EARTHWATCH INSTITUTE FIELD REPORT

Project Title: Mangroves of the Kenyan Coast

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Position/Affiliations: School of Life Sciences, Napier University, Edinburgh

Research Site: Gazi Bay, Kwale District, Kenya

Gazi Bay is situated 50km south of Mombasa on the Kenyan coast (4°25′ S, 39°30′ E). It covers approximately 1.5km^2 and is sheltered from the Indian Ocean by Chale Peninsula. A small, permanent river, the Kindongoweni, flows into the bay from the north. Our base during the research season is Gazi village which lies 1km from the bay. A map of the site and its location is given in Appendix 1.

Local Management Status of the Research Site:

No special conservation status, although the site has been actively managed for mangrove resources for 20 years.

Scientific names of primary species being studied:

Our project involves the planting and management of four species of mangrove tree: *Sonneratia alba*, *Ceriops tagal*, *Avicennia marina*, and *Bruguiera gymnorrhiza.*

Key Research Objectives:

1) To test how the diversity of mangrove species in replanted stands affects a range of ecosystem functions.

2) To use controlled experiments to test the effects of replanted mangroves on sediment dynamics (in both low and high energy areas), and to measure how these effects change as the trees mature.

3) To 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.

4) To measure the capacity of planted mangrove woods to sequester carbon dioxide, and thus help to mitigate climate change, and to explore whether this ecosystem function varies depending on the mix of species present.

5) To work with local people in establishing replanted mangrove plots, which will form part of a sustainably managed local resource.

Data Collection and Results

a) Give a concise account of the data you have collected during the past field season.

Data collection this season included:

- Measuring the productivity (including height and leaf area index) of 512 trees.
- Measuring a suite of environmental variables – including redox potential, salinity and granulometry – from a total of 152 sediment cores.
- Recording the faunal (particularly crab) density and diversity from 152 m^2 quadrats.
- Estimating mean snail abundance in 38 6×6 m experimental plots.
- Recording the new growth of wild trees in 38 experimental plots.
- Recording the above and below ground biomass of trees in 24 crab exclosure plots.
- Recording the wet weight of roots prepared for 240 root decomposition experiment bags.
- Measuring tree density, sediment redox and salinity and height above chart datum at 6 sites established for the root decomposition experiment.
- Collecting 360 samples for granulometry and carbon analysis from 72 soil cores in the crab exclosure experiment.
- Collecting samples for C/N and isotope analysis from 24 crab exclosure plots.
- Collecting samples of fish for community analyses from 6 5×5m mangrove plots
- Measuring the below-ground biomass associated with 324 trees from 3 different mangrove species in 2 or 3 different age classes and divided into different root size categories, vertical positions and horizontal categories.
- Measuring diatom abundance and diversity in 62 plots.

b) What progress have you made towards achieving your original objectives?

We continue to work closely with our team of local employees and volunteers, and to enjoy the full support of the local community. Hence objective 5 is being achieved. Our results this year, particularly on the establishment of wild seeded trees (wildings) and the productivity of trees in our experimental plots, are starting to show some of the anticipated effects of biodiversity on ecosystem functioning; hence we are on course to address objective 1. Data on wildings and on mortality rates are pertinent to objective 3.

Objective 4, concerning carbon sequestration, has been the major focus of work by our supported Masters student Frederick Tamooh. His data collection is now complete and provides a valuable baseline for estimating below ground stocks of carbon at Gazi. It will be used in conjunction with the data collected this year and last by Bernard Kirui (the full time PhD student supported by our project) on carbon dioxide fluxes at our site. In addition, we established a new root decomposition experiment this year, which should give us information on below-ground turnover of carbon and the factors affecting this, when we finish the experiment next year.

The only original objective which is proving difficult to fulfil is number 2, concerning the study of sediment dynamics. This is because of the goat grazing problem we encountered at our low beach site in 2004/5; a problem we have been unable to resolve. Hence growth at this dynamic and unstable site has been very slow, preventing us from

measuring the effects of trees on erosion. We planted a new plot of trees near to this site during this field season and are hoping these trees will fare better.

c) Please provide a summary of your results.

