

# PROGRESS TOWARDS CONSERVATION SCIENCE FOR MARINE PROTECTED AREAS IN KENYA

An Annotated Bibliography Of Marine  
Science Information For Kenyan Mpa's



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## FOREWORD

Effective management of protected areas requires feedback of information throughout the entire management cycle. However, partly due to the lack of scientific knowledge to guide the various stages in the management process, the goals and objectives of protected areas are not always achieved. I am pleased to see the publication of this Annotated Bibliography that should serve as an important source of knowledge for Marine Protected Area (MPA) managers and other stakeholders in Kenya.

Although MPAs have been in existence officially in Kenya since 1968, and have received a great deal of attention from scientists, there is no single reference source that documents the breadth of scientific information that is available and the gaps in knowledge. To this end, this bibliography aims to; 1) serve as a comprehensive reference source for research on MPAs, 2) act as a basic guide for use during MPA management planning and effective evaluations, and 3) act as a source for prioritizing research needs for MPAs. In addition, it is envisaged that the information contained within the bibliography will be utilized to contribute to the improved management of MPAs, and the understanding of a larger regional audience on the benefits of MPAs.

The Kenya Wildlife Service in its new vision places scientific knowledge at the heart of its management. To this end, the KWS will be establishing a Marine Department within the Wildlife Division in the near future. It is our hope that this bibliography will enrich our knowledge about our MPAs and enhance capacity for management. I am therefore pleased to offer my strong endorsement for this bibliography.



Julius K. Kipnge'tich (CBS)  
Director - Kenya Wildlife Service

## ACKNOWLEDGEMENTS

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The authors are grateful to the Western Indian Ocean Marine Science Association for funding the publication of this bibliography. The Director Kenya Wildlife Service Mr. Julius Kipng'etich is gratefully acknowledged for providing the encouragement for production of this bibliography. The Coral Reef Conservation Project, the Kenya Marine and Fisheries Research Institute and the Kenya Wildlife Service coast region libraries were major sources of material and are gratefully acknowledged.

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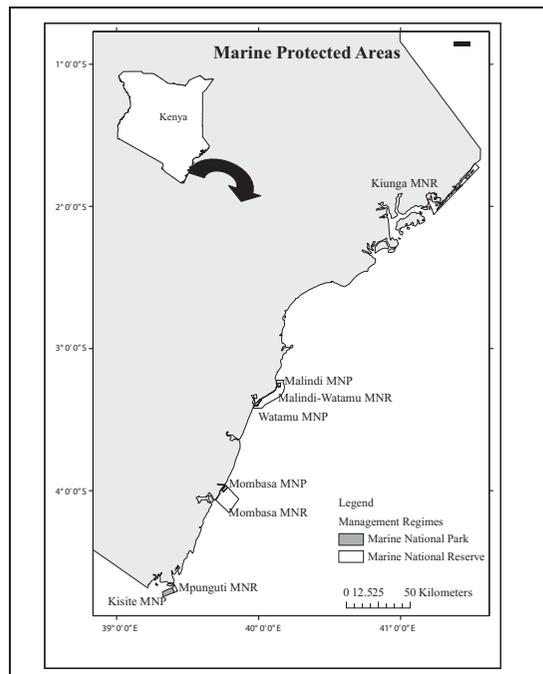
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## INTRODUCTION

The coastal and marine ecosystems of Kenya provide food and income for people as well as other goods and services of strategic importance to the economy, including fisheries, tourism, coastal protection, transportation and trade. Coastal resources in Kenya are, however, facing many threats from increasing human activities such as destructive and overexploitation of marine resources, pollution, siltation, unplanned tourism and urban development, industrial construction and climate change. Increasing human pressure on marine and coastal ecosystems, such as coral reefs, seagrass beds and mangrove forests, sandy beaches and estuaries is leading to the transformation of these ecosystems causing losses of biodiversity and ecological services.

An important strategy for natural resource management is the establishment of protected areas and the government of Kenya has gazetted fifty-seven protected areas, nine of which are marine protected areas (Figure 1).



**Figure 1.** The marine protected areas of Kenya including the additional international conservation designations.

Marine Protected Areas (MPAs) are not only one of the main tools for the protection of marine biological resources and endangered species but are also a key component for climate change mitigation; sometimes are the main impetus for protecting key social and cultural values; and are the benchmark against which human impacts in the wider seascape can be evaluated. In order to achieve national conservation and resource management objectives however, a better understanding of the breath of the available scientific information and the gaps in knowledge on MPAs is needed. The first MPA in Kenya, the Malindi marine park was established in 1968 and

since that time MPAs have attracted a great deal of attention from scientists researching physical, biological, and socio-economic aspects of MPAs, which has generated a large body of literature.

This bibliography is the first comprehensive compilation of scientific contributions on MPAs in Kenya. It aims to serve as a key reference source for marine scientific studies, to act as a basic guide for the evaluation of management and effectiveness of MPAs, and to strategically guide research planning for MPAs and scientific studies by local and international universities. In addition, it is envisaged that the information contained within the bibliography and the analysis of knowledge gaps will be utilized to contribute to improved scientific focus and management of marine resources and increase the awareness and understanding of a larger regional and international audience on the effectiveness of MPAs. The bibliography is expected to form a baseline for evaluating the successes and challenges of management of MPAs while increasing knowledge on critical ecological, social and political issues that will influence future efforts towards marine conservation in Kenya.

## METHODOLOGY AND SCOPE OF BIBLIOGRAPHY

Information was collected and collated primarily from the Wildlife Conservation Society's (WCS) Coral Reef Conservation Project (CRCP) library, the library and information documentation service of the Kenya Marine and Fisheries Research Institute (KMFRI), as well as other holdings from smaller libraries including the Kenya Wildlife Service (KWS) coast library, and the web search engines Google Scholar, Scopus, ScienceDirect, and Web of Science.

### Box 1: Bibliography annotation format

The flow of information for each annotation is organized in the following order:

Author/s. Title. Year of publication

Annotation

Location of the publication: This is the physical location of the publication abbreviated as follows:

CDA, CORDIO, CRCP, KMFRI, KWS

Subject of the publication

AG – Algae, BIOE – Bioerosion, BIOD - Biodiversity, BD – Birds, BOT- Botany, CLI – Climate, CE - Coastal Erosion, CR - Coastal Resources, COM – Community, CON – Conservation, COR - Coral, COREEF – Coral Reef, CRU – Crustaceans, EE - Environmental education, FIS – Fisheries, FOR – Forestry, HD – Hydrology, ICAM - Integrated Coastal Management, MGT – Management, MGT/P - Management Plans, MAN – Mangroves, MAP – Mapping, MPA - Marine Protected Areas, MAR – Mariculture, MM - Marine mammals, MOL - Molluscs, MON – Monitoring, OG – Oceanography, NUT – Nutrients, PK – Plankton, POL – Pollution, PRA – Participatory Rural Appraisal, SC - Sea cucumbers, SG – Seagrasses, ST - Sea turtles, SU - Sea urchins, SW- Seaweeds, SED – Sedimentation, TOU – Tourism, TM – Traditional Management,

Type of publication

R – Report, J – Journal, B – Book, BL – Booklet, T – Thesis, P - proceedings, A - Act

Key words

The source materials included peer-reviewed publications, theses and dissertations, project and research reports, symposium and workshop proceedings, legal documents and management

plans of MPAs in Kenya from 1968 to 2010. All available documents where MPAs are a focus were examined as well as material of relevance to MPAs including: studies of ecosystems and species, studies of impacts of human activities, studies of communities living adjacent to MPAs, and studies of management interventions and effectiveness. The bibliography does not include MPA promotional materials, guides or maps, or documentation of small meetings and seminars.

Each citation in the bibliography is numbered and arranged alphabetically by author, and by year sequentially. Details of the location of the document and keywords to allow electronic searches (Box 1) are also provided for each citation. Indexes of the author, subject, and taxonomic grouping are provided based on the number of the citation to facilitate cross-referencing. The final draft of the bibliography was emailed to more than thirty scientists at local institutions and NGOs for their review before publication.

A database of all citations was created to facilitate the gap analysis. For each document; the year, type of document (journal, report thesis/dissertation, proceedings), name of first author, gender of first author, the key ecosystem and species of the study, the journal, ISI categories, whether the first author was locally or internationally based, the institution of the first author, and the name of the MPA were coded onto an excel spreadsheet prior to drafting an annotation for each source. This data was used in the gap analysis to evaluate the key areas of scientific study; to highlight the type of information that is currently available on MPAs in Kenya; to assess the coverage across the MPAs; to assess the quality of the studies and the key institutions involved in studies on MPAs; and to illuminate the gaps in knowledge on MPAs. The information in the bibliography and the gap analysis is intended to support the strategic expansion of research for MPAs, strengthen and consolidate existing monitoring programs and inform the development of new programs to fill knowledge gaps in the information required for management.

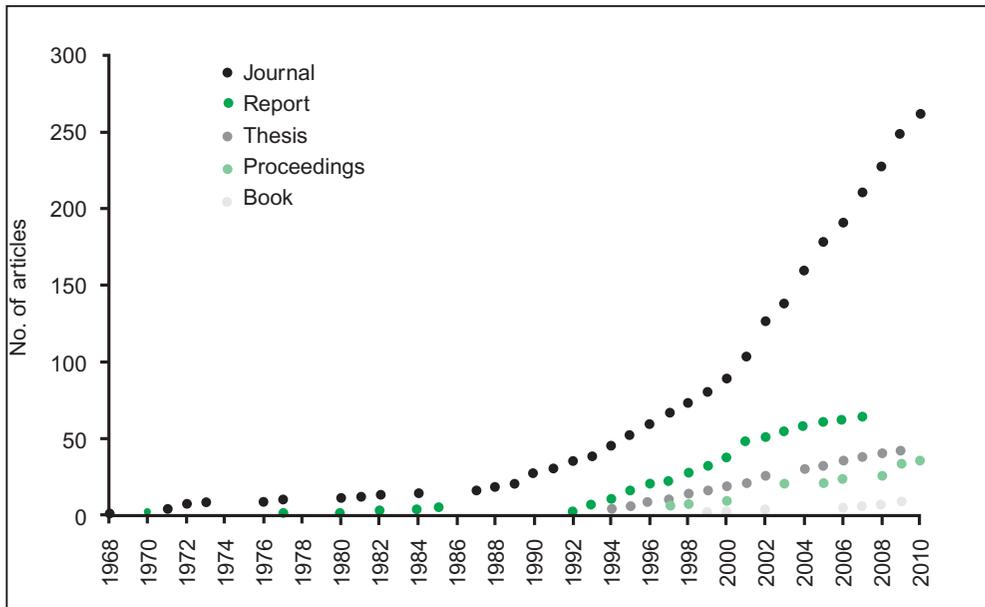
## **KEY FINDINGS AND INFORMATION GAP ANALYSIS**

The following overview provides a snapshot of the key findings that represent the quantity and quality of information now available on MPAs and highlights areas where further research and capacity is needed. The analysis of gaps in the literature is based on information collected in as comprehensive a way as possible in order to minimize any important omissions. However, difficulties retrieving very old manuscripts, difficulties retrieving information due to language (all the material that was reviewed was in English), and difficulties retrieving grey literature mean that some omissions were inevitable. Despite these shortcomings, this bibliography, the first of its kind in Kenya should serve as a reliable baseline and reference document that can be used to guide and measure scientific research in the future, and for ongoing marine conservation planning efforts in Kenya. The analysis is organized into subsections that include a section on publication output and key findings, an assessment of the quality of the information and the key institutions involved in research on the Kenya coast.

### **PUBLICATION OUTPUT**

A total of 414 documents were annotated from 1968 to 2010, more than half were published in peer-reviewed journals (63%), 15% were reports and 10% were theses and dissertations (combined). The productivity of scientists publishing on MPAs was low prior to 1987 totaling only 16 journal journal articles and very few reports, theses and dissertations were completed in the decades between

1960 and 1990 (Figure 2). There was a relatively sharp increase in productivity after the 1990s with the steepest increase occurring after 2000 for journal publications.



**Figure 2.** The cumulative number of citations per year (1968 – 2010) derived from books, journals, proceedings and thesis/dissertations.

The production of journal articles continued to rise at a relative rate of 11 articles per year. Research on MPAs by local and international students for Masters and PhD studies also continued at a steady rate of one per year. A total of ten books were produced but book publication showed sporadic growth. When the documents were categorized using the Institute of Scientific Information (ISI) classification, 70% of the publications were in the agricultural and biological sciences category, 12% were in social sciences and 6% were on earth and planetary sciences. A very low percentage of studies (> 1%) were in the category of multidisciplinary, toxicology or pharmacology and physics and astronomy.

The earliest studies in MPAs were mainly of a descriptive and taxonomic nature such as species inventories and general descriptions of the marine fauna and flora of the Kenya coast. Reliable and relatively comprehensive species inventories are now available for hard corals, coral reef fish, intertidal gastropods and crustaceans, echinoderms including sea urchins, sea cucumbers and brittle stars, mangrove species, marine algae and seagrasses, birds, marine turtles and marine mammals (Table 1). Studies on individual species are highly skewed towards invertebrates with snails, crustaceans and echinoderms receiving the most attention.

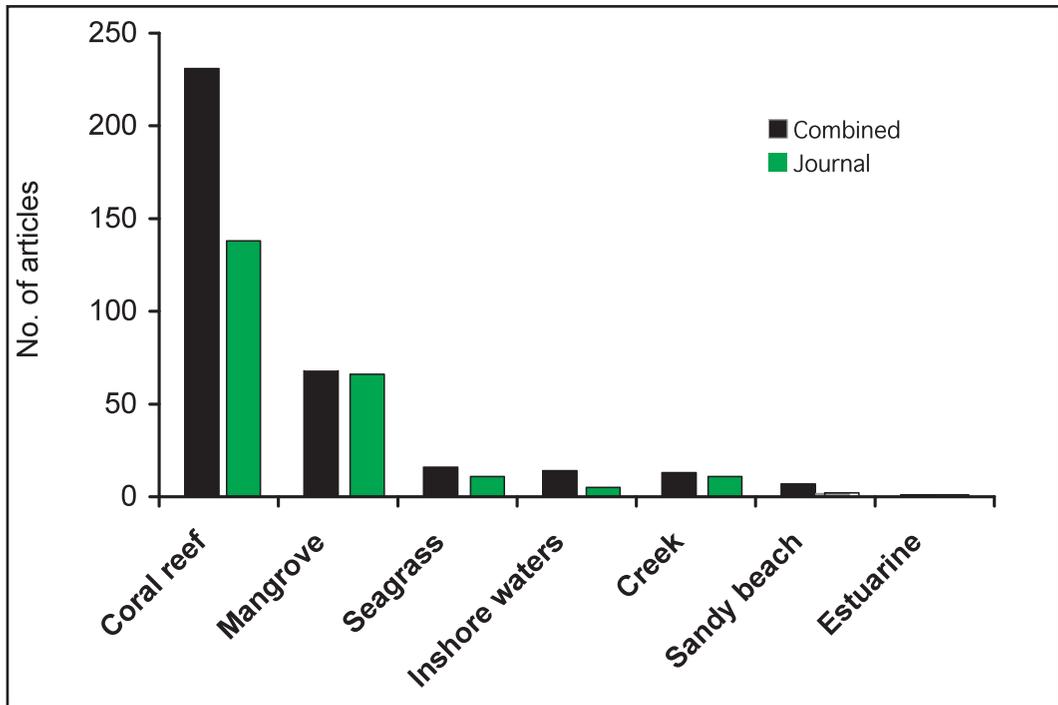
**Table 1: Taxonomic studies of major taxa in marine protected areas in Kenya.**

Community	No. species/genera	MPA	Reference
<b>Scleractinian corals</b>	140 species, 55 genera	Malindi, Watamu	Hamilton & Brakel 1984, Lemmens 1993
	183 species, 55 genera		
<b>Reef fishes</b>	350 species	Diani	Bock 1978, Samoily 1988, McClanahan 1994
<b>Mangroves</b>	9 species	Entire coast	Issac & Issac 1968
<b>Algae</b>	277 species	Entire coast	Issac 1968 Bolton et al. 2007
	386 species		
<b>Seagrasses</b>	12 species	Entire coast	Moorjani & Simpson 1988
<b>Gastropods</b>	135 species	Malindi, Watamu, Mombasa, Diani, Kisite	McClanahan 1989
<b>Sea cucumbers</b>	39 species	Kiunga, Malindi, Watamu, Kisite	Humphreys 1981, Samyn & van den Berghe 2000, Samyn 2000, Samyn et al. 2001
<b>Sea urchins</b>	12 species	Entire coast	Clark & Rowe 1971, Samyn & van den Berghe 2000
<b>Sea turtles</b>	5 species	Entire coast	Frazier 1975
<b>Marine mammals</b>	Dugong 1 species	Kiunga	Pertet & Thorsell 1980, Wamukoya et al. 1996
	Dolphins 7 species	Entire coast	
	Whales 1 species	Mpunguti	

Taxonomic studies have markedly reduced in recent times despite the need for inventories to support management and reporting requirements for international agreements. The discovery of a new species of sea cucumber in the Mombasa marine reserve in 2000 (Samyn et al. 2001) and *Siderastrea savignyana* a previously unreported coral species in the Kiunga marine reserve (Obura et al. 2007) underscores the need to continue developing taxonomic capacity in Kenya.

Ecological research constituted the bulk of the scientific output on MPAs followed by biological studies while very few experimental studies were carried out. There was also a large discrepancy in the attention given to different ecosystems. Studies on coral reefs dominated with more than 55% of total contributions on different aspects of coral reef studies; an indirect indicator of the importance

of coral reefs that occur in all the MPAs of Kenya. Seagrass beds that are closely associated with coral reefs were poorly studied constituting only 4% of contributions while mangrove forests (16%) that occur in the Kiunga and Mida creek marine reserves also received little attention (Figure 3).



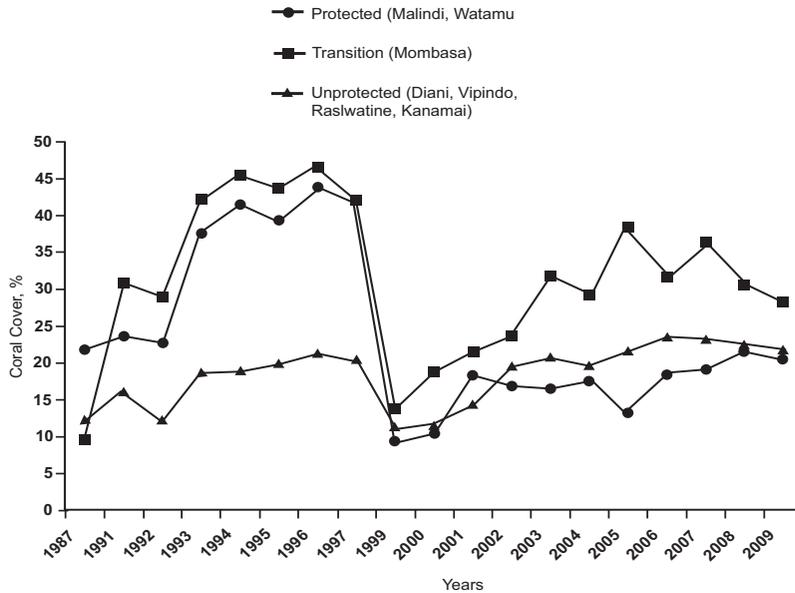
**Figure 3.** The number of articles on different marine ecosystems in Kenyan MPAs (Total combined contributions, blue bar; Journals, light blue bar).

Research and monitoring programs on coral reefs provided information on ecological aspects of coral reefs; species and community assemblage studies and distribution of key groups such as fish, corals, sea cucumbers, sea urchins, gastropods, crabs and other crustaceans; comparative studies of changes inside and outside MPAs; spillover effects and benefits of MPAs; experimental studies assessing reef restoration techniques such as sea urchin and algal removal; coral biology studies including reproduction and recruitment; genetic studies on coral morphology and zooxanthellae diversity; and management related assessments including user perceptions and management effectiveness assessments.

After the 1998 El Niño Southern Oscillation (ENSO) bleaching event that caused severe bleaching and substantial loss in hard coral cover in most reefs in Kenya, research on coral reefs focused more on bleaching and climate change disturbances (Box 2).

### Box 2. Changes in hard coral cover in MPAs

Long-term monitoring of hard coral cover at sites in the Malindi and Watamu marine parks (triangle), the youngest marine park the Mombasa marine park (circle), and in unprotected reefs in Vipingo, Kanamai and Diani (square) indicate severe mortality due to bleaching of coral during the 1998 El Niño Southern Oscillation (Modified from Muthiga & McClanahan 2010).



Studies on rates of coral reef recovery after bleaching; differences in responses by different species of coral and fish (McClanahan et al. 2005); effects of water flow and pollution; GIS and modeling based assessments of environmental susceptibility of coral reefs (Maina et al. 2008); as well as the effects of coral bleaching on coral reef communities, fish and fisheries contributed to a better understanding of the impacts of climate change on coral reefs in Kenya and in the western Indian Ocean.

Fishing and its impacts on habitats and coral reef communities also received a great deal of attention. MPAs in Kenya have been protected for different periods of time and the long-term monitoring programs of fished and protected sites generated data to test various hypotheses about the impacts of MPAs on coral reef communities, rates of reef recovery, changes in biodiversity and community structure that occur under different intensities of fishing, and the impacts of different types of fishing gears. These studies have shown that prior to the 1998 ENSO disturbance, fishing was the main threat to the sustainability of coral reef communities. For example, one study of four fully protected areas (Malindi, Watamu, Mombasa, Kisite) of differing ages showed that although MPAs enhanced recovery of fish biomass, some fish species took many more years to recover abundance and biomass than previously predicted (McClanahan and Graham 2005; McClanahan et al. 2007).

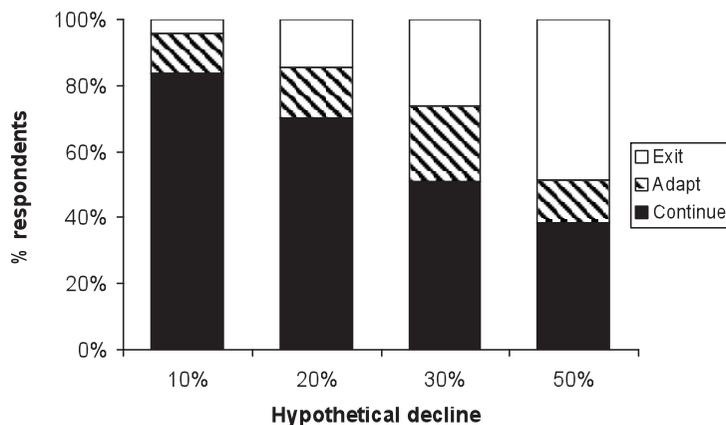
Studies on mangroves in MPAs focused on Mida creek in the Watamu marine reserve and in the Kiunga marine reserve. Mida creek was surveyed in 1998 by a team from KMFRI (Mwatha et al. 1998), and a broad range of other studies on biological, ecological and hydrological aspects have been completed. Examples include an assessment of mangrove utilization and the factors, biological and

social that affect rates of mangrove regeneration, and leaf litter production (Dahdouh-Guebas et al. 2000, Kairo & Gwada 2001, Kairo et al. 2002); seasonality of zooplankton (Mwaluma & Paula 2004, Osore et al. 2004); gastropod (Fratini et al. 2004) and crustacean (Icely 1977) distribution; hydrology (Kitheka 1998), and heavy metal studies (Mwashote 2003). In addition, numerous behavioural studies have been carried out on crabs and snails in Mida creek by teams from the University of Florence. The Kiunga mangroves received the least attention despite being part of the largest expanse of mangrove forests in Kenya. GIS based vegetation maps of Kiunga were produced by Kairo et al. (2002) that estimated a forest cover of ~16,000 ha with a high productivity potential if harvested sustainably.

Research on seagrass beds focused on general descriptions of plant and macrofaunal communities within seagrass beds (Issac 1968, Muthama et al. 2003), herbivory by sea urchins and detrimental effects on seagrasses (Alcoverro & Mariani 2002), and productivity and the effects of nutrients and groundwater inputs on seagrass community structure (Kamermans et al. 2002, Uku & Bjork 2005). More recently incidences of population explosions of the sea urchin *Tripneustes gratilla* in seagrass beds raised concerns due to their ability to overgraze seagrasses with a potential negative impact on fisheries. This led to more experimental studies to assess the role of predation in controlling the population density of this potential 'pest' urchin (Eklof et al. 2009).

### Box 3. Responses of fishers to declining catches in Kenya

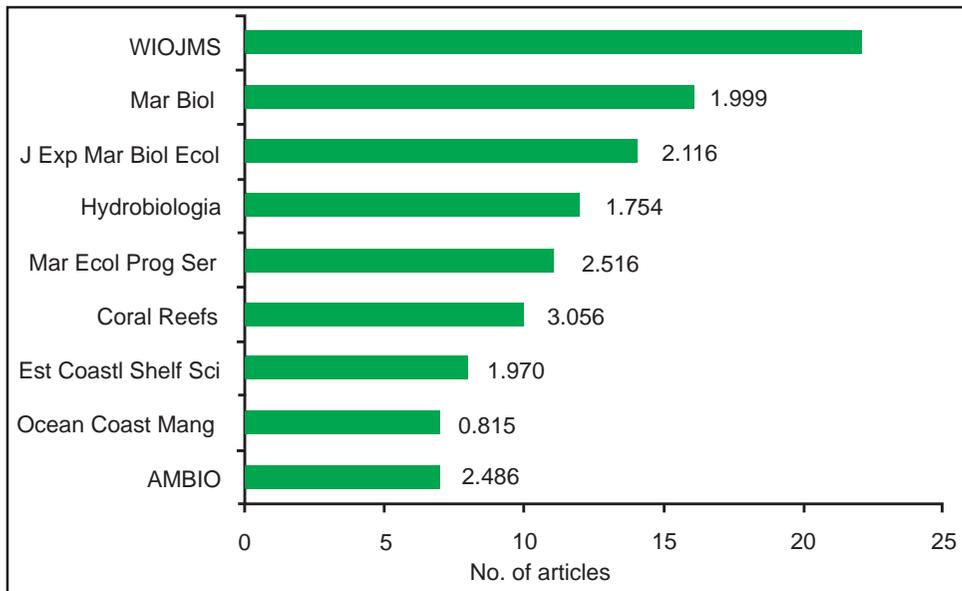
Fishers' responses to four hypothetical scenarios of declining catch rates (10%, 20%, 30%, and 50%) in Kenya. Fishers' responses include continue fishing (continue), exit the fishery (exit), and adapt their fishing practices (adapt). The adapt category includes responses such as fish harder, reduce effort, change gear, and change location (Source: Cinner et al. 2008).



Socio-economic studies of fishing communities also increased over the years improving understanding of socio-ecological systems. For example a study of the factors that influence the exit of fishers from a fishery (Box 3) by Cinner et al (2008) indicated that fishers were more likely to exit a fishery when catches were markedly reduced and when their households had a higher material style of life and more occupations. This suggests that programs directed at alleviating poverty that are targeted at the poorest fishers are an effective tool for fisheries management in the marine reserves where recent management effectiveness assessments have shown that management programs were not meeting the objective of sustainable fishing (Muthiga 2006; Muthiga 2009).

### JOURNALS AND IMPACT FACTOR

The number of journal contributions not only increased over time (Figure 2), the quality of the submissions was also relatively high as evidenced by the impact factors of the journals where the scientist published. Scientist contributed to 106 journals with the Western Indian Ocean Journal of Marine Science (WIOJMS), a regional journal, publishing the most articles (8.4%). The top ten journals included Coral Reefs, Marine Ecology Progress Series and Ambio that have relatively high impact factors for marine journals (Figure 4).



