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Food preferences of *Neosarmatium meinerti* de Man (Decapoda: Sesarminae) and its possible effect on the regeneration of mangroves

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Abstract

Neosarmatium meinerti is a crab which commonly inhabits the landward *Avicennia marina* fringe in East African mangroves. Stomach content analysis of individuals collected at Gazi Bay and Mida Creek (Kenya) showed that their diet mainly consisted of mangrove leaves, completed with little animal matter. Experiments designed to offer the crabs a choice of leaves or propagules of the various mangrove species present indicated that *N. meinerti* has no distinct preference for any of them. Nor is it attracted by spongy material impregnated with the extract of propagules from any particular mangrove species. However, at least for *Rhizophora mucronata*, this crab species has a slight preference for freshly gathered propagules when presented both matured and freshly gathered ones. There is little evidence that the plant-derived diet of *N. meinerti* consists of one mangrove species only, though it is probable that this crab will restrict its feeding area within the landward *A. marina* fringe. Because of the lack of specificity in its feeding behaviour, *N. meinerti* can also be a threat to the successful regeneration or restoration of mangroves through seedling or propagule planting.

Introduction

Mangroves are unique ecosystems which are endangered by over-exploitation or reclamation. These forests are exploited and reclaimed for many purposes: wood, fodder, fuel, bark for tannins, shrimp farming. Mangroves shelter a diverse fauna either as a nursery ground or as the adulthood habitat (Macnae, 1968). They are also assumed to play a very important ecological and geomorphological role in protecting the coastline at the landward side and the coral reefs at the seaward side. Regeneration and restoration of mangroves is imperative. However, insight on factors limiting successful re-establishment of mangroves is lacking. Of all benthic macrofauna inhabiting the mangrove swamps brachyuran crabs are amongst the most important taxa with regard both to number of species and total biomass. *Neosarmatium meinerti* de Man, 1887, is a sesarmid crab widely spread over the Indo-West Pacific Region (= *Sesarma meinerti*, re-diagnosed by Davie (1994) as the *Neosarmatium* genus). Along the Kenyan coast *N. meinerti* is living in the landward *Avicennia marina* (Forsk.) Vierh. mangrove fringe. Like many sesarmid crabs, *N. meinerti* is considered to be mainly herbivorous and it probably plays an important role in the process of leaf degradation and thus in biogeochemical cycles (Emmerson & McGwynne, 1992; Steinke et al., 1993).

Since sesarmid crabs have been reported to consume mangrove propagules (Robertson, 1982) the aim of this study was to detect whether *N. meinerti* may be a threat to mangrove regeneration or restoration through its predation on juvenile trees (propagules, seeds, saplings). In a first approach the stomach content and the feeding behaviour of *N. meinerti* was investigated.

Description of the sites studied

The study was done at Mida Creek (03° 20′S–40° 00′E) and Gazi Bay (04° 25′S–39° 50′E) in Kenya, respectively 100 km North and 50 km South of Mombasa along the Kenyan coast. Mida creek is a closed creek also known as the Watamu Marine National Reserve. Gazi Bay is an open creek and, unlike Mida Creek, fed by two seasonal rivers.

Materials and methods

Stomach analysis

A total of twenty individuals of *N. meinerti* were collected at Mida Creek and Gazi Bay between December 1991 and December 1992. Immediately after collection the crabs were placed in 70% alcohol. Stomach content analysis using a binocular microscope took place in the laboratory of the University of Florence (Italy) within 1 month of sampling. The stomach was carefully dissected from the crab's body and its content was washed into a Petri dish with 70% alcohol. The quantity of ingested food was estimated visually according to the degree of fullness and classified in one of the following 5 classes: circa 100%, 75%, 50%, 25% or 0% full. The stomachs were then dissected and the nature of the diet was examined using the percentage occurrence method as described by Williams (1981). This method, widely used in diet studies of fish and crabs, gives a measure for the regularity with which food has been taken up in the sample or population and it is specifically recommended when different food items contribute to the diet. The occurrence of different food items belonging to a certain category is counted, divided by the total number of individuals with a non-empty stomach and multiplied by 100 in order to obtain the frequency of occurrence.

