THE MAPUTO BAY ECOSYSTEM

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José Paula, Célia Macamo and Salomão Bandeira

Introduction

Mangrove vegetation grows on seashores, between the low and high tide marks, and along the tidal margins of rivers. It forms a plant community adapted to very changeable levels of water, and of salt and oxygen. Mangrove flora is composed of true and associated plant species. True mangrove species are defined by having either or both breathing roots (pneumatophores) and a viviparous fruit (that is, with seeds sprouting or germinating when still on the mother plant) (Hogarth, 1999; Beentje and Bandeira, 2007). The existence of a floating seed, a common characteristic in some riverine or coastal plant species, occurs also in some mangrove forest species such as *Xylocarpus granatum*. Additional adaptations that are common within mangrove plant species are the existence of thick, evergreen and, sometimes salt secreting leaves, and of buttresses that aid in structural support, a function of particular importance in shallow soils.

Mangrove forests, both vegetation and fauna, form an important resource in Maputo bay, providing numerous goods and services. They are regarded as critical habitats, particularly as they are crucial to the functioning and integrity of coastal and marine Maputo Bay ecosystems. These habitats provide a nutrient-rich environment and shelter for young fish and marine invertebrates, with emphasis on prawns much harvested in the bay. Mangrove trees are used as construction material, fuelwood, and as a source of tannins used to preserve and camouflage fishing nets. Maputo Bay mangroves also provide stabilization of the coastline preventing erosion and helping sediment regulation, and protect inland from extreme events such as storm surges and extreme high tide events. In addition, mangroves play a role as natural treatment areas for environmental contamination from sewage (Alongi *et al.*, 2000), a function particularly important in eastern Maputo bay, where are believed to act as key environmental regulators of water quality, namely at Costa de Sol and Matola, due to the high density of urban development. These habitats have been used for shrimp aquaculture, now abandoned. Major impacts on mangrove habitats in the bay area are the heavy deforestation in NW Maputo Bay for fuelwood and house construction material (see Case Study 7.1), past conversion to saltpans, port area and development of the Maputo city, including extensive land reclamation of considerable sections of Costa do Sol mangroves. Localized pollution impacting mangrove forests was observed in Maputo Bay, especially due to discharge of municipal waters, and agricultural and industrial effluents (see Chapter 16 - Pollution in Maputo Bay). This is particularly evident on Incomati River due to extensive activity upstream in Mozambique and from the neighboring countries that share its catchment. Accidental oil spills due to port activity, and in particular the accident occurred in 1992 with a tanker (Katina P) near the entrance of the bay, have also impacted mangroves in this estuary.

In Maputo bay mangroves are distributed quite widely covering most of the perimeter of the Bay (see Figure 1). The first mapping of mangrove forests in the Bay was made at Inhaca Island by Macnae and Kalk (1962), who first published on mangrove swamps of southern and northern bays of Inhaca Island. Detailed maps appeared later in the books by Macnae and Kalk (1969) and Kalk (1995) that show entire coverage of mangrove forests at Inhaca Island, emphasizing Saco (southern bay) and Sangala (northern bay). Hatton and Couto (1992) analyzed the change in the shape of Portuguese island due to impacts of sand accretion and erosion over time, which has also impacted on mangrove coverage. De Boer (2002) was the first to map the mangrove forest cover on the entire Maputo bay, based on aerial photographs, as well as describing the change in cover between 1958 and 1991, documenting an increase in mangrove area.

Accounts of mangrove cover changes using satellite imagery are given by LeMarie *et al.* (2006) and Macamo (2011) for the Incomati Estuary. Recent Landsat TM imagery from A. Ferreira (see Case Study 1.1, and Figure 1 below) shows 17,596 hectares of mangrove forests in Maputo Bay, with the main areas in the Espírito Santo Estuary and the remote forests in Maputo Special Reserve Area. This figure represents an 80% mangrove cover increase when compared to data from de Boer (2002). Differences between these figures may be justified by the different methodologies that were followed, and by slight increases in mangrove area, as documented by de Boer (2002) and LeMarie *et al.* (2006). General accounts of mangrove cover for the total country, including Maputo Bay, are those by Sakete and Matusse (1994) (later updated by Barbosa *et al.*, 2001) and Fatoyinbo *et al.* (2008), who indicated that the mangrove cover of Maputo bay is approximately 6% of the entire Mozambique cover.

Mangrove description and research at Maputo Bay

Flora

Six species of mangrove occur in Maputo bay. *Avicennia marina*, which is euryhaline with typical pencil-like pneumatophores, is the most widespread mangrove species inhabiting both the inner and outer fringes of mangrove forests. *Rhizophora mucronata*, with prop roots, occurs in creeks throughout the bay and tolerates less variation in salinity. *Ceriops tagal* is characterized by having knee pneumatophores and is a middle species in the zonation of mangroves in Maputo Bay, along with *Bruguiera gymnorhiza*. *Xylocarpus granatum* (cannon-ball mangrove), with strap pneumatophores, is a less common species in the bay with the exception to Incomati estuary where it is widespread; Maputo Bay is the southern-most distribution of this species in eastern Africa. *Lumnitzera racemosa*, known for having ephemeral pneumatophores (Tomlinson, 1986) is the uppermost mangrove species occurring right after the limit of the terrestrial vegetation, usually in areas were there is seepage of freshwater (Kalk, 1995). The basic zonation of mangrove forests in Maputo Bay is summarized in Figure 2, although this pattern can be altered by many environmental factors. The common species are shown in Figure 3.

