sclerids in the tissues (Camilleri 1989), and this might inhibit feeding of some crab species, but they are preferred by others, although chelae modification may limit the effect of physical conditions in determining the leaf preference.

The gut content analysis provided additional information about the diet of mangrove crabs in the west coast of Africa. Identifiable gut diet material of mangrove leaves is composed about 45.4% in *Metagrapsus curvatus*, 55% in *Sesarma (Chiromantes) elegans* , 62.5% in *Sesarma (Perisesarma) alberti*, 65.9% in *Goniopsis pelii (G. cruentata)* , 47.8% in *Sesarma (Perisesarma) huzardi* and 37.3% in *Grapsus grapsus*. Other ingested crab matters were animal materials (crustaceans, annelids), sand, and Uni-De (unidentified debris)

The results of the present study, while preliminary in nature, contribute to our understanding of the feeding ecology of mangrove crabs in the west coast of Africa and how mangrove crabs feeding habits could be a potential ecological threat to forest health of mangrove ecosystems.

## REFERENCES

[1] Andresen, M., Kristensen, E. (2002): The importance of bacteria and microalgae in the diet of the deposit-feeding polychaete Arenicola marina-Ophelia 56 : 179–196.


http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: 10.15666/aeer/1204_959973

[2] Bosire , J. O., Kairo, J. G., Kazungu, J., Koedam, N., Dahdouh-Guebas. F. ( 2005): Predation on propagules regulates regeneration in a high-density reforested mangrove plantation - Marine ecology progress series.299: 149–155
[3] Camilleri, J. (1989): Leaf choice by crustaceans in a mangrove forest in Queensland - Marine Biology 102: 453-459.
[4] Cannicci, S. F., Dahdouh-Guebas, F., Anyona, D., Vannini, V. (1996a): Natural diet and feeding habits of Thalamita crenata (Decapoda: Portunidae) -Journal of Crustacean Biology. 16: 678-683.
[5] Cannicci, S., Ritossa, S., Ruwa, R.K., Vannini, M. (1996b): Tree-fidelity and hole fidelity in the tree Sesarma leptosome (Decapoda, Grapsidae)- Journal of Experimental Marine Biology and Ecology 196: 299-311.
[6] Cannicci, S., Ruwa, R. K., Vannini, M. (1997): Homing experiments in the tree-climbing crab Sesarma leptosome (Decapoda, Grapsidae) - Ethology 103:935–944
[7] Clarke, P.J., Kerrigan, R.A. (2002): The effect of seed predators on the recruitment of mangrove - Journal of Ecology 90: 728-736.
[8] Dahdouh-Guebas, F., Verneirt, M., Tack, J.F., Koedam, N. (1997): Food preferences of Neosarmatium meinerti de Man (Decapoda: Sesarminae) and its possible effect on the regeneration of mangroves- Hydrobiologia 347: 1–3: 83–89,
[9] Dahdouh-Guebas, F., Guiggioli, M., Oluoch, A., Vannini, M., Cannicci, S. (1999): Feeding habit of non-ocypodid crabs from two mangrove forests in Kenya - Bulletin of Marine Science 64: 291-297.
[10] Dahdouh-Guebas, F., Koedam, N., Satyanarayana, B., Cannicci, S. (2011): Human hydrographical changes interact with propagule predation behaviour in Sri Lankan mangrove forests. : Journal of Experimental Marine Biology and Ecology 399: 188-200.
[11] Emmerson, W.D., McGwynne, L.E. (1992): Feeding and assimilation of mangrove leaves by the crab Sesarma meinerti de Man in relation to leaf–litter production in Mgazana, a warm-temperate Southern Africa mangrove swamps-Journal of Experimental Biology and Ecology 157: 41-53.
[12] Erickson, A. A., Saltis, M., Bell, S.S., Dawes, C.J (2003): Herbivore feeding preferences as measured by leaf damage and stomatal ingestion: a mangrove crab example - Journal of Experimental Marine Biology and Ecology 289: 123–138.
[13] Giddins, R.I., Lucas, J.S., Neilson, M.J., Richards, G.N. (1986): Feeding ecology of the mangrove crab Neosarmatium smithii (Crustacean: Decapoda: Sesarmidae) - Marine Ecology Progress Series 33: 147-155.
[14] Hogarth, P.J. (1999) : The biology of mangrove. Oxford University Press. New York.
[15] Hill, B.J. (1976): Natural food, foregut clearance rate and activity of the crab Scylla serrata -Marine Biology .34: 109-116.
[16] Islam, S.S., Makoto, T.( 2010): Feeding Choice and the Fate of Organic Materials Consumed by Sesarma Crabs Perisesarma bidens (De Haan) When Offered Different Diets- Journal of Marine Biology. 2010: ID 201932, doi:10.1155/2010/201932
[17] Karen, O. (2000): Developing Strategies for Climate Change: The UNEP Country Studies on Climate Change Impacts and Adaptations Assessment. CICERO Report 2000:2
[18] Kwok, P.W., Lee, S.Y. (1995): The growth performances of mangrove crabs, Chironmanthes bidens and Parasesarma plicata under different leaf litter diets- Hydrobiologia .295: 141-148.
[19] Lee, S.Y. (1998): Ecological role of grapsid crabs in mangrove ecosystems: a review Marine Freshwater Research. 49: 335-345.
[20] Linton, S. M., Greenaway, P. (2007): A review of feeding and nutrition of herbivorous land crabs: adaptations to low quality plant diets - Journal of Comparative Physiology .177: 269–286.
[21] Macintosh, D. J. (1988): The ecology and physiology of decapods of mangrove swamps. Symposium of the Zoological Society of London. 59: 315-341.

