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MANGROVE DEATHS IN KENYA: CAUSES AND RECOMMENDED MANAGEMENT INTERVENTIONS

Technical Paper

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Captions for cover photographs:
Top left: Stack of mangrove wood used for lime burning in Manda Island, Lamu
Top right: Natural regeneration of *Avicennia marina* in Mida Creek
Bottom left: Mangrove KEFRI experimental plot in Manda Island, Lamu
Bottom right: KEFRI research team undertaking inventory of mangrove resources in Lamu

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1.0 Introduction

Mangroves are among the most productive forest ecosystems in the world. Mangroves provide various products and ecosystem services including: fuel; timber; coastal protection; breeding sites for fish; and pollution amelioration. Due to overexploitation and land conversion, mangrove cover has reduced globally by approximately one third in recent years. This reduction in mangrove cover continues at a rate of 1-2% per annum (Polgar, 2009). The main causes for this reduction include; harvesting; conversion of mangrove forests to alternative land use mainly agriculture and urban development; oil spills ; and construction of aquaculture ponds (Macintosh *et al.,* 2002; Walton *et al.,* 2007). Additionally, effects and impacts of climate change have further resulted to reduced mangrove forest cover. These effects and impacts of climate change include; sea level rise, flooding, erosion, sedimentation, fluctuating precipitation and temperatures regimes, and associated phenomena like hurricane and cyclones (McLeod and Salim, 2006; IPCC, 2007; Gilman *et al.,* 2008; Bosire *et al.,* 2013).

In Kenya, mangroves occupy protected shorelines, lagoons, creeks and estuarine distributed along the 600 km coastline. The total mangrove area in Kenya is estimated at 61,271 ha; which is 3.0% of the total natural forests or 1.0 % of the country's area (GoK, 2017). Most of the mangrove forests occur in Lamu and the surrounding islands. Smaller populations of mangroves are found in south of Tana River, Kilifi, Mombasa and Kwale counties. There are nine species of mangroves in Kenya. The dominant species are *Rhizophora mucronata* and *Ceriops tagal* that occupy more than 75% of the mangrove formation. Other common species are *Avicennia marina, Bruguiera gymnorrhiza* and *Sonneratia alba*. Less common species include: *Xylocarpus granatum, Xylocarpus mollucensis, Heritiera littoralis* and *Lumnitzera racemosa.*

Kenya losses about 0.7% of its mangroves forest cover annually (Kirui *et al.,* 2013). However, peri-urban areas have witnessed higher loss of mangrove forest areas. For instance, between 1992 and 2009, Tudor lost 86.9% of the mangrove forest while Mwache lost 45.4% representing very high degradation rates of 5.1 and 2.7% per annum, respectively (Bosire *et al.,* 2013). Losses of mangrove forests have also been accompanied by the loss of ecosystem services such as coastal protection and provision of habitats for juvenile fish. These losses have serious repercussions to local communities (Vannucci, 2004).

Death of mangroves is common especially in Lamu, Mida Creek, Tudor and Mwache. The causes of mangrove deaths have been highlighted in a number of studies. However, information related to mangrove deaths has not been well packaged to inform managers on the affected species and site-specific factors that are responsible. This technical paper presents factors driving mangrove deaths within various mangrove formations in Kenya.

2.0 Methodology

A desktop review on the status of mangroves was undertaken. Field visits were made to sites documented to have massive deaths of mangroves in Kenya. Discussions were held with various stakeholders including; the local community members, Kenya Forest Service (KFS), and Kenya Wildlife Services (KWS) officers involved in mangrove management and conservation activities in Kilifi, Tana River, Lamu and Mombasa counties. The discussions covered; trends, health status, utilization and challenges facing mangrove ecosystems. The causes of mangrove mortality were also identified.

3.0 Causes of Mangroves Mortality in Kenya

3.1 Sewerage disposal and use of inorganic fertilizer

Mangroves in urban and peri-urban areas are intensively exposed to raw sewage. The effluent from the urban centers sewerage system is disposed through canals in the mangrove forest areas and discharged into the creek waters. Consequently, the mangroves are exposed to the sewage during every tidal cycle, with the loading reducing with distance from outlet of the sewage (Bosire *et al.,* 2012). Mangroves in Kilifi, Makupa, Mwache, Tudor creeks, Port Reitz, Kilifi creek and Vanga are exposed to frequent prolonged exposure to high nutrient loading from sewage disposal.