Associated mangrove species lack the obligatory characteristics of pneumatophores and viviparous fruits, and some of these species may occur elsewhere in non-mangrove habitats. Common associated tree and shrub species in Maputo bay are *Hibiscus tiliaceus*, *Thespesia pupulnea*, *Brexia madagascarienses*, *Derris trifoliata* and *Phoenix reclinata*. Halophyte herbs are also common within mangroves salt desert in Maputo bay and are dominated mainly by succulent species such as *Sezuvium portulacastrum* (Aizoaceae), *Arthrocnemon* sp. (Chenopodiaceae), and *Saliconia* sp. (Chenopodiaceae). *Sporobolus virginicus* is a common grass species in Maputo bay high salt concentration mangrove tree areas. Other mangrove associates include the mangrove fern *(Acrostichum aureum)*, sedges *(Cyperus crassipes)* and rushes *(Juncus kaussi)* common in sites where there is a degree of seepage. Furthermore, the botanical community within mangrove habitats encompasses epiphytic mistletoes (*Oncocalyx bolusii*, Loranthaceae), and macroalgae species such as the red algae Bostrychia tenera commonly growing on mangrove pneumatophores. Detailed accounts of mangrove flora associates were published by Macnae and Kalk (1969), Kalk (1995) and Beentje and Bandeira (1997).

The conditions in Maputo Bay are generally excellent for mangrove establishment, growth and development. The shape of the bay and the presence of Inhaca and Portuguese islands provide protective barriers against strong wave action. The six rivers that flow into the bay through the three main estuaries (Incomati, Espírito Santo and Maputo) and the smaller Bembe estuary also provide the necessary freshwater that mangroves require. Therefore, Maputo Bay is one of the major mangrove areas in southern Mozambique (Barbosa *et al.*, 2001).

In the northernmost tip of the Bay there is the Incomati estuary, with the mangrove formations of Marracuene, Macaneta, Bairro dos Pescadores, Costa do Sol/Bairro Triunfo, Benguelene, and Xefina Pequena and Xefina Grande Islands. These well-established forests can go up to 7 km inland. The

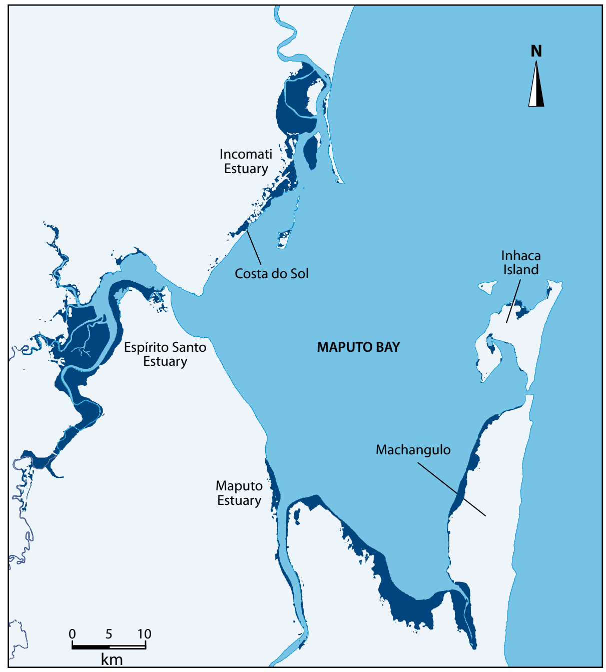

Figure 1. Mangrove distribution in Maputo Bay based on satellite imagery (original map by Adelaide Ferreira).

species composition is diverse, with six species occurring. However, *Avicennia marina* and *Rhizophora mucronata* are the strongly dominant species. Although *Avicennia marina* is found mainly at the sea and land margins of the forest it may also occupy inner areas of stressed forests where the vegetation is dominated by a dwarf form of this species, such as in Costa do Sol. *Rhizophora mucronata* fringes the channels inflowing the forest, as the species has a low tolerance to high salinity. *Ceriops tagal* is the third commonest species, and grows in the inner parts of the forests. The other three species are *Lumnitzera racemosa*, *Xylocarpus granatum* and *Bruguiera gymnorhiza*.