[22] Malley DF. 1978. Degradation of mangrove leaf litter by the tropical sesarmid crab Chiromanthes onychophorum- Marine Biology 49: 377-386.
[23] McGuinness, K. A. (1997): Seed predation in a tropical mangrove forest: a test of the dominance–predation model in northern Australia - Journal of Tropical Ecology 13: 293-302.
[24] McKee, K. L. (1995): Mangrove species distribution and propagule predation in Belize: an exception in the dominance-predation hypothesis - Biotropica 27 334-345.
[25] Meziane, T., Sanabe, M. C., Tsuchiya, M. ( 2002): Role of fiddler crabs of a subtropical intertidal flat on the fate of sedimentary fatty acids- Journal of Experimental Marine Biology and Ecology 270: 191–201.
[26] Micheli, F. (1993): Feeding ecology of mangrove crabs in North Eastern Australia: mangrove litter consumption by Sesarma messa and Sesarma smithii- Journal of Experimental Marine Biological and Ecology 177:165-186.
[27] Neilson, M. J., Painter, T. J., Richard, G. N. (1986): Flavoglycan: a novel glyconjugate for leaves of mangrove (Rhizophora stylosa)- Carbohydrate Research 147: 315-324.
[28] Nfotabong, A.A., Ndongo, D., Longonje, S. N., 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 2009: 5:35
[29] Osborne, K., Smith, T. J. (1990): Differential predation on mangrove propagules in open and closed canopy forest habitats- Vegetatio 89: 1-9.
[30] Robertson, A. I. (1986): Leaf-burying crabs: their influence on energy flow and export from mixed mangrove forests (Rhizophora spp) in northeastern Australia- Journal of Experimental Biology and Ecology 102: 237-248.
[31] Robertson, A. I., Duke, N.C. (1987):Insect herbivory on mangrove leaves in Northern Queensland- Australian Journal of Ecology 12: 1-7.
[32] Robertson, A.I., Giddin, R., Smith, T.J. (1990): Seed predation by insects in tropical mangrove forest: extent and effect on seed viability and the growth of seedlings- Oecologia 83: 213-219.
[33] Russell-Hunter, W.D. (1970): Aquatic Productivity: An Introduction to Some Basic Aspects of Biological Oceanography and Limnology, Macmillan, New York, NY, USA.
[34] Skov, M.W., Hartnoll, R.G. (2002): Paradoxical selective feeding on a low-nutrient diet: why do mangrove crabs eat leaves- Oecologia 131: 1–7
[35] Slim, F.J., Hemminga, M.A., Ochieng, C., Jannink, N. T., Cocheret de la Moriniere, E., Van der, G. (1997): Leaf litter removal by snail Terebralia palustris (Linnaeus) and sesarmid crabs in an East African mangrove forest- Journal of Experimental biology and Ecology 215: 35-48.
[36] Smith, T.J. (1987a): Effects of seed predators and light level on the distribution of Avicennia marina Forsk. in tropical tidal forests- Estuarine Coastal Shelf Science 25: 43-52.
[37] Smith, T.J. (1987b): Seed predation in relation to tree dominance and distribution in mangrove forest- Ecology .68: 266-273.
[38] Smith, T.J., Chan, H.T., Mclvor, C.C., Robblee, M.R. (1989): Comparisons of seed predation in tropical tidal forests from three continents- Ecology 70: 146-151.
[39] Smith, T.J., Boto, K.G., Frusher, S.D., Giddins, R.L. (1991): Keystone species and mangrove forest dynamics: the influence of burrowing by crabs on soil nutrient status and forest productivity- Estuarine and Coastal Shelf Science 33: 419–432.
[40] Steinke, T.D., Barnabas, A.D., Somaru, R. (1990): Structural changes and associated activity accompanying decomposition of mangrove leaf in the Mgeni Estuary- South Africa Journal of Botany 56: 39-49.
[41] Steinke, T.D., Rajh, A., Holland, A.J. (1993): The feeding behaviour of the red mangrove crab Sesarma meinerti de Man, 1887 (Crustacean: Decapoda: Grapsidae) and

its effect on the degradation of mangrove litter- South African Journal of Marine Science 13: 151-160.
[42] United Nation Environmental Programme.( 2007): Mangroves of Western and Central Africa UNEP-Regional Seas Programme/UNEP-WCMC.
[43] Van Spreybroeck, D. (1992): Regeneration strategy of mangroves along the Kenyan coast- Hydrobiologia 247: 243-251.
[44] Vannini, M., Ruwa, R.K., Cannicci, S. (1997): Effect of microclimatic factors and tide on vertical migrations of the mangrove crab Sesarma leptosoma (Decapoda, Grapsidae)- Marine Biology 130:101–108
[45] Von Hagen, H.O. (1977): The tree climbing crabs of Trinidad- Studies on the Fauna Curacao and Other Caribbean Islands 175 : 25-59.
[46] Warner, G.F. (1967): The life-history of the mangrove tree crab Aratus pisonii- Journal of Zoology. London 153: 321-335.
[47] Wilson, K. A. (1981): Tidal associated feeding in the mangrove tree crab, Aratus pisonii- American Zoologist 21 : 1005.
[48] Wolcott, D. L., O'Connor, N. J. (1992): Herbivory in crabs: adaptations and ecological considerations- American Zoologist 32: 370-381.


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