**Figure 4.** The number of articles on MPAs published in the top ten journals.

### INSTITUTIONS

There are several government and non-governmental organizations that routinely conduct research and monitoring on marine and coastal ecosystems on the Kenyan coast (Table 2). Monitoring programs include ecological and socioeconomic assessments in coral reefs, mangrove and seagrass beds within and outside MPAs, fisheries catch monitoring at landing sites adjacent to the marine

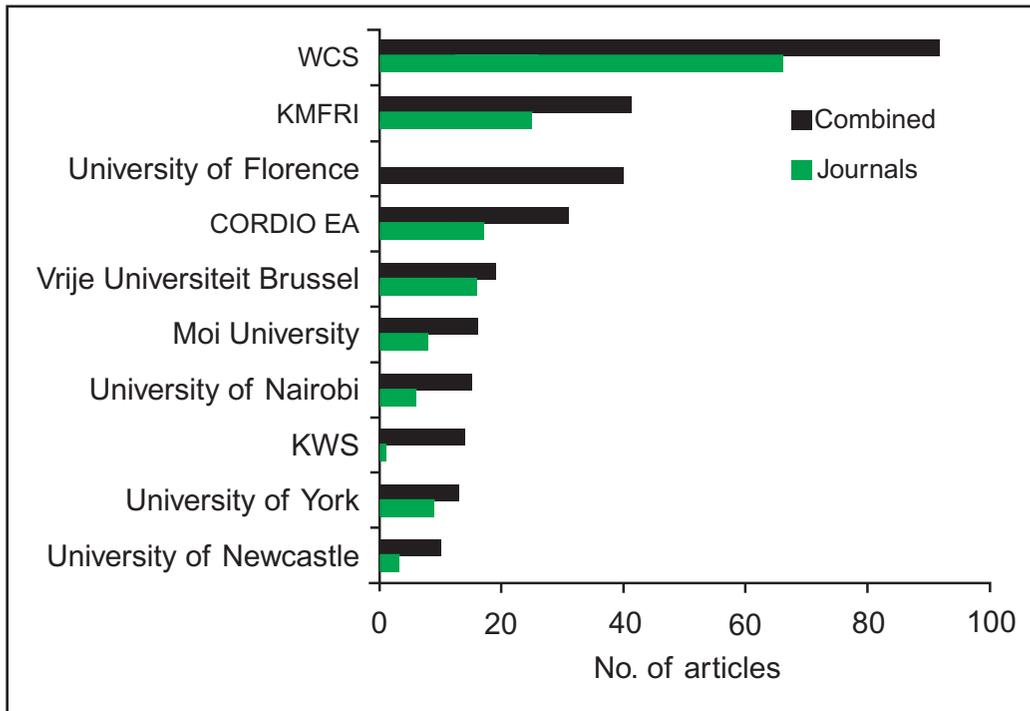
**Table 2: Institutions and organizations conducting marine and coastal studies in Kenya.**

Organization	Activity	Website
Kenya Marine & Fisheries Research Institute (KMFRI)	Biophysical and socioeconomic research on entire coast	<a href="http://www.kmfri.co.ke">www.kmfri.co.ke</a>
Kenya Wildlife Service (KWS)	Research and monitoring in MPAs	<a href="http://www.kws.org">www.kws.org</a>
Fisheries Dept	Monitoring fish catch and gear entire coast	<a href="http://www.fisheries.go.ke">www.fisheries.go.ke</a>
Kenya Forestry Research Institute (KEFRI)	Research on coastal forests	<a href="http://www.kefri.org">www.kefri.org</a>
Wildlife Conservation Society (WCS)	Research and monitoring of coral reefs, MPAs, fisheries, social organization, management, and climate change.	<a href="http://www.wcs.org">www.wcs.org</a>
Coastal Research and Development in the Indian Ocean (CORDIO – EA)	Research and monitoring coral and fisheries socioeconomics and climate change	<a href="http://www.cordioes.org">www.cordioes.org</a>
Global Vision International (GVI)	Marine mammal and sea turtle monitoring	<a href="http://www.gvi.co.uk">www.gvi.co.uk</a>
Moi University	Marine studies based at the Coastal Environment Research Station (CERS) in Malindi	<a href="http://www.mu.ac.ke">www.mu.ac.ke</a>
Kenya Sea Turtle Conservation and Management Trust (KESCOM)	Research and monitoring on sea turtles along entire coast	<a href="http://www.kescom.org">www.kescom.org</a>
University of Nairobi	Marine studies based at Moana marine biological station in Diani	<a href="http://www.uondi.ac.ke">www.uondi.ac.ke</a>

reserves of Mombasa and Diani, nesting, mortality and sighting of sea turtles and marine mammals. Although physicochemical parameters play a role in coastal and marine processes, there are no regular monitoring programs except of sea surface temperatures and tidal levels.

The combined research activities of these institutions cover most of the ecosystems of the coast. Although many factors influence the focus of research within these institutions including the skills of the scientists, proximity to the study sites and age of MPA possibly played a major role. More than a quarter of studies were carried out in the Mombasa MPA (26%) that is the closest to most institutions, and the Watamu MPA (29%) that is one of the oldest. The Kiunga MPA, which is farthest and least accessible, received the least attention (4%).

Research on MPAs in Kenya also attracted scientists from many countries including Australia, Belgium, the Netherlands, Sweden, the UK and USA. Research output was variable among institutions (Figure 5) with WCS producing a quarter of the journal articles followed by the University of Florence (15%) and KMFRI (10%).



**Figure 5.** The number of publications produced by the top ten local and international institutions (Blue = all publications combined; Light blue = journal articles).

Overall, individual scientists from internationally based institutions had a lower contribution than scientists based in Kenya (40% and 60% respectively). In addition of the locally based scientists, there were fewer contributions from female (25%) than male scientist (75%), which partly reflected the low number of female scientists in marine sciences in the country.

One of the main factors that impacts scientific output is the amount of resources allocated to research. Although it is difficult to estimate this cost from Kenyan MPAs, the contribution of government institutions, the contribution and long-term presence of research based NGOs, and numerous donor-funded projects have injected resources for marine research in Kenya. One such initiative, the Marine Science for Management (MASMA) program of the Western Indian Ocean Marine Science Association (WIOMSA), a competitive research program that funds multi-country, multi-disciplinary marine and coastal projects in the western Indian Ocean supported more than 10 research projects led by Kenyan scientist since its initiation in 2001. The national allocation towards science and technology has remained relatively low (<0.5% of GDP). It is hoped that the

revitalization of the National Council for Science and Technology and the recognition under Kenya's Vision 2030 of the importance of scientific knowledge for national development will substantially increase the focus on science and the resources allocated to research in Kenya.

## SUMMARY

While great progress was made over the last three decades in the generation of scientific information on MPAs in Kenya, it is clear that considerable gaps remain in the type of science and research that is being carried out and in the provision of management information. In general, the analysis identified a lack of information that is key to measuring and understanding the effectiveness and benefits of protection and management including:

- How ecosystems are changing in the short and long term after closure. This information was lacking for most ecosystems except for coral reefs where long-term ecological monitoring provided data;
- Which species are impacted by anthropogenic and environmental disturbances, their vulnerability and how they respond. This is especially important for keystone and target species. Again more information was available on coral reef species than species from other ecosystems;
- Key processes including biological processes such as reproduction and recruitment and ecological processes such as primary production, and nutrient cycling. Except for monitoring of predation and herbivory and recruitment of corals in reefs, little information was available on other processes and ecosystems;
- Biophysical parameters especially those that affect water quality and pollution. There were no systematic and regular programs to monitor physicochemical parameter in MPAs;
- Species inventories and taxonomic studies, which contribute to valuation and other scientific information;
- Socioeconomic and institutional barriers as well as other political factors that prevent the effective management of MPAs. This is a rapidly growing area of research throughout the western Indian Ocean region.

Gaps in information specific for management included:

- Measures of success, although baseline management effectiveness assessments had been carried out on most Kenyan MPAs, more comprehensive studies are needed;
- Research on social conflict and mitigation that will guide management interventions and conflict resolution. The resolution of conflicts takes up a large proportion of management time and resources so understanding the key drivers of conflicts should assist in their mitigation;
- Research on regulatory compliance, policy, and legislative approaches. Basic assessments on perceptions, attitudes and management preferences of MPA stakeholders and how these affect their behaviour and compliance had been carried out, however, more comprehensive studies aimed at providing management authorities with information at a scale suitable for local planning and management are needed;
- Research on carrying capacity and sustainable use that will guide licensing, zoning and introduction of new tourism activities;
- Valuation studies that better communicate the costs of not managing marine and coastal ecosystems and the good and services contributed by these ecosystems to the local and national economy;

- Alternative livelihood studies that are consistent with the protection of biodiversity conservation and that include assessments of the preferences, needs and capacities of MPA adjacent communities and their abilities to manage livelihood projects.

Research plays an important role in the management process providing key information and linkages between knowledge and use. This Annotated Bibliography provides a collection of all key references and documents from 1968 to 2010 on the MPAs of Kenya. It is aimed towards information generation, analysis and dissemination, and facilitating the identification of research needs and priorities that will guide how MPAs are managed in the future. The bibliography is intended for dissemination to scientists, natural resources managers and decision-makers in Kenya and the western Indian Ocean, government and non-governmental organizations that work in coastal and marine ecosystems and students with an interest in the natural resources of the Kenya coast.

## ANNOTATED BIBLIOGRAPHY

001

**Abuodha PAW (1992) Geomorphology and sedimentology of the Mombasa-Diani area: implications to coastal zone management. MSc. Thesis. University of Nairobi, Kenya. 158 pp.**

Coastal zones are continually changing and the effects of currents, tides, waves, winds and coastal development all influence the rates of erosion and deposition and the profile of the coastal zone. Few studies however, have evaluated the coastal management challenges on the Kenyan coast. This MSc. research study examined the geomorphology and sedimentology of the beaches of Mombasa and Diani and evaluated the effectiveness of the existing coastal erosion control measures. The results of sedimentological work showed that beaches at Nyali, Tiwi, Galu and Kinondo were relatively stable, while Likoni, Diani and Gazi were classified as depositional beaches. Coastal erosion, coastal development, the lack of a coastal zone management system and construction of erosion stabilizing structures along some beaches were identified as major challenges. The study recommended a national coastal zone management system and legislation for Kenya that addresses the management and protection of coastal habitats.

**KMFRI, MGT, T**

Coastal zone management, geomorphology, sedimentology, coastal erosion, Mombasa, Diani, Kikambala, Kenyatta, Nyali, Tiwi, Galu, Kinondo, Likoni, Gazi

002

**Abuodha PAW (1999) Status and trends in Kenyan recreational marine fisheries. The Fisheries Centre, University of British Columbia. Vol 7 (2): 46-50.**

Recreational fishing involves both fishing for subsistence and for leisure. In Kenya data are only available on recreational fishing for leisure; termed sports fishing. This article reviews trends of Kenya's recreational marine fisheries and billfish tag and release program based on records from the Kenya Association of Sea Angling Clubs (KASAC) from 1988 to 1998. Results showed that; barracuda, kingfish, the black, blue and striped marlin, sailfish, the hammerhead, mako and tiger sharks, yellowfin tuna and wahoo were commonly caught. Catch composition varied throughout the year possibly due to seasonal variation in oceanographic conditions, supply of food, life cycles and migration patterns. Recreational fishing was practiced mainly by foreign tourists and chiefly as a sport but the decline in the tourism industry, increasing costs of angling, poaching and increased diversity of leisure activities constrained the further growth of the fishery. The author recommended an improved data collection system as well as promotion of the fishery.

**KMFRI, CRCP, FIS, R**

Recreational fishing, capture release

003

**Abuodha PAW, Kairo JG (2001) Human-induced stresses on mangrove swamps along the Kenyan Coast. Hydrobiologia 458: 255-265.**

Mangrove forests occur as creek or fringe communities along creeks and bays on the Kenyan coast. Most studies on mangroves have concentrated on distribution and zonation and little information was available on human impacts on mangroves. This paper reviews human activities such as overharvesting, illegal cutting, allocation of areas of mangrove to private developers, conversion of mangrove areas for other land uses (salt production, mariculture,

agriculture) and pollution of mangroves swamps and their impacts on mangrove ecosystems in Kenya. The authors estimated that 20% of mangrove cover had been lost as a consequence of these activities and although there had been some reforestation efforts, these were limited in spatial extent. The authors recommended sustainable use, mangrove rehabilitation and improved government policies for the management of mangrove forests.

**KMFRI, CRCP, MAN, J**

Deforestation, mangrove conversion, overharvesting, sustainable management

**004**

**Abuodha JOZ (2003) Grain size distribution and composition of modern dune and beach sediments, Malindi Bay coast, Kenya. *Journal of African Earth Sciences* 36: 41-54.**

The coastline along Malindi bay is composed of a system of coastal sand dunes whose mineralogy is unknown. This study used grain size analysis to gain insight into the mineralogy of the area. Grain sizes were determined by dry sieving sediments and the mineral composition of the heavy fractions were measured using a petrographic microscope during three sampling periods in 1993 and 1994. Results showed that the sediments of the area were dominated by terrigenous fine to medium-grained quartz sand deposits from the Sabaki River and heavy minerals averaged between ~15% and up to 67% of the weight of samples. Significant differences occurred in grain size close to the Sabaki river mouth and mean grain size was coarser, sorting was worse and the grain distribution was more positively skewed during the northeast monsoons. The author concluded that the sediments of the area reflected an active aeolian (wind) driven system.

**KMFRI, CRCP, SED, J**

Sediments, grain size, geomorphology, Sabaki river, Malindi

**005**

**Abuodha JOZ (2004) Geomorphological evolution of the southern coastal zone of Kenya. *Journal of African Earth Sciences* 39: 517-525.**

The coastal profile of Kenya has been shaped by several geological events including changes in sea level. This paper reviews the processes shaping the coastal landscape of southern Kenya. The review described the evolution of four main terraces: the Ganda, Kilifi, Malindi, and Shelly Beach Terraces. The author concluded that the Kenyan coastal landscape was shaped by eustatic, isostatic and tectonic movements.

**KMFRI, CRCP, SED, J**

Geomorphology, Pleistocene, terraces, sea level

**006**

**Alcoverro T, Mariani S (2002) Effects of sea urchin grazing on seagrass *Thalassodendron ciliatum* beds of a Kenyan lagoon. *Marine Ecology Progress Series* 226: 255-263.**

Sea urchins are common grazers on seagrass beds and their grazing effects can be beneficial or detrimental depending on population size and structure. This study described the effects of dense sea urchin aggregations on seagrass beds in the Mombasa marine reserve between October 1997 and February 1998. Results showed that the seagrass species *Thalassodendron ciliatum* dominated the substrate cover (49.6%) and the sea urchin *Tripneustes gratilla* was the dominate benthic grazer at a density of 1.6m<sup>-2</sup>. The impact of grazing was significant with more than a third of the *T. ciliatum* meadows being heavily grazed by the sea urchin. The passage of sea urchin fronts through the seagrass bed revealed a rate of 34 months and a T.

*ciliatum* recovery time of 44 months. The authors concluded that sea urchin aggregations in the Mombasa lagoon impacted *T. ciliatum* density by their grazing activity.

**CRCP, SG, J**

Seagrass, sea urchin, herbivory, *Thalassodendron ciliatum*, *Tripneustes gratilla*, Mombasa, marine reserve

007

**Alcoverro T, Mariani S (2005) Shoot growth and nitrogen responses to simulated herbivory in Kenyan seagrasses. *Botanica Marina* 48: 1-7.**

Herbivory of seagrass beds by sea urchins is a common and natural disturbance. This study investigated the potential effects of grazing by sea urchins on leaf growth and nutrient dynamics of six seagrass species in the Mombasa marine reserve between 1997 and 1998. The results indicated variable responses to simulated herbivore pressure by the different species. The average shoot re-growth of clipped plants was ~45% to 50% lower than controls in *Thalassodendron ciliatum*, *Syringodium isoetifolium*, and *Cymodocea serrulata* beds. The nitrogen content was not affected by clipping in young, fully expanded leaves, except in *T. ciliatum* (20% reduction in nitrogen) but was significantly lower in old leaves in treatment than in controls of *T. ciliatum*, *Halodule uninervis*, *C. serrulata* and *C. rotundata*. Leaf resorption efficiencies of nitrogen were 35% higher in treatments than in controls. The author concluded that the results supported the hypothesis that resorption of nitrogen in seagrasses is a response to changes in the internal nutrient pools and this mechanism helps in nitrogen conservation resulting from herbivory.

**CRCP, SG, J**

Herbivory, seagrasses, *Thalassia hemprichii*, *Thalassodendron ciliatum*, *Cymodocea rotundata*, *Cymodocea serrulata*, *Halodule uninervis*, *Syringodium isoetifolium*, nitrogen resorption, Mombasa, marine reserve

008

**Alidina HM (2005) Local level fisheries management in Diani-Chale, Kenya: current status and future directions. *Coastal Management* 33 (4): 459-470.**

Co-management is often touted as one of the solution to the difficulties of managing tropical marine fisheries. This paper reviewed the prospects for attaining a more locally oriented, collaborative system in the Diani-Chale marine reserve area. Management of fisheries in the area was characterized by decreased capacity for enforcement and regulation by the fisheries department and weak local institutions. The author suggested that management at the local level through fish landing beaches and associated fishing grounds was the appropriate governing level in the area and that the strengthening of those local institutions could lead to improved fisheries management. However, several challenges including; the socioeconomic condition of fishers, the loss of landing sites through coastal development, and continued negative perception of marine reserves by local fishers needed to be addressed.

**CORDIO, CRCP, MGT, J**

Co-management, fisheries management, Diani-Chale, marine reserve

009

**Angwenyi CM, Rydberg L (2005) Wave-driven circulation on the coral reef at Bamburi lagoon, Kenya. *Estuarine Coastal and Shelf Science* 63: 447-454.**

The hydrology of the Bamburi lagoon in the Mombasa MPA that is adjacent to the most

highly developed tourist beach on the Kenyan coast has received little attention. This paper describes circulation within the reef lagoon at Bamburi. Measurements of sea level, currents and waves were taken within and outside an open-ended bar in the lagoon during three sampling periods in 1996 to 1998. Results showed that the reef was usually submerged by 0.7 m relative to mean sea level, and that 0.5m high waves broke over the reef every 8-10s continuously throughout the tidal cycle. Circulation within the lagoon was driven by this flow over the reef, which varied in magnitude during the neap and spring tides. Although this wave driven circulation was smaller than the tidally driven circulation, it played an important role by limiting the inflow of polluted water from tidal creeks on the northern and southern borders of the lagoon.

**KMFRI, CRCP, OG, J**

Wave circulation, tidal circulation, Bamburi, coral reef, Mombasa, marine reserve

**010**

**Ateweberhan M, McClanahan TR (2010) Relationship between historical sea-surface temperature variability and climate change-induced coral mortality in the western Indian Ocean. *Marine Pollution Bulletin* 60: 964-970.**

The 1998 El Niño Southern Oscillation caused the most widespread bleaching event in the world's oceans due to anomalously high sea surface temperatures (SST). Because SST and bleaching vary within and between reefs, predicting which reefs will bleach is difficult. This study undertook a meta-analysis of coral cover and historical SST patterns at 36 major coral reef areas in the Western Indian Ocean (WIO) including in Kenyan MPAs to determine whether the response to bleaching could be predicted from previous environmental and ecological characteristics. The results showed that coral mortality was highly correlated with thermal stress and that the warmest areas experienced the highest mortalities. The area north of Mayotte/Comoros and NW Madagascar had the least SST rise and showed the lowest bleaching mortality. The authors suggest that the background SST environment is a key factor in coral response to bleaching and recommend identification of areas that have the environmental and ecological capacity to tolerate climate disturbances as high priority conservation areas.

**CRCP, COREEF, MAN, J**

1998 El Niño Southern Oscillation, climate change, coral bleaching, temperature variability, marine park

**011**

**Baker AC, Starger CJ, McClanahan TR, Glynn PW (2004) Corals' adaptive response to climate change. *Nature* 430: 741.**

How corals respond to climate change in the long-term will depend in part on the adaptive ability of the coral – zooxanthellae symbioses to warmer temperatures. This brief review summarizes the findings of a study on zooxanthellae clades in Kenya (Malindi, Mombasa and Kisite-Mpunguti MPAs), Panama and Saudi Arabia that have differing tolerances to temperature. Molecular assessments of zooxanthellae were undertaken on coral tissue samples collected from shallow-reefs (>7m depth) at five locations in these countries that had variable responses to the coral bleaching event of the 1997-98 El Niño Southern Oscillation. The study found that corals that contained zooxanthellae that are thermally tolerant (clade D) were more abundant in reefs that had previously been severally affected by bleaching. The authors suggested that this shift to thermally more adapted zooxanthellae could allow a higher resistance to future thermal stress.

**CRCP, COR, J**

Coral bleaching, coral clades, *Symbiodinium*, El Niño Southern Oscillation, Kanamai, Ras Iwatine, Malindi, Lamu, marine park, marine reserve

**012**

**Babcock R, Alcalá A, Barrett N, Edgar G, Lafferty K, McClanahan T, Russ G, Shears N (2010) Decadal trends in marine reserves: differential rates of change for direct and indirect effects. *Proceedings of the National Academy of Science, USA*. doi/10.1073/pnas.0908012107.**

Marine protected areas are affected by complex ecological and socioeconomic conditions that make it difficult to predict the rates of change. Closures can lead to direct effects on species due to recovery of populations or indirect effects due to changes in trophic levels. In this review long-term ecological data sets of sites within and outside closures in different regions including in Kenya were compared. Results showed that approximately five years were required for target species to show increases due to direct effects of reduced fishing but that other species took up to 13 years due to indirect effects such as changes in trophic interactions. Several factors caused decreases including natural fluctuations, fishing impacts from outside the closures, or predation. Results also showed a higher level of stability in target species within closures indicating increased ecological resilience, which has positive implications for closures as a conservation management tool.

**CRCP, MPA, MGT, J**

Fishing effects, trophic cascade, marine reserves

**013**

**Baratti M, Goti E, Messana G (2005) High level of genetic differentiation in the marine isopod *Sphaeroma terebrans* (Crustacea Isopoda Sphaeromatidae) as inferred by mitochondrial DNA analysis. *Journal of Experimental Marine Biology and Ecology* 315: 225 - 234.**

The isopod *Sphaeroma terebrans*, lives exclusively on the aerial roots of the mangrove *Rhizophora* species in tropical and subtropical areas. This paper compares the genetic diversity of different populations in East Africa and American mangroves including samples collected at Gazi Bay and Mida Creek on the Kenyan coast. Results showed significant geographic differentiation between populations and restricted gene flow between populations. The authors suggested that the group is not a single species but a species complex and recommended reevaluation of the taxonomic status of this taxon.

**CRCP, CRU, MAN, J**

Isopod, *Sphaeroma terebrans*, mangroves, Gazi Bay Mida Creek, marine reserve

**014**

**Beadle RA (2005) Management, conflict and compliance: The case of the Kenyan sea cucumber (Echinodermata: Holothuroidea) fishery. MSc. thesis report, University of Newcastle, UK, 17 pp.**

The management of the sea cucumber fishery has received little attention in Kenya. This MSc. study aimed to identify the key issues that influenced the effectiveness of management of this fishery. Perceptions of key stakeholders were collected through semi-structured interviews and focus group discussions in Malindi, Kilifi, Mombasa and Kwale districts between May and June 2005. Results indicated that the Kenyan sea cucumber fishery was over-exploited and management strategies, including a ban on the use of SCUBA, were insufficient for managing the resource. The author recommended addressing challenges including; lack of sufficient

biological data and reliable catch statistics, insufficient enforcement of regulations, conflict between fishers and the management authority and differences in perception about future management strategies between resource users and resource managers in order to improve future governance of the fishery.

**CRCP, SC, MGT, R**

Sea cucumbers, stakeholders, perception, management, Malindi, Kilifi, Mombasa, Kwale

**015**

**Bennun L, Njoroge P (1999) Important bird areas in Kenya. National Museums of Kenya and Birdlife International. 318 pp.**

This is the first book to provide a comprehensive documentation of the Important Bird Areas (IBA) of Kenya. Many of these IBAs are within or adjacent to marine protected areas including; Arabuko-Sokoke Forest, Kisite Island, Kiunga marine reserve, Mida Creek and Diani forest. The book presents an analysis of the functional role of birds in diverse ecosystems and the threats to their existence. The authors argued that birds could be used as important indicators of habitat suitability for a variety of species, and their abundance could be an indicator of impacts on their habitats. Periodic national bird counts were suggested as a measure of changes to the environment. Since many IBAs were important to local community food security and livelihoods, conservation and management strategies were recommended to protect these valuable habitats and their biodiversity.

**CRCP, KWS, BD, B**

Important Bird Areas, Arabuko-Sokoke Forest, Kisite Island, Kiunga Marine National Reserve, Mida Creek, Diani, coastal forests

**016**

**Berti R, Cannicci S, Fabbroni S, Innocenti G (2008) Notes on the structure and the use of *Neosarmatium meinerti* and *Cardisoma carnifex* burrows in a Kenyan mangrove swamp (Decapoda Brachyura). *Ethology Ecology and Evolution* 20 (2): 101 – 113.**

The distribution, structure and morphology of the burrows of the crabs *Neosarmatium meinerti* and *Cardisoma carnifex* that inhabit the same environments were investigated at Mida Creek. Results showed that the burrows of both species had a simple linear shape but differed in size and shape since *C. carnifex* was much larger than *N. meinerti*.

**CRCP, CRU, J**

Burrows, crabs, mangroves, *Cardisoma carnifex*, *Neosarmatium meinerti*, Mida Creek, marine reserve

**017**

**Blom J, Hagen HV, Hove EV, Katwijk MV, Loon RV, Meier R (1985) Decline of the Malindi-Watamu reef complex: quantitative and qualitative survey of the coral growth. Kenya-Belgium project in marine ecology. 162 pp.**

This report details coral reef health in the Malindi-Watamu reef complex during the Watamu reef expedition in 1984. A modified line-transect method was used to estimate qualitative and quantitative aspects of coral growth, condition and size of individual coral colonies. Three coral growth assemblages were suggested characterized by *Porites*, *Acropora* and *Pachyseris*. The authors reported indications that sedimentation originating from the Sabaki River and to a lesser extent Mida Creek had a negative effect on the Malindi-Watamu reef complex.

**CRCP, COREEF, R**

Coral reef, corals, sedimentation, *Pachyseris*, *Porites*, *Acropora*, Sabaki, Malindi, Watamu, marine park, marine reserve,

018

**Bock KR (1972) Preliminary checklist of lagoonal fishes of Diani, Kenya. Journal of the East African Natural History Society and National Museum 137: 1-6.**

This checklist detailed the first baseline survey of finfish families that were surveyed in the lagoon within the Diani-Chale marine reserve. Observations were made at low tides during daylight hours between late 1970 and 1971 during the northeast monsoon period. A brief description of the Diani lagoon was provided including notes on the absence of coral gardens and abundant coral growth. A total of 50 finfish families were recorded. While there was a low number of species of parrotfish (Callyodontidae) and butterflyfish (Chaetodontidae), species of the families Pomacentridae, Labridae, and Apogonidae were abundant, which indicated favourable habitats for these species.

**CRCP, FIS, J**

Fish, lagoon, Callyodontidae, Chaetodontidae, Pomacentridae, Labridae, Apogonidae, Diani-Chale, marine reserve

019

**Boera PN, Okeyo-Owuor JB, Wangila BCC (2003) The impact of human activities on epibenthic bivalve communities. In: Hoorweg J, Muthiga N (eds) Recent advances in coastal ecology, studies from Kenya. Research report 70: 81- 95.**

Bivalves are common inhabitants of shallow marine habitats and have ecological and commercial value. This study examined the effects of protection on the diversity and community structure of bivalves. Bivalves were sampled in reef lagoons, reef flats and seagrass beds within the Malindi and Mombasa marine parks and at Kanamai (an unprotected reef) from October 1997 to March 1998. Human activities within the lagoon were also recorded. A total of 17 bivalve species belonging to 13 families were identified at low densities averaging 2 ind/m<sup>2</sup>. Species diversity (Shanon index) was higher in the MPAs than at Kanamai and in the reef flats and reef lagoons than in the sea grass beds. The authors concluded that the distribution of the bivalve fauna at these sites was density independent and was potentially influenced by human activities, management regime as well as other biological and environmental factors such as substrate type, tide range and wave activity.

**CRCP, MOL, P**

Bivalves, human activities, Malindi, Mombasa, marine reserve, Kanamai

020

**Bolton JJ, Oyieke HA, Gwada P (2007) The seaweeds of Kenya: Checklist, history of seaweed study, coastal environment, and analysis of seaweed diversity and biogeography. South African Journal of Botany 73 (1): 76-88.**

This study provides a checklist and analysis of the biogeographic patterns of distribution of the seaweeds of Kenya. The list of the seaweed species was extracted from the website www.Algaebase.org in March 2005 and comprised a total of 386 species including 56 brown algae (Phaeophyceae), 116 green algae (Chlorophyta) and 214 red algae (Rhodophyta) species. Ordination analysis of the relationship between the Kenyan and global flora showed that 50% of the Kenyan flora occurred in the Indo-Pacific cluster. Less than 4% of the Kenyan

flora was cosmopolitan. The seaweed flora of Tanzania, Kenya, Madagascar, South Africa and Mozambique formed a tight cluster and the Tanzanian fauna showed the most similarity to the Kenyan fauna (68% similarity).