The mangroves that grow in the west side of the bay colonize an estuary that results from the confluence of four rivers (Infulene, Matola, Umbeluzi and Tembe) forming the Espírito Santo Estuary. These forests are similar to those growing in the Incomati Estuary, although they go further upstream. The mangrove formations of Maputo and Catembe are

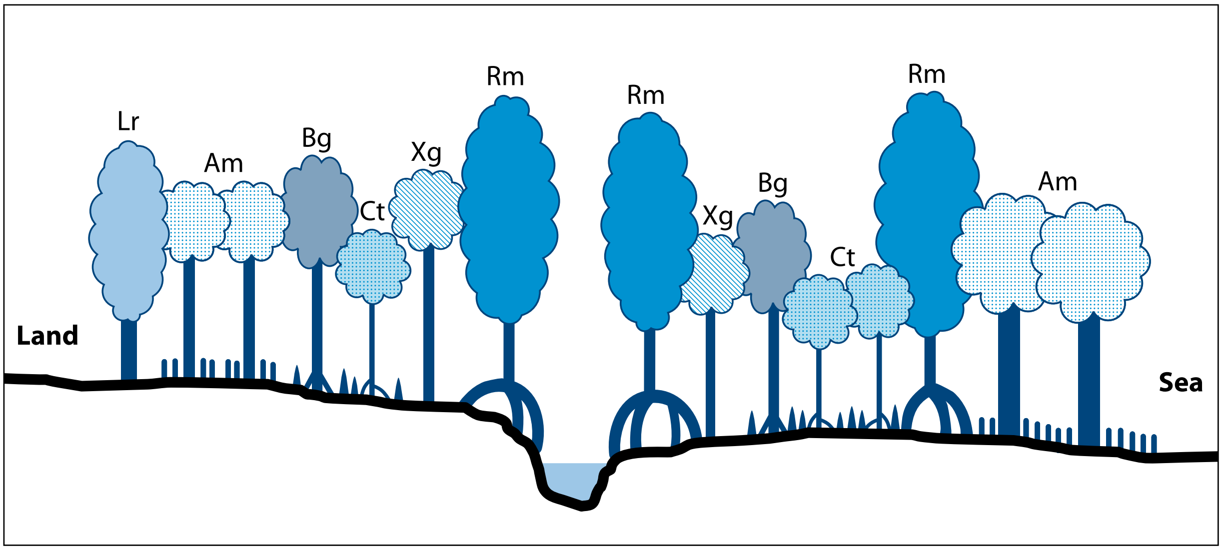

Figure 2. Basic zonation pattern of true mangrove species in Maputo Bay. **Lr** – *Lumnitzera racemosa*, **Am** – *Avicennia marina*, **Bg** – *Bruguiera gymnorhiza*, **Ct** – *Ceriops tagal*, **Xg** – *Xylocarpus granatum*, **Rm** – *Rhizophora mucronata.*

included in this group.

Southernmost in the Bay, within Maputo and the smaller Bembe estuaries, are mangrove formations that stretch from around Bela Vista (Maputo Estuary mouth) towards Bembe and inner Machangulo Peninsula. These forests grow in a narrower band along the coastline, where the three commonest species are *A. marina*, *R. mucronata* and *C. tagal*.

In the east of Maputo Bay, are the important mangrove formations of Machangulo Peninsula and Inhaca Island (Saco, Sangala and Ponta Rasa). These forests are fringed in the land and seaward margin by *A. marina* (which tends to be dwarf in the drier margins), while *C. tagal* and *B. gymnorhiza* form true thickets in the forest. *Rhizophora mucronata* colonizes the muddier areas along the channels (Kalk, 1995; Pechisso, 1998).

Research in Maputo Bay mangrove flora is relatively scarce, most studies being related to mapping as mentioned above. Very few dealt with other aspects of mangrove ecology. To refer as Fernando and Bandeira (2009), who looked at litter fall and decomposition at Saco, in both wet and dry seasons; Bandeira *et al.* (2009) who looked at structural and condition aspects of Inhaca Island forest and Macamo (2011), which dealt with mapping, and both structural and condition aspects at the Incomati Estuary.

Fauna

The fauna associated with mangroves along the Eastern African latitudinal gradient has its maximum diversity in the equatorial region, and tends to decrease at higher latitudes in both hemispheres, as seen for the tree diversity (Beentje and Bandeira 2007). Faunal elements follow the floral trend, and Maputo Bay is located at a clinal point of this latitudinal gradient. Further south on the African coast, tropical species and their distribution progressively end according to their specific environmental requirements. Macnae and Kalk (1969) and Kalk (1995) have provided a general overview of mangrove-associated fauna for Inhaca Island forests, which can be generalized to the whole Maputo Bay in qualitative terms.

Crabs constitute the most conspicuous macrobenthic faunal elements in mangroves globally, and Maputo Bay is no exception. Besides the accounts of Macnae and Kalk (1968) and Kalk (1995), a list of species of decapod crustaceans in the region was published by Kensley (1981), including mangrove-associated species. The fiddler crabs of the family Ocypodidae are represented by five species: *Uca annulipes* shows a bimodal distribution along the zonation pattern associated to the *Avicennia marina* pneumatophore zone, *Uca inversa* occurs on the flats amongst *A. marina* trees at the landward side of the mangrove, *Uca chlorophthalmus* and *Uca urvillei* on the middle and muddier parts of the swamps, mainly around *Ceriops tagal*, *Bruguiera gymnorhiza* and *Rhizophora mucronata* trees, and *Uca vocans* occurs in the tidal flats dominated by sand below the mangrove. Other ocypodids occurring in close association with mangroves are *Macrophthalmus depressus* in the lower bare flats, and *Dotilla fenestrata* on the lower sandier substrates.