Growth of wild trees

We have preliminary evidence that our experimental plots are now encouraging the establishment and growth of wild trees, in an area that has remained barren of new growth for 25 years. The analysis below shows the difference between the mean (log transformed) number of new wild trees recorded in plots with our dominant species (*Avicennnia marina*) and those without this species. These data suggest that *Avicennia* may be acting as a 'nursery species' allowing the establishment of more fragile species.

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            Individual 95% CIs For Mean Based on Pooled StDev
+Av      Mean  --+---------+---------+---------+-------
1    0.679514                (-------*-------)
2    0.314468  (-------*------)
            --+---------+---------+---------+-------
            0.20      0.40      0.60      0.80
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Productivity in experimental plots

Productivity, as measured by leaf wet weight per square metre, is strongly influenced by the treatments in each plot; three species treatments are much more productive (figure 1). This might result from the high productivity of *Avicennia*, which is present in all three species plots.

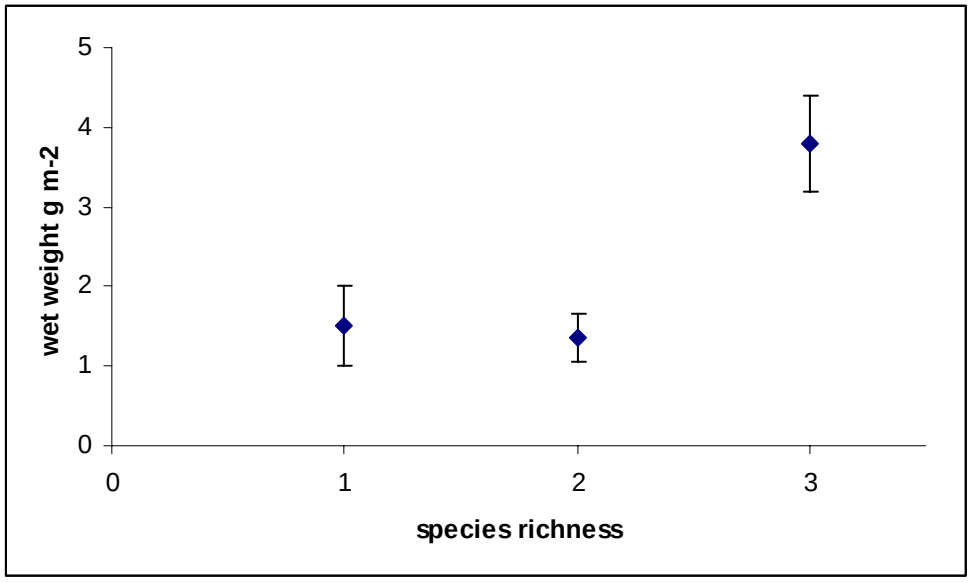

Figure 1. Mean leaf wet weight in treatments with 1, 2 and 3 species

Mortality in Experimental Plots

Our work has clearly identified the central importance of salinity in causing mortality in replanted trees (see figure 2 below). Not all species are equally susceptible; *Avicennia marina* has shown significantly better survival than the other species we have used. Hence restoration efforts at extreme sites such as ours at Kinondo need to focus on species with good salinity tolerance.