Preference experiments

In Gazi Bay in September 1993, near the end of the dry season, preference experiments were done with *N. meinerti* in order to gain insight into possible impacts of their predation on seedling or propagule establishment. The rate of predation was examined as well as the preference of *N. meinerti* for juveniles of a particular mangrove species. Juveniles can be either propagules, seeds or saplings (these are defined as young plants with a maximum of 6 leaves). All the observations were carried out during diurnal low tides, when *N. meinerti* proved to be very active.

Rate of predation
For the predation rate experiment the following main mangrove species were used: *Bruguiera gymnorrhiza* (L.) Lam., *Ceriops tagal* (Perr.) C. B. Robinson and *Rhizophora mucronata* Lam. with propagules, *Avicennia marina* and *Sonneratia alba* Sm. with saplings and *Xylocarpus granatum* Koen with seeds. Together with *Heritiera littoralis* Dryand. and *Lumnitzera racemosa* Willd. these species constitute the mangroves at our sites. The distribution of *Pemphis acidula* (Forst.) is also reported for the study area (Tomlinson, 1986), but it was not observed in any of the mangrove sites. The species choice for the experiments was also dictated by their suitability and availability. Nomenclature of mangrove species follows Tomlinson (1986).

For this experiment all saplings were planted by burying the root system, leaving the other plant parts above ground. Of all viviparous propagules 50% was aselectively planted flat and 50% upright (Figure 1). Flat planting, i.e. horizontally, represents the natural condition where the propagule is dispersed by floating on the water ('stranding strategy dispersal'), upright planting, i.e. vertically, is equivalent to the 'planting strategy dispersal' when the propagule plants itself into the mud when dropping from the adult tree (Van Speybroeck, 1992). Seeds were placed randomly on the substratum.

Predation on freshly gathered vs matured propagules or seeds
The crabs were simultaneously offered freshly gathered and matured propagules or seeds. Earlier studies have shown that the age of mangrove leaves may affect the food preference of herbivores consuming those leaves (see discussion). Maturation was simulated by storage for 8 weeks in a humid saline environment. This treatment did not affect the viability of the material. The mangrove species used were *B. gymnorrhiza, C. tagal, R. mucronata* (propagules) and *X. granatum* (seeds).

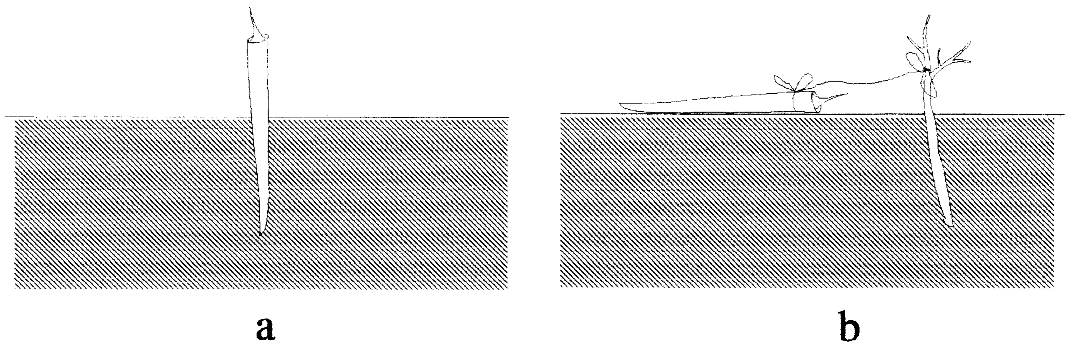

Figure 1. (a) Vertical experimental propagule planting. The vertical position represents the natural condition where the propagule drops from the parental tree (planting strategy). (b) Horizontal experimental propagule planting, attachment with a wire to a stick. The horizontal position represents the natural condition where the propagule floats on the water (stranding strategy).

