Mangroves of Kenya: effects of species richness on growth and ecosystem function of restored East African mangrove stands

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Background

Coastal ecosystems, including estuaries, saltmarshes, coral reefs, and mangrove forests support a diversity of plant and animal species. These environments are very sensitive to change, either as a result of human actions or natural events such as hurricanes, and in many places humans have dramatically altered the balance of marine ecosystems and the key goods and services that they provide..

Mangrove forests, consisting of trees and shrubs growing in tropical coastal habitats, are among the most productive coastal ecosystems on Earth. Mangrove forests provide a variety of ecosystem services including coastal protection from storms and tsunamis, woodland resources, wildlife habitat, and carbon storage. Despite their importance, mangroves suffer one of the fastest rates of destruction of any habitat - about 2% of global mangrove cover is lost annually, mainly as a result of shrimp farming or unsustainable exploitation for firewood and building materials. Over the past 50 years, approximately one-third of the world's original mangrove forests have been lost. This has serious implications for local communities who not only benefit from the woodland resources mangroves supply, but are also reliant on the fish that use the mangroves as nursery habitats and on the protection that they provide to coastlines in times of severe weather events. Hence the conservation and rehabilitation of mangroves is a global conservation priority.

This project is situated in Gazi Bay in Kenya, 50 km south of Mombasa (figure 1). The local people at Gazi are heavily dependent on the mangroves for direct economic uses, such as firewood and building poles, as well as for ecological services, such as nursery provision for fish. The extractive uses of the mangroves present a threat to their survival, but also an opportunity for community involvement in their conservation.

Project overview

This project involves long-term, large-scale experiments measuring a range of ecosystem functions in replanted mangrove stands. This information will be used to develop effective rehabilitation and restoration strategies for degraded mangrove habitats that simultaneously provide increased potential to function as carbon sinks.

Specific objectives:

- Test how the diversity of mangrove species in replanted stands affects ecosystem functions.
- Use controlled experiments to test the effects of replanted mangroves on sediment dynamics and to measure how these effects change as trees mature.
- Collect data of direct relevance to practical restoration projects (such as the role of intercropping in enhancing productivity and reducing disease), thus helping to inform future restoration efforts.
- Study the carbon cycle in mangroves, leading to a better understanding of how these ecosystems could be managed to sequester carbon and help mitigate climate change.
- Work with local people in establishing replanted mangrove plots, which will form part of a sustainably managed local resource.