**CRCP, SW, J**

Seaweeds, algae, biogeography, Phaeophyceae, Chlorophyta, Rhodophyta

**021**

**Borri M, Cianfanelli S, Martignono R, Volpi C (2005) Taxonomic and ecological remarks on the marine molluscs of the Mida Creek area (Kenya, Western Indian Ocean). *Atti della Società Italiana di scienze naturali e del museo civico di storia naturale di Milano* 146 : 79 -94.**

The snail species of Mida Creek were surveyed in 1999 and 2000 by scientists from University of Florence (Italy). A total of 291 species of molluscs especially gastropods and bivalves were recorded.

**CRCP, MOL, J**

Gastropods, bivalves, Mida Creek, marine reserve

**022**

**Bourjea J, Nel R, Jiddawi NS, Koonjul MS, Bianchi G (2008) Sea turtle bycatch in the West Indian Ocean: Review, recommendations and research priorities. *Western Indian Ocean journal of Marine Science* 7(2): 137-150.**

Sea turtles are distributed throughout the western Indian Ocean and are exposed to several threats from fishing. This review detailed the main causes of mortality of sea turtles for 11 countries in the West Indian Ocean including Kenya. The results from available data and other anecdotal information identified gillnetting, prawn/shrimp trawling and longlining as the main threats to sea turtles. The authors noted that reliable data in the region are scarce except in Seychelles, South Africa and La Reunion (France) and recommended several research and management priorities and interventions for the region. The authors also noted the importance of involving fishers, scientists and other stakeholders in the development and implementation of any management interventions.

**CRCP, ST, J**

Sea turtles, bycatch, fisheries, mortality, West Indian Ocean

**023**

**Brydolf J (1999) Coral assemblage structure in Mombasa Marine National Reserve in Kenya, East Africa, University of Stockholm. 19 pp.**

The fringing reef of the Mombasa marine park and reserve was studied in order to compare the hard coral community structure in the park (no-take zone) and the reserve (partially protected). Assemblage structure of 15 species and genera of scleractinian corals were assessed in terms of coral cover and species/genera distribution and abundance along line transects in both the park and in the reserve. Coral cover and species/genus distribution and abundance were greater in the park than in the reserve. In all sites, *Porites* constituted a significant part of total coral cover.

**CRCP, COR, R**

Corals, distribution, abundance, Mombasa, marine park, marine reserve, *Porites*

024

**Byron G (1995) The potential for underwater trails in Kenya's marine national parks. Kenya Wildlife Service, Mombasa, Kenya. 6 pp.**

Nature trails have become important tourist facilities, which play a leading role in promoting ecotourism. However their establishment has been limited to terrestrial settings with little or no replication within the marine environment. This report was an evaluation of the 'nature trail' suitability of various sites within Kenya's marine parks (Mombasa, Malindi and Kisite). The report detailed trail designs and the challenges of concentrating snorkelers within confined trails. The effects could be mitigated by appropriate design and placement of the trails and by managing the behaviour of snorkelers.

**KWS, MGT, R**

Nature trail, ecotourism, underwater trails, Mombasa, Malindi, Kisite, marine park

025

**Cahill R (1992) Birds of Watamu. Majestic Printing Works, Nairobi, Kenya. 61 pp**

Bird watching is one of the fastest growing outdoors activities globally. This booklet provides a brief account of bird watching within the Watamu area that is an important ecotourism location in Kenya. The author details the main species of birds observed over a period of several years focusing on Mida Creek in the Watamu marine reserve. The mangroves, the shore and the exposed reef at low tide provided feeding grounds for many bird species including the palearctic migrant waders (Curlew sandpiper, Terek sandpiper) and onshore birds (bee-eaters, sunbirds, waxbills, starling). These birds offered bird watching opportunities to both the local community and tourists especially visitors to the Watamu MPA.

**KWS, BD, B**

Bird watching, Watamu, Mida creek, marine reserve,

026

**Calnan JM (2006) Changes in benthic communities in Kenyan marine protected areas, MA thesis, Columbia University, USA.**

The rates of recovery and changes in the community structure of fish after a bleaching disturbance are of interest to management. This MA research study examined the recovery trends of common coral reef fish families as well as the productivity of crustose coralline and turf algae at fully protected (Malindi, Watamu, Mombasa, and Kisite marine parks), partially protected (Ras Iwatin in the Mombasa marine reserve) and unprotected (Vipingo, Kanamai, Diani) reef lagoons in Kenya. Fish family data were obtained from the Coral Reef Conservation Project's database. Algal productivity was estimated insitu through measurements of chlorophyll fluorescence, wet weight and chlorophyll a concentration using pulse-amplitude-modulated (PAM) fluorometry in August 2005. Results indicated that protection significantly affected the fish population but not algal productivity. The rates of recovery of the biomass, density and species richness of fish families were highly dependent on the length of protection, which has implication for management.

**CRCP, AG, FIS, T**

Crustose coralline, turf algae, fish, MPAs, Malindi, Watamu, Mombasa, Kisite, Vipingo, Kanamai, Diani, Ras Iwatin

027

**Cannicci S, Dahdouh-Guebas F, Anyona D, Vannini M (1995) Homing in the mangrove swimming crab *Thalamita crenata* (Decapoda: Portunidae). *Ethology* 100 (3) 242 – 252.**

The mangrove crab *Thalamita crenata* restricts its movements to within 5 m of its shelter. The cues used by this crab to return to its shelter were investigated by experiments displacing crabs in the mangroves of Mida Creek. Results showed that crabs that were allowed full view of the sky and landscape were able to return to their shelters within 1 hour of displacement but crabs that were blinded did not succeed in returning to their shelters. Detour experiments also showed that the direction chosen pointed towards the shelters. The authors suggested that homing was accomplished by use of orientating information observed during the outward movements from the shelters.

**CRCP, CRU, J**

Homing, crabs, *Thalamita crenata*, Mida Creek, marine reserve

028

**Cannicci S, Dahdouh-Guebas F, Anyona D, Vannini M (1996). Natural diet and feeding habits of *Thalamita crenata* (Decapoda: Portunidae). *Journal of Crustacean Biology* 16(4): 678 - 683.**

The swimming crab, *Thalamita crenata* is a common species in the mangroves of East Africa. The feeding ecology of this species was investigated in Mida Creek by observations of the gut contents of individuals collected in 1992. Results showed that the species was a generalist predator feeding mainly on bivalves and other crustaceans. The stomach fullness indicated that the crabs' feeding activity was highest during the day and that feeding intensity was also affected by the tides being higher during spring than neap tides. The authors concluded that given the abundance of the crab in Mida creek, the species played an important ecological role in the food web of the Creek.

**CRCP, MAN, CRU, J**

Predation, crab, *Thalamita crenata*, Mida Creek, marine reserve

029

**Cannicci S, Ruwa RK, Ritossa S, Vannini M (1996) Branch-fidelity in the tree crab *Sesarma leptosoma* (Decapoda, Grapsidae). *Journal of Zoology* 238: 795 – 801.**

The crab *Sesarma leptosoma* is the only species of crab that can climb mangrove trees in East Africa. The behaviour of this species was investigated in Mida Creek, by observations at stations built on *Rhizophora mucronata* trees. Results showed that crabs used the same feeding sites, the migration patterns to the feeding sites were constant and crabs fed mainly on mature fresh mangrove leaves and utilized fresh water accumulated on leaf-buds. The authors suggested that the high level of fidelity to feeding sites was more related to the chances of finding leaf-buds that were rare and patchily distributed than to finding fresh leaves for feeding which were relatively abundant.

**CRCP, CRU, J**

Site fidelity, crabs, *Sesarma leptosoma*, Mida Creek, marine reserve

030

**Cannicci S, Ritossa S, Ruwa RK, Vannini M (1996) Tree fidelity and hole fidelity in the tree crab *Sesarma leptosoma* (Decapoda, Grapsidae). *Journal of Experimental Marine Biology and Ecology* 196: 299-311.**

The grapsid crab *Sesarma leptosoma* resides amongst the roots of mangrove crabs in East

Africa. This study investigated the fidelity of this crab to mangrove trees at Gazi Bay and Mida Creek. Results of mark and release experiments showed that individuals translocated 7 m away from their original tree were able to return within a few days but not when translocated up to 12 m away. Observations of marked individuals also showed homing to root crevices where the crabs hid when not foraging during the day. The authors concluded that the high tree fidelity and crevice homing behaviour were adaptations against predation.

**KMFRI, CRCP, MAN, CRU, J**

Homing, *Sesarma leptosoma*, tree fidelity, Gazi Bay, Mida Creek, marine reserve

**031**

**Cannicci S, Ruwa RK, Vannini M (1997) Homing experiments in the tree-climbing crab *Sesarma leptosoma* (Decapoda, Grapsidae). *Ethology* 103 (11): 935 – 944.**

The mangrove climbing crab *Sesarma leptosoma* migrates daily from branches to feed at the roots of mangrove trees. This study conducted experiments to test whether visual or chemical cues were used to orient the crabs at Mida Creek. Results showed that alteration of chemical cues did not change the crabs orientation neither did the placement of artificial junctions along the branches. The authors suggested that *S. leptosoma* did not rely on chemical or visual cues from the substrate but on visual information including the sun's position and memory of previous pathways.

**CRCP, KMFRI, CRU, J**

Orientation cues, *Sesarma leptosoma*, Mida Creek, marine reserve

**032**

**Cannicci S, Ruwa RK, Guigglioli M, Vannini M (1998) Predatory activity and spatial strategies of *Epixanthus dentatus* (Decapoda: Oziidae), an ambush predator among the Mangroves. *Journal of Crustacean Biology* 18(1): 57 -63.**

Xanthoid crabs are common predators in mangrove swamps of East Africa. Their effect on prey species was studied at Mida Creek by observations of the predatory species *Epixanthus dentatus* to determine the impacts on prey behaviour. Results showed that *E. dentatus* fed primarily on slow moving invertebrates mainly at night using an 'ambush' technique. The crab restricted its feeding to within 3m radius of individual dens amongst the mangrove roots. Some prey species such as various grapsid crabs reduced their climbing activity when *E. dentatus* were most active indicating the impact of their predatory behaviour on mangrove prey species.

**CRCP, CRU, J**

Predation, *Epixanthus dentatus*, Mida Creek, marine reserve

**033**

**Cannicci S, Fratini S, Vannini M (1999) Short-range homing in Fiddler Crabs (*Ocypodidae*, Genus *Uca*): A homing mechanism not based on local visual landmarks. *105* (10): 867 – 880.**

The fiddler crabs *Uca lactea annulipes* and *Uca vocans hesperiae* live in the mangrove forests of East Africa. This study investigated the use of space by these co-habiting species. The results showed a defined use of space with *U. l. annulipes* occurring higher in the shore level than *U. v. hesperiae*. Individuals showed different uses of space depending on sex, females tended to stay close to burrows but males of the species differed with *U. l. annulipes* staying close to burrows and *U. v. hesperiae* foraging further away from burrows. In displacement experiments, both species were not able to return to their burrows indicating only short-range homing ability that was not dependent on local visual landmarks.

CRCP, CRU, J

Fiddler crabs, *U. I annulipes*, *Uca vocans hesperiae*, Mida Creek, marine reserve

034

**Cannicci S Morino L, Vannini M (2002) Behavioural evidence for visual recognition of predators by the mangrove tree climbing crab *Sesarma leptosoma*. *Animal Behaviour* 63: 77 – 83.**

This study investigated the visual ability of the tree climbing mangrove crab *Sesarma leptosoma* to detect danger such as predators. Different dummies were presented to *S. leptosoma* during their daily migrations up and down the trees and their responses were noted. Results showed that *S. leptosoma* stopped normal migratory activity only when they visually detected the open claws of the predator. The authors concluded that the crab could perceive shape, could distinguish motionless objects of different shapes and could associate shapes with danger.

KMFRI, CRU, MAN, J

Crab, visual detection, Mida Creek, marine reserve

035

**Cannicci S, Fratini S, Vannini M (2010) Use of time, space and food resources in the mangrove climbing crab *Selatium elongatum* (Grapsidae: Sesarminae). *Marine Biology* 135 (2): 335 – 339.**

The mangrove dwelling crab *Selatium elongatum* occurs in mangrove forests in East Africa. This study investigated the activity and use of space by this crab in Mida Creek. Results showed a high adaptation to living on mangrove trees. The crab fed on floating algae at night and during the day but was most active at high tide on the tree trunks just above the high water mark. A comparison with other *sesarminae* crabs in East Africa showed that despite little diet differentiation, there was no niche overlap due to horizontal and vertical spatial partitioning and differences in the activity rhythms of individual species.

CRCP, CRU, J

Crab, feeding, activity pattern, *Selatium elongatum*, Mida Creek, marine reserve

036

**Carreiro-Silva M (1999) Echinoid bioerosion and herbivory on Kenyan coral reefs: The role of Marine Protected Areas. MSc. thesis, University of Wales, UK, 54 pp.**

The relative importance of protection on the rates of bioerosion and herbivory by echinoid (sea urchin) species on reefs in Kenya was investigated in this MSc. thesis. Rates of bioerosion and herbivory were measured in the Malindi, Watamu, Mombasa marine parks, Ras Iwatine in the Mombasa marine reserve and at Vipingo, Kanamai and Diani that are unprotected by laboratory gut content analysis and gut evacuation experiments in the field, using exclusion cages. The rates of bioerosion were greater than herbivory and proportional to the body size of the urchin species. The large bodied *Echinothrix diadema* had the highest bioerosion and herbivory rates followed by *Diadema setosum* and *D. savignyi*. *E. mathaei* had the highest rates of bioerosion and herbivory on unprotected reefs due to its high abundances while *E. diadema* was the main echinoid herbivore and bioeroder in protected reefs. The author concluded that echinoid grazing affects almost 50% of the total calcification of the reef in unprotected areas, 15% in intermediate and only 1% in protected areas.

**CRCP, BIOE, SU, T**

Bioerosion, herbivory, sea urchins, *Echinometra mathaei*, *Diadema setosum*, *Diadema savignyi*, *Echinothrix diadema*, Malindi, Watamu, Mombasa, Ras Iwatine, Vipingo, Kanamai, Diani, marine park, marine reserve

037

**Carreiro-Silva M, McClanahan TR (2001) Echinoid bioerosion and herbivory on Kenyan coral reefs: the role of protection from fishing. Journal of Experimental Marine Biology and Ecology 262: 133-153.**

This paper investigates the role of marine protected areas in mediating echinoid herbivory and bioerosion on reefs in Kenya. The paper is based on the research that was carried out by Carreiro-Silva for a Masters thesis annotated in the previous reference (above).

**CRCP, BIOE, SU, J**

Bioerosion, sea urchins, coral reefs, grazing, Malindi, Watamu, Mombasa, Ras Iwatine, Vipingo

038

**Coast Development Authority (1996) Towards integrated management and sustainable development of Kenya's coast. ICAM Kenya report. 77 pp.**

Integrated coastal area management (ICAM) has been advocated as an effective management tool for decades. This report summarizes the process and results of the first ICAM pilot project in the Nyali-Bamburi-Shanzu area that is adjacent to the Mombasa MPA. The ICAM process culminated in the development of a strategy through a broad-based participatory process that was undertaken under the leadership of the Coast Development Authority (CDA). The strategy summarized the key issues, identified the main stakeholders in the area and detailed several actions that needed to be addressed to enhance coastal management.

**CDA, CRCP, MGT, R**

Integrated Coastal Area Management, Coast Development Authority, Nyali, Bamburi, Shanzu, MPA

039

**Coast Development Authority (2000) Moving coastal management forward: Kenya progress reports 1994-1999. Coast Development Authority Mombasa, Kenya. 14 pp.**

This report was an appraisal of the performance of the Integrated Coastal Area Management (ICAM) process with special reference to experiences in implementing ICAM activities at Nyali-Bamburi-Shanzu and Diani-Chale pilot sites. ICAM activities that were completed included small infrastructure developments at the Jomo Kenyatta public beach adjacent to the Mombasa MPA for fishers, community boat operators and beach users. In Diani, the Diani-Chale Management Area Committee was established comprising about 25 representatives of the main interest groups in the area.

**CDA, CRCP, MGT, R**

Integrated coastal management, Nyali, Bamburi, Shanzu, Diani, Chale, ICAM,

040

**Cinner JE, Daw T, McClanahan TR (2008) Socioeconomic factors that affect artisanal fishers' readiness to exit a declining fishery. Conservation Biology 23 (1): 124 -130.**

Despite accumulating evidence of declining fish stocks in many poor nations, little is known about how fishers may respond to declines in catch, information that is crucial to developing

effective management strategies. This study investigated the readiness of Kenyan fishers (including in the Mombasa and Malindi MPA) to stop fishing under hypothetical scenarios of declines in catch and how socioeconomic conditions influenced their decisions. Results showed that exiting a fishery was highly dependent on the magnitude of decline in catch and the socio-economic level of fishers as willingness to stop fishing increased with the increase in material style of life and a greater number of occupations. Fishers from poorer households were less likely to exit even a severely declining fishery, which supported previous literature on poverty traps. The authors recommended programs that generated wealth and employment opportunities directed at the poorest fishers to help reduce fishing effort on overexploited fisheries but cautioned that such interventions would require an understanding of the socioeconomic context in which fishers operated to be successful.

**CRCP, COM, J**

Artisanal fishery, coral reef, livelihoods, poverty trap, socioeconomics, Mombasa, Malindi, MPA

**041**

**Cinner JE, McClanahan TR, Abunge C, Wamukota AW (2009) Human dimensions of conserving Kenya's coral reefs. In: Hoorweg J, Muthiga N (eds) Advances in coastal ecology: People, processes and ecosystems in Kenya. African Studies Centre, African Studies Collection Vol 20:60-78.**

Conservation theory and practice has developed towards a participatory model of creating partnerships with resource users, hence the need to understand people and the key socio-economic factors that drive their decisions. This study carried out a socio-economic assessment of nine coastal communities between Mombasa and Malindi on the Kenyan coast between June and August 2005. Results showed considerable variability in the dependence on marine resources with smaller communities having a high percentage (60%) of households engaged in fishing, but this reduced if the communities were close to highly urbanized areas. Households that fished generally ranked fishing as their most important occupation. Appreciation of the benefits of MPAs was lowest near areas that bordered MPAs and the use of illegal gears especially beach seining was common in these areas. The authors concluded that the poor understanding of the factors that influence fisheries and the means to improve them and the marine environment constrained the ability to effectively manage fishing in this area.

**CRCP, COM, P**

Community, households, coral reef, livelihood, Malindi, Mombasa, marine reserve

**042**

**Cinner JE, Wamukota A, Randriamahazo H, Rabearisoa A (2009) Towards institutions for community-based management of inshore marine resources in the Western Indian Ocean. Marine Policy 33 (3): 489-496.**

Throughout the western Indian Ocean, inshore marine resources are increasingly overexploited and community based management interventions are touted as the most viable strategy to improve their management. However, community based programs are established under varying political, socioeconomic and biophysical conditions that can affect the success of co-management. This study compared the development of co-management programs in Kenya particularly the beach management units, and Madagascar against ten key design principles thought to regulate the success of such interventions. Results

showed that the current programs adopted frameworks that were designed for terrestrial and lake systems and were unsuitable for the management of marine systems. The authors recommended a co-management design that reflects the diverse and dynamic nature of the marine environment.

**CRCP, COM, J**

Co-management, marine resources, Beach Management Units

043

**Cinner JE, McClanahan TR, Graham NAJ, Pratchett MS, Wilson SK, Raina JB (2009) Gear-based fisheries management as a potential adaptive response to climate change and coral mortality. *Journal of Applied Ecology* 46(3): 724-732.**

Understanding how to manage fisheries across climate-induced bleaching and coral mortality events may influence management interventions and the potential of reefs to recover. This study examined the effectiveness of the management of fishing gears in artisanal coral reef fisheries at 15 sites in Papua New Guinea and Kenya (including in marine reserves). Results showed that a low percentage (6%) of targeted fishes were susceptible to the immediate effects of coral mortality and that reduced habitat structure affected 56% of targeted species. Although a relatively high proportion (25%) of targeted species had feeding characteristics (reef scrapers/excavators and grazers) that contributed to the recovery of coral reefs, there was no clear relationship between these species with gear type. On the other hand, a high proportion of bleaching susceptible but recovery-enabling species were taken by spear guns and traps while line fishing caught the lowest proportion of these species. The authors recommended that selectively banning or restricting fishing gears such as spear guns and traps was a potentially powerful tool for reducing the detrimental ecosystem effects of climate change disturbances on coral reefs.

**CRCP, FIS, J**

Adaptive management, artisanal fishery, climate change, coral bleaching, coral reef, herbivory, spear guns, traps, marine reserve

044

**Cinner JE, McClanahan TR, Daw TM, Graham NAJ, Maina J, Wilson SK, Hughes TP (2009) Linking social and ecological systems to sustain coral reef fisheries. *Current Biology* 19:206-212.**

Coral reefs in the western Indian Ocean are increasingly overexploited and degraded, but the socioeconomic conditions that drive this exploitation are poorly studied. In this paper, the relationship between human population density, an index of socioeconomic development, coral reef complexity and fish biomass are compared in five countries (Kenya, Madagascar, Mauritius, Seychelles, Tanzania). Results showed that while fish biomass in fished sites was lower in sites of high human population, biomass showed a much stronger and U-shaped relationship with socioeconomic development. Reef fish biomass was four times lower at sites with intermediate economic development than at sites with high or low development. In closures however, fish biomass was three times higher than in fished sites and showed no association with socioeconomic development. The authors concluded that an integrated approach that includes marine protected areas and improving socioeconomic conditions was needed for sustaining coral reef fisheries and reducing reef degradation.

**CRCP, FIS, J**

Fisheries, coral reefs, economic development, reef complexity, fish biomass, MPA

045

**Cinner JE (2010) Poverty and the use of destructive fishing gear near east African marine protected areas. *Environmental Conservation* 36(4): 321-326**

The socioeconomic conditions of fishers are often thought to affect fisher behaviour and their use of destructive gears and understanding this relationship can inform management interventions. This concept was tested by examining the socioeconomic conditions and the relationship with the use of the destructive beach seine nets by fishers at sites in Kenya (Mombasa and Malindi marine reserves) and in Tanzania (Dar-es-salaam MPA). The study was conducted through systematic sampling of households in villages adjacent to these MPA using 13 socioeconomic conditions to characterize the households. Results showed that fishers who used destructive gears were poorer, had significantly lower fortnightly expenditures and were significantly younger and less likely to own capital in the fishery. The author concluded that the use of destructive gears is driven by poverty and that managing the use of these gears would require a combination of improving the socioeconomic conditions of fishers, strengthening the evolving community based management systems such as the Beach management units in Kenya and gear exchanges and micro financing to empower fishers to use legal gears.

**CRCP, COM, FIS, J**

Artisanal fishing, beach seines, destructive fishing, socioeconomic, poverty, Malindi, Mombasa, marine reserve

046

**Cinner JE, McClanahan TR, Wamukota A (2010) Differences in livelihoods, socioeconomic characteristics, and knowledge about the sea between fishers and non-fishers living near and far from marine parks on the Kenyan coast. *Marine Policy* 34:22-28.**

Fisheries management in the tropics is often ineffective because of a failure to incorporate knowledge of the socioeconomic conditions of fishers and how these drive fisher behaviour. This study undertook to assess the socioeconomic conditions of artisanal fishers in Kenya and their knowledge of the sea. A total of 434 respondents were surveyed in nine communities between Mombasa and Malindi including communities that fished within marine reserves. Results showed that fishers were poorer on average than non-fishers, had higher occupational diversity, more community participation, and higher knowledge about the sea than non-fishers. Fishers living adjacent to MPAs had a higher socioeconomic status, and more knowledge about the sea than fishers living further away, which the authors interpreted as due to the close proximity of urban centres to the MPAs studied. The author concluded that fishers had a distinct character that differentiated them from non-fishers and that this should be taken into consideration when developing management interventions.

**CRCP, FIS, COM, J**

Artisanal fishery, traditional knowledge, Malindi, Mombasa, marine reserve

047

**Cole JE, Robert BD, McClanahan TR, Muthiga NA (2000) Tropical Pacific forcing of decadal SST variability in the Western Indian Ocean over the past two centuries. *Science* 287: 617-619.**

Coral cores are increasingly being used to study climatic events across decadal periods. This study summarizes the results derived from the annual skeletal record of a 194 - year massive *Porites* coral head growing at Malindi marine park, Kenya. Results showed that the coral preserved a history of sea surface temperature (SST) change that compared favourably

with instrumental and proxy temperature records of tropical Pacific climate variability over interannual to decadal periods. The record showed a warming of ~1.3°C since the early 1800s. The results suggested that the tropical Pacific, which was also expected to influence other regions with strong El Niño Southern Oscillation (ENSO) connections, influenced the observed decadal climate variability within the Western Indian Ocean.

**CRCP, CLI, OG, J**

Coral core, El Niño Southern Oscillation, sea surface temperature, Malindi, marine park

**048**

**Coppejans E, Beeckman T (1990): *Caulerpa* (Chlorophyta, Caulerpales) from the Kenyan coast. *Nova Hedwigia* 50: 111 - 125.**

This paper describes the species of the green algae of the genus *Caulerpa* that were collected along the Kenyan coast including in Mida Creek. Twelve species of *Caulerpa* were collected and described and a key provided including illustrations of the species.

**CRCP, AG, J**

Algae, *Caulerpa*, Mida Creek, marine reserve

**049**

**Cox PA (1991) Hydrophilous pollination of the dioecious seagrass *Thalassodendron ciliatum* (Cymodoceaceae) in Kenya. *Biotropica* 23 (2): 159 – 165.**

The seagrass *Thalassodendron ciliatum* is one of the dominant seagrass species in East Africa. In Mida Creek it forms large beds in the lagoon. The flowering of this species was observed in Mida to coincide with extreme low spring tides. Flowers were released just before the low tide began to return, flowers then floated to the surface released filamentous pollen, which floated on the water surface where it mixed with the female flowers a category two hydrophilous pollination system. This study was the first to describe the flowering of a seagrass species in Kenya.

**CRCP, SG, J**

Seagrass, pollination, *Thalassodendron ciliatum*, Mida Creek, marine reserve

**050**

**Crabbe M, McClanahan TR (2006) A Biosocioeconomic evaluation of shipwrecks used for fishery and dive tourism enhancement in Kenya. *Western Indian Ocean Journal of Marine Science* 5 (1): 35-53.**

Shipwrecks are a unique component of the dive and fishery industry but have been poorly studied in East Africa. This study aimed to assess the socioeconomic contribution of the Globestar, in the Mombasa marine reserve, the MV Dania, in the Mombasa marine park and the MV Alpha Funguo, in the Diani marine reserve. Social and economic data were collected for eight weeks from May to July 2004, while fisheries catch data for Mombasa and Diani were collated from the Coral Reef Conservation Project (CRCP) database. The results showed a short-term increase in catch for the speargun fishers estimated at US\$ 1000 annually although the Fishers perceived no benefits from the shipwreck. The Dive industry was more positive about the shipwrecks and derived an estimated US\$75,000 to 174,000 annually. The study demonstrated that Kenyan shipwrecks were effective in generating economic and social benefits through the dive industry and recommended enhanced involvement of dive operators in the management of shipwreck sites to maximize maintenance costs and minimize resource use conflicts.

**CRCP, FIS, J**

Artificial reefs, shipwreck, ecotourism, fisheries enhancement, Mombasa, Diani, marine reserve, marine park

051

**Cros A (2002) Comparison of damage caused by beach seining vs. corallivory on coral transplants in Mombasa, Kenya. MSc. thesis, University of Newcastle, UK 40 pp.**

Despite a ban on the use of beach seines since 2001, this destructive gear continued to be used in Kenyan reef lagoons. This study aimed to experimentally measure the damage caused by beach seines in fished areas compared to damage caused by predation on corals (corallivory). Fragments of the corals *Porites palmata* and *P. lutea* were transplanted into a 'no-take' site in the Mombasa marine park, a 'restricted fishing' site at Ras Iwatine and a 'beach seining' site off Nyali Beach in the Mombasa marine reserve. Estimates of percent mortality from corallivory by fish or breakage from beach seining were calculated for 57 days. The massive species *P. lutea*, showed less susceptibility to disturbance and no difference in mortality rates between the three sites. Branching *P. palmata* were more affected by corallivory within the no-take MPA than by beach seining or in the restricted fishing site. The author recommended experiments of longer duration to differentiate between long and short-term effects and the rates of recovery for each management regime.