Palatability experiments

The crabs were also presented with both propagules and leaves, and with synthetic spongy material impregnated with propagule extract from the species *B. gymnorrhiza, C. tagal* and *R. mucronata*. The extract was prepared by cutting one fresh propagule into slices which were immediately collected in a small plastic recipient of 150–200 ml filled with 25 ml freshwater. The recipient was then closed, shaken for several minutes and then left for 24 hours. After that small pieces of spongy material (120 × 80 × 2 mm) were saturated with the liquid and aselectively laid on the forest floor among the *N. meinerti* burrows. One sponge not containing any extract was used as a control.

All experiments were done in the area where *N. meinerti* is active, i.e. the landward zone reached by the mean high water level of spring tides. The *N. meinerti* burrows in and near our experimental area were all inhabited and reached densities up to l0 m^{-2}. The first 3 hours, or until all experimental food items were cleared, the experimental site was continually observed from a distance, using binoculars, or from the trees which overhung the observation area. After this period the area was checked at regular time intervals. Three levels of predation were defined following Smith (1987a, b): a juvenile was considered predated either:

– when the epicotyl was eaten,

– when 50% of the hypocotyl was cut through,

– when the propagule was pulled into the burrow of *N. meinerti*.

Results

Stomach content analysis

The stomachs of *N. meinerti* were almost all filled, only one individual in twenty was found with an empty stomach. The diet of *N. meinerti* consisted mainly of leaf fragments, complemented with some animal matter (Figure 2). The leaf fragments could be identified as *Avicennia marina* leaves on basis of stomatal features.

Preference experiments

Rate of predation
In general predation of all types of mangrove juveniles occurred very fast: after 2 hours more than 50% was predated and after 24 hours 85%. During the first 3 hours a clear preference was observed for horizontally 'planted' propagules, irrespective of the mangrove species (Figure 3). However, after 48 hours predation was 100%, whatever planting method was applied.

Predation on freshly gathered vs matured propagules or seeds
N. meinerti showed a distinct dislike for matured propagules of *Rhizophora mucronata* (Figure 4), in a total of fifteen, 5 matured propagules survived after 5 days while none of the freshly gathered ones did ($\chi^2 = 6$, df = 1, $p < 0.01$). For the other species no preference was observed between freshly gathered and matured propagules.