The sewage released to the creeks increases the available nutrients through eutrophication. Mangroves exposed to high nutrient availability suffer greater mortality during drought. The nutrient-induced mortality is greater in sites subjected to prolonged periods of low rainfall, low humidity and high sediment salinity (Lovelock *et al.,* 2009). As nutrient availability increases, mangroves invest less in root growth and more in above-ground biomass (Grime, 1979; Chapin, 1980; Tilman, 1991; Lambers and Poorter, 1992). Mangroves without well-developed root system are more susceptible to environmental stressors, such as drought (Chapin, 1991). The water stress becomes acute when salinity levels increases thereby limiting mangroves' capacity for water uptake by roots while low atmospheric humidity exacerbates rates of water loss by shoots during drought period, hence causing tree death along natural gradients of increasing soil salinity. This particular phenomenon is responsible for the massive deaths of mangroves reported in Kilifi, Mwache, Port Reitz, Tudor and Makupa creeks. This areas receive low rainfall and are therefore prone to mangrove deaths due to increased nutrient loading from sewage disposal coupled with increasing salinity during the drought season. Vanga mangroves have been less affected by this phenomenon due to the high amount of rainfall in the area which neutralizes the salinity levels. Heavy application of inorganic fertilizers in smallholder farms in the hinterland boarding mangrove areas has also been blamed for increased nutrient loading in the mangrove forests.

3.2 Poor agricultural land use practices in the hinterland

The land surrounding the creeks that harbor mangroves in Kenya is mainly agricultural, largely small-holdings with coconut plantations and grazing land further inland. As a result of poor agricultural practices, the vegetation on the lands bordering the mangrove creeks have been cleared to create space for informal settlements and subsistence farming. These poor land use practices in the hinterland result to soil erosion that increase sediment load into the mangrove forest areas. The sediments smothers mangrove breathing roots leading to death of the mangrove species mainly *Avicennia marina* which uses pneumatophores to obtain oxygen directly from the air (Kitheka *et al.,* 2002; Alemayehu and Wekesa, 2017). The foot prints of these poor land use practices are common in mangroves of Mwache, Tudor, Kilifi and Mida creeks.

Dead mangroves (*Avicennia. marina*) in Mwache due to sedimentation attributable to poor land use practices in the hinterland

3.3 Oil spills

Oil spillage has been the leading cause of mangrove deaths in Tudor and Mwache creeks and Port Reitz area of Mombasa. Between 1983 and 1993, Mombasa port and surrounding waters were polluted through 39,680 metric tons of oil spills that affected mangroves of Mwache and Tudor creeks. The total area of mangroves lost in these areas due to oil spillage is estimated at 10,310 ha which represents about 16.7 % of the total mangrove forest in the country (Bosire *et al.,* 2008). The spilled oil is deposited on mangrove roots when the tide drops and contaminates the sediments. Consequently, the mangroves die from suffocation or toxic effects of the oil. The deaths is also attributed to decline of keystone burrowing animals such as crabs and worms, which are essential in maintaining the health of mangroves ecosystem. Spot assessments in some impacted sites within Mwache and Tudor creeks indicated limited post-impact recovery of mangroves (Kitheka *et al.,* 2002; Bosire *et al.,* 2008).

3.4 Clearing of mangroves

Clearing of mangrove trees to create access routes to shorelines and pave way for physical developments like the by-pass through Mwache area contributes to deaths of mangroves. The clearing of the mangroves cause changes in sea currents and hence encouraging erosion of the shoreline (Abuodha and Kairo, 2001). The shoreline erosion causes sedimentation and siltation which kills mangroves. The death of mangroves due to overcutting is common in Mwache and Mida creeks mangrove formations.


Degraded mangrove area in Manda Island due to over-cutting


Mangrove community nursery in Mida

3.5 Increased salinity

The intertidal position of mangrove forests gives rise to exposure to increased salinity levels arising from changes in both the ocean and adjacent terrestrial environments. While sea level rise due to climate change poses a significant threat to many mangrove forests (Woodroffe and Grindrod, 1991; Lovelock *et al.,* 2015a), studies demonstrate that fluctuations in sea level, and particularly periods of low sea level, poses threats to mangrove forests in relatively dry areas where inputs of fresh water is limited (Lovelock *et al.,* 2015b). As soil salinity rise, trees lose their capacity for water uptake and salt exclusion and thereby exhibiting signs of stress consistent with those induced by drought (Sobrado, 2001; Bompy *et al.,* 2014; Méndez-Alonzo *et al.,* 2016; Kodikara *et al.,* 2018; Watzka and Medina, 2018; Rahman, 2020; Devaney, 2020; Cabanas-Mendoza *et al.,* 2020) including progressive loss of leaves, death of branches and eventually death of entire trees when salinity exceed tolerance limits (Jimenez *et al.,* 1985; Lovelock *et al.,* 2009).