The Sesarmidae are represented by several species occupying different niches in the mangrove. Two species of the large *Neosarmatium* genus occur: *N. meinerti* and *N. smithii*. *Neosarmatium meinerti* burrows in the upper mangrove, mainly around *A. marina* and *L. racemosa*, but also on the halophyte zone further up in the tidal profile. *Neosarmatium smithii* burrows in the middle swamp among *C. tagal* and *B. gymnorhiza* trees. Both these species collect and carry mangroves leaves into their burrows, but their trophic position remains unclear. The most abundant sesarmid is however the opportunistic red clawed *Perisesarma guttatum*, inhabiting the low and mid swamp areas and preferring the shelter created by the mangrove root systems and sediment crevices. Other sesarmids include *Chiromantes ortmani*, *C. eulimene* and *Parasesarma catenata* in the halophyte zone, and the tree climbing *Parasesarma leptosoma* (a rare species in Maputo Bay).

Other common crab species include the grapsids *Metopograpsus tukuhar* and *Ilyograpsus paludicola* and the xanthids *Eurycarcinus natalensis* and *Epixanthus frontalis*. The only commercial crab is the large portunid *Scylla serrata*, which burrows as a juvenile in the middle swamp. This species recruits as post-larva to the mangrove and remains there during the juvenile phase until maturity, then leaves the intertidal areas and moves to creeks and shallow bay waters for reproduction and adult life. Major findings of biological aspects of this species in the Incomati Estuary mangrove areas constitute the scope of Case Study 7.3.

The equatorial systems (e.g. Kenya: Hartnoll *et al.*, 2002) have a higher ocypodid crab biomass compared to the subtropical Maputo Bay systems that are dominated by sesarmid biomass. A number of crab species typical of lower latitudes are absent or rare in Maputo Bay (e.g. *Perisesarma samawati*: Gillikin and Schubart, 2004; *Parasesarma leptosoma*: Emmerson *et al.*, 2003), while a number of Southern African species are present in Maputo Bay and absent in equatorial region (e.g. *Parasesarma catenata*: Kalk, 1995). Cannicci *et al.* (2009) confirm the shift in dominance from the Ocypodidae in Kenya to the Sesarmidae in Mozambique (Maputo Bay), found by Hartnoll *et al.* (2002).

The mangrove environment provides shelter and food sources for a number of species of commercial interest that use mangroves as a nursery area during the juvenile phase. One example is the above-mentioned edible crab *Scylla serrata*, confined to the mangrove during the pre-maturity phase. Also, penaeid shrimps are known to depend on coastal shallow habitats as nursery zones (Macia, 2004), and Maputo Bay constitutes the second major fishing ground of Mozambique. In particular, the species *Fenneropenaeus indicus*, one of the commercially most important species locally, is known to depend on mangroves during the juvenile stages (Macia, 2004), invading the pneumatophore zone of lower *Avicennia marina* during high tides. The pneumatophores are protec-

Figure 3. Mangroves of Maputo Bay. **(A)** View of lower *Avicennia marina* belt at Saco, **(B)** upper *A. marina* belt at Ponta Rasa, **(C)** isolated *A. marina* at south Inhaca, **(D)** dwarf *A. marina* at Costa do Sol, **(E)**, *Rhizophora mucronata* bordering Saco creek, **(F)** *Ceriops tagal* and **(G)** *Bruguiera gimnorhyza* at Saco, **(H)** *Xilocarpus granatum* at Incomati Estuary. Photographs by José Paula (A-G) and Salomão Bandeira (H).