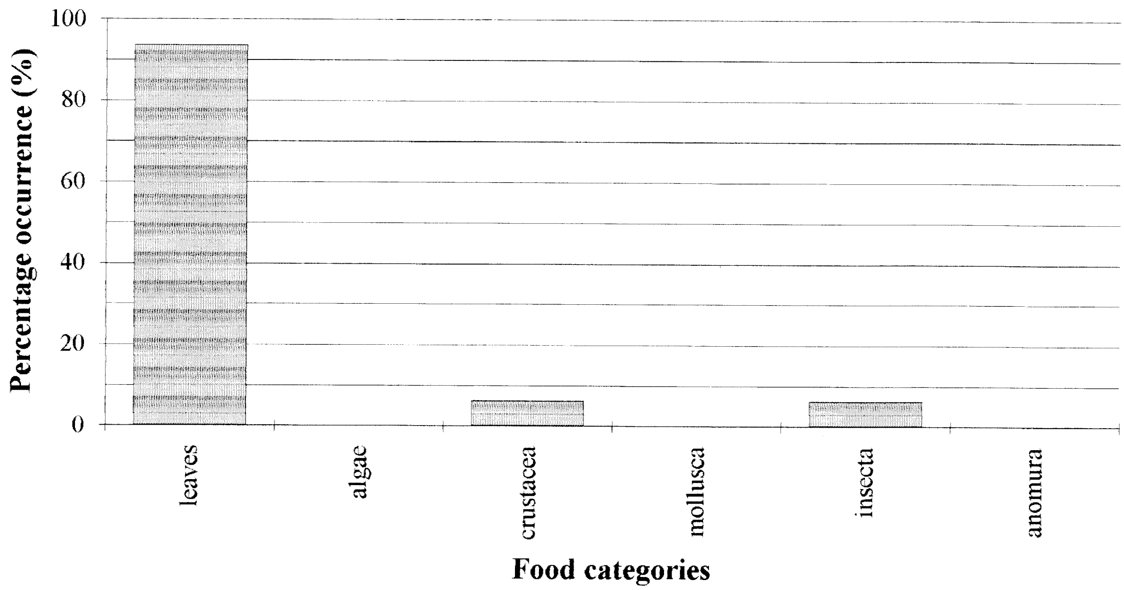

Figure 2. Stomach content analysis of *Neosarmatium meinerti.* (The natural diet mainly consists of mangrove leaves completed with some animal matter.)

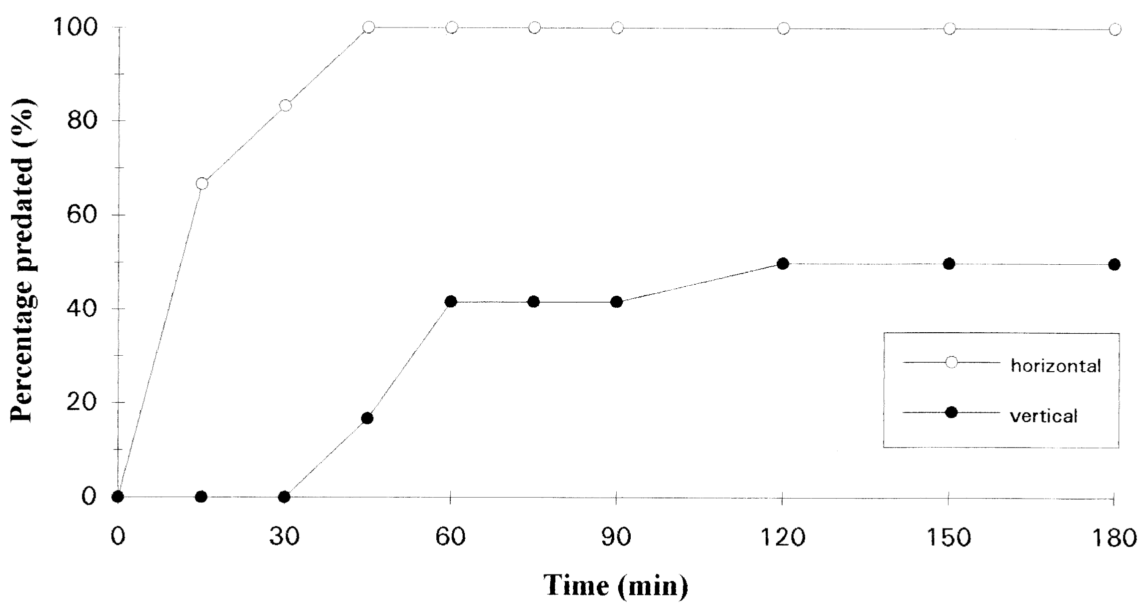

Figure 3. Rate of juvenile mangrove predation by *Neosarmatium meinerti.*

Palatability experiments

The results for the experiments with propagules and leaves can be found in Table 1, those for the experiment with impregnated spongy material in Table 2. The non parametric Friedman test was applied to the results of Table 1 to check if a preference for any of the presented items existed (Fr = 7.718, df = 6, n.s.). Since the Friedman test is more powerful if $n \geq 5$ (Conover, 1980), it was preferred not to use this test to compare the 4 sponges impregnated with propagule extract (Table 2), but to use the Spearman rank correlation coefficient between each possible pair of species instead, namely *R. mucronata/B. gym-*