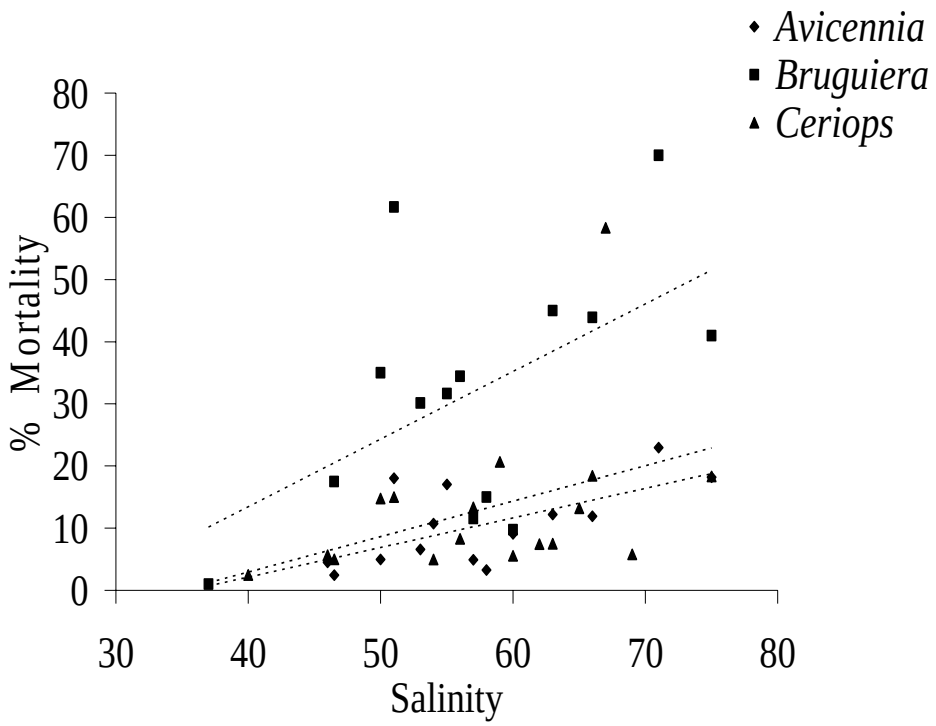

Figure 2. Mean mortality per species per plot against salinity

Root biomass

We are interested in calculating root biomass so we can produce estimates of the total carbon present in forests of different types, and also to help us understand carbon dynamics and turnover in the mangroves. Our work has shown that most roots are concentrated in the top 20cm of soil, and that a large proportion of roots are 20mm or less in diameter. Some species have higher root biomass than others – for example *Sonneratia* (figure 4) produces higher biomass than *Rhizophora* (figure 3) – and the patterns of distribution of biomass between trees of different ages varies with species.

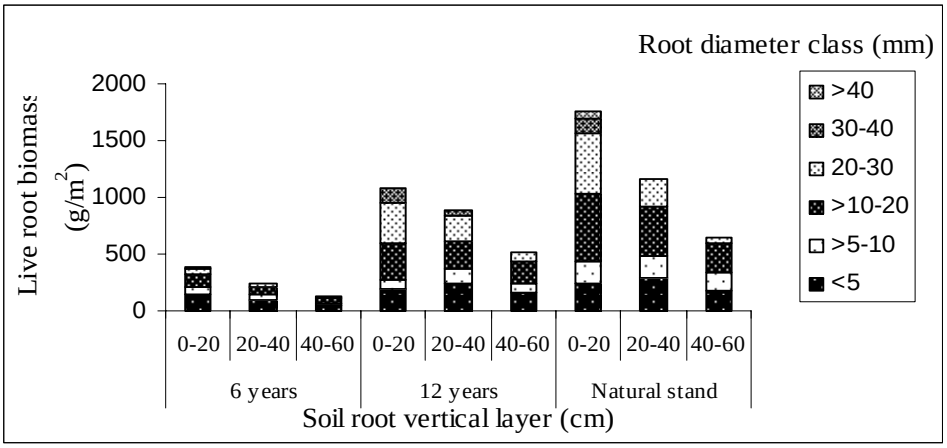

Figure 3. Live root biomass in three different ages, from three different soil depths and in six different diameter classes collected from *Rhizophora mucronata* woods.