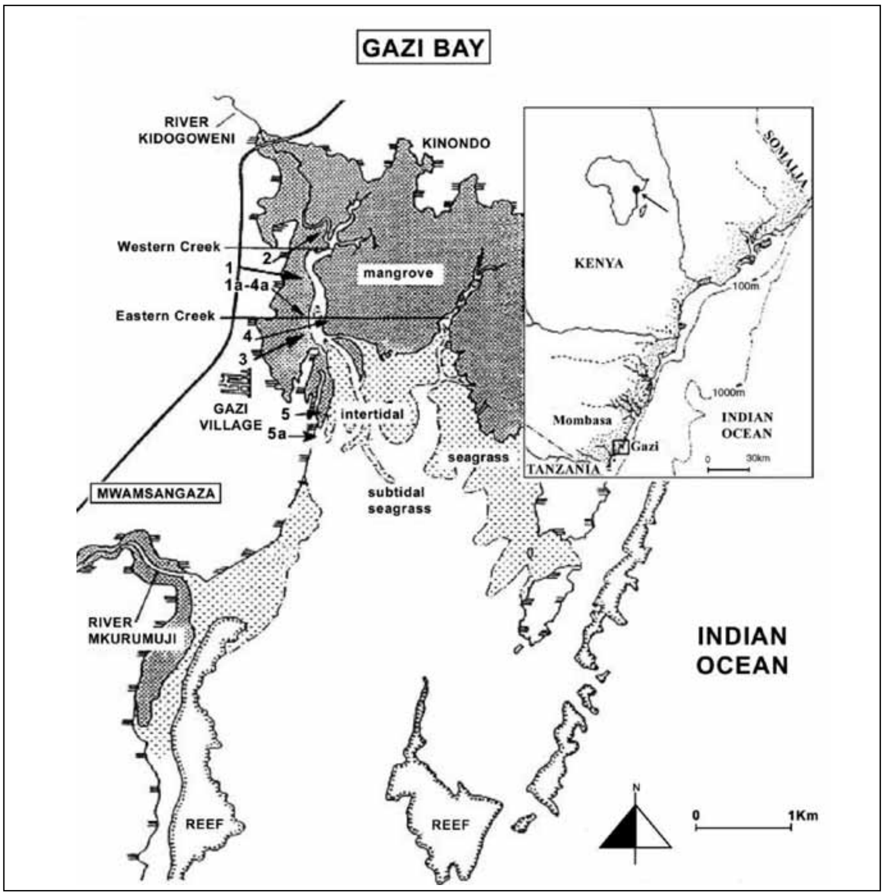

Figure 1. Gazi Bay, in the Kwale district of Kenya, is located 50 kilometres (34 miles) south of Mombasa. This 18 km^2 (6.9 mi^2) bay is sheltered from strong sea waves by the presence of Chale Peninsula to the east and a fringing coral reef to the south. The reef supports a local subsistence and commercial fishery.

The project, led by Dr Mark Huxham and Dr James Kairo, has been supported by Earthwatch since 2004. The main experiment tests intercropping (mixing two or more species) in mangrove restoration by growing three tree species in mixed and mono-specific stands. It has long been recognised that intercropping in terrestrial agriculture can enhance productivity. Experimental plots were planted in the first season, and their progress is now being monitored. Earthwatch volunteers help with assessing productivity, animal species diversity, root weight and biomass and new growth of mangroves species grown under different planting regimes. Volunteers have also help with database management and participated in visits to local schools to present the mangrove restoration project to local communities.

One of the most important functions provided by mangroves is their ability to trap and sequester carbon. Mangroves are particularly efficient carbon sinks because of their high productivity and the long term stability of below-ground carbon stores (usually in the form of peat) that they develop. Mangroves also trap carbon rich sediments from the water, which add to their total carbon storage potential. There is a need to create incentives for mangrove forest restoration, and in the second phase of the project, which started in 2008, the research team seeks to quantify and cost-out the carbon sequestration potential of mangrove plantations, including harvested stands, and to develop a demonstration, community-run sequestration plantation. If sustainably managed mangrove forests are found to represent effective carbon stores, mangrove restoration could be incentivised by demand from a future carbon trading market.

Increasing knowledge on the sustainable use of coastal resources such as mangroves is part of Earthwatch's Climate Change Research Area.

Outcomes and actions

Results from this year have added to the five-year dataset from which strong conclusions are being drawn. A key result has been the discovery that the grey mangrove (*Avicennia marina*) is a dominant species when replanted – it grows vigorously, has a high survival rate, and also appears to facilitate growth and natural recruitment of other species, making it ideal for restoration efforts (figure 2). Such facilitative effects, either between individuals of different species or those from the same species, can operate at sites with a range of different conditions (i.e. across the tidal gradient from the high tidal zone which is hypersaline, dry, and has low sediment supply, to the brackish, wet, high sediment low tidal zone). The project has clearly demonstrated that environmental changes occur as a result of replanting, with plots with high plant growth becoming wetter as trees provide shade, and carbon content increasing as trees grow and accumulate more organic material.

Experiments regarding tree survival have tested species, treatment and various environmental variables. Results have demonstrated that salinity is the most important determinant of survival, with *Bruguiera* species showing particular sensitivity. The size of plot and size of tree at planting have been shown to have little effect, which has relevance for the economics of restoration, as there is therefore no reason to keep trees in nurseries until they reach a large size. Density has also been shown to be a key