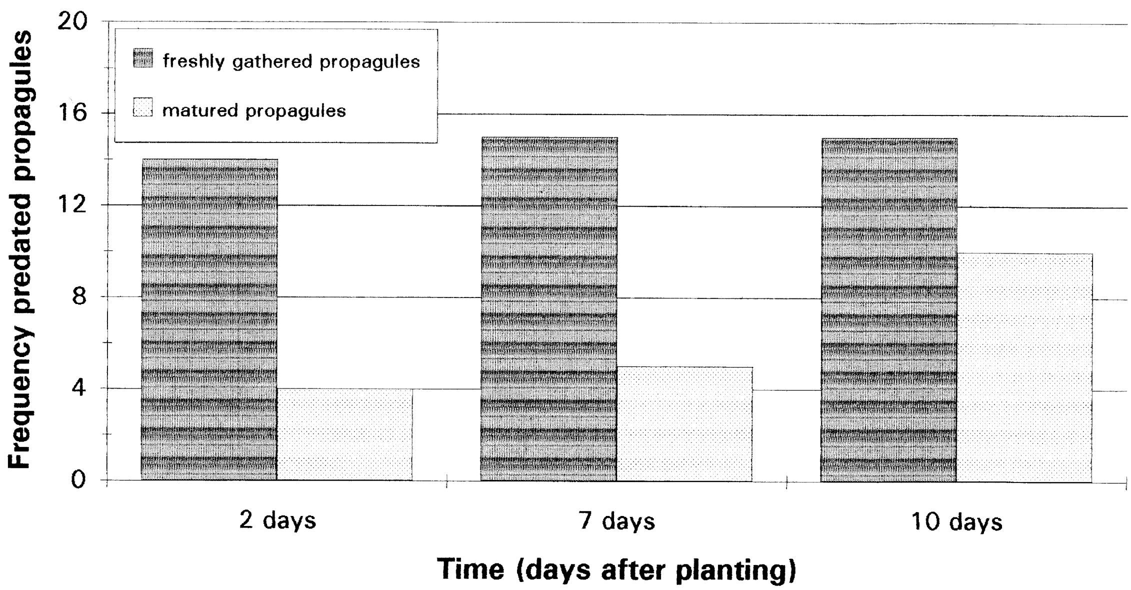

Figure 4. Food intake preference of *N. meinerti* when presented with matured and freshly gathered propagules.

Table 1. Order in which all the propagules and leaves were removed from the soil by *N. meinerti* in 4 different experiments.

Mangrove species/item	1st experiment	2nd experiment	3rd experiment	4th experiment
R. muc propagules	3	2	3	2
R. muc leaves	2	4	1	7
B. gym propagules	2	3	2	5
B. gym leaves	6	5	6	4
C. tag propagules	1	3	6	3
C. tag leaves	4	5	4	6
A. mar leaves	5	1	5	1

Table 2. Order in which the sponges containing different mangrove tree species extracts were removed from the soil by *N. meinerti* in 5 different experiments.

Mangrove species	1st experi-ment	2nd experi-ment	3rd experi-ment	4th experi-ment	5th experi-ment
Rhizophora mucronata	1	1	2	3	2
Bruguiera gymnorrhiza	2	3	3	4	3
Ceriops tagal	3	2	3	2	4
Control	3	4	1	1	1

norrhiza ($p = 0.6$, df = 3, n.s.), *R. mucronata/C. tagal* ($p = 0.45$, df = 3, n.s.), *R. mucronata/control* ($p = 0.05$, df = 3, n.s.), *B. gymnorrhiza/C. tagal* ($p = 0.65$, df = 3, n.s.), *B. gymnorrhiza/control* ($p = 0.05$, df = 3, n.s.), *C. tagal/control* ($p = 0.1$, df = 3, n.s.). The statistic tests revealed that no preference existed for any of the species.