Typically, the die-back of mangroves observed in response to increase in soil salinity is similar to other forest dieback events induced by severe drought (Van Mantgem *et al.,* 2009) and consistent with hydraulic failure leading to tissue desiccation (Allen *et al.,* 2010). Substantial natural mortality of mangroves has been observed in Kiunga area due to die-back attributed to unusually long period of submergence. The Kiunga mangroves are connected to Boni forest, and therefore exposed to the pressures stemming from continuous changes that occur both in the mangrove and Boni forests leading to irregular inundation frequencies which result into large scale die-backs of mangroves particularly *Rhizophora mucronata*.

3.6 Senescence

Some mangroves like those in Kiunga which is a marine park under total protection from any form of utilization have died. Such deaths are attributed to senescence. The dominant mangroves in Kiunga is *R. mucronata* that have grown into tall and big diameters trees with enormous biomass. The *R. mucronata* has prop-roots. The stem and branches take up more nutrients during dry season when the salinity levels are high (Lovelock *et al.,* 2009), and thus are able to build up huge quantities of biomass that overwhelms the ability of the roots to anchor the trees in the soil. Over time, the anchorage of the trees into the soil is weakened due to wave erosion and eventually fall down and die. Thus, massive deaths of mangroves in Kiunga area has been attributed to the high population of old mature *R. mucronata* whose above-ground biomass is too heavy to be supported by the prop-roots that are exposed to erosion.

Dead *Rhizophora mucronata* in Kiunga, Lamu

Healthy *Rhizophora mucronata* in Kiunga, Lamu

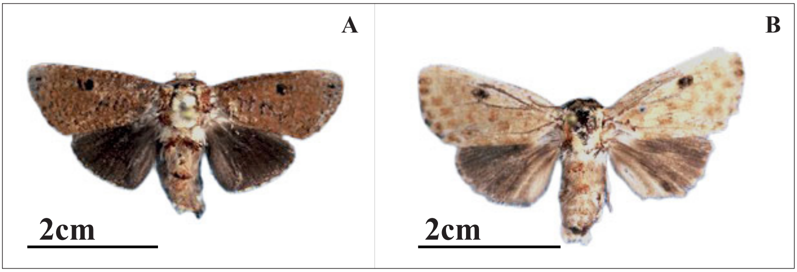
3.7 Climate change and sea-level rise

There is considerable relationship between mangrove extent and sea-level changes associated with climate change (Saintilan and Williams, 1999; Rogers *et al.,* 2005). Mangrove may respond to sea-level rise by migrating upslope, or increasing their elevation through processes of vertical accretion or sedimentation so that they remain within the same tidal range (Rogers *et al.,* 2006). Lack of such a response, area covered by mangrove shrinks in size at the shoreline due to erosion or extended periods of unusual submergence and also lead to death of mangroves (Vanderzee, 1988; Xie *et al.,* 2020; Caldwell, 2020). Prolonged submergence causes a significant decline in photosynthetic rates of mangroves (Mwita *et al.,* 2014). Submergence time and water salinity affect the performance of mangroves, such that mangroves in areas exposed to prolonged submergence with flooding dominated by saline water dry and eventually die (Mwita *et al.,* 2014). This is a typical case for mangroves in Mida creek which died in large numbers during the Elnino rains of 1997/1998 when the *A. marina* was submerged for unusually long period of time.

3.8 Pests and diseases

Infestation of mangroves by pests threatens mangrove forest health and management globally (Thi Mai *et al.,* 2019). Presence of beetles and high pneumatophore siltation have been reported to be associated with the die-back and canker levels of *A. marina* (Osorio *et al.,* 2017). In Kenya, two wood-boring insects: a metarbelid moth (Lepidoptera, Cossoidea) and the beetle *(Bottegia rubra)* have been identified as causes of mangroves deaths among different mangrove formations in Kenya (Jenoh *et al.,* 2016). The metarbelid moth infests mangroves in northern coast, from Ngomeni to Kiunga and southern coast, from Vanga to Mtwapa.

Bottegia rubra is found in low density in Gazi, and in high density at Mida, Kilifi, and Ngomeni. In Kiunga Marine Park, an unknown insect pest has been reported to be responsible for the dieback of *R. mucronata*. Cases *S. alba* being infested by the undescribed metarbelid moth have also been reported in Vanga, Gazi, Tudor, Mtwapa, Ngomeni, and Lamu. There have been reports that the population of *S. alba* is declining due to an insect infestation that rapidly spread northwards towards the mangroves of Somalia (Mwangi, 2002). The pests have the ability to infest young mangrove trees and expand their range, posing a danger to seedlings and saplings; hence hampering recovery of degraded sites.