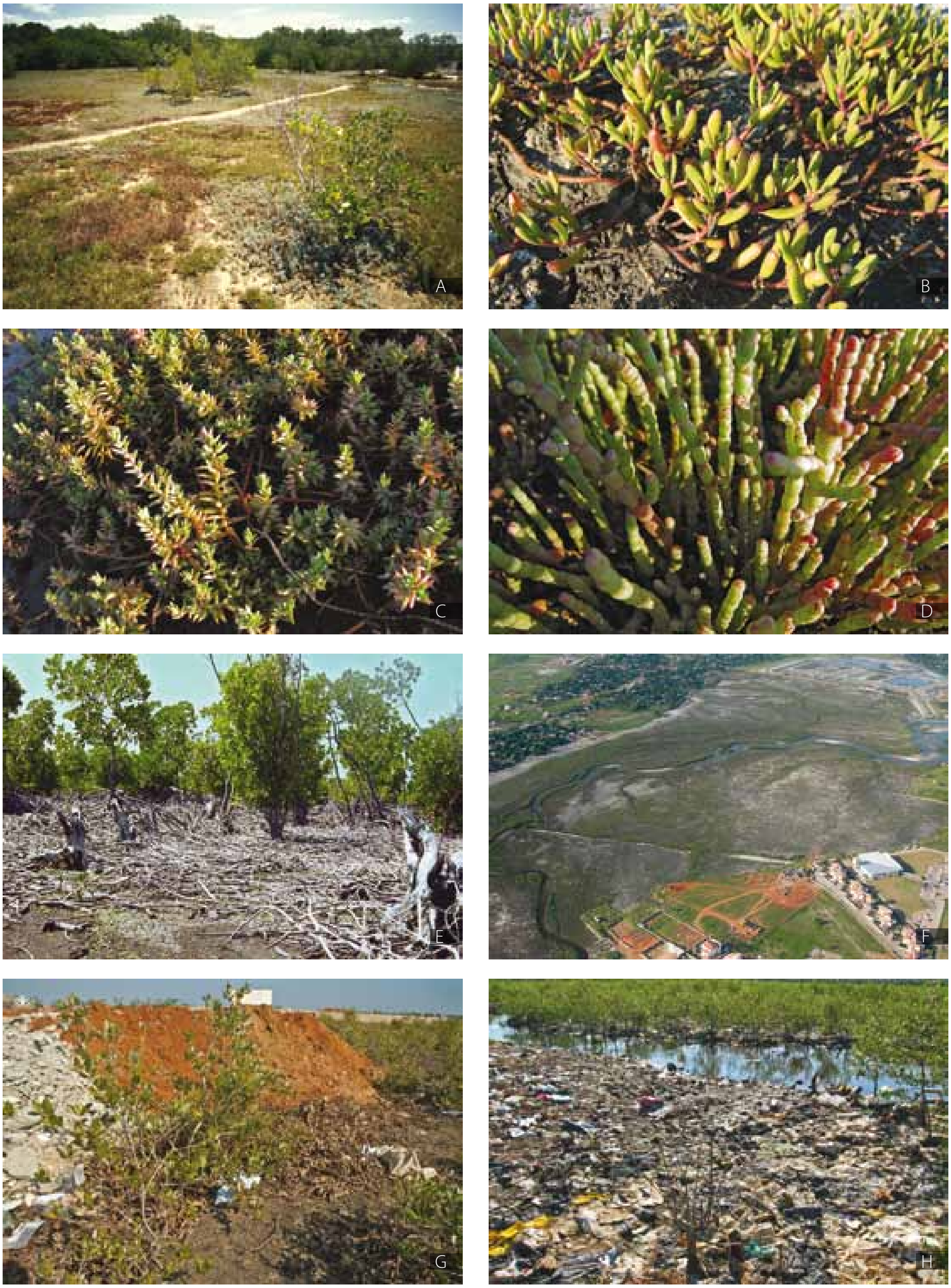

Figure 4. Mangroves of Maputo Bay. **(A)** Salt marsh at Saco, and halophyte plants **(B)** *Sesuvium portulacastrum*, **(C)** *Chenolea diffusa*, and **(D)** *Sarcocornia perenne*, **(E)** Xefina Pequena Island (Incomati Estuary), **(F)** aereal view of degraded Costa do Sol mangrove, **(G)** housing invading the mangrove, and **(H)** polluted creek at Costa do Sol. Photographs by José Paula (A-D, F-H) and Salomão Bandeira (E).

tive against predation (Macia *et al.*, 2003) by fishes, and the high levels of particulate organic matter enhance growth rates.

Gastropod molluscs are also key macrofaunal elements of mangroves. The genus *Littoraria* has a wide distribution around the world, with a number of mangrove associated species (Reid, 1986). At Maputo Bay four species are present: *L. scabra, L. pallescens*, *L. intermedia* and *L. subvittata*. Abundance and diversity decrease abruptly south of Maputo Bay, confirming the transitional character of the region, although values at the Bay are still high both in diversity and abundance (Torres *et al.*, 2008). All species have a large-scale spatial variation in abundance; with *L. subvittata* showing the greatest abundance while *L. intermedia* is rare. *Littoraria scabra* and *L. intermedia* are found mainly at the seaward edge of the forests. *Littoraria subvittata* increases in abundance in the middle of the forest and towards the landward side. *Littoraria pallescens* occurs mainly at the seaward edge and in the middle areas in the *Rhizophora* zone. These small-scale variations show contrasting specific distribution patterns within the mangrove, likely reflecting different tolerances to physical factors and biological interactions. There is also a trend of size decrease from the equatorial area down to Maputo Bay and South Africa, and *L. scabra* is significantly larger than other species at all mangroves in including Maputo Bay (Torres *et al.*, 2008).

Other important gastropod species in Maputo Bay mangroves include *Cerithidia decollata*, which shows migratory patterns from the sediment to the mid height of mangrove trees, and the mud whelk *Terebralia palustris*. This last species is very abundant locally, and thrives on filtering the surface sediment while juvenile, shifting to mangrove leaf eating at maturity, when it attains circa 5 cm in total length. As a consequence, the distribution of size-classes is not similar, with adults preferring the shaded areas of the lower *Avicennia marina* trees, where falling leaves present maximum food, while juveniles live in the exposed lower pneumatophore zone (Penha-Lopes *et al.*, 2009a). Also abundant are the air-breathing gastropods *Melampus semiaratus* and *Cassidula labrella*, abundant in the dark muds, especially bordering the mangrove channels.