Discussion

Crabs may contribute to leaf degradation as shown here through the analysis of their diet. This confirms the results of previous studies in other parts of the world. Crabs are a major factor in leaf degradation (Emmerson & McGwynne, 1992; Steinke et al., 1993) and in regeneration of mangroves (Smith, 1987a, b). In a southern African mangrove swamp Emmerson & McGwynne (1992) recorded for a mean crab density of 4 m^{-2} leaf consumption rates up to 0,78 g m^{-2} d^{-1} dry matter (284 g m^{-2} y^{-1} or 6462 kJ m^{-2} y^{-1}), accounting for approximately 44% of the leaf fall. In Gazi Bay this percentage might even be higher, considered that the area is more than twice as densely inhabited by *Neosarmatium meinerti*. Although this species was found to be strictly nocturnal by other authors (Micheli et al., 1991) in Gazi Bay it was very active during daytime.

Stomach content analysis of *N. meinerti* shows indeed that this species is mainly herbivorous but like certain other sesarmid crabs, *Selatium elongatum* A. Milne-Edwards and *Sesarma leptosoma* Hilgendorf, it has a diet which is complemented with animal matter (Dahdouh-Guebas et al., in press). Hence, this crab species should rather be considered as omnivorous instead of strictly herbivorous.

The preference experiments show that *N. meinerti* has no preference for any particular mangrove species amongst the six species considered. The items offered are almost cleared within one day and apparently without preference as might have been concluded from a particular sequence. Micheli et al. (1991) also could not detect a significant leaf preference for *N. meinerti* in Mida Creek (Kenya). Crabs were also observed to remove items belonging to our experimental material such as propagules (before plantation), pencils, paper or wire.

The preference for horizontally planted propagules is important in the study of natural colonisation of a naked habitat since this habitat can only be colonised through a stranding strategy, i.e. the equivalent of horizontal propagule planting (Figure 1b). The planting strategy is the dominant strategy in a natural mangrove forest (Van Speybroeck, 1992). This strategy is the equivalent of vertical propagule planting, which was here the best way to avoid immediate predation. However, when crabs are not saturated with food, they will consume irrespective of the planting strategy. In reafforestation plots in Sulawesi, Weinstock (1994) observed artificial planting of propagules at 25 cm intervals, even though the local population is taught that 50 cm is sufficient. They experienced that this allows at least some propagules to survive. This can be translated to natural conditions to large cohort formation and subsequent saturation of the local crab population. The latter can be supported by observations of *C. tagal* trees with more than 500 mature propagules. Colonisation of a bare habitat occurs through the stranding strategy (horizontal propagules), the preferred position for the predating crabs. With respect to maturation earlier studies concluded that *Neosarmatium smithii* H. Milne-Edwards preferred old or decaying over young leaf litter possibly because of the higher tannin content of leaves just fallen from trees (Giddins et al., 1986; Neilson et al., 1986; Micheli, 1993). These polyphenolic compounds can bind to digestive enzymes and in this way decrease animal absorption efficiency. Tannins have also been shown to deter herbivory by various grazers (Swain, 1979; Hay & Fenical, 1992). Unlike these observations the present experiment with freshly gathered and matured propagules shows that because of the lower predation on mature propagules, at least for *Rhizophora mucronata*, maturation may be a means of decreasing palatability and therefore predation. The low C:N ratio of *Avicennia marina* leaves (Micheli, 1993), which constitute the natural leaf litter in the *Neosarmatium meinerti* dominated forest zone, could be a general explanation why crabs predate on mangrove juveniles.

The lack of specificity in its diet can make *Neosarmatium meinerti* a problem in the regeneration of mangroves because of the predation of juveniles within the accessible area. Stomach content and feeding behaviour alone are not sufficient to determine impact of *N. meinerti* on mangrove (re)establishment. However, in view of *Neosarmatium meinerti* densities of 10 m^{-2} in Gazi Bay, of its unselective food preference and of the eventual survival rate of mangrove propagules and juveniles, the crab may hinder efficient (re)establishment of mangrove tree species, particularly in open plots within mangrove areas. These open plots indeed unfavourably combine the presence of *Neosarmatium meinerti* with a lack of adult trees and concomitant planting of propagules. Mangrove regeneration and restoration policies should therefore take into account this very mobile predator.

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