**CRCP, COR, T**

Beach seining, corallivory, coral transplants, *Porites lutea*, *P. palmata*, Mombasa, Ras Iwatine, Nyali, marine park, marine reserve

052

**Cros A, McClanahan TR (2003) Coral transplant damage under various management conditions in the Mombasa Marine National Park, Kenya. Western Indian Ocean Journal of Marine Science 2 (2): 127-136.**

This paper is based on the research that was carried out by A. Cros for a Masters thesis annotated in the previous reference (above).

**CRCP, COR, T**

Beach seining, corallivory, coral transplants, *Porites lutea*, *P. palmata*, Mombasa, Ras Iwatine, Nyali, marine park, marine reserve

053

**Dahdouh-Guebas F, Verneirt M, Tack JF, Koedem N (1997) Food preferences of *Neosarmatium meinerti* de Man (Decapoda: Sesarminae) and its possible effect on the regeneration of mangroves. Hydrobiologia 347: 83-89.**

Mangrove restoration programs are often touted as effective tools for the management of mangrove forests. However, the factors that enhance or inhibit regeneration of mangrove forests are poorly understood. In this study, the impacts of crab predation on mangrove propagules were investigated at Mida Creek and Gazi Bay between 1991 to 1992. Stomach contents of the common and abundant decapod crab *Neosarmatium meinerti* were examined after individuals were provided a choice of leaves or propagules of different mangrove species. Results showed that *N. meinerti* had no specific preference for various mangrove species except for a slight propensity for the propagules of *Rhizophora mucronata*. The authors concluded that the non-specificity of the feeding behaviour of this species posed a threat to successful regeneration or restoration of mangroves using seedlings or propagules.

KMFRI, CRCP, MAN, CRU, J

Mangrove regeneration, food preference, propagules predation, *Neosarmatium meinerti*, Gazi Bay, Mida Creek, marine reserve

054

**Dahdouh-Guebas F, Giuggioli M, Oluoch A, Vannini M, Cannicci S (1999) Feeding habits of non-ocypodid crabs from two mangrove forests in Kenya. *Bulletin of Marine Science* 64 (2): 291 – 297.**

The feeding behaviour of crabs is known to affect the energy flow and nutrient recycling in mangrove crabs. The effects of individual species is not known however in East African mangrove forests. This study examined the stomach contents of eleven species of crabs collected from Gazi Bay and Mida Creek. Results showed that most species were generalist being neither wholly herbivorous nor wholly carnivorous. The authors concluded that most of the mangrove crabs were opportunistic feeders feeding on a variety of items in the mangrove forests.

KMFRI, CRCP, MAN, CRU, J

Stomach contents, crabs, mangrove, Gazi, Mida Creek, marine reserve

055

**Dahdouh-Guebas F, Mathenge C, Kairo JG, Koedem N (2000) Utilization of mangrove wood products around Mida Creek (Kenya) amongst subsistence and commercial users. *Economic Botany* 54 (4) 513-527.**

The mangrove forests of Mida Creek are of economic, ecological, and environmental value to the local communities yet little is known about the level of human reliance on the mangrove resources in the Creek. A socioeconomic survey was carried out of 116 households living adjacent to the creek. Results showed that mangroves were a major resource of wood for house construction, fuel wood, charcoal, and boat building as well as for medicinal purposes. The mangrove species *Rhizophora mucronata*, *Ceriops tagal*, and *Bruguiera gymnorrhiza* were the major resources for house construction and fuel wood, while *Sonneratia alba* and *Xylocarpus granatum* were reported to be useful for boat building and medicinal uses respectively. Overexploitation and banning of mangrove export led to the drastic depletion of the supply of wood resulting in the communities using other non-traditional sources of wood and increases in poaching. The authors conclude that local utilization data is most useful for designing management interventions that meet the requirements for sustainability of a mangrove forest.

KMFRI, MAN, J

Utilization, mangroves, wood products, *Rhizophora mucronata*, *Ceriops tagal*, *Bruguiera gymnorrhiza*, *Sonneratia alba*, *Xylocarpus granatum*, Mida Creek, marine reserve

056

**Dahdouh-Guebas F, Kairo JG, Jayatissa LP, Cannicci S, Koedam N (2002) An ordination study to view vegetation structure dynamics in disturbed and undisturbed mangrove forests in Kenya and Sri Lanka. *Plant Ecology* 161: 123 – 135.**

This study investigated the difference between the composition and structure of exploited and undisturbed mangroves forests in Sri Lanka and Kenya (Gazi Bay and Mida Creek). Adult, young and juvenile trees were sampled in 25 sample points in each site. Environmental parameters including salinity, light intensity, land/water ratio, abundance of herbivorous

crabs and snails were also recorded. Results showed that while no single environmental factor contributed to the total variation between sites, the abundance of propagule predators especially crabs and the water/land ratio contributed significantly to the variability between sites. The authors concluded that the dynamic or non-dynamic nature of forests and the ability to rehabilitate should be taken into consideration in forest management.

**KMFRI, MAN, J**

Disturbance, forestry, mangroves, rehabilitation, propagule predation, Mida Creek, marine reserve

**057**

**Dahdouh-Guebas F, Verneirt M, Cannicci S, Kairo JG, Tack JF, Koedem N (2002) An exploratory study on grapsid crab zonation in Kenyan mangroves. *Wetlands Ecology and Management* 10: 179-187.**

Grapsid crabs are thought to play an important role in mangrove forests in East Africa. In this study, the relationship between the distribution of mangrove species and of grapsid species is examined at Mida creek and Gazi Bay. Zonation of mangrove and crab species were noted along transects and the relationship was analyzed using detrended correspondence analysis. Results showed that although crab species were grouped according to the dominant mangrove zones, there was no specific factor that controlled this pattern. The authors conclude that the relationship between crab and mangrove species was complex and controlled by multiple factors.

**KMFRI, CRCP, MAN, CRU, J**

Grapsid crab, distribution, mangrove zonation, Gazi, Mida Creek, marine reserve

**058**

**Dahdouh-Guebas F, Verheyden A, Kairo JG, Jayatissa LP, Koedem N (2006) Capacity building in tropical coastal resource monitoring in developing countries: A re-appreciation of the oldest remote sensing method. *International Journal of Sustainable Development and World Ecology* 13: 1.**

This brief note discussed the use of aerial photographs of mangroves using data from Kenya (Gazi Bay and Mida Creek) and Sri Lanka and the consistency and constraints of using aerial imagery. The authors suggested that some commonly used identification keys such as 'ecological positions' were informative, that attributes for particular species were robust and could be more widely applicable than previously assumed, but emphasized the need to do ground-truthing for verification.

**CRCP, KMFRI, MAN, J**

Aerial photos, mangroves, Mida Creek, marine reserve

**059**

**Darling ES, McClanahan TR, Cote IM (2010) Combined effects of two stressors on Kenyan coral reefs are additive or antagonistic, not synergistic. *Conservation Letters* 3: 122-130.**

Marine ecosystems are affected by natural as well as anthropogenic disturbances. These disturbances may act synergistically yet few studies have tested this concept. Using a long-term dataset of hard coral cover, this study examined the effects of two stressors, fishing and bleaching that occurred in 1998 on the Kenyan coast. Seven sites including the fully protected Malindi, Watamu and Mombasa marine parks, and fished sites at Vipingo, Kanamai, Ras Iwatine were assessed. Results showed that although fishing caused a 51%

decline and bleaching a 74% decline in coral cover, the effects were not synergistic but were either antagonistic or weakly additive. The authors concluded that the response indicated that bleaching was the dominant driver and although protection could confer some benefits to reef ecosystems, these were reduced due to climate change.

**CRCP, COR, J**

Climate change, fishing, coral reefs, multiple stressors, Malindi, Watamu, Mombasa, Vipingo, Kanamai, Ras Iwatine, marine park, marine reserve

**060**

**Davies JG (2002) The attitudes of fishermen and management staff towards three marine protected areas. MSc. thesis, University of Newcastle, UK 24 pp.**

The relationship between people and protected areas are a central issue for protected areas world-wide. This relationship is often shaped by peoples' perceptions of protected areas. In this study, the attitudes of fishers living adjacent to three MPAs in Kenya (Malindi-Watamu, Mombasa and Diani) were compared with those of staff of the MPAs. Data was collected primarily through questionnaires designed to measure the attitudes of fishers and MPA managers and staff towards the perceived benefits of marine reserves (restricted fishing area) and marine parks (no-take areas). A higher percentage of fishers (89%) perceived no benefit to fishers or their communities due to the existence of the MPA than management staff (32%). In contrast, >65% of fishers and 100% of staff believed that Kenya benefited from MPAs. The author concluded that there is a need for a more integrated approach in which the management body better articulates the links between conservation efforts, food security and livelihoods. The study recommended strengthening relationships between management authorities and other stakeholders.

**CRCP, COM, T**

Fishermen, management, MPAs, perceptions, Malindi, Watamu, Mombasa, Diani

**061**

**De Sanctis A, Biddau L, Fasola M (2005) Post-migratory care of young by Crab Plovers *Dromas ardeola*. IBIS 147 (3): 490 – 497.**

The feeding behaviour of the juveniles of the Crab Plover *Dromas ardeola* which is the only waterbird species known to take care of young long after the post-reproductive migration period was studied in Mida Creek in 1998. Results showed that juveniles begged frequently for food and depended partly on adults at the beginning of the wintering period but were able to fully provide for themselves by the end of that period. The authors suggested that the prolonged provision to juveniles was due to the need to migrate from the breeding grounds quickly if environmental conditions became extreme. This was crucial because while adult Crab Plovers were able to overwinter in several areas, juveniles required wide beaches whose distribution was more restricted.

**CRCP, BD, J**

Crab Plovers, juveniles, feeding, *Dromas ardeola*, Mida Creek, marine reserve

**062**

**Dusek E (2000) Effects of fishing gear on coral reef recovery in Kenya following the El-Niño induced coral bleaching. MSc. thesis, Stanford University, USA, 41 pp.**

Overfishing and use of destructive fishing gear can greatly influence fishing and coral

reef ecology and negatively impact the process of recovery. These impacts were tested by measuring coral recruitment at 26 sites under different fishing regimes; beach seining, traditional fishing, and no fishing. Damage to adult coral colonies were also measured for massive, encrusting and branching corals as well as for three size groups of corals: small, medium and large. Results showed that the total number of coral recruits did not differ significantly between fishing regimes. The author suggested that variation between sites due to benthic complexity and geographic location may have disguised any differences in recruitment. Damage to corals however, was size dependent increasing with coral size in the massive and encrusting forms and large branching corals in beach seined areas showed significantly more damage than smaller branching colonies. The author concluded that the low abundance of large corals in beach-seined areas indicated that beach seining was particularly destructive to large corals.

**CRCP, COR, T**

Coral recruitment, fishing gear, coral reef recovery, Mombasa, marine reserve, marine park

063

**Eklöf SJ, Fröcklin S, Lindvall A, Stadlinger N, Kimathi A, Uku JN, McClanahan TR (2009) How effective are MPAs? Predation control and 'spill-in effects' in seagrass-coral reef lagoons under contrasting fishery management. *Marine Ecology Progress Series* 384: 83-96.**

Although marine protected areas (MPAs) have been shown to be an effective management tool in coral reefs, few studies have been carried out in seagrass beds. The sea urchin *Tripneustes gratilla* has been linked to overgrazing in seagrass beds within and outside MPAs in Kenya. This study evaluated the role of MPAs in facilitating predation control over sea urchins in the Mombasa and Watamu MPAs during two sampling periods in 2006. The results showed a negative correlation between *T. gratilla* density and predation pressure (from sea stars, fish and gastropods) in seagrass beds indicating the importance of predators in *T. gratilla* population control. However, there was no significant effect due to protection in seagrass beds. The authors postulated that this could be due to (1) low predator densities in the younger Mombasa MPA; (2) 'spill-in' of aggregated *T. gratilla* into the older Watamu MPA; and (3) the buffering effect of seagrass canopies on predation. The study recommended additional interventions such as banning fishing of urchin predators and reduced nutrient input from land runoff to protect seagrass beds.

**CRCP, SG, J**

Trophic cascades, *Tripneustes gratilla*, *Thalassodendron ciliatum*, Malindi, Mombasa, marine park

064

**Emerton L (1999) Financing the management of Kisite marine park and Mpunguti marine national reserve through partnership with stakeholders. IUCN Nairobi, Kenya. 36 pp.**

Conservation agencies face challenges in raising sufficient revenues for operating expenses. This case study of the Kisite/Mpunguti MPA highlighted the economic challenges of MPAs and proposed an innovative model for park financing and management. The study showed that the usual sources of revenue including donor funds and government subventions which had always been limited in both amount and scope, had declined in real terms. It illustrated how the dependence of multiple stakeholders on park resources presented a number of opportunities for simultaneously enhancing the financial sustainability, increasing local and private economic incentives for marine conservation and spreading both the costs and

benefits of park management between different stakeholder groups. The author concluded that community involvement and private sector participation in the management process would increase the economic benefits accruing from marine resources conservation and lower the economic costs incurred in the form of expenditures and opportunity costs.

**CRCP, KWS, MGT, R**

Management, financing, stakeholders, Kisite, Mpunguti, marine park, marine reserve

**065**

**Emerton L (1999) Economic tools for the management of marine protected areas (MPAs) in East Africa. IUCN, Nairobi. 22 pp.**

This report documented the discussions from a workshop organized by IUCN-EARO on economic tools for the management of MPAs. Since economic factors impacted the marine environment through the traditional market forces of demand and supply, the application of economic tools in MPA management were addressed. The report reviews several economic tools including tools to address issues of equity, efficiency and sustainability. The report recommends the use of economic tools to assess the effectiveness of MPAs through measurement of parameters such as the economic costs of MPAs, valuing the benefits and costs and analyzing their distribution amongst the different stakeholders.

**CRCP, MGT, R**

Management, MPAs, economic tools, East Africa

**066**

**Emerton L, Tessema Y (2001) Economic constraints to the management of marine protected areas: the case of Kisite Marine National Park and Mpunguti Marine National Reserve, Kenya. 26 pp.**

With the increasing interest in the establishment of MPAs in the western Indian Ocean, understanding the challenges to financing of their operations has become crucial. This report documented the findings of a study based on a preliminary scoping of the financing mechanisms for the Kisite and Mpunguti marine park and reserve in Kenya. The review showed that the MPA contributed significantly to the welfare of the local community by offering direct, indirect, option and existence benefits. A high percentage (80%) of the households around the MPA depended on the marine reserve for their livelihood. Tourism yielded the highest economic rent while indirect benefits such as coastal protection, accounted for 2.1% of the total economic value of the MPA. However the management of the MPA was hampered by an insecure financing base and lack of willingness among the local communities to conserve the resource in the face of low rates of return. This resulted in increasing the opportunity costs of conservation. The authors recommended the implementation of multiple innovative financial instruments including a mooring tax, fishing tax, forging stakeholder partnerships and a fair sharing of costs and benefits.

**CRCP, KWS, MGT, R**

Management, financing, Kisite, Mpunguti, marine park, marine reserve

**067**

**Erfteemijer PLA, Mwakoyo D (1995) Information and management review of Malindi marine national park and reserve. Kenya Wildlife Service. 27 pp.**

This review was based on visits to the Malindi MPA during April 1995 after establishment of the KWS/Netherlands Wetlands Conservation and Training Program and constituted the first

review of management of the MPA. The review was based on interviews of a broad range of institutions, communities, and individuals involved in the management and the use of the Malindi MPA. The review included an analysis of the management structures, management information and infrastructure of the MPA and recommended several actions that could be undertaken in addressing the challenges of managing the MPA.

**KWS, MGT, R**

Management information, Malindi, MPA

**068**

**Erfteemeijer PLA, Mwakoyo D (1995) Infrastructural upgrading of Kenya's marine parks and reserves; an assessment justification and strategy. KWS/Netherlands Wetlands Conservation and Training Programme, Mombasa, Kenya. 50 pp.**

This report is based on an assessment of the infrastructural status of MPAs in Kenya. The assessment was carried out in 1995 and consisted of collection of information on existing infrastructure/equipment in each MPA, a review of the needs and requirements for new and additional infrastructure, equipments/infrastructure costs and a comparison of requirements and prices against the budget. The report concluded that the infrastructural needs outweighed the budget and recommended increased allocation to the MPA. The report formed the main justification and strategy for infrastructural development of Kenyan MPAs by the KWS/Netherlands Wetlands Conservation and Training Programme.

**KWS, MPA, R**

Infrastructure, MPAs, Kenya

**069**

**Evans LS (2008) Governing resilience: inclusion, knowledge and complexity in marine socio-ecological systems in Kenya. University of East Anglia. PhD. 267pp.**

Conventional resource management usually emphasizes control of exploitation or protection and specialised technical knowledge and decision-making directed by external rather than local agendas. These approaches often fail because they exclude stakeholder knowledge and experiences, require centralised decision-making and try to control socio-ecological systems that are complex and often unpredictable. This PhD. research study evaluated the effectiveness of the management of marine resources in Kenya using the Mombasa and Diani-Chale MPAs as case studies. Results from institutional analysis showed that local level interactions depended on a combination of institutional, socio-cultural, and historical factors as well as perceptions of ethics and collective rights. Although more complex and diverse knowledge was available at the national level, power dynamics and slow institutional reform reduced the potential for effective coastwide decision-making. The author noted however, the slow emergence of democratic and inclusive practises adapted by national management institutions.

**CRCP, MGT, T**

Management, institutional context, Mombasa, Diani-Chale, marine park, marine reserve.

**070**

**Evans L (2009) Understanding divergent perspectives in marine governance in Kenya. Marine Policy 33 (5): 784-793.**

The effectiveness of governance of marine resources depends on several factors including institutional conditions, their current and historical social and political contexts. This study

part of the PhD. dissertation of Evans (2008 detailed above) used a two-tiered stakeholder analysis to gauge the perspectives of different stakeholders in the Mombasa and Diani-Chale MPAs. The author concluded that since historical and contextual factors mediated how stakeholders perceived and responded to management they should be taken into consideration when developing management interventions.

**CRCP, MGT, J**

Management, institutional context, Mombasa, Diani-Chale, marine park, marine reserve.

**071**

**Fanshawe J (1992) Birding at Mida Creek. In: Bennun L, Gichuki C. Kenya Birds 1 (1): 21-22.**

Mida Creek is an important site for wintering birds on the Kenya Coast providing a habitat to a wide range of waders and terns. This brief article gives directions on the best sites for bird watching at Mida Creek, which lies within the Watamu marine reserve. It also provides useful contacts for support services such as boat hire and accommodation.

**KWS, BD, J**

Bird watching, Mida creek, Watamu

**072**

**Fasola M, Canova L, Biddau L (1996) Foraging behaviour of crab Plovers *Dromas ardeola* overwintering on the Kenya coast. Colonial Waterbirds 19: 207 – 213.**

Mida Creek is one of the main overwintering areas of the Crab Plover *Dromas ardeola* yet little is known about the behaviour of this bird in East Africa. This study investigated the feeding and foraging behaviour of this species at Mida. Results showed that roosting and foraging followed the tidal cycle and foraging occurred during the day and night and prey mainly consisted of crabs, snails and worms. The author concluded that the feeding behaviour of the crab plover was similar to the plovers of the genus *Charadrius* and *Pluvialis*.

**CRCP, BD, J**

Crab Plover, feeding behaviour, *Dromas ardeola*, Mida Creek, marine reserve

**073**

**Feraro PJ (2007) A global survey of sea turtle payment incentive programs. National Oceanic and Atmospheric Administration. 40pp.**

The use of economic incentives in sea turtle conservation is rare, but using performance based incentives is even rarer. This report reviews programs around the world including the Watamu Turtle Watch in the Malindi-Watamu MPA, the Kiunga marine national reserve conservation and development project a joint KWS/WWF project and Baobab Trust adjacent to the Mombasa MPA, that provide incentives for the conservation of sea turtles. Globally, the programs used three main mechanisms, conservation through sustainable exploitation, alternative livelihoods and goodwill gestures. The author concluded that the low costs of these schemes enabled longer-term conservation action for sea turtles.

ST, R

**074**

**Fleitmann D, Dunbar BR, McCulloch M, Mudelsee M, Vuille M, McClanahan TR, Cole JE, Eggins S (2007) East African soil erosion recorded in a 300 year old coral colony from Kenya. Geophysical Research Letters 34 (4) L04401.**

The impacts of soil erosion on the marine environment have been a subject of interest for

decades in Kenya. However, the lack of long-term continuous records has hampered an understanding of this problem. In this study, a 300-year Barium/Calcium record from cores of two Kenyan coral colonies (*Porites sp.*) collected in the Malindi MPA was evaluated. The record showed the dynamic history of soil erosion from the Sabaki River on the northern border of the Malindi MPA. Results showed that although sediment flux from the Sabaki River was relatively constant between 1700 and 1900, the rise in human settlements in the area starting with the British settlements in the 1900 and later due to steadily increasing population pressure on land use increased sediment flux that peaked between 1974 and 1980. The authors attributed the trend to the combined effects of dramatically increasing population, unregulated land use, deforestation and severe droughts in the early 1970's. The study concluded that although there were soil conservation measures along the Sabaki catchment, soil erosion would continue to be a challenge unless the socioeconomic conditions in the catchment area were dramatically improved.

**CRCP, COR, J**

Sabaki River, soil erosion, Barium, Calcium, *Porites sp.*, Malindi, marine reserve

075

**Flores AAV, Paula J, Dray T (2003) First zoeal stages of grapsoid crabs (Crustacea: Brachyura) from the East African coast. Zoological Journal of the Linnean Society 137 (3): 355 – 383.**

The larvae of 14 grapsoid species collected from East Africa including at Mida Creek were described in this study. The paper provided the first original descriptions of the larvae of *Grapsus fourmanoiri*, *G. tenuicrustatus*, *Pachygrapsus minutes*, *P. plicatus*, *Sarmatium crassum* and *Sesarma leptosoma* and redescrptions of the larvae of *Metopograpsus messor* and *Cardisoma carnifex*. The larvae of *Ilyograpsus paludicola* had a combination of characteristics that led the authors to suggest a removal of this species from the Grapsoidea family as previously suggested by other authors.

**CRCP, CRU, J**

Zoeal stages, *Grapsus fourmanoiri*, *G. tenuicrustatus*, *Pachygrapsus minutes*, *P. plicatus*, *Sarmatium crassum*, *Sesarma leptosoma*, *Metopograpsus messor*, *Cardisoma carnifex*, *Ilyograpsus paludicola*, Mida Creek, marine reserve

076

**Fratini S, Cannicci, Vannini M (2000) Competition and interaction between *Neosarmatium smithi* (Crustacea: Grapsidae) and *Terebralia palustris* (Mollusca: Gastropoda) in a Kenyan mangrove. Marine Biology 137 (2): 309 – 316.**

The interaction between the crab *Neosarmatium smithi* and the gastropod *Terebralia palustris*, during foraging in the mangroves of Mida Creek were investigated in this study. Results showed that the two species overlapped in terms of the area of activity (*Rhizophora mucronata belt*), the preferred foods (mangrove leaves) and the activity period (during the day at low tide). The snails had a wider foraging area than the crabs, but the crabs were able to limit competition for leaves by dragging leaves into their burrows. The authors suggested that this separation in space allowed co-existence of these species.

**CRCP, CRU, MOL, J**

Competition, crab, gastropod, *Neosarmatium smithi*, *Terebralia palustris*, Mida Creek, marine reserve

077

**Fratini S, Cannicci S, Abincha LM, Vannini M (2000) Feeding, temporal, and spatial preferences of *Metopograpsus thukuhar* (Decapoda; Grapsidae): an opportunistic mangrove dweller. *Journal of Crustacean Biology* 20 (2): 326 – 333.**

The grapsid crab *Metopograpsus thukuhar* is common in Indo-Pacific mangroves. The behaviour of this crab was investigated in Mida Creek through field observations and gut analysis. Results showed that the crab was active mostly during low tide, inhabited the roots of the seaward *Rhizophora mucronata* mangrove zone, limited activity to within a few meters of individual trees, and fed on macroalgae and mangrove leaves. The crabs were also observed preying on invertebrates in the mangroves indicating that the crab was an opportunistic feeder.

**CRCP, KMFRI, CRU, J**

Feeding behaviour, crab, *Metopograpsus thukuhar*, Mida Creek, marine reserve

078

**Fratini S, Cannicci S, Vannini M, (2001) Feeding clusters and olfaction in the mangrove snail *Terebralia palustris* (Linnaeus) (Potamididae: Gastropoda). *Journal of Experimental Marine Biology and Ecology* 261 (2): 173 – 183.**

The mangrove snail *Terebralia palustris* can be observed feeding in single large clusters on mangrove leaves yet nearby leaves may remain untouched indicating a potential ability to locate quality food. This was tested by observations of *T. palustris* in Mida Creek in 1999. Results showed that the snails were attracted by conspecifics and by feeding snails, which the authors suggested indicated an olfactory ability to detect airborne and waterborne odours released when the leaves were damaged through the feeding activity of conspecifics.

**CRCP, MOL, J**

Olfactory, snail, *Terebralia palustris*, Mida Creek, marine reserve

079

**Fratini S, Vigiani V, Vannini M, Cannicci S (2004) *Terebralia palustris* (Gastropoda; Potamididae) in a Kenyan mangal: size structure, distribution and impact on the consumption of leaf litter. *Marine Biology* 144: 1173-1182.**

Macroinvertebrates are known to play an important role in nutrient cycling in mangroves but most studies in Kenya have concentrated on decapods. This study aimed at evaluating the role of the gastropod *Terebralia palustris*, the most dominant and largest potamidid species in mangroves. The size structure, distribution in relation to micro-environmental factors, and the feeding ecology of two populations of *T. palustris* in mangroves in Mida Creek were studied between March and April 1999. Both juveniles and adults of *T. palustris* preferred patches characterized by soil with high organic content although juveniles were primarily detritivores while adults consumed leaf-litter. In situ experiments on the grazing activity of adults estimated an hourly consumption rate of ~0.65 g per adult snail and a total of 10.5 leaves m<sup>2</sup> per tidal cycle. The authors suggested that given the high density of *T. palustris* in Kenyan mangroves, the gastropod played a major role in the food web, mangrove litter degradation and nutrient cycling.

**CRCP, MAN, J**

Gastropods, *Terebralia palustris*, mangroves, nutrient cycling, Mida creek, marine reserve

080

**Fratini S, Vannini M, Cannicci S, Schubart CD (2005) Tree-climbing mangrove crabs: a case of convergent evolution. *Evolutionary Ecology and Research* 7: 219 – 233.**

Some species of crabs are known to climb mangrove trees but only a few live a wholly arboreal life. This study investigated the phylogeny of several tree climbing grapsid species collected in Africa (including Gazi Bay and Mida Creek in Kenya), Asia and America. Results showed that arboreal life specialization evolved several times independently in grapsid crabs indicating convergence in evolutionary biology in this group.

**CRCP, CRU, J**

Evolution, Grapsidae, mangrove crabs, Gazi Bay Mida Creek, marine reserve

**081**

**Fratini S, Vannini M, Cannicci S (2008) Feeding preferences and food searching strategies mediated by air- and water-borne cues in the mud whelk *Terebralia palustris* (Potamididae: Gastropoda). *Journal of Experimental Marine Biology and Ecology* 362 (1) 26-31.**

The whelk *Terebralia palustris*, is a dominant snail that feeds on leaves in mangrove forests in the Indo-Pacific. In this study, the food preferences of *T. palustris* and its feeding strategy was investigated at Mida Creek. Results showed that the snail could locate underwater grazed leaves, consumed all mangrove species except *Xylocarpus granatum* leaves but was more attracted to *Rhizophoraceae* leaves. The authors concluded that the ability to locate food through chemical cues was adaptive allowing the snail to locate its preferred foods. In addition, *T. palustris* as able to detect and locate food during high and low tides increasing its feeding efficiency.

**CRCP, KMFRI, CRU, J**

Food choice, *Terebralia palustris*, Mida Creek, marine reserve

**082**

**Fratini S, Ragionieri L, Cannicci S (2010) Stock structure and demographic history of the Indo-West Pacific mud crab *Scylla serrata*. *Estuarine, Coastal and Shelf Science* 86: 51 – 61.**

The mud crab *Scylla serrata* is commercially exploited throughout the Indo-West Pacific. This study investigated the level of genetic exchange of populations of *S. serrata* from the western Indian Ocean (WIO) including specimen collected from Gazi Bay, Mida creek and Lamu and compared these with data in the Genbank from South East Asia, Australia and Pacific Islands. Results showed that *S. serrata* could be distinguished into unique metapopulations that coincided with well-defined geographic regions namely the WIO, Eastern Australia and Pacific Ocean, and North-Western Australia regions.