Woodborer species infesting *Sonneratia alba*

4.0 Management Interventions

4.1 Treatment of sewage

The companies involved in waste management should establish efficient waste management systems. This can be undertaken through proper coordination between the county governments' departments of Environment and National Environment Management Authority (NEMA). The effluent should be treated before being disposed to reduce the negative impact on mangroves through excessive nutrient loading. The sewage waste should also be subjected to quality analysis to ensure it complies with recommended standards before it is disposed.

4.2 Establishment of woodlots in the hinterland

Agencies involved in tree growing should establish woodlots in the hinterland boarding mangrove areas to prevent soil erosion to control sedimentation which has been reported as one of the leading causes of mangroves deaths. Such woodlots will also provide alternative source of wood products such as fencing posts and poles for construction which communities obtain from mangrove forests. Woodlots of fast-growing commercial tree species such as *Casuarina equisetifolia* and *Gmelina arborea* are recommended because they provide multiple benefits to the local communities are alternative sources of income.

4.3 Promoting agroforestry in the hinterland

Integrated land use practices such as agroforestry should be promoted in the hinterland bordering mangrove forests. Integration of trees in farming systems improves soil fertility hence reducing the need of inorganic fertilizers required to enhance yields. Practicing agroforestry in the hinterland will contribute to reduction in nutrient loading in mangroves, hence making them less susceptible during dry season when the salinity levels are high. Agroforestry trees provide multiple benefits including fodder for livestock hence addressing the issue of overgrazing in the hinterland.

4.4 Removal of dead mangrove wood material

Rotting dead mangrove wood, drift algae from algal blooms and wrack from sea grass and excess input of sediments asphyxiate mangrove pneumatophores causing death of trees. Moreover, in areas where large mangrove trees have fallen down, the sea water is retained for a long time increasing the submergence period; this results in increased salinity levels hindering any form of natural regeneration. With prolonged period of submergence and increased salinity, even aided regeneration is impossible. Under such circumstances whereby the mangroves are protected and any form of utilization is not allowed yet they are massive mortalities due to die-back, removal of dead wood materials is a prudent strategy. There should be concerted efforts to remove dead mangrove trees to allow water to drain away during low tide thus reducing the submergence period, to create favourable conditions for mangrove natural regeneration.

4.5 Replanting degraded areas

Technologies for restoring degraded mangroves have been developed for the different species that occur in Kenya. Consequently, degraded mangrove areas could be restored through aided regeneration

4.6 Minimizing oil spillage

The handling of petroleum imports at the port should be improved to minimize the quantities of oil that spills in the sea, causing suffocation of mangroves when deposited on the roots, and hence death. In case of oil spillage the authorities should expedite cleaning of the spills to minimize environmental pollution.

4.7 Integrated pest management and surveillance

Given that the marine environment is very sensitive, chemical control of pests is not recommended. Instead, integrated pests control approach that is premised on biological control methods is recommended. Most pests including *B. rubra* attack the lower parts of the trees hence providing an opportunity to manage the pests using biological control methods. The biological pests control methods entails - creating channels through young and short trees to prolong the submergence period. Long periods of submergence ensures that the larvae and pupae drown and suffocate. Moreover, predators like ants, which forage on larvae and pupae of wood boring insects could be introduced in the infested mangrove areas to feed on the insects and reduce their population to numbers that are not ecologically harmful to the mangrove trees.

Forest managers should address the increasing levels of pests' infestation in Kenyan mangroves by working with forest entomologists to identify pests that poses the greatest threat to mangroves survival. Although, incidences of mangrove diseases are not common in Kenya, researchers, forest managers and local communities should be on the lookout for any outbreak of mangrove diseases for necessary actions to avoid losses of mangroves.

4.8 Public awareness

Sensitization of the public on the importance of conserving mangroves is key to addressing over-exploitation of the resource. Awareness instills a sense of ownership of the mangrove resources by the local population and their legal empowerment so that they are able to institute and execute control measures on the resource for sustainable utilization and management. Public awareness facilitates community participation in mangrove restoration programmes and nature based micro-enterprises that promote mangrove conservation.

5.0 Conclusion

Sedimentation and siltation caused by erosion in the hinterland, increased levels of salinity, oil and sewage pollution and over-harvesting of mangroves are the main causes of mangroves deaths in Kenya. Notably, different mangrove formations are affected by either one of these factors/stressors or a combination of all depending on their location and the connected terrestrial landscapes. Peri-urban mangroves in Tudor, Makupa, Mwache, Kilifi, Mtwapa and Ngomeni are affected by a combination of all these factors while other mangrove formations in Vanga, Mida, Lamu and Gazi die mainly because of sedimentation and increased salinity levels. Awareness creation among stakeholders including local communities on the need to conserve the mangroves, and the development of site and species-specific restoration technologies are key in addressing the massive mangroves deaths.

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