The role of disturbances in mangrove wood formation and forest structure

Effect of large sedimentation events

Summary

Mangrove ecosystems constitute a relatively small areal coverage as compared to other tropical forests, yet they are of great benefits to humans as well as an important component of marine biodiversity. These ecosystems are shaped by an interaction of several factors including tides, sediment fluxes, topography and soil and water salinity as well as freshwater input. Secondary influence comes from anthropogenic activities such as exploitation or any other activity that may alter the aforementioned factors. When at a dynamic equilibrium, these factors interact to create a balance and within some level of disturbance, the system in its entirety, the mangroves can still ensure resilience. Extreme forms of disturbances may however disrupt this natural equilibrium resulting in stressful conditions which compromise the resilience capacity of these ecosystems. The ultimate result is degradation of the mangrove wetlands, which in turn not only depletes the resources within their boundaries, but also affects the productivity of adjacent coastal and marine ecosystems.

Sediment deposition and accumulation in mangrove ecosystems play a major role in enhancing substrate stability for better anchorage of the trees, creating new mudflats for further mangrove colonisation and protecting associated ecosystems (sea grass beds and coral reefs) against siltation and eutrophication. However, with increasing demand for agricultural land upstream, the delivery of riverine sediment to the coastal areas is currently increasing with large rivers transporting up to 17.8×10^9 t yr^{-1} (Wilkinson, 2005; Vanacker *et al.*, 2007). Coupled with the Intergovernmental Panel on Climate Change (IPCC) projection of likelihood of heavy rain storms within short durations in the East African region (WWF, 2006; Christensen *et al.*, 2007), the problem may just be accentuated. Sedimentation in mangrove forests results in smothering of the breathing roots of the trees and reduces sediment oxygen. The current study looks at disturbance in mangroves from two perspectives, i) as it occurs in nature and (ii) projected large forms of disturbance as a result of increased anthropogenic pressure and predicted climate change related events with a focus

on sedimentation. This information will be important in designing management plans and in deciding management options under climate change scenarios.

Part I of this study evaluates the self-sustenance potential of peri-urban mangroves from an exploitation perspective with a focus on Mtwapa Creek in Kenya. We determined forest structural characteristics (**Chapter 2**) followed by a socioeconomic evaluation of the local human community living in the vicinity (**Chapter 3**). Structural data of the forest studied showed this mangrove forest as having rather sufficient natural regeneration but poor tree development hence compromising the forest's self-sustenance potential. Additionally, proximity to human settlement largely contributed to selective harvesting hence influencing the forest structure. The perception of the local community on the forest status varied with gender, wealth status, education level and knowledge on mangroves, bringing out mixed opinions from the survey. Local communities mainly considered the forest in Mtwapa Creek as degraded but there is a sharp division between lack of suitable construction poles as a form of degradation and cover loss particularly based on gender. More than 50% of the population engaged in farming and the agricultural farms were observed close to the creek with some sighted on the steep slopes facing the creek. This suggests potential increased sediment deposition in the tidal flat. Though they admit depending on mangrove wood, the people distance themselves from full responsibility, blaming the government of not supporting their conservation initiatives and laxity in protecting the forest.

In **Part II** of this study, we assessed phenological dynamics (**Chapter 4**); structure and functioning of xylem vessels and stomatal properties (**Chapter 5)**; and root and bark development (**Chapter 6**) of mangrove trees following experimental instantaneous partial burial. Three mangrove tree species (*Avicennia marina*, *Ceriops tagal* and *Rhizophora mucronata*) which constitute more than 70% of the mangrove forest formation in the Western Indian Ocean region, were subjected to experimental sediment burial simulating different levels of sedimentation (15, 30 and 45 cm).

Phenological traits of the partially buried trees were monitored over a period of one year **(Chapter 4)**. Leaf loss was found to increase with sedimentation level only in *C. tagal* during the first quarter of the experiment suggesting acclimatisation to the new conditions. There was no significant shift in timing in the phenological events and the leaves produced were of relatively larger surface area in the buried trees of all species as compared to controls. Other observations such as improved fecundity and increased shoot growth as a result of sedimentation were more specific to the different tree species.

In **Chapter 5**, hydraulic conductivity, xylem vessel characteristics of branches and stomata properties of leaves from the partially buried trees were assessed after 14 months of exposure to sedimentation. The results showed an increased hydraulic conductivity capacity in the partially buried trees with up to 3 fold in *C. tagal*. There was, however, a threshold of 15 - 30 cm in some cases above which conductivity had decreased. Based on the observed alteration in vessel diameter, grouping and density following sedimentation (some of which enhanced hydraulic conductivity), the results do not entirely rule out possibility of reduced water uptake imposed by sedimentation but rather suggest a combination of acclimatisation and adaptation of the trees to the exposure.

In **Chapter 6** I attempt to explain the increased hydraulic conductivity and phenological success in the partially buried trees based on adaptation of morpho-anatomical traits of roots and bark in silted trees. The results showed an induction of the phellogen to produce more outer tissue in the buried section of stems in all the three studied species (2 fold increase in *A. marina* and *C. tagal* and 4 fold in *R. mucronata*) following subjection of the trees to increased levels of sedimentation (15, 30 and 45 cm). Root density increased over time with increased levels while the controls maintained a stable number of roots with the new roots assuming anatomical features similar to the original roots.

The study generally established that disturbances (including selective harvesting) may indeed create a structural imbalance in a mangrove forest. However, increased sedimentation in mangrove areas as an outcome of anthropogenic disturbances coupled with climate change impacts may not pose an immediate threat to the mangroves of Mtwapa Creek. Further, my results from the sedimentation experiment affirmed that mangrove tree species like other plants exhibit plastic growth and that sedimentation induces cambial activity hence ability of trees to adapt to resulting changes in environmental conditions. Mangroves are however not solely affected by sedimentation, but face a variety of impacts compounded by human activities. I therefore do not intend to extrapolate these results yet to fit into natural and expected major anthropogenic flooding and sedimentation events that mangroves can withstand in general. Nevertheless, this study provides a good fact-based argument on mangroves' resilience to sedimentation at least under the conditions in the experimental setup.