**CRCP, CRU, J**

Gene flow, mud crab, *Scylla serrata*, Mida Creek, Gazi Bay, Lamu, marine reserve

**083**

**Gang PO, Agatsiva JL (1992) The current status of mangroves along the Kenyan coast: a case study of Mida Creek mangroves based on remote sensing. *Hydrobiologia* 247: 29-36.**

Remote sensing is a common tool for documenting the extent and status of habitats. In this study, the suitability of SPOT multispectral satellite imagery in providing baseline data for the monitoring and management of mangrove in Mida creek is evaluated. The study also aimed to prepare a checklist of fauna growing in close proximity to the Mida Creek mangroves. Remote sensing techniques provided initial stratification of the area into major cover types while ground-truthing was used to verify the satellite images. The authors noted that the

double sampling approach yielded good results on the mangrove species distribution and the superior resolution of SPOT data made it possible to identify different cover types in the study area. The authors recommended the use of satellite imagery in monitoring mangrove areas and further studies into the parameters controlling the distribution of mangroves in a given habitat.

**CRCP, MAN, J**

Mangroves, remote sensing, species composition, distribution, Mida creek, marine reserve

084

**Gartaula HN (2008) Practices of participation in coastal area management: Experiences from Kenya. *Ocean and Coastal Management* 51: 528-535.**

Integrated Coastal Area Management (ICAM) was piloted in Kenya between 1995 and 1999 and involved the implementation of several community-based activities. This paper reviewed the process of participatory planning and implementation of one of these ICAM projects: a fisheries development intervention in the Nyali-Bamburi-Shanzu area adjacent to the Mombasa marine reserve. The study was conducted in 2004 and data was collected from key stakeholders involved with or affected by the intervention. Results revealed a relatively high level of uncertainty about the process used during the identification and development of the intervention, which led to suspicion and misinterpretation of situations. The results illustrated that although development practitioners preferred participatory interventions due to positive evaluation by donors, the practical implementation of such participatory projects was more complex. The author recommended the strengthening of participatory processes for ICAM projects so as to ensure that the end users were involved in all levels of decision-making and implementation.

**CRCP, MAN, J**

Participatory process, ICAM, Nyali, Bamburi, Shanzu, Mombasa, marine reserve

085

**Gherardi F, Micheli F, Vannini M (1990) Movement patterns and dispersal of the hermit crab *Clibanarius longitarsus* in a mangrove swamp. *Marine and Freshwater Behaviour and Physiology* 16 (4): 209 – 223.**

The hermit crab *Clibanarius longitarsus* was investigated at Mida Creek. The crab is known to be active during high tide and stay in refuges during low tide. Results from radio-telemetry and displaced animals showed that the activity pattern may be missed for one or more days, that hermit crabs when displaced followed a course parallel to the coastline but within a narrow zone between the edge of the mangrove and the sea. The crabs displayed a nomadic behaviour that the authors suggested allowed for interception of resources such as empty shells that were rare.

**CRCP, KMFRI, CRU, J**

Hermit crabs, movement patterns, *Clibanarius longitarsus*, Mida Creek, marine reserve

086

**Gherardi F, Vannini M (1992) Hermit crabs in a mangrove swamp: Clustering dynamics in *Clibanarius laevimanus*. *Marine and Freshwater Behaviour and Physiology* 21: 85 – 104.**

The behaviour of the mangrove-dwelling hermit crab *Clibanarius laevimanus* was studied over a semi-lunar tidal cycle at Mida Creek. Results showed that clustering occurred every low

tide when crabs were non-active. At ebb tide, the crabs spread out to forage and returned to clusters as the tide receded. The proximate and ultimate factors that control this behaviour were discussed.

**CRCP, CRU, MAN, J**

Hermit crabs, activity cycle, mangroves, *Clibanarius laevimanus* Mida creek, marine reserve

**087**

**Gherardi F, Vannini M (1993) Hermit crabs in a mangrove swamp: proximate and ultimate factors in the clustering of *Clibanarius laevimanus*. *Journal of Experimental Marine Biology and Ecology* 168: 167 – 187.**

The hermit crab *Clibanarius laevimanus* had been shown in earlier studies to cluster using orientation referenced to the sky, landscape and substrate. The adaptive significance of this behaviour was discussed in this paper and the authors speculate that the clusters may serve as 'shell exchange markets'. Although shell exchange was rare, the authors concluded that such a function would have a highly adaptive significance.

**CRCP, CRU, J**

Clustering, hermit crabs, mangroves, *Clibanarius laevimanus*, Mida Creek, marine reserve

**088**

**Gherardi F, Zatteri F, Vannini M (1994) Hermit crabs in a mangrove swamp: the structure of *Clibanarius laevimanus* clusters. *Marine Biology* 121: 41 – 52.**

The hermit crab *Clibanarius laevimanus* occurs in the mangrove forests of Mida Creek and is characterised by large clusters during low tide. The characteristics of the clustering behaviour of this crab was studied in 1988 by measuring shell size and status, and sex of individuals in 11 clusters. Results showed that shells that provided protection against predators were preferred and that empty shells were a limiting factor. The authors suggested that clustering served a social function, bringing together crabs of similar size that would benefit from shell exchange during the interaction.

**CRCP, CRU, J**

Hermit crab, clustering, *Clibanarius laevimanus*, Mida Creek, marine reserve

**089**

**Gherardi F, Russo S, Lazzara L (1999) Burrow-orientated activity in the ocypodid crab, *Dotilla fenestrata*, living in a mangrove swamp. *Journal of the Marine Biological Association of the UK* 79 (2):281-293.**

The activity pattern and behaviour of the common mangrove crab *Dotilla fenestrata*, was studied at Mida Creek in 1995 and 1997. Results showed that the pattern was a mix of flexible and rigid actions that depended on tidal level, size of crab, and foraging and burrow cleaning behaviours. The authors concluded that the ability to use a range of actions and modes of activity was adaptive given that intertidal environments that the crab inhabited included predictable and unpredictable periods.

**CRCP, CRU, J**

Activity pattern, tidal cycle, *Dotilla fenestrata*, Mida Creek, marine reserve

090

Gherardi F, Russo S (2001) Burrowing activity in the sand-bubbler crab, *Dotilla fenestrata* (Crustacea, Ocypodidae), inhabiting a mangrove swamp in Kenya. *Journal of Zoology* 253 (2): 211 – 223.

The crab *Dotilla fenestrata* is the only species of the subfamily Scorpimerinae in East Africa. The burrowing behaviour of the species was studied at Mida Creek. The results showed that part of the population burrowed while most of the population occurred in large aggregations that foraged in droves during low tide. Burrows differed in design and only 50% of burrowing individuals remained with their original burrows. The authors concluded that combination of foraging, burrowing, excavation and re-deposition of substrate all contributed to reworking of the sediments within the mangrove ecosystem.

**CRCP, KMFRI, CRU, J**

Burrowing, *Dotilla fenestrata*, Mida Creek, marine reserve

091

Gherardi F, Russo S, Lazzara L (2002) The function of wandering in the sand-bubbler crab, *Dotilla fenestrata*. *Journal of Crustacean Biology* 22(3): 521-531.

The sand-bubbler mangrove crab *Dotilla fenestrata* is known to forage either in groups leading away from burrows or individually staying close to the burrows. The significance of this behaviour was investigated in Mida Creek. Results showed that small individuals and ovigerous females chose the burrow oriented foraging activity. The authors suggested that this minimized predation risk to these vulnerable members of the population. The area foraged by the rest of the crabs, on the other hand, depended on the risk of predation weighed against the benefits of foraging further from the burrow for organically richer substrate.

**CRCP, CRU, J**

Crab, *Dotilla fenestrata*, foraging behaviour, Mida Creek, marine reserve

092

Gherardi F, Russo S, Lazzara L (2002) Assessing substrate quality by the sand-bubbler crab *Dotilla fenestrata* (Brachyura, Ocypodidae): Preliminary results from a field experiment. *Crustaceana* 75 (2): 187 – 191.

The ability of the sand-bubbler crab *Dotilla fenestrata* to assess the quality of substrate was investigated at Mida Creek in 1997. An experiment was carried out by placing quadrates at mean water level and randomly enriching quadrates either with diatoms or animal protein or reducing nutrient levels by removal of sediments. Results showed that more active crabs were recorded in enriched quadrates. The authors concluded that this indicated that crabs were able to evaluate the quality of substrate and suggested that the crabs used chemoreception to discern high nutrient substrates.

**CRCP, CRU, J**

Crab, foraging, *Dotilla fenestrata*, chemoreception, Mida Creek, marine reserve,

093

Giesen W, Kerkhof K (1984) The impact of river discharge on a Kenya coral reef ecosystem - the physical processes. *Watamu Reef Expedition Report*. 80 pp.

The fringing reefs of the Malindi-Watamu marine protected area were surveyed during the 'Watamu Reef Expedition' from October 1982 to May 1983. The aim of the survey was

to quantify and qualify the contribution of different parameters of disturbance to the condition of the reefs. Physico-chemical parameters including water temperature, depth, visibility, suspended matter and benthic organic matter were measured at 29 sites between Malindi and Watamu. Sabaki river water quality and other parameters were collated from the Meteorological Department. Results showed that the Sabaki River and Mida creek were the main contributors of sediments. The distribution of large fractions of silicates in bottom sediments also indicated that Sabaki River sediments were transported longitudinally along the coast and that these sediments were subsequently reworked towards the inshore region by the strong currents occurring near Mida Creek. The authors concluded that sedimentation was a major impact on the reefs of the area.

**CRCP, SED, J**

Coral reefs, sedimentation, Watamu, Sabaki River, Mida creek, Malindi, Watamu, marine reserve, marine park

094

**Gillikin DP, De Grave S, Tack, JT (2001) The occurrence of the semi-terrestrial shrimp *Merguia oligodon* (de Man 1888) in *Neosarmatium smithi* H. Milne Edwards, 1853 burrows in Kenyan mangroves. *Crustaceana* 74(5): 505 – 507.**

This brief article details the first observations of the shrimp *Merguia oligodon* in the burrows of the crab *Neosarmatium smithi* in Kenya. Burrows of the crab were investigated in September and October 1999 at Gazi Bay and Mida Creek to assess the presence and abundance of the shrimp. Results showed that many burrows of *N. smithi* were inhabited with up to 60 shrimp.m<sup>-2</sup>. The authors suggested that the shrimp was coprophagous consuming the faeces of the crab but also that the crab could occasionally feed on the shrimp, providing a rich source of animal protein.

**CRCP, CRU, J**

Mangrove crab, shrimp, Gazi Bay, Mida Creek, symbiosis

095

**Gillikin DP, Schubart CD (2004) Ecology and systematics of mangrove crabs of the genus *Perisesarma* (Crustacea: Brachyura: Sesarmidae) from East Africa. *Zoological Journal of the Linnean Society* 141: 435 – 445.**

The mangrove species fauna of East Africa has received little attention compared to Asian mangroves, which show a higher species richness. For example, only one species of the mangrove crab *Perisesarma* has been previously described in East Africa. This study describes a new species of *Perisesarma*, *P. samawati* sp. nov. collected at Mida Creek between 1998 and 1999. The study compares molecular data of the new species with the sympatric *P. guttatum* and show that these are not sister species. The authors suggest that given the abundance of this new species in Mida, the importance of their ecological cannot be underestimated.

**CRCP, CRU, J**

Grapsoidae, mangroves, *Perisesarma samawati*, *P. guttatum*, Mida Creek, marine reserve

096

**Gillikin DP, De Wachter B, Tack, JF (2004) Physiological responses of two ecologically important Kenyan mangrove crabs exposed to altered salinity regimes. *Journal of Experimental Marine Biology and Ecology* 301: 93 – 109.**

Gazi Bay and Mida Creek are exposed to fluctuations in salinity due to groundwater influx. The effects that salinity fluctuations would have on the common mangrove crab species

*Neosarmatium meinerti* de Man, 1887 and *Neosarmatium smithi* H. Milne Edwards, 1853 were investigated at Gazi Bay and Mida Creek in 1999. Individuals were experimentally exposed to varying salinity concentrations and their physiological responses were measured. Results showed that the species exhibited different responses to variations in salinity with *N. meinerti* showing a higher sensitivity to variations in salinity and lower ability to osmoregulate. Both species were negatively affected by hypersaline conditions however, that led the authors to conclude that long-term alterations in mangrove salinity regimes due to mangrove exploitation would significantly affect the populations of these crabs.

**CRCP, CRU, J**

Salinity fluctuations, osmoregulation, crabs, *Neosarmatium meinerti*, *Neosarmatium smithi*, Gazi Bay, Mida Creek

097

**Glaesel H (1997) Fishers, parks and power: The socio-environmental dimensions of marine resource decline and protection on the Kenyan coast. PhD. dissertation. University of Wisconsin-Madison, USA. 331 pp.**

In this study of fishing communities in Kenya, a common property resource and political ecology approach was used to document local systems of fisheries management. The study focused on how such systems varied based on regional history, fishing techniques and presence of MPAs. The study was structured around three periods spanning approximately 45 years; the early years prior to 1950, a mid period from the late 1950s to late 1970s, and the final period, from the early 1980s to the late 1990 at Malindi, Watamu, Mombasa, Kisite-Mpunguti and Diani MPAs. Results indicated that fishers primarily viewed their problems/issues as limited to those that government and international conservation organizations could address. Challenges associated with general poverty were rarely voiced hence making conflicts more complex than on first assessment. "Fishers" were not a cohesive group and differed based on age, ethnicity and other characteristics but generally perceived the 'park' as focusing primarily on park personnel, politicians, the hotel industry and others. Fishers also interpreted strict enforcement of park policy as favouring 'foreigners' over locals and the wealthy over the poor.

**CRCP, COM, T**

Socio-environment, fishing communities, common property, MPAs, Malindi, Watamu, Mombasa, Kisite-Mpunguti, Diani, marine reserve, marine park

098

**Glaesel H (2000) State and local resistance to the expansion of two environmentally harmful marine fishing techniques in Kenya. *Society and Natural Resources* 13: 321-338.**

Although conflicts between different users of the marine environment are common in East Africa, very few studies have documented the causes and process of resolution of these conflicts. In Kenya, fisheries conflicts mainly arise from competition for dwindling stocks, use of highly effective but destructive gears, and, loss of access to fishing grounds. This study reviewed the expansion of environmentally damaging pull seines and spear guns on the Kenyan coast. The results showed that although local fishers shared religion, language and coastal origins more often with pull seiners than with spear gunners, local fishers showed greater resistance towards pull seining. The author argues that the greater negative environmental impact caused by pull seines made this fishery the main target of local resistance. The author concluded that increasing conflicts over differences in gear use, and

between fishers and government authorities, had caused changes in the formal and informal management systems making it more difficult to manage the marine environment.

**CRCP, FIS, COM, J**

Artisanal fishers, identity politics, marine management, political ecology

099

**Gordon I, Koen M (2003) Die-back in *Sonneratia alba* in Kenyan mangroves is due to attack by a cerambycid beetle and metabellid moth. In: Hoorweg J, Muthiga N (eds) Recent advances in coastal ecology, studies from Kenya. African Studies Center Research Report 70: 281-290.**

*Sonneratia alba*, a dominant mangrove on the Kenyan coast experienced extensive die-back in 1992. This study evaluated the cause of the die-back in Mida creek and in Gazi. Results showed that the die-back was caused by infestation by a cerambycid beetle *Bottegia spinipennis* and a moth *Salagena obsolescens*. The beetle attacked small branches boring directly into stems and laying single eggs, while the moth, attacked large branches, feeding gregariously on the bark of *S. alba* before boring into the stem and laying eggs in batches. The feeding and breeding activities of these insects was destructive enough to cause the death of infected mangrove trees. The beetle was found at Mida Creek and Gazi, while the moth was only found at Gazi. Both these species have an Afrotropical distribution, and are common in Africa. The authors recommended further monitoring of *S alba* at reference sites over longer time periods to ascertain whether infestation by these insects is cyclical or a one-off event.

**CRCP, MAN, P**

Mangrove, *Sonneratia alba*, cerambycid beetle, metabellid moth, Gazi, Mida creek, marine reserve

100

**Grimsditch G, Mwaura J, Kilonzo J, Amiyo N, Obura D (2009) Seasonal fluctuations in zooxanthellae densities in corals in the Mombasa marine park, 1998-2006. In: Hoorweg J, Muthiga N (eds) Advances in coastal ecology: People, processes and ecosystems in Kenya. African Studies Centre, African Studies Collection Vol 20: 151-159.**

Since the extensive coral bleaching event in 1998-99 in East Africa, interest in many aspects of bleaching has increased. This study evaluated the symbiotic relationship between corals and zooxanthellae and whether these symbiotic algae exhibit seasonal fluctuations. Zooxanthellae densities were estimated in coral fragments from eleven coral species/genera sampled periodically between 1998 and 2006 in the Mombasa MPA during the northeast and southeast monsoon seasons. Results showed that coral species differed in their seasonal fluctuations in zooxanthellae densities and that in general, species with faster growth rates displayed higher densities during the northeast monsoons while those with slower growth rates displayed higher densities during the southeast monsoons. The authors argue that the lack of regularity in zooxanthellae density fluctuations could be due to the lower seasonal variability of environmental factors at Mombasa.

**CORDIO, CRCP, COR, P**

Zooxanthellae, latitude, seasonality, bleaching, Mombasa, marine park, marine reserve

101

**Grimsditch G, Mwaura J, Kilonzo J, Amiyo N (2009). The effects of habitat on coral bleaching responses in Kenya. *AMBIO* 39:295-304.**

Corals have been shown to exhibit varying responses to environmental stress including acclimatization and physiological tolerance. This study compared coral bleaching response at sites that were relatively shallow (Vipingo and Kanamai) and at deeper sites (Coral gardens and Nyali within the Mombasa MPA) to ascertain whether acclimatization occurred in these populations. Bleaching responses was recorded between 2006 and 2007 during a period of non-bleaching and mild bleaching. Coral fragments were also collected for estimation of zooxanthellae density and chlorophyll a and light, SST and water flow were measured monthly. Results showed that corals in the shallower sites exhibited less bleaching and that these sites had highly fluctuating environmental profiles. The authors concluded that the corals in the shallower sites acclimatized to the more stressful environment but showed slower rates of recovery when they did bleach.

**CORDIO, CRCP, COR, J**

Bleaching, resilience, coral, Mombasa, marine park, marine reserve,

102

**Hale LZ, Amaral M, Issa AS, Mwandotto BAJ (2000) Catalyzing coastal management in Kenya and Zanzibar: Building capacity and commitment. *Coastal management* 28: 75 – 85.**

The Coastal Zone Management approach was introduced in East Africa through a multi-donor project between 1994 and 1995. This paper reviews the effectiveness of this process that was carried out at two pilot sites in Chwaka Bay-Paje, Zanzibar and the Nyali-Bamburi-Shanzu area adjacent to the Mombasa MPA. The project employed three main strategies: the use of interagency teams for planning and implementing activities, adopting a recognised Integrated Coastal Management framework and incorporating capacity building strategies into project management and implementation. The authors concluded that the successful completion of ICM activities and the creation of committed interagency teams indicated that the traditional sectoral based mode of management probably had a limited future in East Africa.

**CRCP, ICAM, J**

Coastal management, Nyali-Bamburi-Shanzu, marine reserve, marine park.

103

**Hamilton HGH, Brakel WH (1984) Structure and coral fauna of east African reefs. *Bulletin of Marine Science* 34: 248-266.**

This publication summarized the findings of one of the earliest surveys of coral reefs in Kenya and Tanzania. Six reefs were studied, two in the Malindi marine park and four in the Kunduchi area, north of Dar-es-Salaam representing the range of East African reef types. Direct observations were made using snorkeling and SCUBA along 10-20 m wide transects laid perpendicular to the slope of the reef. Results showed the development of spurs and grooves on exposed (windward) reefs dominated by acroporids and *Pocillopora* in the turbulent upper zone, and a zone of massive poritids and faviids below. Sheltered reef slopes were steeper, less diverse and were dominated by a staghorn *Acropora* or by *Galaxea clavus*, which sometimes formed extensive monospecific stands. *Pocillopora* and *Porites* were common, along with *Psammocora* and *Pavona* on reef flats. The lagoon behind the reef flat, where present, supported a more diverse mixed coral fauna. Over 140 species of scleractinian corals

belonging to 55 genera were recorded. The authors concluded that although contemporary reef growth was healthy, increasing degradation and over-exploitation of reef resources threatened the continued growth of these reefs.

**CRCP, COREEF, T**

Reef structure, *Acropora*, *Galaxea clavus*, *Pavona*, *Psammocora*, *Pocillopra*, *Porites*, Malindi, marine park

104

**Hémery G, McClanahan TR (2005) Effect of recreational fish feeding on reef fish community composition and behaviour. Western Indian Ocean Journal of Marine Science 4 (2): 123-133.**

Fish feeding is often used to enhance tourism attraction in the dive industry in MPAs; however, the potential impacts of this activity have received little attention in East Africa. The aim of this study was to determine the potential influence of recreational fish feeding on fish community structure and to assess the effect of human food input on fish behaviour at feeding and control sites in the Mombasa, Malindi and Watamu marine parks. Underwater visual surveys and fish feeding experiments were used to evaluate the community structure and feeding behaviour from May to June 2001. The results showed that although the number of fish individuals and species diversity was higher at feeding than control sites, the abundance of bread-feeding fish did not significantly negatively affect the non-bread feeder population or total biodiversity. It was also noted that fish moved faster in response to bread at feeding sites than at non-feeding sites, which suggested a learning response towards bread in some species. The authors noted the short time span of the study and recommended a larger study during both the low and high tourist season and awareness programs for the tourism industry to encourage non-feeding aspects of human-animal interactions.

**CRCP, FIS, J**

Human-animal interaction, reef fish, recreational fish feeding, tourism impacts, MPAs, coral reefs, Malindi, Mombasa, Watamu, marine park

105

**Hendrick JV (1997) A survey of fish populations and feeding patterns in a Kenyan coral reef: The short-term impact of macroalgal removal and its potential in reef rehabilitation. MSc. thesis, University of Newcastle, UK. 94 pp.**

Studies of coral reefs have shown that damaged reefs usually show low coral cover and increased macroalgal cover. Removal of macroalgae could reduce the impacts on corals, however few experimental studies have been carried out to test this potentially useful management intervention in Kenya. In this study, the cover of macroalgae was substantially reduced (84% reduction of fleshy algae) in experimental plots in the Watamu marine park, where an increase in macroalgal cover had previously been recorded. The results showed a reduction of fleshy and calcareous algae and sand, and an increase of hard coral, algal turf and coralline algal cover within a short period after algal removal. Soft coral, seagrass or sponge cover showed no changes. Abundances, diversity and biomass of fish were also higher in the experimental than in the control plots (except for wrasses). However, these differences were no longer observed three months after the removal except for the calcareous algae. The author concluded that the long-term impact of algal removal at the study site was small

and recommended repeated reduction if this technique was to have more than a limited potential for reef rehabilitation.

**CRCP, MAN, T**

Coral reefs, macroalgae, Watamu

106

**Hicks CC, McClanahan TR, Cinner JE, Hills JM (2009) Trade-offs in values assigned to ecological goods and services associated with different coral reef management strategies. *Ecology and Society* 14 (1): 10.**

The services that ecosystems provide are valued by societies depending on the trade-offs associated with managing ecosystems, which will vary depending on socioeconomic and management conditions. This study examined the values of goods and services under differing management regimes; the Mombasa marine reserve, a gear co-managed area in Diani-Chale, and a community-initiated no-take area (Kuruwitu) to compare how the history of these sites, their social conditions, and different management styles were associated with ecosystem values. The results showed that although MPAs generated the highest total economic value, some local community-level values and the social capital of the resource-user community were lost. Local communities near the MPA had the lowest value for measures of biological knowledge. The sites that had greater community-level values were also sites with high social capital and a high level of confidence in the ability to manage marine resources. The authors concluded that the interests of the users and the responsibilities of management authorities affected the values placed on ecosystem services. Where government interests were strong, communities were less likely to adapt to disturbances in their environment.

**CRCP, COM, J**

Co-management, social-ecological systems, fisheries management, adaptive management, Mombasa, Kuruwitu, Diani-Chale, marine park, marine reserve

107

**Hockey PAR, Turpie JK, Velásquez CR (1998) What selective pressures have driven the evolution of deferred northward migration by juvenile waders? *Journal of Avian Biology* 29 (3): 325-330.**

Young wading birds often defer northward migration probably due to the risks of long-distance migration, however these risks have not been explored. In this study data from waders in South Africa and Kenya (Mida Creek) are compared. The authors suggest that the low foraging success of young waders influenced the evolution of deferred migrations.

**CRCP, BD, J**

Migrations, waders, Mida Creek, marine reserve

108

**Hockey PAR, Turpie JK, Plagányi EA, Phillips TE (1999) Scaling patterns in the foraging behaviour of sympatric plovers: effects of body size and diet. *Journal of Avian Biology* 30: 40-46.**

The foraging behaviour of five species of plovers was assessed at Mida Creek in order to investigate how foraging affected body size and/or diet. Results showed that all five species had functionally identical instantaneous foraging behaviours but there was no relationship between body size and the scale of different components of foraging. The authors concluded that predicting foraging behaviour based on body size was of limited use.

CRCP, BD, J

Plovers, foraging behaviour, Mida Creek, marine reserve

109

**Holdich DM, Jones DA (1973) The systematics and ecology of a new genus of sand beach isopod (Sphaeromatidae) from Kenya. Journal of the Zoological Society London 171: 385-395.**

Although isopods are an important component of marine food webs, very few studies have been carried out on this group of crustaceans in the East Africa. This paper details the taxonomy and ecology of a new species of isopod found in the beaches of the Watamu marine park. Samples were collected in the intertidal using a 252 cm quadrant to a depth of 15cm during the University of Bangor expedition in 1971. The new species *Sphaeromopsis amathitis* was reported to prefer relatively exposed coarse-grained beaches.

CRCP, CRU, J

Isopod, taxonomy, Watamu, marine park

110

**Holiday L (1993) Kenya Shimoni marine park expedition: report on the distribution of habitats and species of Kisite marine park and Mpunguti marine national reserve, Part 1. Universities of York and Hull, UK. 90 pp.**

Marine protected areas are expected to benefit biodiversity and fisheries but evidence of the ecological benefits of protection are scarce. This report is the first of a series of surveys carried out by teams from the Universities of York and Hull on coral reefs in Kenya. The report detailed the findings from a quantitative survey of the finfish community in the Kisite marine park and the Mpunguti marine reserve. The catches of the artisanal fishery was believed by local fisheries officers and fishermen to have increased as a result of efficient enforcement of prohibition of fishing within the marine park. Results showed that species diversity and densities were higher within the marine park than the reserve suggesting protection effects. The report recommended the development of a management plan to curb uncontrolled habitat destruction within the marine reserve.

CRCP, BIOD, R

Marine habitats, Kisite, Mpunguti, marine park, marine reserve

111

**Holiday L (1994) Report of the Diani marine reserve expedition: distribution of habitats and species of the Diani coast, Part 1. Universities of York and Hull, UK. 107 pp.**

The Diani-Chale marine reserve was gazetted in 1994, this report is the second of the series of surveys carried out by teams from the Universities of York and Hull on coral reefs in Kenya. This survey assessed the spatial extent and biodiversity of marine habitats within the Diani-Chale area between November and December 1993 using above water observations of critical habitats, qualitative underwater observations using the 'Reefwatch' methods and detailed quantitative observations. The author concluded that the reefs of the Diani coastline were relatively diverse but were subjected to ecological impacts driven by anthropologic activities and recommended that planning for the area should take into consideration ecological impacts and be included in an integrated coastal zone management plan.

CRCP, BIOD, R

Coral reef, Diani, marine reserve, biodiversity

112

**Holiday L (1995) Report of the Malindi and Watamu Park expedition-Kenya: Distribution of habitats and species of Malindi and Watamu marine national parks and marine national reserve. Universities of York and Hull, UK. 140 pp.**

The Malindi and Watamu marine protected areas are the oldest MPAs in Kenya. This report is the third from the series of surveys carried out by teams from the Universities of York and Hull on coral reefs in Kenya. The report details findings from fieldwork carried out between November and December 1994 at 11 sites between Malindi and Watamu. Survey work was carried by above water observations of critical habitats, qualitative underwater observations using the 'Reefwatch' methods and detailed quantitative observations. Results indicated that coral communities were mainly distributed as offshore reefs and a fringing reef ran parallel and almost unbroken along the entire Malindi coastline. Sedimentation effects were noted on the northern reefs of the study area. Seagrass beds were recorded especially within the shallow lagoons. The report recommended the establishment of coastal management zones and a detailed management plan for the coast between Malindi and Watamu.