There is variability of infaunal community abundance and composition both between mangrove strata, as expected due the zonation and patchy character of the mangrove environment, but also between the mangroves around Maputo Bay, reflecting different environmental conditions and degrees of degradation. For example at Inhaca Island, the main differences in macrobenthic species composition and abundance can be attributed to different sediment properties and the characteristics of the tidal inundation (Guerreiro *et al.*, 1996). But also the environmental condition modulates diversity and qualitative and quantitative balance between species. The mangroves in western Maputo Bay suffer strong impacts of pollution and other forms of degradation (see above and Chapter 16 - Pollution in Maputo Bay) and function quite differently when compared to those in the south and east, such at Inhaca Island.

Regarding macro-infaunal communities, densities of Oligochaeta decrease significantly at peri-urban Costa do Sol mangrove (Penha-Lopes *et al.*, 2010a). Also macro crustaceans (ocypodids: *Uca* spp., and sesarmids: *Perisesarma guttatum* and *Neosarmatium meinerti*) and meiofauna density increase and molluscs decrease (e.g. *Terebralia palustris*) in this mangrove (Cannicci *et al.*, 2009), and general diversity calculated using major meiofaunal groups is lower at contaminated sites. Differences observed between the peri-urban and pristine mangroves may be attributable to a higher content of organic matter in the peri-urban mangroves, which increases sources of food for meiofauna and the biofilm crabs feeders.

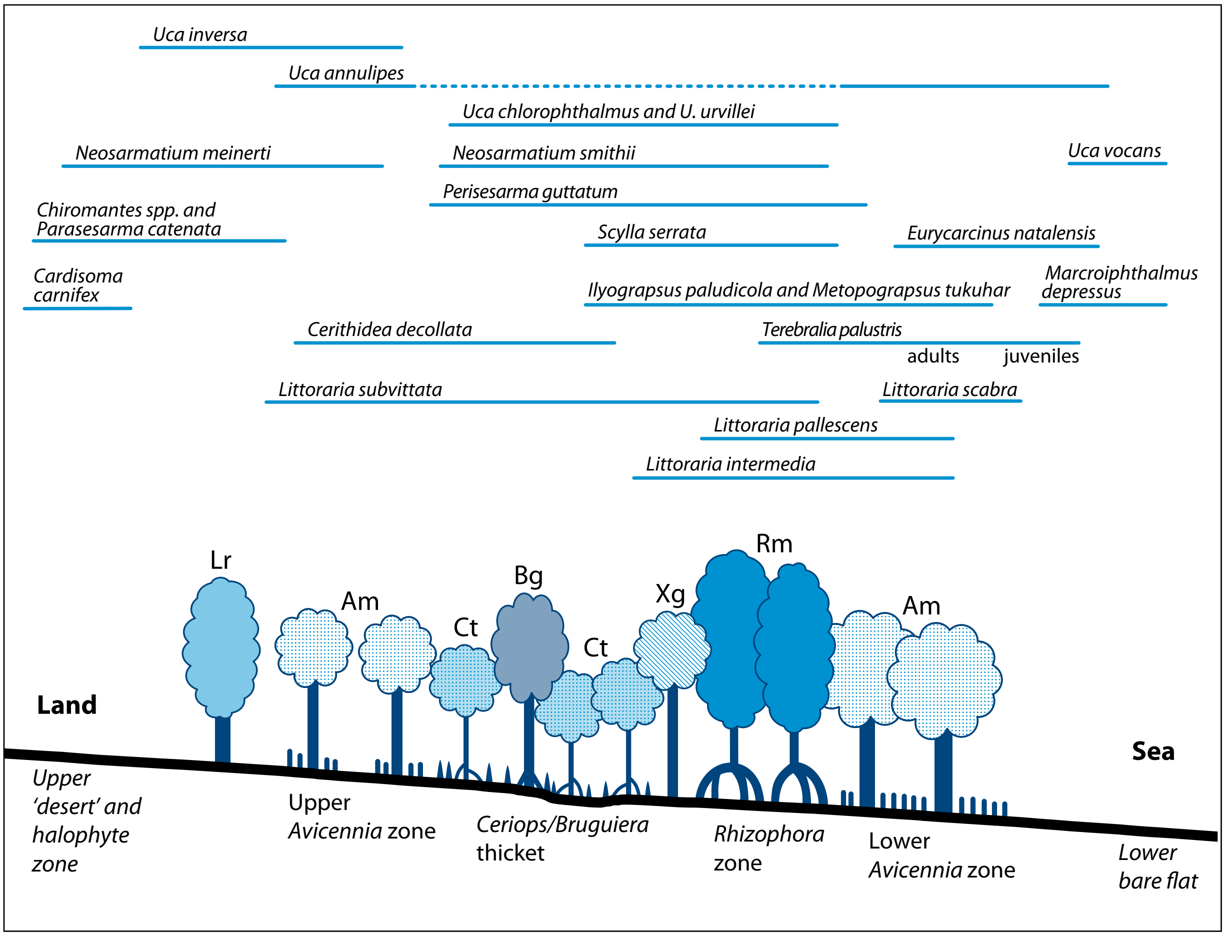

Figure 5. Distribution of most abundant crustaceans and gastropods along the zonation profile of Maputo Bay mangroves. Trees abbreviation as in Figure 2.