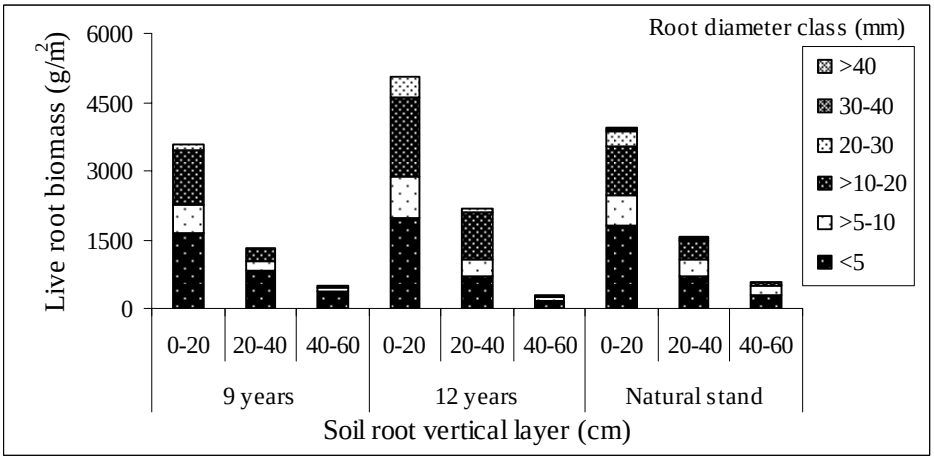

Figure 4. Live root biomass in three different ages, from three different soil depths and in six different diameter classes collected from *Sonneratia alba* woods.

Significance/Benefits of Research

a) What is/are the significance/benefits of your research at the following levels?

- Local (in the area of the research site)
  All of our experimental plots will become mangrove resources for local people – who rely heavily on mangroves for a range of goods and services - once our study is completed. One of our PIs lives in the local village and has been managing mangrove rehabilitation projects there for many years; our work builds on and consolidates his previous efforts. Our work is helping to support a team of five local people employed to work on mangrove management, and providing additional occasional work (for example in preparing nurseries for future planting)

for other villagers.

- National
  Kenya is a country suffering from a severe shortage of woodland. Along the coast, mangroves are often the major woodland resource. As a result, there is an urgent need to develop better mangrove management plans. One of the PIs, James Kairo, has been asked to lead a group developing a national management plan. The plots that we are establishing will provide information of relevance to this plan.

- International
  Mangroves suffer one of the fastest rates of destruction of any habitat; it is estimated that ~2% mangrove cover is lost annually. Hence their conservation and rehabilitation are global conservation priorities. Our work will contribute important information on how mangroves can be restored, and also considers the role of mangroves in stabilising coastlines and absorbing carbon dioxide. Both of the latter are issues of global significance in the face of climate change.

b) How do your findings contribute to issues of sustainability?

Our work contributes to sustainability in two main ways. First, we are conducting an experiment looking at how the species richness of an ecosystem affects the ability of that system to provide goods and services. This question is of fundamental ecological interest, but also underpins much of the discussion about the effects of species losses on sustainability; can ecosystems function effectively with fewer species in them? Second, we are engaged in a very practical way in enhancing the sustainability of the mangroves near Gazi, by planting more trees, and through this in providing information which will be of use to mangrove management in other parts of the world.

Dissemination of Results

Scientific papers (indicate status; e.g., peer reviewed or in progress/press)

Kirui, B., Huxham, M., Kairo, J. and Skov, M. (2007) Influence of Environmental Variables, Size, Position and Diversity on early Survival of Replanted Mangrove Saplings at Gazi Bay, Kenya. Hydrobiologia (submitted).

Management plans and reports (in progress or completed)

Not yet, but we are in the process of writing an application to the Darwin Initiative to expand our work to a pilot sustainable use and restoration project, which would inform the Kenya national mangrove management plan.

Presentations (given or planned)

Two presentations to KMFRI (an audience of Kenyan scientists), one to the Kenya postgraduate research forum (an audience of Kenyan postgraduate researchers), one to the Mangrove Macrofauna Meeting (international conference of mangrove scientists), one to the University of Sydney Biological Sciences seminars (audience of students and Australian researchers), one to the Napier Environmental Research Symposium

(postgraduate researchers and UK staff), one to the Southampton Biology Seminar series (UK students and staff).

- Popular articles or films (in progress or completed)

Part of a full page article in a national Kenyan newspaper.

Volunteer Tasks and Accomplishments

a) How did the volunteers contribute ideas, skills, expertise and motivations beyond that which you anticipated?