**CRCP, BIOD, R**

Coral reef, Malindi, Watamu, marine park, marine reserve

113

**Hoorweg J, Foeken D, Obudho RA eds (2000) Kenya Coast Handbook. Culture, resources and development in the East African littoral. Transaction Publishers. 527pp**

This monograph examines the Kenya Coast from different angles: The economy and resources; the population and cultural characteristics; and the potential and obstacles for development. The book begins by reviewing the process of regional development and the growing regional inequalities in Kenya. Physical characteristics, physical and social infrastructure, environmental challenges, and urbanization, are described, all in different chapters. Also described is the state of the 'human sciences'. Development activities and existing bibliographical and statistical information are reviewed.

**CRCP, CR, BK**

coastal resources, development, culture

114

**Humphreys WF (1981) The Echinoderms of Kenya's marine parks and adjacent regions. Zoologische Documentatie 19: 1 – 39.**

The holothurians (sea cucumbers) of Watamu marine park and environs were surveyed in 1969 during the University of Bangor expedition in Watamu. Twenty-two species of sea cucumber were reported including the first report of the synaptid *Opheodesoma sp.* that the author tentatively recorded as *O. spectabilis*, which is a range extension from the western Pacific for this species. The authors concluded that the high diversity of holothurians in such a small area indicated the potentially rich biodiversity of this group across the Kenyan coast.

**CRCP, SC, J**

Sea cucumbers, *Opheodesoma spectabilis*, marine park, Watamu

115

**ICAM (2002) The Riches of Diani-Chale: An integrated approach to coastal area management. Integrated Coastal Area management: Mombasa. 32 pp.**

The biodiversity, natural resources and cultural attributes of the Diani-Chale area on the south coast of Kenya are detailed in this booklet that was intended to raise awareness about

the area as a preliminary awareness exercise for the coastal zone management initiative. The natural resources of the area included a long white sandy beach, diverse coral reefs and mangroves, a rich cultural history and traditions including historic buildings and sacred forests (Kayas), as well as abundant marine and terrestrial wildlife such as marine turtles, whale sharks, dolphins, colobus monkeys, and unique birds and plants. These resources contribute to beach tourism the main economic sector in the area. The booklet also outlined the key issues that needed to be addressed to ensure sustainable management of the resources of the area, and described existing management approaches and the challenges and opportunities of incorporating these within the framework of integrated coastal area management.

**CRCP, CR, BL**

Diani-Chale, integrated coastal management, marine reserve

116

**Icely JD, Jones DA (1977) Factors affecting the distribution of the genus *Uca* (Crustacea: Ocypodidae) on an East African shore. Estuarine Coastal Marine Science 6: 315-325.**

Fiddler crabs are ubiquitous in mangrove habitats in Kenya. This study reviewed the distribution of the four species of fiddler crab (*Uca lactea*, *U. tetragonon*, *U. vocans*, *U. chlorophthalmus*) along four widely separated muddy shores within the Watamu marine park and reserve. Results showed that although all four species occurred on the same shore, populations of each species remained relatively discrete. Species distribution was controlled by height above low water and substratum type. The feeding and jaw structures of the species reflected the type of sediment fed upon. While *U. lactea* inhabited sandy areas with large particle sizes, it was able to overlap with other species that inhabited sediments of higher organic content due to modified jaw structures. The distribution of *U. chlorophthalmus* on the other hand was restricted to muddy sediments since this species was adapted to feed primarily on mud with a high organic content.

**CRCP, CRU, J**

Crabs, distribution, Watamu, *Uca lactea*, *U. tetragonon*, *U. vocans*, *U. chlorophthalmus*

117

**INCO-DC (1998) Anthropogenically induced changes in groundwater outflow and quality, and the functioning of Eastern African nearshore ecosystems. GROFLO Final Report Annexes. 106 pp.**

The rapid expansion of coastal development in East Africa has led to increased anthropologic effects including the contamination of ground water in urban areas. However, the hydrodynamics of groundwater in marine ecosystems has not been adequately studied in the region. This report summarized the results of a study of physical hydrological processes influencing groundwater flow dynamics in sandy beaches along the east African coast; the GROFLO project. Beach ground water level variation experiments were conducted at Nyali and Diani reserves between April and September to evaluate the relationship between tidal forcing and beach ground water level variations and its influence on physico-chemical parameters, particularly temperature and salinity. The report concluded that the studied sites were affected by anthropogenically-induced changes in groundwater outflow and quality.

**CRCP, HD, R**

Groundwater flow, East Africa, Tanzania, Diani, Nyali, marine reserve

118

Isaac FM (1968) Marine botany of the Kenya coast. *Journal of East Africa Natural History Society and National Museum* 27 (116): 7-27.

This paper was one of the earliest botanical contributions and provides a comprehensive but general account of the marine and coastal environment, flora and vegetation of the Kenya coast, the regional and global distribution and the reproductive cycle of the common plant species. The report indicates that marine flowering plants are a prominent feature of the intertidal zone extending from the low water level to deeper areas. The distribution with some species was controlled by the tidal cycle, surviving exposure for considerable periods during low spring tides while other species only occurred in pools and depressions where a certain amount of water was left by the receding tide. A taxonomic description of the seagrasses *Zostera*, *Cymodocea*, *Syringodium*, *Halodule*, *Halophila*, *Thalassia* and *Enhalus* was also provided.

**CRCP, BOT, J**

Marine plants, *Zostera*, *Cymodocea*, *Syringodium*, *Halodule*, *Halophila*, *Thalassia*, *Enhalus*

119

Jones DA (1971) The systematics and ecology of some sand beach isopods (Crustacea: Eurydicidae) from the coast of Kenya. *Journal of Zoology* 165: 201 – 227.

The isopods fauna of the sand beaches and inshore waters of Watamu and Mida Creek were surveyed in 1969 during the University of Bangor Expedition. Eight species were identified of which seven were new to science. The paper describes the species, their distribution, ecology and behaviour and their use as indicators of zones on the sand beaches.

**CRCP, CRU, J**

Isopods, Mida Creek, marine reserve

120

Jones DA (1972) Aspects of the ecology and behaviour of *Ocypode ceratophthalmus* (Pallas) and *O. Kuhlii de Haan* (Crustacea: Ocypodidae). *Journal of Experimental Marine Biology and Ecology* 8: 31-43.

Ghost crabs are common inhabitants of sandy beaches in the Indo-Pacific yet few ecological studies have been carried out on this group of crustaceans. This paper details the feeding behaviour of *Ocypode ceratophthalmus* and *O. Kuhlii* on five beaches of the Watamu marine park and one beach in Malindi in 1969 during the University of Bangor Expedition. At each site, beach profiles were measured, sand samples were collected for particle size analysis, burrows were counted and the diameter of their mouths measured, and crab occupants were dug out identified and sexed. Observations of the burrowing and feeding behaviour of both species were also made. Results showed that *O. ceratophthalmus* occurred in more sheltered beaches and lower along the shore than *O. Kuhlii*. Although stomach contents showed differences in the preferred foods, the mouth parts of these species did not differ. The activity pattern of the species also differed and while *O. ceratophthalmus* was nocturnal, *O. Kuhlii* was active both at night and during the day. The author concluded that differences in habitat and feeding controlled activity patterns.

**CRCP, CRU, J**

Ghost crabs, *Ocypode*, Watamu, marine park, Malindi, feeding behaviour.

121

**Jones DA (1976) The systematics and ecology of some isopods of the genus *Cirolana* (Cirolanidae) from the Indian Ocean region. *Journal of Zoology* 178: 209 – 222.**

Three new species of the isopod *Cirolana* collected at different locations in East Africa including in Mida Creek Kenya are described in this article. The isopod specimens were collected in hard substrate in Watamu during the University of Bangor Expedition in 1969. Notes on the ecology of the species are also included.

**CRCP, CRU, J**

Isopod, taxonomy, *Cirolana*, Mida Creek, marine reserve

122

**Jones DA (1982) New isopod of the genus *Lanocira* (Corallanidae) from the Indian Ocean. *Crustaceana* 42: 65 – 75.**

This paper details the description of isopods of the genus *Lanocira* that were collected in hard substrate in Watamu during the University of Bangor Expedition in 1969. Five species were collected including 2 new species (*Lanocira glabra* and *L. anasicula*) and the morphology, ecology and geographical distribution of the genus were described. The species *L. glabra* was found in dead coral while *L. anasicula* were found in the live coral *Montipora*.

**CRCP, CRU, J**

Isopod, taxonomy, *Lanocira glabra*, *L. anasicula*, Mida Creek, marine reserve

123

**Kairo JG, Gwada P (2001) Litter production in three mangrove stands of Mida Creek, Kenya. *South African Journal of Botany* 67(3): 443-449.**

Leaf litter comprises a major component of the food web within mangrove ecosystems. In this paper, leaf litter productivity is assessed using litter-traps from 1996 to 1997 on mangrove stands of *Rhizophora mucronata*, *Ceriops tagal* and *Avicennia marina* that are dominant in Mida Creek. Results showed that total production was on average higher in the wet than in the dry season. Stands of *Ceriops* had the highest production and *Avicennia* the lowest. Litterfall corresponded to production with higher litterfall in *Rhizophora* and *Ceriops* occurring in the wet season while a peak litterfall for *Avicennia* occurred during the dry season. The authors concluded that the hydrologic and seasonal patterns in the area played a role in the production and litterfall in this mangrove forest.

**KMFRI, MAN, J**

Mangrove, litterfall, *Rhizophora mucronata*, *Ceriops tagal*, *Avicennia marina*, Mida creek, marine reserve

124

**Kairo JG, Dahdouh-Guebas F, Bosire J, Koedam N (2001) Restoration and management of mangrove systems – a lesson for and from the East African region. *South African Journal of Botany* 67: 383-389.**

Reforestation is often touted as an effective restoration tool for the management of mangrove forests. However, few studies have evaluated existing mangrove restoration initiatives in the region. This paper reviews mangrove restoration and management initiatives in Eastern Africa including in the Kiunga marine reserve. The authors note that although extensive research had been carried out on the ecology, structure and functioning of East African mangrove ecosystems, the findings had not been interpreted into a management

framework thus mangrove forests in Eastern Africa continued to be overexploited, converted to aquaculture ponds and polluted. The paper recommended the strengthening of links between research and management authorities to improve the sustainable management of mangrove ecosystems.

**KMFRI, MAN, J**

Reforestation, restoration, management, mangrove, Kiunga, marine reserve

125

**Kairo JG, Kivyatu B, Koedam N (2002) Application of remote sensing and GIS in the management of mangrove forests within and adjacent to Kiunga marine protected area, Lamu, Kenya. *Environment, Development and Sustainability* 4: 153-166.**

The mangroves of the Kiunga marine reserve lie within the largest expanse of mangrove forests on the Kenyan coast. Despite a national ban on mangrove export, there was concern that the forest was still under threat from harvesting, however there was little information to assess changes in mangrove cover over time. This study details the findings of an assessment of the status of mangroves in the Kiunga marine reserve using aerial photographs and ground truthing. Results indicated that the forest had a net volume of 2.3 million m<sup>3</sup> over an area of ~16,000 ha. The authors concluded that the mangrove forest in Kiunga had a high productivity potential and could be harvested sustainably.

**KMFRI, MAN, J**

Mangroves, GIS, Kiunga, marine reserve, mangrove management, remote sensing

126

**Kairo JG, Dahdouh-Guebas F, Gwada PO, Ochieng C, Koedam (2002) Regeneration status of mangrove forests in Mida Creek Kenya: A compromised or secured future? *Ambio* 31 (7/8): 562-568.**

Factors including environmental and biological aspects that control natural recruitment as well as socio-economic conditions that control harvesting rates affect the regeneration of mangrove forests which then affect the design of management interventions. This study examined the structure and regeneration patterns of mangroves at Uyombo and Kirepwe forests in Mida creek. The results showed that *Ceriops tagal* and *Rhizophora mucronata* were the dominant mangrove species, that although the density of trees was greater at Uyombo than at Kirepwe, the average tree height was higher at Kirepwe than at Uyombo. Results also showed that there were more small trees than large trees in both forests, which suggested intense harvesting. While tree distribution was uniform for adult trees, juveniles showed a random distribution indicating variability in regeneration. The study concluded that the exploitation of mangrove trees in these forests not only exerted community structure changes, but also potentially impacted economic value since harvesting led to a switch in dominance from the higher value species, *R. mucronata* to the less valuable *C. tagal*.

**KMFRI, MAN, J**

Regeneration, mangrove, Mida creek, Kirepwe, Uyombo, marine reserve

127

**Kairu KK (1997) Vulnerability of the Kenyan shoreline to coastal instability. In: Sustainable coastal development through integrated planning and management focused on mitigating the impacts of coastline instability. UNESCO, Nairobi, Kenya. 13-25 pp.**

Interest in coastal erosion on Kenyan beaches increased as concerns that in areas where

seawalls were common, alteration of the intertidal regime caused increased erosion on adjacent beaches. This was especially obvious on beaches adjacent to MPAs that are also the most highly developed tourist beaches on the coast. This report reviews the impacts of coastal zone developments on the Kenyan shoreline and discusses several factors including natural events such as changes in sea level and the evolution of coastal geology that worked synergistically with coastal construction to impact the stability of the coastal zone. The author concluded that any efforts to address coastal erosion should take into consideration the intricate nature of these interactions. Since the rapid development of the coastal zone in Kenya was driven by the emphasis on tourism and economic development, the report recommended the development of a coastal zone management policy and provides guidelines for addressing this problem.

**KMFRI, CE, J**

Coastal erosion, seawalls, coastal zone management

128

**Kamau JN (2002) Heavy metal distribution and enrichment at Port-Reitz creek, Mombasa. Western Indian Ocean Journal of Marine Science 1(1): 65-70.**

Inputs of heavy metals into the marine environment from anthropogenic sources are a concern especially in areas of high human population. This study investigated levels of copper (Cu), zinc (Zn) cadmium (Cd) and Iron (Fe) in Port Reitz creek, a mangrove fringed creek adjacent to Mombasa town and Port and that drains into the Indian Ocean near the Mombasa marine reserve. Surface sediment samples were collected in July 1998 from 6 stations situated from the mouth to the back of the creek and analyzed using flame atomic absorption spectrometry. Results showed that concentrations of heavy metals were generally higher at the stations closest to the Mombasa Port suggesting some anthropogenic input although there was high variability in the data. The concentrations of Cu and Zn were within environmentally safe levels, but the Cd concentrations at some stations were higher than safe levels. The author concluded that a combination of fluvial sediment input, inputs from urban and Port activities as well as physical factors due to changes in tidal height and flushing of the creek all affected the concentrations of heavy metals and recommended continued monitoring especially of Cd.

**KMFRI, POL, J**

Heavy metals, fluvial sediments, Port-Reitz, pollution, Mombasa, marine reserve

129

**Kamermand P, Marten AH, Jurgen FT, Miguel AM, Marbà N, Mtolera M, Stapel J, Anouk V, Toon VD (2002) Groundwater effects on diversity and abundance of lagoonal seagrasses in Kenya and on Zanzibar Island (East Africa). Marine Ecology Progress Series 231: 75-83.**

In this study, the effects of groundwater flow on seagrass species diversity and abundance were studied on back-reef lagoons in Kenya (Diani, Watamu, Nyali and Kenyatta) and on Zanzibar Island. The sites were selected based on a groundwater flow model developed during the GROFLO project discussed above (INCO-DC 1998). Results showed that groundwater outflow had an effect on species diversity since sites with a higher outflow had lower species diversity than sites with lower outflow. Of the 10 seagrass species observed at the study sites, *Thalassodendron ciliatum* dominated at high outflow sites and *Thalassia hemprichii* at low outflow sites. A significant increase in the nitrogen-stable isotope signature of seagrass leaves with increasing outflow rates was reported, which suggested that groundwater was

one of the sources of nitrogen at these sites and that competition for nitrogen could explain the variability in the species distribution. The authors recommended additional experiments to confirm the link between nitrogen and seagrass species diversity.

**KMFRI, CRCP, SG, J**

Seagrasses, ground water flow, *Thalassia hemprichii*, *Thalassodendron ciliatum*, Diani, Nyali, Kenyatta, Watamu, marine reserve

130

**Kanyange NW (2006) Data management tools to assess the status of artisanal reef fishery: the case of Diani-Chale and Gazi, Kenya. MSc. thesis, Vrije Universiteit Brussel (VUB) 46 pp.**

The effectiveness of fisheries assessments and management are dependent on the quality of data collected and the management of these data. This MSc. research study aimed to construct and test a relational database for Diani-Chale. The database was designed using the Microsoft Access program and tested using data collected at seven landing beaches in Diani-Chale from 1998 to 2005. The data consisted of 41, 841 records and information on location, species caught (scientific and vernacular name), gears used, season of sampling, standard length of fish, fishers names and mode of transportation. The database was tested through queries and was found to produce results consistent with other studies. The author notes that the database provides information that is useful for fisheries management and in resolving conflicts between stakeholders and managers.

**CORDIO, CRCP, FIS, T**

Data management, assessment, artisanal reef fishery, Diani, Chale

131

**Kaunda-Arara B (2003) The influence of marine reserves on biodiversity conservation and adjacent fisheries in coastal Kenya. Moi University, Kenya. 74 pp.**

The role of MPAs in conserving fish stocks and their potential influence in adjacent fisheries production was the focus of this study. The study compared fish biomass and diversity across the park boundaries using traps for two years ending in April 2002 in the Mombasa and Malindi MPAs. Results showed that for most species, fish densities from visual censuses and CPUE in traps fished across park boundaries, were higher within the parks than outside. The parrotfish *Leptoscarus vaigiensis* and rabbitfish *Siganus sutor* however, had higher CPUE and sizes outside the parks. The potential spillover of fishes from the parks to adjacent fished areas was tested with a logistic decay model that showed that spillover of most species was lower off the Malindi patch reef than the fringing reefs, especially at Watamu. The study concluded that *Siganus sutor* a valuable food and commercial species showed significant spillover to the adjacent fishery. The author recommended enhanced surveillance of fishing activities in the reserve in order to track trends and minimize poaching.

**CRCP, FIS, R**

Fishing, CPUE, spillover, Malindi, Watamu, *Leptoscarus vaigiensis*, *Siganus sutor*

132

**Kaunda-Arara B, Rose AG, Muchiri MS, Rashid K (2003) Long-term trends in coral reef fish yields and exploitation rates of commercial species from coastal Kenya. Western Indian Ocean Journal of Marine Science 2 (2): 105-116.**

This review analyzed the long-term trends in the yields of coral reef associated fish families in

Kenyan waters. Data from the landing records in the annual statistical bulletin from 1978 to 2001 were analyzed. Results showed that coral reefs produced an estimated 2 - 4 metric t/km/yr of demersal fish and a rapid overall decline (~55%) in landings occurred especially during the 1990s. While catches of the commercially important Siganidae, Lethrinidae, Lutjanidae and Serranidae declined by ~40%, the groupers (Serranidae) showed the steepest (72%) decline. The overall decline was also greatest in the more populated Mombasa district (78%) than in the less populated districts such as Kilifi. Catches in Kwale district however increased overtime. Results of length-frequency analysis also showed an overexploitation of some of the commercially important species. The report recommended a precautionary approach in the management of Kenya's coral reef fisheries.

**CRCP, FIS, J**

Fisheries, Mombasa, Kwale, Kilifi, Siganidae, Lethrinidae, Lutjanidae, Serranidae.

133

**Kaunda-Arara B, Rose GA (2004) Homing and site fidelity in the greasy grouper (*Epinephelus tauvina*: Serranidae) within a marine protected area in coastal Kenya. Marine Ecology Progress Series 277:245-251.**

Marine protected areas are reported to be important sources of larvae to adjacent reefs and species with homing and site-fidelity characteristics may increase the likelihood of sustaining locally reproductive populations that could provide the sources of larvae. In this study, the homing and site-fidelity of the commercially valuable greasy grouper *Epinephelus tauvina* was studied at the Malindi marine park between January and April 2002 using acoustic telemetry. Results showed that; there was a 67% homing success in displaced individuals, returns to the capture sites appeared to be cued by oceanographic conditions, return time ranged between 4 to 15 days and, home ranges that were established upon return were negatively correlated with fish size. The study concluded that given that grouper catches have declined steadily over the last 2 decades in Kenya, the ability to home and establish stable home ranges indicates that MPAs may help in protecting breeding populations of this fish.

**CRCP, FIS, J**

Groupers, homing, coral reefs, marine reserve, Malindi, *Epinephelus tauvina*

134

**Kaunda-Arara B, Rose AG (2004) Out-migration of tagged fishes from marine reef national parks to fisheries in coastal Kenya. Environmental Biology of Fishes 700: 363-372.**

Local resistance to no-take zones that is often common in Kenya is partly due to a lack of understanding of how no-take zones could benefit local fisheries. In this study, the spillover of fish from marine parks was estimated by studying the movements of 25 species of coral reef fishes from Malindi and Watamu marine parks from February 2001 to March 2002. Movements were assessed using experimental fishing and tagging. Results showed that the commercially important rabbitfish, *Siganus sutor*, the sky emperor, *Lethrinus mahsena* and the trumpet emperor, *L. miniatus*, consistently moved out of the parks. Movements varied between the species, from patch and fringing reefs and with season. The authors argued that the results suggested that marine reserve design should be based on species-specific behaviors that are related to available reef and habitat types and that the movement patterns of commercial species was an important consideration, if the objective was to enhance adjacent fisheries through spillover.

**CRCP, FIS, J**

Marine reserves, spillover rates, Malindi, Watamu, *Lethrinus mahsena*, *L. miniatus*, *Siganus sutor*

135

**Kaunda-Arara B, Rose GA (2004) Long-distance movements of coral reef fishes. Coral Reefs 23: 410-412.**

The movements of coral reef fishes were measured in order to estimate distance travelled and the potential for enhancing fisheries outside MPAs in this study. A total of 3,916 coral reef fishes of 26 species were trapped, tagged and released inside Watamu and Malindi marine parks, from February 2000 to April 2002. Recapture sites were located with the help of experienced fishermen and estimates were made of the direct distance between release and recapture sites. Results showed that 7 species moved out of the parks to distances less than 5km from park boundaries. Individuals of 3 species travelled long distances of greater than 30km. Four individuals of the lemon sweet lips *Plectorhincus flavomaculatus* tagged inside Watamu Park travelled ~ 138 – 180 km after 40 to 340 days. All movements were southwards along the coast. The authors concluded that more studies were required to ascertain long distance movements of coral reef fish, the function of these movements and their contribution to the connectivity of marine populations.

**CRCP, FIS, J**

Tagging, recapture, reef fish, *Plectorhincus flavomaculatus*, Malindi, Watamu, marine park

136

**Kaunda-Arara B, Rose AG (2004) Effects of marine reef national parks on fishery CPUE in coastal Kenya. Biological Conservation 118: 1-13.**

This paper summarizes the findings of the research of Kaunda-Arara detailed above (Kaunda-Arara 2003) on the role of MPAs in conserving fish stocks and their potential influence on adjacent fisheries in the Malindi and Watamu marine parks.

**CRCP, FIS, J**

CPUE, MPAs, reefs, *Siganus sutor*, *Leptoscarus vaigiensis*

137

**Kaunda-Arara B, Rose GA (2006) Growth and survival rates of exploited coral reef fishes in Kenyan marine parks derived from tagging and length-frequency data. Western Indian Ocean Marine Science Association 5(1):17-26.**

Measurements of growth are a key parameter for fisheries management yet little is known about the growth of most commercial fishes in the Kenyan coastal artisanal fishery. This study aimed to estimate growth parameters of commercially valuable species focusing on 157 species recaptured in a tag and release program conducted between 2001 and 2002. Results showed that the rabbitfish *Siganus sutor* had both the highest absolute growth rate and growth coefficient, while the emperor *Lethrinus nebulosus* had lower rates and the lowest growth rates were recorded for the triggerfish, *Balistapus undulatus*. Growth coefficient (K) estimates differed depending on the method used with length-frequency analysis (LFA) showing lower or higher growth rates than tagging depending on the species. Annual survival rates (S) derived from length-converted catch curves were higher for *S. sutor* than for *L. mahsena*, whereas, natural annual mortality rates (M) were comparable for *S. sutor* and *L. mahsena*.

CRCP, FIS, J

Coral reef, fishes, tagging, growth, mortality, marine park, *Lethrinus nebulosus*, *L. mahsena*, *Siganus sutor*, *Balistapus undulatus*.

138

**Kaunda-Arara B, Mwaluma JM, Locham GA (2009) Temporal variability in fish larval supply to Malindi marine park, coastal Kenya. Aquatic conservation: Marine and Freshwater Ecosystems. 19 (Spec. ISS) 10-18**

Fish larval supply studies are increasingly being used to determine the adult population structure and connectivity between populations. However, very few studies have been done on larval supply in the western Indian Ocean. This study examined fish larval supply to the Malindi marine park using light-traps from 2005 to 2006. Larval abundance was estimated as catch rate (number trap<sup>-1</sup> night<sup>-1</sup>) and compared at two sites and across seasons. Results showed that 33 species in 15 families were caught and there was a higher abundance and diversity of larvae during the northeast monsoon season, a significant difference in abundance between the two years and higher abundances during the new moon than the full moon. In addition, there was a positive relationship between larval supply and chlorophyll-a concentrations and a negative relationship with depth. The authors noted that the results increased the knowledge of the role of larval supply in coral reef fish communities in the western Indian Ocean.

CRCP, FIS, J

Larval supply, reef fish, Malindi, marine park, seasonality,

139

**Kay QON (1971) Floral structure in the marine angiosperms *Cymodocea serrulata* and *Thalassodendron ciliatum* (*Cymodocea ciliata*). Botanical Journal of the Linnean Society 64 (4): 423 – 429.**

The structure of the female flower of the seagrass *Cymodocea serrulata* that was collected from Mida Creek in 1969 is described for the first time in this article.

CRCP, SG, J

Seagrass, female flower, *Cymodocea serrulata*, Mida Creek, marine reserve

140

**Kayanne H, Iijima H, Nakamura N, McClanahan TR, Behera S, Yamagata Y (2006) Indian Ocean Dipole index recorded in Kenyan coral annual density bands. Geophysical Research Letters 33, doi:10.1029/2006GL027168.**

The Indian Ocean Dipole (IOD) plays a role in climate variability in the Indian Ocean and controls the short rainy period from October to November in East Africa. This study aimed to evaluate the feasibility of using coral cores for long-term reconstruction of the IOD. The coral core was obtained by drilling a living colony of *Porites lutea* in the Malindi marine park in October 2002. The monthly oxygen isotope variability and density of the coral were analyzed. Results showed a precipitation signature of the IOD. High and low precipitation were indicated by positive and negative indices of the IOD, which correlated well with the results of the anomalies of the oxygen isotope values. The results suggested that the coral annual band record was a reliable method for reconstructing IOD events and could be used to reconstruct the IOD record prior to instrumental observations.

**CRCP, COR, J**

Indian Ocean Dipole, *Porites lutea*, oxygen isotope, Malindi, Marine Park

141

**Kennedy AD (1990) Marine reserve management in developing nations: Mida Creek - A case study from East Africa. *Ocean and Shoreline Management*. 14: 105-132.**

This study details one of the earliest attempts to assess the management of Mida creek. The assessment was undertaken between February and March 1988, through a series of surveys around the creek by boat and on foot, to record the condition of the biological communities and the level and type of human activities occurring in the area. The paper described the increasing environmental stress caused by local population expansion and a growing tourist industry on the biotic resources of Mida creek. The author noted that although there were policies to protect the marine resources of the creek, overexploitation and damage from human activities continued. The author recommended improved management interventions and reconciliation of the conflicting needs of conservation, exploitation and recreation.

**CRCP, MGT, J**

Mida creek, management, marine reserve

142

**KESCOM (1996) Kenya Marine Turtle National Conservation Strategy. 12 pp.**

Marine turtles are protected under national, regional and international legal and other instruments in Kenya. However, the conservation and management of their populations was not guided by a national strategy. This was the first attempt led by the Kenya Sea Turtle conservation Committee (KESCOM) in partnership with mandated national institutions including the Kenya Wildlife Service and the Fisheries Department to develop a framework that would drive marine turtle conservation activities in Kenya. The strategy highlighted the key threats to sea turtles including poaching of nesting females, poaching of eggs, incidental capture in fishing gears and habitat destruction, and outlines actions that could be undertaken to address these threats. The strategy also detailed the legal framework within which sea turtles were protected, the level of community and stakeholder participation, as well as institutional capacity and argued for the strengthening of partnerships as a key conservation strategy.