Research on mangrove fauna of Maputo bay region was intense during the past 20 years, targeting different aspects and following the funding opportunities. Besides the studies of a general nature, mainly targeting distribution and abundance of faunal elements of biological components of the mangrove ecosystem in Maputo Bay, numerous research contributions to various aspects of the ecology of mangroves and their resources were published. Mangroves, due to their importance for providing goods and services for human coastal populations, have been a natural central model system in research activities in the Maputo Bay area.

The main environmental cycles, such as the tidal, diel and semi-lunar periods, modulate biological activities and the whole ecology of mangroves. Mangrove organisms are affected by these rhythms throughout their entire life phases, and these aspects have been studied in some detail at Maputo Bay mangroves, with special emphasis on Inhaca Island. Hatching rhythmicity was studied for a number of species, such as *Uca annulipes*, *U. chlorophthalmus*, *U. vocans*, and *Perisesarma guttatum* (Gove and Mambonhe, 2000), which showed comparable results to other species from other habitats at Inhaca (Gove and Paula, 2000).

The larval stages of Inhaca mangrove invertebrates disperse in the neritic water mass in discrete pulses that relate to environmental cycles. This has be traced in the mangrove creeks where the newly-hatched stages are exported during particular ebbing tides, as was demonstrated by Paula *et al.* (2004) for the Saco mangrove at Inhaca island. These larval stages can be found in the plankton, mixed with those of other origins and disperse according to local hydrographical conditions. The plankton of the Bay has a large component of the larval stages of bottom invertebrates, including mangrove species (e.g. Paula *et al.*, 1998), and one of the major difficulties in tracing the dispersal of the important planktonic phase of mangrove invertebrates is the lack of adequate descriptions of the morphology of larval stages for most Western Indian Ocean mangrove invertebrate species (and also from other coastal habitats as well). A number of investigations were performed to fill this knowledge gap at Maputo Bay, by obtaining and describing the newly hatched stages obtained from ovigerous females (e.g. Clark and Paula, 2003; Flores *et al.*, 2003). Recruitment was studied at Maputo Bay using Saco mangroves (Paula *et al.*, 2001b) and Ponta Rasa mangroves (Paula *et al.*, 2003b) at Inhaca Island as model systems. Details of the known aspects of recruitment of crustaceans to mangrove areas are presented in Case Study 7.4.

Reproductive parameters were studied for a number of crustaceans in Maputo Bay, such as *Perisesarma guttatum* (Flores *et al.*, 2002), *Uca annulipes* (Litulo, 2004a), *U. inversa* (Litulo, 2004b; 2005a), *U. chlorophthalmus* (Litulo, 2006), *U. urvillei* (Litulo, 2005b), *U. vocans* (Litulo, 2005c), *Neosarmatium meinerti* (Litulo, 2007) and *Macrophthalmus depressus* (Litulo *et al.*, 2005d). Also the five species of the genus *Uca* occurring at Maputo Bay were comparatively investigated for fatty acid composition during embryonic development (Torres *et al.*, 2008), and fecundity and brood loss (Torres *et al.*, 2009) at the mangroves of Inhaca Island.

Brachyuran crabs were used in a number of studies for comparing the effects of environmental contamination in mangroves around Maputo Bay, namely addressing fecundity, embryo quality (fatty acid composition) and egg loss throughout embryonic development (*Uca annulipes*: Penha-Lopes *et al.*, 2009b), and RNA/DNA ratio in animal tissues (*Uca annulipes* and *Perisesarma guttatum*: Amaral *et al.*, 2009). Further search for bioindication of environmental contamination used the mangrove creek shrimp *Palaemon concinnus*, and included growth, reproductive parameters (egg loss and embryo fatty acid composition), as well as susceptibility for parasite infection (Penha-Lopes *et al.*, 2010b).

Connectivity between populations of the fragmented mosaic of mangrove distribution along the coast is mainly driven by the dispersal of the pelagic developmental stages of species. This dispersal is dependent on larval duration in the plankton, larval behaviour in terms of dynamical vertical positioning, and ultimately by the hydrographical phenomena at the local and mesoscales. These processes define the degree of interchange between separate populations and thus their differentiation based on evolutionary genetic divergence. The specificity of Maputo Bay populations was evidenced by a number of model mangrove organisms, studied for genetic differentiation along the Eastern African latitudinal gradient. The different mangrove biological models were the crabs *Uca annulipes* (Silva *et al.*, 2010c) and *Perisesarma guttatum* (Silva *et al.*, 2010b), and the gastropods *Cerithidea decollata* (Madeira *et al.*, 2012) and *Littoraria scabra* (Silva *et al.*, in press). However, much work remains to be done in order to understand connectivity of mangroves within Maputo Bay and between the bay and adjacent areas, and the underlying physical and biological mechanisms that control gene flow.

Figure 6. Associated mangrove dominant macrofauna in Maputo Bay. **(A)** *Uca annulipes,* **(B)** *U. inversa,* **(C)** *U. urvillei,* **(D)** *U. chlorophthalmus,* **(E)** *U. vocans,* **(F)** *Neosarmatium smithii,* **(G)** *N. meinerti,* **(H)** *Perisesarma guttatum.* Photographs by José Paula.