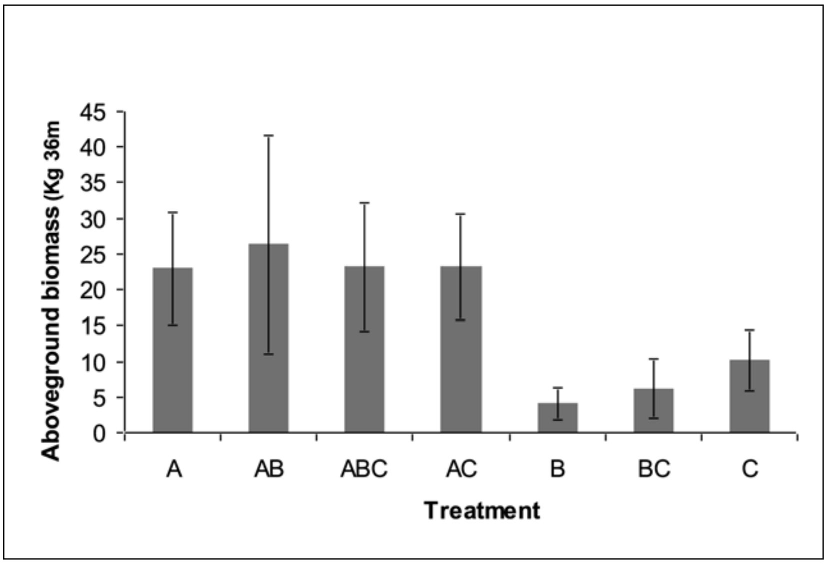

Figure 2. Mean (and error bars) for above-ground dry weight in species mix treatments after four years of growth. A = *Avicennia marina*, B = *Bruguiera gymnorrhiza*, C = *Ceriops tagal*, other treatments are combinations of these three species. Note the higher biomass of all plots which contained *A. marina*.

factor, with results showing highest percentage survival after 702 days in the highest density plots and lowest survival in the lowest density plots. Positive effects of density on survival occurred at both high and low tidal sites. A problem previously thought to be faced by managers of mangroves was having to make a trade-off between encouraging sedimentation by planting trees at high densities and suffering higher mortality as a result. However, the results here showing that increasing seedling density enhanced both sedimentation and survival suggest this is not the case. The reason for increased survival may have been enhanced trapping of nutrient rich sediment.

Experimental plots showed positive elevation change from sedimentation compared to controls. In a related experiment studying the effects of density of trees on erosion, the highest elevation rate measured was 2.1 mm per year in the highest density treatment. This rate would be sufficient to keep pace only with the lower end of sea level rise projections. However, the trees were only 29 months old at the last measurements and rates of elevation are likely to increase as the roots develop

Mangroves store large amounts (up to 50%) of their total carbon absorption in their roots, and some of these roots may become permanent carbon stores in the form of peat. The project has carried out pioneering research on the processes governing the amount of carbon mangrove forests can fix by measuring the carbon content of plots with varying site conditions and mangrove species mixes. By September 2007, over 2,000 mangrove trees had been planted on the project and conservative estimates predict that 180 tons of carbon could be absorbed over 25 years of forest growth.

Throughout the duration of the project, the team has informed and engaged local communities through school visits and providing full-time local employment opportunities for villagers. The mangrove plots planted will become resources for local people once the study is completed. This will build capacity in the community and provide them with knowledge and skills to manage replanted mangrove forests sustainably. The project works in close partnership with local research institutes in Kenya, who have used results to advise mangrove restoration work elsewhere in Kenya. Extra support from past Earthwatch volunteers has also enabled the addition of a new block to the primary school, including a library, staff and administration, to cater for the 1,000-strong community. By Kenyan standards, the school is now relatively modern and well-built.

In light of the rapid rate of destruction suffered by mangroves, results from this project will be valuable contributions to mangrove management strategies on a regional and international scale. Pioneering research on the carbon sequestration potential of mangroves, in particular below ground in their root systems, will increase their value and provide numerous benefits from the rehabilitation of such a precious natural resource.

Lead scientists profiles

Dr Mark Huxham is a Reader in Environmental Biology at Edinburgh Napier University, UK, where he teaches a range of undergraduate and graduate courses and has an active interest in the theory and practice of teaching. After earning a degree in Ecology, Dr Huxham went on to complete his PhD on food web theory and estuarine ecology at Aberdeen University. His specialist areas include ecosystem functions, experimental design and analysis, macrobenthos and fish community structure.

Dr James Kairo is Principal Research Officer for the Kenya Marine and Fisheries Research Institute and specializes in the areas of mangrove ecology, restoration and management. He lives in Gazi village with his wife and three children.

Additional key scientists

Dr Martin Skov – University of Wales, Bangor.

Collaborative organisations

- Kenya Marine and Fisheries Research Institute
- Kenya Forest Department

Project website

http://www.earthwatch.org/exped/huxham_research.html

Key publications

Tamooh, F., Huxham, M., Karachi, M., Mencuccini, M., Kairo, J.G. & Kirui, B. 2008. Below-ground root yield and distribution in natural and replanted mangrove forests at Gazi bay, Kenya. *Forest Ecology and Management*, **256**: 1290–1297

Kirui, B.Y.K., Huxham, M., Kairo, J. & Skov, M. (2008) Influence of species richness and environmental context on early survival of replanted mangroves at Gazi bay, Kenya. *Hydrobiologia*, **603**: 171-181