Once again, volunteers this year excelled in their contributions to scientific work, to life in the village and to our enjoyment of the fieldwork. Everybody performed well in the tasks they were asked to do, and often brought skills from their work and home lives to bear on these tasks. For example, volunteers helped with database management and with financial planning, and with suggestions for streamlining fieldwork. The volunteer presentations were once again a highlight, with contributions ranging from virtual tours of their home countries to dance lessons. We had strong performances on the sports fields and volunteers provided a range of useful suggestions in their feedback for how we can refine and improve the experience next year. Finally, a number of volunteers have contributed since their return home from Gazi with suggestions for fund-raising for local people and to the email contact and distribution lists that they have maintained.

b) How have volunteers helped you to achieve your research or educational objectives?

On educational objectives, volunteers visited two schools in the local area and were entertained and provided entertainment, as well as educational experiences, for the students. They also joined educational experiences with local undergraduate and postgraduate students. On the data collection, volunteers helped with all the specific areas of data collection identified in the section ‘data collection and results’ above, with the exception of the last three bullet points.

Project Development

a) What logistical or scientific challenges have you encountered in the past season and how will you address them during the next field season?

The main new challenge this year was the unexpectedly wet weather, which may reflect a shift in weather patterns in Kenya. Wet weather makes some of our sampling impossible, and other sampling difficult; for the latter category we simply got on with the job and relied on the good humour and commitment of our volunteers. For the former we adjusted tasks between teams while waiting for suitable weather. We will clearly need to retain flexibility between teams in the future in case we are faced with this issue again.

b) Have you used any additional methods/strategies to meet your research objectives?

We collected samples for isotope and diatom analyses this year. The first method will help us understand how our plants move nutrients into their leaves and compete for them in the soil, the second will help with determining the influence of crabs on diatom

communities, and in understanding what crabs are eating. Both of these techniques are possible for us because of new collaborations with scientists in the UK and Australia.

c) How will you develop your research in the coming field season?

We will continue to measure environmental variables in our current plots, and anticipate seeing some significant effects emerge next year (given that we are working with trees we anticipated a time scale of 4-5 years before completing our science). We will also continue planting trees, for conservation and restoration as well as scientific reasons. We also initiated a major new experiment this season, on root decomposition, and will be taking samples and analysing them next season.

Educational Opportunities

a) Does your project directly or indirectly involve the following groups in your research topic?
   - Local communities
   - Students
   - Early career scientists
   - Other groups

We work closely with the local community in Gazi (in fact, one PI is a member of this community), employing a team of people there and inviting local people to attend educational events with us and to teach us too. We usually also have students and local schoolchildren as volunteers, and employ one or two Kenyan early career scientists.

b) Please tell us the ways your research helps these groups better understand the conservation of a sustainable environment.

Our educational events, which include discussions, lectures and field trips, are attended by local people and are all relevant to conservation and sustainable development.

c) Has your project helped lead to the completion of Masters' theses, or other educational research findings?

We have two Masters students (both completed) and a PhD student associated with our project; all three students are Kenyans.

Partnerships

a) List partnerships or collaborations with other organizations that you have developed or maintained in the past season.

Kenya Marine and Fisheries Research Institute, Kenya Forest Department, Edinburgh University, University of Wales.

b) How have these organisations contributed to your project objectives?

KMFRI is our main partner organisation and is essential to our project. KFD is a new partner with whom we are discussing a proposal to extend and apply our work. We are working with colleagues in Edinburgh and Wales Universities in order to benefit from their expertise in carbon and isotope science.

c) How do you anticipate these organisations will use the results generated by the project, and in what timeframes?

KMFRI uses our results in its annual reporting procedures, and in the longer run when planning new mangrove restoration projects. The Forest Department will be involved if we are successful in applying our work to larger scale reforestation projects – this is likely to take another five years. Colleagues at Edinburgh and Wales Universities are already using our data in writing papers and designing new projects.

Acknowledgements

Thanks again to the team at Gazi who look after us so well, to all the volunteers, who once again were great, and to Jen and the team at Earthwatch for their consistent and professional support.