**KWS, KESCOM, ST, R**

Sea turtles, conservation, strategy

143

**Khamala CPM (1971) Ecology of *Echinometra mathaei* (Echinoidea: Echinodermata) at Diani beach, Kenya. *International Journal on Life in Oceans and Coastal Waters* 11 (2) 167-172.**

This was one of the earliest studies of the distribution, density and behavior of the sea urchin *Echinometra mathaei* a widely distributed urchin on shallow Kenyan reefs. Surveys were carried out on the reef flat and reef lagoon of Diani along belt transects in 1970. The sizes of *E. mathaei* in each site were measured and observations of their movements, gregariousness, homing and feeding behavior were recorded. Results showed that population density was significantly higher on the inner reef lagoon than on the reef flat, individuals were mainly exposed on the substrate in the lagoon but inhabited crevices in rock pools and under coral boulders in the reef flat. On average individuals had smaller tests on the inner reef lagoon

than on the reef flat and gregarious or homing behavior was not observed at any of the sites studied.

**CRCP, SU, J**

Urchin, *Echinometra mathaei*, Diani, coral reef, population density

144

**Kimani EN, Mavuti KM (2002) Abundance and population structure of the Blacklip pearl oyster, *Pinctada margaritifera* L. 1758 (Bivalvia: Pteriidae) in Coastal Kenya. Western Indian Ocean Journal of Marine Science Association 1 (2) 169-179.**

The Blacklip pearl oyster, *Pinctada margaritifera*, is a large oyster of commercial value that has been shown to have potential for small-scale community mari-culture activities in East Africa. This study detailed the first surveys of this species in Kenya. Results showed that *P. margaritifera* was widely distributed in shallow lagoons, bays and channels and was most abundant in Gazi Bay in sheltered back reefs and lagoons, and on an intertidal reef flat and back reef in Shimoni. During the survey, the wing oysters, *Pteria penguin* and *P. chinensis* were also recorded. There was a high variability in the abundance of *P. margaritifera* which ranged from <1 per 100m<sup>2</sup> in Mombasa and Malindi to >100 per 100m<sup>2</sup> in Shimoni. The size structure showed that density and sizes declined with depth and small individuals dominated the population. The authors argued that environmental factors including variability in temperature and suspended matter may explain the differences in the life history pattern in the oyster populations.

**KMFRI, CRCP, MOL, J**

Blacklip pearl oyster, *Pinctada margaritifera*, *Pteria penguin*, *Pteria chinensis*, Shimoni, Gazi, Malindi, Mombasa.

145

**Kimani EN (2003) The Kenya pearl oysters. In: Hoorweg J, Muthiga N (eds) Recent advances in coastal ecology: Studies from Kenya. African Studies Centre Research Report 70:243-254.**

This study detailed biological, ecological and fisheries information about pearl oysters in Kenya. Information was gathered from population surveys as well as interviews of artisanal fishers, shell collectors and Fisheries officers in Malindi, Mombasa and Shimoni. Detailed surveys using timed searches and belt transects were conducted in the Malindi, Mombasa and Kisite-Mpunguti MPAs and unprotected reefs in Vipingo, Kanamai, Diani, Gazi, Funzi and Shimoni. Preliminary results showed that oyster populations existed in most of the areas visited during the study and that the black-lip oyster *Pinctada margaritifera*, was the most common. The winged oyster *Pteria penguin*, was only recorded in the Wasini channel and *Pteria chinensis* was recorded in Malindi, Mombasa and Shimoni. The largest *P. margaritifera* were recorded at Kisite marine park. Results showed that on average oysters were more abundant in shallow water, the sex ratio was skewed towards males and that males achieved sexual maturity at a smaller size than females. The author concluded that the reproductive strategy served to maintain the population of oysters.

**CRCP, KMFRI, MOL, W**

Pearl oysters, Gazi, Shimoni, Malindi, Mombasa, *Pinctada margaritifera*, *Pteria penguin*, *Pteria chinensis*.

146

**Kimani EN, Mavuti KM, Mukiyama TK, Wambiji N (2008) Macrofauna settlement on Pearl oyster collectors in Kenya: seasonality and abundance. *Western Indian Ocean Journal of Marine Science*. 7(1): 81-94.**

Interest in pearl culture has increased in the western Indian Ocean because of the potential for alternative livelihood projects. However, information on biological and ecological aspects including distribution, recruitment and growth are scarce. This study contributes to information on the recruitment of pearl oysters through artificial collectors that were deployed in the Kisite-Mpunguti MPA, in the Mombasa MPA and Tudor channel between 2002 and 2005. Settlement of all macrofauna was significantly higher during the northeast than the southeast monsoons with slightly different settlement peaks between the lagoon and channel sites. The authors concluded that the settlement of the pearl oyster *Pinctada margaritifera* was variable and driven by oceanographic conditions while *Pteria penguin* settled during the southeast monsoon season.

**CRCP, KMFRI, MOL, J**

Pearl oysters, Kisite, Mombasa, Tudor, macrofauna, recruitment, *Pinctada margaritifera*, *Pteria penguin*

147

**Kimani P, Obura DO (2004) Participatory mapping of terrestrial fishery resources in Kwale District, Kenya. *Western Indian Ocean Journal of Marine Science* 3 (2) 209-220.**

Participatory mapping is often used as a tool to document local knowledge and integrate community needs and concerns into management. This paper detailed a participatory mapping exercise that was conducted in Kinondo location in Kenya focusing on fisheries related information. The spatial arrangement, access, ownership and use of land-based resources (shrubs, grasses and trees) were documented at four landing sites along the north-south population gradient using participatory techniques (sketch maps, livelihood diagrams and transect walks). Results showed that resources were arranged in distinct vegetation zones parallel to the shore and that a north-south increase in resource availability and abundance prevailed reflecting the pattern of increased use of resources with increasing population. Local access to vegetation resources was limited in the northern part and where beachfront developments had closed access routes to fish landing sites. The authors concluded that the participatory mapping exercise revealed the spatial areas and issues of conflict over resource access and recommended solutions to address these problems.

**CORDIO, CRCP, MAP, J**

Participatory mapping, Diani, Kinondo, marine reserve.

148

**King A (2000) Managing without institutions: the role of communication networks in governing resource access and control. PhD. dissertation, University of Warwick, UK 250 pp.**

The ways people tackle resource access and control challenges do not always reflect identifiable institutional processes. This was evaluated through a case study of livelihoods and resource access challenges of the Biga community in Galu-Kinondo area south coast Kenya, that were dependent on small-scale fisheries. The study involved a reconstruction of the community's historical relations with other groups in their area, socio-economic analysis of the livelihoods of different people within the community and social network analysis of people's actions in response to resource access and control challenges. The results indicated

that; the community depended on a range of activities for food and income, but fishing dominated, decreased resources led to decreases in household productivity over the last five decades and, government administrative and political actors were found to be more important than actors with a legal mandate in solving resource related problems. The author recommended a better understanding of local people's socio-economic and socio-political situation before developing resource management strategies.

**CRCP, COM, T**

Resource access, Galu, Kinondo, social networks, socio-political, marine reserve

149

**King A (2003) Strategies used by local fishers to ensure access to and control over scarce resources in Galu and the wider implications for marine resources management. In: Hoorweg J, Muthiga N (eds) Recent advances in coastal ecology: Studies from Kenya. African Studies Center Research Report 70:215-231.**

This paper focused on the problem of access to and control over resources in the fishing community of Biga in Galu, south coast Kenya and is based on PhD. research by King detailed above (King 2000). The ways fishers tackled problems of resource access and control were investigated for three key situations with major consequences on resource use: the establishment of the Diani-Chale marine reserve; the grabbing of trust land earmarked for fisher community use at Mwaepo and; the conflict between local Digo fishers and migrant Wapemba fishers. The importance of different actors (group, individuals and organizations) in solving the fishers' problems was determined using social network analysis. The results showed that many interacting institutions and ad hoc processes shaped resource access and control including the inordinately important role played by actors without an institutional mandate. The paper concluded that management institutions such the Fisheries Department and the Kenya Wildlife Service would be more effective by acting as facilitators of natural resource use initiatives taken by local communities, rather than dictating initiatives themselves.

**CRCP, COM, MGT, P**

Resource access, Galu, Kinondo, Diani-Chale, marine reserve

150

**Kirugara D, Ciderlof U, Rydberg L (1998) Wave-induced net circulation in a reef-fringed lagoon: Bamburi, Kenya. *Ambio* 27 (8): 752-757.**

The hydrodynamics of the Bamburi coral reef lagoon in the Mombasa MPA was evaluated using sea level and current measurements. Results showed that during neaps, the reef was completely submerged and the flow consisted of ocean water into the lagoon with corresponding outward flow through the channels on the north and south borders of the lagoon. At spring tide, the lagoon was cut off from the ocean at low tide, and there was a short period of intense inflow through the channels until the oceanic sea level reached the reef top and the flow direction was reversed. Factors such as reef submergence, characteristics of the incoming swell, pressure head and reef-bottom friction combined to control the magnitude of the flow. The authors concluded that the continuous pumping of water over the reef and its exit through the channels was an important process that assured efficient flushing of the lagoon, securing good water quality inside the reef.

**KMFRI, CRCP, OG, J**

Water circulation, coral reef lagoon, Bamburi, Mombasa, marine reserve

151

**Kirugara D (2000) Temperature and water exchange in a semi-closed lagoon. Bamburi, Kenya. In: Souter D, Obura D, Linden O (eds) Coral reef degradation in the Indian Ocean: Status reports and project presentations. 129-133.**

Hydrodynamic characteristics on coral reefs play a role in the rate and progression of coral bleaching. This study investigated the heat balance of a semi-enclosed coral reef lagoon system in the Mombasa MPA and the contribution of UV radiation as a trigger for bleaching. Salinity and temperature inside the lagoon and adjacent oceanic waters, solar radiative heat flux at the sea surface, and attenuation of this radiation into the lagoon and ocean were measured from September to December 1999. Results showed that the waters in the lagoon stations were well mixed while the oceanic station showed a relatively stable cooler temperature profile, and no influence of tides. The heat balance showed that spring low tides coincided with maximum insolation, which resulted in maximum heating of the exposed reef surfaces and interstitial waters. The flooding tide transferred much of this heat into the lagoon resulting in a peak during and immediately after spring low tides in lagoonal temperatures.

**KMFRI, CRCP, OG, R**

Wave dynamics, tidal cycles, temperature, Mombasa, marine reserve

152

**Kirugara D, Wawiye P (2002) UV radiation and recruitment of microalgal assemblages in a coastal lagoon. In: Linden O, Souter D, Wilhelmsson, D, Obura D (eds) Coral reef degradation in the Indian Ocean Status report 2002: 47-54.**

This study was carried out to investigate the role of UV radiation on the recruitment of microalgal in the Mombasa marine park. The experiment involved manipulations of grazing (consumption) and light regimes on settlement traps held in containers adapted for differences in grazing in uncaged, partially caged and fully caged treatments. Radiation was manipulated by placing filters over the top of the containers at 4 levels of light manipulation. Results showed that the mean value for the instantaneous radiation fluxes at midday were 0.36Wm<sup>-2</sup> and 60 Klux for UV-B and PAR respectively. The cover of macroalgae recruiting onto the tiles varied between 81% and 95% with no significant differences between treatments. The authors recommended a larger scale experiment with increased replication to tease out seasonal factors in macroalgal recruitment.

**CORDIO, KMFRI, RAD, R**

Microalgae, recruitment, UV-radiation, Mombasa, marine park

153

**Kitheka JU (1998) Groundwater outflow and its linkage to coastal circulation in a mangrove fringed creek in Kenya. Estuarine Coastal and Shelf Science 47: 63-75.**

Groundwater outflow may have a significant role in shaping the hydrological processes of mangrove-fringed creeks. This study investigated evidence of groundwater outflow in Mida creek by calculating salinity differences and anomalies, the level of water tables in wells and groundwater recharge and storage within the Mida creek basin. Results showed vertical salinity anomalies, ebb-flood tide salinity differences, the occurrence of groundwater in shallow wells a short distance from the mangroves and enormous groundwater recharge and storage in the Mida basin all indicting groundwater outflow in Mida creek. The annual groundwater storage was estimated at 70x10<sup>6</sup> m<sup>3</sup>annum<sup>-1</sup> equivalent to 50% of the total

volume of water in Mida Creek. The ground water flow rate was estimated as 3.9m<sup>3</sup>day<sup>-1</sup> over an estimated total surface area of 64,000km<sup>2</sup>, which was only ~0.2% of the total surface area of the creek but was suggested to play role in sustaining mangroves during the dry season.

**KMFRI, CRCP, HD, J**

Groundwater flow, Mida creek, mangrove, Watamu, marine reserve

154

**Kitheka JU, Mwashote BM, Ohowa BO, Kamau J (1999) Water circulation, groundwater outflow and nutrient dynamics in Mida Creek, Kenya. Mangroves and Salt Marshes 3: 135-146.**

Physical hydrodynamic processes play a role in nutrient cycling. This study used spot and time series measurements to assess the nutrient dynamic of Mida Creek. Measurements of nutrients, temperature, salinity, sea level and tidal current were taken at sites located in the front, middle and back zones of Mida creek for one year between March 1996 and May 1997. The level of groundwater, total dissolved solids and nutrient concentrations were also taken in wells near the upper region of the creek. Result showed that the tidal regime had a significant influence on nutrient concentrations and dispersal within the creek while groundwater was found to affect nutrient flux mostly during the dry season. The authors concluded that groundwater outflow into the lagoon played a significant role in sustaining the mangrove forest of Mida creek during the dry season through limiting salinity increase and increasing nutrient supply.

**KMFRI, HD, NUT, J**

Mangrove, nutrients, Mida creek, marine reserve, groundwater outflow.

155

**Knight-Jones P (1972) New species and a new subgenus of Spirorbinae (Serpulidae: Polychaeta) from Kenya. Journal of Zoology 166: 1-18.**

This paper describes four species of polychaete worms that were collected from seagrasses in Mida Creek, the first taxonomic record of these species in the Watamu marine reserve. The most abundant species was *Pileolaria daijonesi* that was easily distinguished from the rest. The other two species belonged to the genus *Janus* namely *J. (D) Formosa* and *J. (D) steueri* Sterzinger, were redescribed and distinguished from each other taxonomically for the first time. The fourth species *J. (Fauveldora) kayi* subgen. et sp.n. belonged to a group that is widely distributed in the tropics.

**CRCP, SG, J**

Polychaetes, seagrasses, *Janus (D) Formosa*, *J. (D) steueri*, Mida Creek, marine reserve

156

**Koch EW, Barbier EB, Silliman BR, Reed DJ, Perillo GME, Hacker SD, Granek EF, Primavera JH, Muthiga N, Polasky S, Halpern BS, Kennedy, CJ, Kappel CV, Wolanski E (2009) Non-linearity in ecosystem services: temporal and spatial variability in coastal protection. Frontiers in Ecology and the Environment. 7 (1): 29 – 37.**

Coastal systems offer enormous value in terms of economic, cultural and other social values and quantifying these values is crucial for their sustainable management. Valuation methods however often assume that ecosystem values vary linearly and independently of forcing factors such as seasonality, disturbance and species interactions. This paper describes variability in mangroves, seagrasses and coral reefs and how non-linearity can affect the

ecosystem service of wave attenuation using examples from many locations including the Mombasa marine park. To test the effects of non-linear variables, a valuation of mangroves incorporating different species and tidal level was modeled. Results showed that these factors had a significant effect on the value. The authors concluded that although there are some general responses in wave attenuation, many factors including plant density, location, species, tidal regime, seasons and latitude can influence the results and recommended that natural variability and cumulative effects must be considered when quantifying ecosystem services.

**CRCP, MGT, J**

Valuation, ecosystem services, wave attenuation, coastal protection, coral reef, mangrove, seagrass, Mombasa, marine reserve

157

**Lambo AL, Ormond RFG (2006) Continued post-bleaching decline and changed benthic community of a Kenyan coral reef. *Marine Pollution Bulletin* 52(12): 1617-1624.**

The global coral bleaching event of 1997/1998 had a significant impact on Kenyan reefs causing high coral mortality on most reefs. This study investigated the health of reefs in the Malindi MPA in 2004. Results showed that coral cover had continued to decline with study sites at North reef in the marine park averaging 5.1 % and 2.3% at Leopard reef in the marine reserve. Fifty-five genera of coral had been reported prior to the bleaching event and only 23 genera were recorded during this study. Results also showed increased algal cover, especially of the calcareous green alga *Halimeda* while algal cover on the partially protected Leopard Reef was twice that of the fully protected North Reef indicating a protection effect. The authors concluded that the combined impact of coral bleaching, sedimentation and fishing potentially reduce the ability of this reef to recover.

**CRCP, COR, J**

Bleaching, coral, El Niño, Kenya, sedimentation, Malindi, marine reserve, marine park.

158

**Lazareth CE, Putten EV, André L, Dehairs F (2003) High-resolution trace element profiles in shells of the mangrove bivalve *Isognomon ehippium*: a record of environmental spatio-temporal variations? *Estuarine, Coastal and Shelf Science* 57: 1103 – 1114.**

Snails incorporate chemicals from the environment within their shells as they grow which can be used as indicators of pollution. This ability was tested on the shells of the common mangrove bivalve *Isognomon ehippium* at Tudor, Gazi and Mida Creek in August 1998. The concentration of Magnesium (Mg), Strontium (S), Barium (Ba) and Manganese (Mn) were estimated using laser ablation and plasma-mass spectrometry. The concentrations of these elements varied with site and season, which indicated the potential for *I. ehippium* shells serving as recorders of environmental variability.

**CRCP, MAN, J**

Shell chemistry, trace elements, environmental variability, *Isognomon ehippium*, Tudor, Gazi, Mida Creek, marine reservet

159

**Lemmens J (1993) Reef-building corals (Cnidaria: Scleractinia) from the Watamu marine national reserve, Kenya: an annotated species list. *Zoologische Mededelingen* 67: 453-465.**

This paper provides one of the earliest descriptions of the hard coral fauna (Scleractinia) of the Watamu marine reserve that was surveyed between November 1982 and April 1983. Of

the 283 samples of corals collected, 116 species were described belonging to 46 genera. Eleven genera were added to the genera record for East Africa reported by Rosen (1971).

**CRCP, COR, J**

Scleractinia, coral, Watamu, marine park, marine reserve.

160

**Linklater MR (2004) Stakeholders perceptions of the benefits and disadvantages of marine protected areas. MSc. thesis, University of Newcastle upon Tyne, UK 19 pp.**

The perceptions and attitudes of users and other stakeholders of MPAs can enhance or limit their management. This MSc. research focused on the perceptions and attitudes of fishers and stakeholders living and working within and adjacent to Malindi, Kisite and Mombasa MPA. The study was conducted in May and June 2004 through interviews and questionnaires with open-ended questions designed to find out the perceived benefits and disadvantages of MPAs. Results showed that fishers had the most negative attitudes whilst the staff of the management authority, Kenya Wildlife Service, had the most positive attitude. Those with higher levels of education and more experience of MPAs, also showed a more positive attitude. Respondents recorded 'conservation' as the main advantage of MPAs and the 'reduction in fishing grounds' as the main disadvantage. The author concluded that since stakeholders respond in different ways, management strategies should be designed to take this into consideration.

**CRCP, MPA, T**

Attitude, perception, stakeholder, Malindi, Kisite, Mombasa, marine park, marine reserve.

161

**Locham GA, Kaunda-Arara B, Mlewa CM (2010) The influence of reef type and seasonality on population structure of coral-reef fishes within Malindi Marine Park, Kenya. Marine Ecology doi:10.1111/j.1439-0485.2010.00363.x.**

It is well known that the availability of different habitats affects the distribution and abundance of coral reefs organisms. This paper assessed the correlation between reef morphology and seasonality on the abundance of coral reef fishes in the Malindi marine park. Fish were censused in patch and fringing reef sites using modified local traps (Dema) that were deployed for a year in 2007. Results showed no significant relationship between the total abundance of fish in patch and fringing reefs but species diversity was higher in the fringing reef sites in both the northeast and southeast monsoon seasons. The commercially important groups such as *Siganus sutor* and *Lethrinus mahsena* were more abundant on patch reef sites, fish sizes varied with reef morphology with smaller sized fish dominating in fringing reefs and trophic structure showed greater variability within reefs than between reefs. The authors suggest that the results indicate the importance of reef morphology and environmental variability within reefs in controlling coral reef fish assemblages and recommended taking these factors into consideration when designing MPAs.

**CRCP, FIS, COREEF, J**

Coral-reef fishes, fringing reef, patch reef, monsoons, trophic assemblage, Malindi, marine park

162

**Maina J, Venus V, McClanahan TR, Ateweberhan M (2008) Modelling susceptibility of coral reefs to environmental stress using remote sensing data and GIS models in the western Indian Ocean. *Ecological Modelling* 212: 180-199.**

This paper is based on the MSc. research study by Maina Mbui detailed below (Mbui 2007). The study used remotely sensed oceanographic data and coral bleaching to model and map reefs that had a high susceptibility to thermal stress in the western Indian Ocean. The authors recommended additional studies using data of higher resolution to improve the model predictability in order to contribute to the establishment of MPAs in the region.

**CRCP, MOD, COREEF, J**

Climate change, ecological resilience, GIS, remote sensing, coral bleaching, Kisite, Mombasa.

163

**Malleret-King D (2000) A food security approach to marine protected area impacts on surrounding fishing communities: The Kisite marine national park in Kenya. PhD. dissertation, University of Warwick, UK 229 pp.**

Studies have shown that MPAs that are managed as no-take zones show increased fish biomass and species diversity and may improve surrounding fisheries yields through fish migration and increased recruitment. This study evaluated the importance of no-take zones to adjacent fisher communities by testing the hypothesis that if no-take zones were of benefit to surrounding communities, their food security situation would be improved. The study was carried out in the villages that are adjacent to the Kisite-Mpunguti MPA. Results showed that; households dependent on tourism and a combination of livelihood activities were more food secure than households that depended only on fishing, fisher families that fished nearer the no-take area were more food secure, MPA benefits were not equally shared amongst the communities surrounding the MPA and factors including distance from the MPA or donor support could determine the type and magnitude of benefits from the establishment of MPAs. The author recommended ensuring the inclusion of surrounding communities when planning MPAs and their tourism related activities.

**CRCP, MPA, COM, T**

MPAs, communities, food security, Kisite, marine park, marine reserve,

164

**Malleret-King D (2003) Food security benefits of the Kisite marine national park for the surrounding fishing communities. In: Hoorweg J, Muthiga N (eds) *Recent advances in coastal ecology: Studies from Kenya*. African Studies Centre Research Report 70:201-212.**

This paper summarizes the findings of PhD. research carried out by Malleret-King on the contribution of MPAs that are managed as no-take areas to the food security of adjacent communities (Malleret-King 2000 detailed above).

**CRCP, COM, W**

MPAs, communities, Kisite, marine park, marine reserve

165

**Mangi SC, McClanahan TR (2003) The effect of a marine protected area and the exclusion of beach seines on coral reef fisheries. In: Hoorweg J and Muthiga NA (eds) *Recent Advances in Coastal Ecology: Studies from Kenya*. African Studies Centre Research Report 70:171-184.**

In this paper, the influence of protection and the management of a destructive fishing gear

(beach seine) were assessed. The study was carried out at fish landing beaches adjacent to the Mombasa MPA and seven sites in Diani. Catch trends, fishing effort and fishery yields were compared at these sites from 1996 to 1999. Results showed a significant decline in annual catches irrespective of the management in place or the exclusion of beach seines. On average however, the marine reserve had the highest catch per area (5.5kg/ha). There was also a progressive decline in the catch per man despite the differential exclusion of beach seines. The study concluded that a suite of management tools including no-take zones such as the Kenyan marine parks, restricted fishing areas such as the marine reserves, and gear and effort restrictions were all required to regulate complex tropical artisanal fisheries.

**CRCP, FIS, J**

Beach seines, marine reserve, Diani, Mombasa, fisheries management, marine reserve

166

**Mangi SC (2006) Gear management in Kenya's coastal fisheries. PhD. dissertation, University of York, 255 pp.**

The management of artisanal fisheries requires information on many different aspects of the fishery. In this PhD. research, the impacts of different types of fishing gears on species diversity and community structure of coral reef fish, and their relative profitability were evaluated in the Mombasa and Diani-Chale coral reef fisheries. The temporal pattern of catches for each gear was analyzed from nine fish landing sites over a 5-year period. Damage to the benthic substratum, and, the proportion of juvenile fish and discards were used to quantify the level of impacts of each gear on coral reef biodiversity. Results indicated that the fishery was overexploited and many species were overfished. The density of fishers was the strongest factor influencing fish catch levels, and fishing effort was generally very high. The study recommended strategies to alleviate poverty among fishers as well as enhanced enforcement of illegal gear bans and mesh size regulations.

**CRCP, MGT, T**

Fishing gear, management, fishing effort, Diani-Chale, Mombasa, marine reserve

167

**Mangi SC, Roberts CM (2006) Quantifying the environmental impacts of artisanal fishing gear on Kenya's coral reef ecosystems. Marine Pollution Bulletin 52 (12): 1646-1660.**

Fishing gears have varying impacts on the environment but the lack of knowledge on the type and level of impact constrains the enforcement of gear restrictions. This paper based on PhD. research by Mangi (Mangi 2006 above) focused on the impacts of artisanal fishing gear on coral reef ecosystems in Mombasa and Diani-Chale marine reserves. The authors concluded that on average, beach seines had the highest negative impact on reef biodiversity and recommended enforcement of the ban on this illegal gear and mesh size regulations.

**CRCP, FIS, J**

Beach seine, fishing gears, management, Diani-Chale, Mombasa, marine reserve.

168

**Mangi SC, Roberts CM (2007) Factors influencing fish catch levels on Kenya's coral reefs. Fisheries Management and Ecology 14(4): 245-253.**

In this paper based on PhD. research by Mangi (Mangi 2006), the impacts of different fishing gears on the coral reefs of Diani-Chale were further elaborated. The authors concluded that overall beach seines had the highest negative impacts on the biodiversity of reefs in Diani-

Chale. The study showed that the best predictors of catch levels were the number of fishers and live coral cover which suggests that high levels of fishing effort coupled with the use of destructive gear types, exacerbate the effects of overfishing on these reefs.

**CRCP, FIS, J**

Beach seine, fisheries management, marine reserve, spear gun, Diani-Chale.

169

**Mangi SC, Roberts CM, Rodwell LD (2007) Financial comparisons of fishing gear used in Kenya's coral reef lagoons. *Ambio* 36(8):671-676.**

This study focused on the economic factors determining gear choice by fishers in Diani-Chale marine reserve. Data were collected through direct observations and key-informant interviews. Results showed that while spear guns had the lowest and large traps the highest monthly costs, the fishers who used beach seines and contributed to the purchase of the seine net earned the highest income. Beach seine fishers with no capital costs earned the lowest. The findings suggested that the choice of gear was dependent on the income earned and the profitability of the gear. Since the favored gears, beach seines and spear guns were not only illegal but also caused the highest damage to reefs the authors recommended improved enforcement and the development of alternative livelihood programs.

**CRCP, FIS, J**

Beach seine, fisheries management, marine reserve, spear gun, Diani-Chale.

170

**Mangi SC, Roberts CM, Rodwell LD (2007) Reef fisheries management in Kenya: Preliminary approach using the driver pressure state impacts response (DPSIR) scheme of indicators. *Ocean and Coastal Management* 50: 463-480.**

The management of small-scale artisanal fisheries requires a holistic approach because of the complexity of interactions. This paper reviews the use of the driver–pressure–state–impacts–response (DPSIR) framework approach in understanding fishing in Kenyan coral reefs (mainly in Diani-Chale and Mombasa) and the tropics. The approach is based on carefully selected indicators that show the connections between environmental changes, socio-economic conditions and management responses within a fishery. The authors concluded that although the DPSIR framework approach was useful because it simplified the complexity of the fishery, the approach had some shortcomings including difficulties in selecting, interpreting and scaling the indicators.