Uses and impacts

As peri-urban forests, the mangroves of Maputo Bay suffer different types of anthropogenic impacts. A major cause of degradation of mangroves is deforestation for wood and domestic fuel. Fuelwood and charcoal are prime sources of domestic fuel for peri-urban populations in Maputo Bay (Brower and Falcão, 2005), and wood from mangroves is widely collected both for domestic consumption and commercial purposes (see Case Study 7.1). Wood is also used for boat and house construction and to produce various household utensils. Those forests located close to major human settlements are prone to rather heavier anthropogenic pressure, while the most remote (such as the mangrove forests in Maputo River Estuary, Maputo Especial Reserve and Saco forests) are kept in a good although not pristine condition. Land use changes were also responsible for the loss of several hectares of mangroves. Conversion was made to saltpans (most of them concentrated in the Matola region) and to a shrimp aquaculture farm (yet abandoned). The forest is also being cleared for urban development. At Costa do Sol, for example, a new upmarket neighborhood continues to encroach vital mangroves forests that would help support floods and seawater swells. Localized pollution impacts on mangrove, especially due to discharge of municipal waters, agricultural and industrial effluents (Maputo Bay holds the biggest industrial park of Mozambique). The Incomati Estuary is possibly one of the most severely impacted mangrove forests of the Bay, resulting from the combined effects of deforestation, pollution (municipal, agricultural and industrial from the 3 countries through which the river runs) and freshwater abstraction (Monteiro and Marchand, 2009). Although degraded, the total area of the forest has barely changed (see Case Study 7.1) due to the growing of new forest in recently accreated areas. In 1992, a tanker carrying 72,000 tones of oil went through a storm during which two tanks were damaged. The accident resulted in the spill of more than 13,000 tones of oil in Mozambique Channel and Maputo Bay, where the ship was aground (40 km north of Maputo). The mangrove forests of the Incomati (including both Xefina Islands) and Matola River estuaries, Muntanhana, Catembe, Costa do Sol and Bairro dos Pescadores were severely affected. Vestiges of the oil spill are still visible in some areas of the Bay, after 18 years.

Legally, all mangrove forests should enjoy protected status in Mozambique as the Regulation for Pollution Prevention and Protection of the Marine and Coastal Environment state that all the area within 100m measured from the highest spring tide line mark is protected. The same regulation forbids the exploitation of the native littoral flora for non-scientific purposes, except if practiced by local populations and in non-degraded areas. Pollutants deposition in rivers and wetlands, as well wildfires and livestock and forest exploitation, which implies substantial loss of the habitat quality and change in hydrological regimes, are also forbidden. Particularly in Maputo Bay, the Saco mangroves at Inhaca Island and the mangroves in the Maputo Especial Reserve grow within protected areas. However, in practice intensive deforestation occurred more than a decade ago in most of the forests in the Bay, especially at Incomati while Inhaca mangroves enjoy strict protection due to reinforcement carried out mainly by the Marine Biological Station of Inhaca, who controls the nearby terrestrial reserves. Generally at Inhaca the mangroves are still in a good condition despite being used by the local population (see LeMarie *et al.*, 2006; Bandeira *et al.*, 2009). Nevertheless, mangrove cutting may become an issue as the population in the island grows and tourism activities are

Figure 7. Associated mangrove dominant macrofauna in Maputo Bay. **(A)** *Chiromantes ortmanni,* **(B)** *Macrophthalmus depressus* **(C)** *Neocarcinus natalensis,* **(D)** *Littoraria scabra,* **(E)** *L. pallescens,* **(F)** *Terebralia palustris,* **(G)** *Cerithidea decollata,* **(H)** *Periophthalmus argentilineatus.* Photographs by José Paula.

expected to develop further.

Knowledge gaps and research perspectives

The mangroves of Maputo Bay are highly heterogeneous formations, influenced by a complex set of environmental factors. The south of the bay is not well studied and there is very limited information available. Also these mangroves can be expected to be the most pristine in the Bay, due the lower human population and general lack of impacts. There should be an effort to obtain data from the area, namely the forests associated to the Maputo Estuary and Machangulo Peninsula.

In more global perspective, it will be of high interest to establish a better understanding of the influence of mangroves on the ecology of the Maputo Bay, including the coastal water quality and resource sustainability. Mangroves are known to act as potential filters to domestic sewage, and the vanishing forests around Maputo City (Costa do Sol and Espírito Santo) may play a major role in maintaining water quality at acceptable levels. On the other hand, the decrease of mangrove cover in the Bay can compromise the stability of the large shrimp fishery, the second largest in the country, due the dependence of juvenile shrimps from the mangrove areas. It is important to better assess the role of mangroves in Maputo Bay in order to provide managers and decision-making structures with the necessary information for wise management of the forests.

Further connectivity studies are also needed in order to assess the natural capacity of mangroves to regenerate from degradation derived from multiple causes, such as climate change trends (such as sea level rise, floods and increase of extreme events) and direct impacts from human activities (such as cutting, reclamation, pollution etc.).

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