**CRCP, FIS, J**

Fisheries management, driver–pressure–state–impacts–response framework, Diani, Mombasa, marine reserve

171

**Mangubhai S, Harrison PL (2007) Gametogenesis, spawning and fecundity of *Platygyra daedalea* (Scleractinia) on equatorial reefs in Kenya. *Coral Reefs* 27 (1): 117-122.**

This is one of the first studies to focus on the gametogenesis, spawning and fecundity of the common coral *Platygyra daedalea* in East Africa. The study was carried out in the lagoon within the Mombasa MPA from 2003 to 2005. Results indicated that the two recently described morphotypes of this species (Mangubhai et al 2007 below) had different gametogenic cycles. The dominant morphotype that consisted of 84% of the colonies studied, exhibited an annual cycle with an extended gametogenic cycle with spawning occurring predominantly

in February - March of each year. The second morphotype that consisted of only 16% of colonies exhibited a biannual spawning cycle with a major spawning event in February - March and a minor event in August - October. The authors suggested that although the annual cycle was the common mode of reproduction, the presence of biannual reproduction in the population served the purpose of enhancing the potential to improve reproductive success in the event of a catastrophic event destroying the main annual reproductive effort.

**CORDIO, CRCP, COR, J**

Coral, sexual reproduction, spawning, Mombasa, *Platygyra daedalea*, marine reserve

172

**Mangubhai S, Harrison PL, Obura D (2007) Patterns of coral larval settlement on lagoon reefs in the Mombasa marine national park and reserve, Kenya. Marine Ecology Progress Series 348:149-159.**

The settlement patterns of coral are a key factor in determining community structure in coral reefs yet little is known about coral larval settlement in East Africa. In this study, the settlement of coral larvae was studied on tiles placed in the Coral gardens and Nyali reef in the Mombasa MPA from 2003 to 2005. Results showed that larvae of the coral family Pocilloporidae dominated (93.7% of spat) and there were very low densities of Acroporidae, Poritidae and Faviidae (4.7% of spat). Coral settlement patterns were seasonal and coral spat mainly settled between February and May in the northeast monsoons. Settlement was also significantly higher at Nyali reef in the marine reserve than at the Coral gardens in the marine park. The authors suggested that since there was little evidence of competition between coral larvae and larvae of other organisms on the tiles, the asynchronous and long breeding patterns of corals in these reefs may have served to reduce competition for settlement space for larvae.

**CORDIO, CRCP, COR, J**

Coral, settlement, reproduction, Mombasa, marine park, marine reserve.

173

**Mangubhai S, Souter P, Grahn M (2007) Phenotypic variation in the coral *Platygyra daedalea* in Kenya: morphometry and genetics. Marine Ecology Progress Series 345:105-115.**

The coral *Platygyra daedalea* is highly variable which makes field identification of this common coral difficult. This study used molecular and morphological techniques to study the variations within *P. daedalea* colonies collected from the Mombasa MPA (Kijembe, Nyali reef and Coral gardens) between 2003 and 2005. Results showed that two morphotypes could be distinguished using ten skeletal characters. Molecular techniques also showed genetic differentiation between the two morphotypes. The authors note that the lack of sequence divergence between the two morphologically different types of *P. daedalea* suggested a shared gene pool, or a recent genetic divergence. The study concluded that the *P. daedalea* population was characterized by these two morphotypes that could be distinguished using both genetic and morphological characteristics.

**CORDIO, CRCP, COR, J**

Coral, taxonomy, morphotypes, *Platygyra daedalea*, Mombasa, marine park, marine reserve, genotype, phenotype.

174

**Mangubhai S, Harrison PL (2008) Asynchronous coral spawning patterns on equatorial reefs in Kenya. *Marine Ecology Progress Series* 360:85-96.**

The lack of environmental variability at the equator has led to the assumption that reproduction in marine invertebrates would be less synchronized than in temperate regions. This paper tests this assumption by following the reproduction of 20 species of the hard coral *Acropora* sampled in the Mombasa marine reserve between 2003 and 2005. Results supported the hypothesis showing an asynchronous pattern of reproduction with an extended period of spawning in most of the species studied. Spawning varied between species depending on a number of factors including both rising and maximum sea surface temperatures, neap and spring tides, and lunar periodicity. The authors suggest that these corals were able to maintain extended breeding seasons without reducing fertilization success because they had very high fecundities.

**CORDIO, CRCP, COR, J**

Sexual reproduction, gametogenesis, fecundity, spawning, reproductive patterns, corals, Mombasa, marine reserve.

175

**Mangubhai S (2009) Reproductive ecology of the scleractinian corals *Echinopora gemmacea* and *Leptoria phrygia* (Faviidae) on equatorial reefs in Kenya. *Invertebrate Reproduction and Development* 53 (2):67-79.**

Seasonality in reproduction in marine invertebrates is thought to occur in environments that exhibit marked fluctuations in environmental factors. However, few studies have been carried out in equatorial environments where environmental variability is lower. This study focused on the reproduction of two common coral species, *Echinopora gemmacea* and *Leptoria phrygia* in the Mombasa marine reserve from 2003 to 2005. Results from permanently marked colonies that were sampled periodically showed that the reproductive cycle was annual with a tidal component; spawning in both species occurred in the northeast monsoon season at the peak of water temperature in Kenya and around spring tides. The gametogenic cycle in *E. gemmacea* was tightly synchronized with oocytes of the same size developing over an extended period of 6 -7 months and gametes released over 3 months (February to April). In contrast, the gametogenic cycle in *L. phrygia* was less synchronized; oocytes of different sizes were present through out the year but spawning peaked between December and February. The author concluded that the results from the *L. phrygia* study partly supported the hypothesis of a breakdown in spawning synchrony at the equator.

**CORDIO, CRCP, COR, J**

Reproduction, seasonality, synchrony, asynchrony, *Echinopora gemmacea*, *Leptoria phrygia*, Mombasa, marine reserve

176

**Matiru V, Muthiga N, Waweru S, Mwangi SN (1999) Community guide to environmental issues and to the environmental management and co-ordination act, 1999, Coast Province. Environmental Liaison Center International. 56 pp.**

The Environmental Management and Co-ordination Act (EMCA) 1999 has important implications for the conservation and management of coastal and marine resources. However, despite the potential impacts of this law on the coastal economy and livelihoods, the local communities in the coast Province knew little about this law. This booklet

attempted to address this gap by reviewing the various environmental issues experienced in the Coast Province and how the Act empowers local communities in the management of the environment.

**CRCP, COM, MGT, BL**

Environmental management, environmental legislation, Environmental Management and Co-ordination Act.

177

**Matsue N (2009) Gender and participation in Fisheries: A case study of female fish traders. MSc. Thesis University of East Anglia, U.K. 43p.**

Women play a role in post-harvest economic activities on the Kenya coast yet few studies have examined their role in any detail. This study evaluated the extent of empowerment of women, their socioeconomic status, the rules used in negotiating supplies and bargaining power at Mtwapa and Mombasa landing beaches that are adjacent to the Mombasa marine reserve. Results showed that women mainly at several levels were marginalized. This was fuelled by factors such as inability to procure loans, inability to negotiate for favorable prices and fish sizes and cultural limitations.

CRCP, FIS, T

Gender, fisheries, traders, marine reserve, Mombasa, Mtwapa.

178

**Mbui JM (2007) Modeling ecological susceptibility of coral reefs to environmental stress using remote sensing, GIS and in situ observations: A case study in the western Indian Ocean. MSc. thesis, International Institute for Geo-Information Science and Earth Observation, Enschede, the Netherlands. 81 pp.**

It is becoming increasingly clear that the severity of coral bleaching leading to mortality of corals is moderated by a number of environmental factors. Understanding the spatial interaction between coral bleaching and physical factors may lead to the identification of resilient reefs and contribute to the designing of MPAs. This MSc. research study used remotely sensed oceanographic data and correlated these against observations of coral bleaching in the western Indian Ocean including at sites in Kenyan MPAs. GIS and fuzzy logic techniques were used to develop two models that showed the predicted areas where environmental conditions would likely lead to low bleaching and mortality and potentially high recovery after bleaching. The author concluded that reefs along the northwest boundary of the Indian Ocean and some Indian Ocean Islands were the most susceptible and least resistant to environmental stress and that more than half of no-take MPAs in the region occurred in areas of medium to high susceptibility pointing to the need for a reevaluation of the current placement of MPAs in the region.

**CRCP, MOD, COREEF, T**

Climate change, ecological resilience, MPA design, GIS, remote sensing, coral bleaching, Kisite, Mombasa, marine reserve

179

**Mcmillan C (1980) Flowering under controlled conditions by *Cymodocea serrulata*, *Halophila stipulacea*, *Syringodium isoetifolium*, *Zostera capensis* and *Thalassia hemprichii* from Kenya. *Aquatic Botany* 8: 323 – 336.**

This paper describes the conditions for the culture and the timing of flowering of five species

of seagrasses *Cymodocea serrulata*, *Halophila stipulacea*, *Syringodium isoetifolium*, *Zostera capensis* and *Thalassia hemprichii* collected from Mida Creek.

**CRCP, SG, J**

Seagrasses, *Cymodocea serrulata*, *Halophila stipulacea*, *Syringodium isoetifolium*, *Zostera capensis*, *Thalassia hemprichii*, Mida Creek, marine reserve

180

**McClanahan TR (1987) Overfishing and coral reef degradation: A preliminary report from East Africa. Conservation Biology 1(2): 97-102.**

The community structure of reefs may differ due to fishing pressures. This study compared lagoonal reefs in Diani, Kanamai and Mombasa marine park. Results showed that the community structure of reefs differed depending on the distance from developed coastal areas and protection from fishing particularly the density of sea urchins. The reef at Diani adjacent to a highly developed tourist beach were the most heavily fished, and had the highest density of sea urchins. The reefs at Kanamai were less degraded and had intermediate densities of sea urchins. At all sites, outer reefs appeared to be relatively intact. The author recommended more detailed experimental studies on the effects of overfishing on the community structure of reefs.

**CRCP, COREEF, SU, J**

Coral reefs, sea urchins, overfishing, Kanamai, Diani, Mombasa, marine park, marine reserve.

181

**McClanahan TR (1988) Coexistence in a sea urchin guild and its implications to coral reef diversity and degradation. Oecologia 77:210-288.**

Sea urchins are an important component of coral reefs and understanding the factors that control their populations can assist in reef management. In this study how different species of urchins co-exist was explored. Data on body morphology, distribution, diet; susceptibility to predators, intra and interspecific competition and settlement of the dominant urchins, *Echinometra mathaei*, *Diadema savignyi* and *D. setosum* was collected at Kanamai reef lagoon. Results showed that the smaller urchin *E. mathaei* was the top competitor for crevice space and was preyed upon more intensively than the *Diadema* species. Competition was somewhat less intense amongst the *Diadema* species except when crevice space was limited which resulted in the larger individuals winning regardless of the species. The author concluded that these species could co-exist because predation controlled *E. mathaei* densities and because the *Diadema* species were able to use different niches due to differences in body morphologies and aggregating behavior, which allowed spatial resource partitioning of the reef.

**CRCP, SU, J**

Kanamai, coral reef, sea urchins, coexistence, *D. savignyi*, *D. setosum*, *E. mathaei*

182

**McClanahan TR, Muthiga NA (1988) Changes in Kenyan coral reef community structure due to exploitation. Hydrobiologia 166:269-276.**

How coral reefs respond to fishing pressure varies depending on a number of factors. This is tested in this study by comparing key components of reef community structure including the densities of sea urchins, coral cover and fish abundances and sizes on Kenyan reefs of differing levels of fishing (Malindi marine park, Diani, Kanamai). Results showed that the

reef with the highest fishing pressure (Diani) had the highest abundances of sea urchins, lowest coral cover and lowest abundances of fish. In addition, the biomass of the burrowing sea urchin *Echinometra mathaei* had increased dramatically during the previous 15 years in Diani reef. The authors suggested that the reduction in the predators of *E. mathaei* through fishing in Diani led to the ecological release of this urchin resulting in increased bioerosion, reduced topographic complexity, and reduced fish biomass.

**CRCP, COR, J**

Coral reef, bioerosion, sea urchins, Malindi, Diani, Kanamai, marine park.

183

**McClanahan TR (1989) Kenyan coral reef-associated gastropod fauna: a comparison between protected and unprotected reefs. Marine Ecology Progress Series 53:11-20.**

Concern that shell collection for the souvenir trade was having a detrimental impact on Kenyan coral reefs led to the first comparative survey of gastropods. A time search method was used to census gastropods in three reefs that were protected (Kisite, Watamu, Malindi marine parks) and three unprotected reefs (Diani, Bamburi, Kanamai) between 1986 and 1988. Results showed that low densities and high diversity characterized the Kenyan coral reef gastropod fauna. The highest diversity was recorded on reef edges and lagoons and the lowest on reef flats. Gastropod densities within the reef lagoons were on average higher in the unprotected reefs than in MPAs but densities of the commercial species *Lambis truncata* and *L. chiragra* were significantly higher in MPAs. The author suggests that the differences between the reefs could be a result of a combination of factors including reef aspect and wave energy, shell collection and reduction in predation attributed to fishing and concluded that shell collecting appeared to be affecting a few commercial species but not most populations of gastropods.

**CRCP, MOL, J**

Gastropods, shell collecting, diversity, Diani, Bamburi, Kanamai, Kisite, Watamu, Malindi, marine parks, marine reserves

184

**McClanahan TR, Muthiga NA (1989) Patterns of predation on a sea urchin, *Echinometra mathaei* (*de Blainville*), on Kenyan coral reefs. Journal of Experimental Marine Biology and Ecology 126:77-94.**

Predation is a key factor in controlling the community structure of coral reefs but no experimental studies had been done in East Africa to test this hypothesis. In this first study, the rates of predation on the sea urchin *Echinometra mathaei* a dominant urchin on reefs was measured in order to test whether predation would differ depending on protection, water depth and body size. Measurements were made on tethered *E. mathaei* individuals in protected (Malindi and Watamu marine parks) and unprotected (Kanamai and Diani) reefs between 1986 and 1988. The abundance of fish was also estimated using visual census at these sites. Results showed that most of the predation was done by fish (90%) followed by asteroids and gastropods suggesting that fishing rather than shell collection potentially had higher impacts on these reefs. Amongst the factors tested, protection showed the strongest impact; predation rates were significantly higher in MPAs than in fished reefs, followed by depth and body size. The authors concluded that predation rates on *E. mathaei* are a good indicator of fishing impacts on reefs in Kenya.

**CRCP, SU, J**

Predation, sea urchins, fishing, *Echinometra mathaei*, Malindi, Watamu, marine parks, marine reserve, Kanamai, Diani

185

**McClanahan TR (1990) Kenyan coral reef-associated gastropod assemblages: distribution and diversity patterns. Coral Reefs 9:63-74.**

This paper provides a taxonomic and biogeographic analysis of the prosobranch gastropods of the shallow reefs of Kenya based on a survey carried out from 1986 to 1988 (McClanahan 1989 above). Results showed that the fauna, which consisted of 135 species in 25 families was similar to gastropods in the Indian ocean with little endemism or faunal affinities. The number of species almost halved since the Pleistocene with densities and diversity decreasing towards northern Kenya. The author attributed this decrease to river discharge, the patchy nature of reefs in northern Kenya and reduced refuge. Reef flats, reef edges and lagoons did not differ significantly between locations but lagoons had significantly fewer species than reef flats and reef edges. There was a negative correlation at some reefs between gastropod densities and Balistid (triggerfish) densities and a positive correlation with sea urchin densities. The author concluded that fishing had a stronger impact than shelling on gastropod densities.

**CRCP, MOL, J**

Gastropods, distribution, diversity patterns, Balistid, marine reserve, marine park

186

**McClanahan TR, Shafir SH (1990) Causes and consequences of sea urchin abundance and diversity in Kenyan coral reef lagoons. Oecologia 83:362-370.**

This paper expands on the studies of predation of sea urchins started by McClanahan and Muthiga (1988 above). The objectives of this study were to identify the major finfish predators of urchins, determine the effect of predation on sea urchin community structure and the impacts of the increase of urchins and decrease of finfish on the coral reef substrate. The study was carried out in the Malindi and Watamu MPA and fished reefs at Vipingo, Kanamai, Bamburi and Diani. Substrate cover and complexity, sea urchin and finfish densities and diversity were measured using visual census and standard line transect methods. Results indicated that finfish were four times denser in protected than unprotected reefs and urchins 100 times denser in fished than unfished reefs. Correlation analysis showed that the density of Balistids (triggerfish) was positively correlated with predation rates on tethered *E. mathaei* and negatively correlated with total sea urchin density. The protected reefs also had significantly higher hard coral, calcareous and coralline algal cover, and greater substrate diversity and topographic complexity than fished reefs, which had greater algal turf and sponge cover. Coral cover and topographic complexity were negatively correlated with total sea urchin density. The authors suggest that these substrate changes could be due to an increase in sea urchin densities resulting from removal of their predators.

**CRCP, SU, J**

Sea urchins, diversity, triggerfish, Malindi, Watamu, Vipingo, Kanamai, Bamburi, Diani, marine park, marine reserve.

187

**McClanahan TR, Kurtis JD (1991) Population regulation of rock-boring sea urchin *Echinometra mathaei* (de Blainville). *Journal of Experimental Marine Biology and Ecology* 147:121-146.**

The sea urchin *Echinometra mathaei* has been shown to be a dominant and important component of the coral reef community in East Africa. This study was undertaken to determine the factors that control the population density of *E. mathaei* in Diani, Kanamai and Vipingo reef lagoons in Kenya. Density manipulation experiments, behavioral studies, feeding experiments and population counts were made between December 1987 and July 1988. Results from the experimental density manipulations showed that although there was a low level of mortality with increased densities, which suggested some density-dependent mortality, the populations on heavily fished reefs continued to increase despite high densities and decreased food availability. In the high-density reef (Diani), *E. mathaei* individuals were smaller but had larger jaws and gonads suggesting a reallocation of metabolic partitioning from growth to feeding and reproduction. Individuals in this population also lacked agonistic behavior or territorial defence, which suggested that the reduction in predators removed the restraints on population increases.

**CRCP, SU, J**

Population regulation, coral reef, predation, *Echinometra mathaei*, Diani, Kanamai, Vipingo, marine reserve

188

**McClanahan TR (1994) Coral-eating snail *Drupella cornus* population increases in Kenyan coral reef lagoons. *Marine Ecology Progress Series* 115:131-137.**

Although population explosions of sea urchins and crown-of-thorns starfish on coral reefs have received much attention, the increase in other predators of coral (Corallivores) such as gastropods has received less attention. This paper details the findings of the first survey of coral eating snails on reef lagoons at Kisite, Malindi, Watamu, Mombasa, Mpunguti, Diani MPAs and Kanamai and Vipingo between 1987 and 1993. Coral cover was estimated by line-transect, finfish were censused by visual census and gastropods were sampled by time searches. The results showed that corallivore snails were fewer and less diverse in MPAs than in fished reefs and that *Coralliophila violacea* was the most common corallivore at the start of the sampling in 1987. By 1993 however *Drupella cornus* had increased dramatically by a factor of 40 showing a larger increase in fished reefs. There was a stronger relationship between corallivore snail abundance and the abundance of their predators than with their coral prey. The author concluded that although predation may control the corallivore snail population, other factors such as oceanographic conditions that could have increased the recruitment success of *D. cornus* larvae could have caused its dramatic increase. The interaction between predation, protection and recruitment of corallivore snails therefore needs further study.

**CRCP, MOL, J**

Gastropods, corallivores, *Drupella cornus*, *Coralliophila violacea*, Kisite, Malindi, Watamu, Mombasa, Mpunguti, Diani, Kanamai, Vipingo, marine reserve, marine park

189

**McClanahan TR (1994) Kenyan coral reef lagoon fish: Effects of fishing, substrate complexity, and sea urchins. *Coral Reefs* 13: 231-241.**

The impacts of fishing on coral reef fishes have not been sufficiently studied in East Africa. In this study the population dynamics of the key coral reef families are studied under varying

levels of fishing pressure. The study was conducted in sites in marine parks (Malindi, Watamu, Kisite), sites with unregulated fishing (Diani, Vipingo, Kanamai, Ras Iwatine), and a reef protected from fishing since 1990 (Mombasa marine park) from 1991 to 1992. Coral cover was estimated using the line transect method, quadrates to estimate sea urchin abundance and visual censuses to estimate fish abundance and species richness. Results showed a dramatic decrease (~50%) in the abundances and species richness of surgeonfishes, triggerfishes, butterflyfishes, angelfishes and parrotfishes in fished reefs. The abundance and diversity of finfish was positively correlated with coral cover while sea urchin densities were negatively correlated with fish densities and fish species. The author noted that the strongest controlling factor was fishing but that it was difficult to tease out the impact of sea urchins, substrate complexity, coral cover and management because of the interrelationships between these variables. The author recommended studies at a larger spatial scale to identify species that are in imminent danger of extinction.

**CRCP, FIS, J**

Coral reef fish, abundance, diversity, Malindi, Watamu, Kisite, Diani, Vipingo, Kanamai, Ras Iwatine, marine reserve, marine park

190

**McClanahan TR, Mutere JC (1994) Coral and sea urchin assemblage structure and interrelationships in Kenyan reef lagoons. *Hydrobiologia* 286:109-124.**

The structure of hard corals and the interaction with sea urchins was studied to determine the impacts of *anthropogenic* pressure on reefs at sites that differed in the level and age of protection, the level of coral collection and the distance from highly developed tourist beaches. Results showed that the newly protected reef (Mombasa marine park) had the highest coral cover, followed by the older protected reefs (Malindi and Watamu marine parks) while the fished reefs (Vipingo, Kanamai and Diani) had the lowest coral cover. Coral cover recovered relatively quickly in the Mombasa marine park by 250% since full closure in 1990 due mainly to the growth of *Porites nigrescens*. Coral species richness and diversity was also higher in protected areas as was the relative abundance of the genera *Acropora*, *Montipora* and *Galaxea* than on the fished reefs. Overall, sea urchin densities were negatively correlated with coral cover, species richness and diversity except where *Porites* dominated. The authors note that coral collection was only evident for the genus *Acropora* (*staghorn corals*). The authors concluded that hard corals were affected by a combination of direct and indirect effects of human resource use.

**CRCP, KMFRI, COR, SU, J**

Coral reefs, diversity, human impacts, *Porites nigrescens*, Malindi, Watamu, Mombasa, Vipingo, Kanamai, Diani, marine parks, marine reserves.

191

**McClanahan TR, Nugues M, Mwachireya S (1994) Fish and sea urchin herbivory and competition in Kenyan coral reef lagoons: the role of reef management. *Journal of Experimental Marine Biology and Ecology* 184:237-254.**

The relative importance of fishing in controlling herbivore populations although widely debated in the scientific literature is not well studied in tropical reefs. This paper presented a study of the effects of fishing on finfish herbivores in reefs with differing levels of protection. The study experimented with assays of *Thalassia* and *Sargassum* to determine whether herbivory by fish and urchins could be distinguished and to measure rates of herbivory by sea

urchins and herbivorous fishes in reefs at Malindi, Watamu and Mombasa marine parks, and Vipingo, Kanamai and Diani unprotected reefs. Results showed that parrotfishes and the sea urchin *Echinothrix diadema* were the dominant herbivores feeding on the assays. When sites with high numbers of *Echinothrix* were excluded from the analysis, most of the herbivory on the *Thalassia* assay were attributed to a few species of parrotfish, and comparisons of relative herbivory between sites and between treatments could be distinguished. Results from experimental reduction of sea urchins also showed that herbivory by parrotfishes increased in the protected sites but not the fished sites suggesting that sea urchins may play a role in mediating grazing rates of some species of parrotfishes. The authors hypothesized that since parrotfish and *Echinothrix* favor areas dominated by the seagrass *Thalassodendron* while the urchins *Diadema setosum*, *D. savignyi* and *Echinometra mathaei* favour *Thalassia* beds, the species composition of seagrass communities could be controlled by urchin grazing activity.  
**CRCP, FIS, SU, J**

*Herbivory, fishing, Sargassum, Thalassia, Thalassodendron, Echinothrix diadema, Diadema setosum, D. savignyi, Echinometra mathaei, marine park, marine reserve.*

192

**McClanahan TR, Gilgaber M, Kamukuru AT, Muthiga NA, Obura D (1994). Sea urchin removal studies on Kenyan coral reefs. Report to the Kenya Wildlife Service, 16 pp.**

Sea urchins are among the dominant grazers in coral reefs and although their influence can be beneficial, their grazing impacts can be detrimental if they occur in high numbers. This report described the findings of a study that was undertaken to determine whether sea urchin removal could be used as a management tool for reef restoration. Sea urchins (90% by biomass) were reduced in 50 m by 50 m plots in reef lagoons in Diani, Vipingo and Mombasa marine park in March and April 1993. Results indicated that reducing sea urchins resulted in increases in brown algal abundance and the density and biomass of fish. The greatest response was found among the parrotfish, wrasse and scavenger families especially in Mombasa marine park. Brown algae increased the least in the protected site. The coral community was unaffected in terms of genera diversity and cover at the end of the 1 yr study. The authors concluded that sea urchin removal was a good reef restoration method for reefs that were heavily degraded or for reefs that had received some protection from fishing but recommended experimental removal at a scale greater than 10,000m<sup>2</sup> to determine the effects of large-scale reductions that are more likely to be initiated by MPA management.

**CRCP, SU, R**

*Sea urchins, removal, restoration, MPAs, Vipingo, Diani, Mombasa, marine park, marine reserve*

193

**McClanahan TR (1995) Fish predators and scavengers of the sea urchin *Echinometra mathaei* in Kenyan coral reef marine parks. *Environmental Biology of Fishes* 43: 187 – 193.**

*Echinometra mathaei* is the dominant sea urchin on shallow reefs in Kenya and predation has been shown to play an important role in the regulation of its population. This study investigated the predators of *E. mathaei* in the Malindi, Watamu and Mombasa marine parks by recording species that preyed on individuals placed out in the open in shallow coral reef sites. Eight fish species were recorded preying directly on the sea urchin with the Redline triggerfish *Balistapus undulatus* causing 65% of the mortality while ten species cleaned out the carcasses. The author recommended the protection of *B. undulatus* as a management

tool to control the numbers of *E. mathaei*.

**CRCP, COREEF, J**

Predation, *Echinometra mathaei*, Watamu, Malindi, Mombasa, marine park,

194

**McClanahan TR, Rubens J, Glaesel H, Kiambo R (1996) The Diani-Kinondo coral reefs, fisheries and traditional management. Coral Reef Conservation Project Report, 28 pp.**

Cultural traditions around sacred sites are common on the Kenyan coast. This study focused on the relationship between cultural traditions and fisheries management of the Diani-Kinondo area. The results showed that although the main purpose of the traditions was to appease ancestral spirits, they were similar to modern fisheries management as they restricted fishing gear, fishing times and places. Results also showed that a combination of national government policies and introduction of foreign gears had weakened the authority of the traditional leaders and their capacity to control activities carried out in their fishing grounds. The authors recommended discussions between communities and management authorities to design effective enforcement policies and reef restoration programs that are compatible with community traditions and capacity.

**CRCP, MGT, R**

Fisheries, traditional management, Diani-Kinondo, coral reefs, marine reserve.

195

**McClanahan TR, Kamukuru AT, Muthiga NA, Yebio MG, Obura D (1996) Effects of sea urchin reductions on algae, coral and fish populations. Conservation Biology 10 (1):136-154.**

This paper is based on the sea urchin removal study that is detailed above (McClanahan et al 1994). The study concluded that sea urchin removal is a potentially effective tool for restoration of heavily degraded reefs or for reefs that had received some protection from fishing but recommended experimental removal at the larger spatial scale that is more likely to be initiated by MPA management.

**CRCP, SU, J**

Sea urchin reductions, heavily fished reefs, Diani, Vipingo, Mombasa, marine park

196

**McClanahan TR (1997) Primary succession of coral-reef algae: differing patterns on fished versus unfished reefs. Journal of Experimental Marine Biology and Ecology 218:77-102.**

Biotic disturbances and physical processes that can result in beneficial or detrimental effects on coral reefs influence the succession trends of algal growth in coral reefs. These factors were assessed at reefs in Malindi and Watamu marine parks and Vipingo and Diani unprotected reefs by measuring algal composition, standing crop and chlorophyll concentrations on experimental coral plates placed in these reefs over a period of 450 days. Results showed that algal growth rates and composition depended on whether grazing was dominated by sea urchins or by herbivorous fishes. Filamentous algal turfs colonized plates in reefs where sea urchin grazers dominated and succession was completed within 50 days. Algal biomass (wet weight) and functional group composition remained stable within this period despite seasonal environmental changes due to the monsoons. In contrast, succession took longer (~120 days) and resulted in a greater diversity of functional groups, higher standing crop and chlorophyll concentrations on fish-dominated reefs. The author concluded that grazing by fish not only affected algal biomass but also that through its influence on sedimentation

and nutrient inputs, could complicate the interpretation of the impact of grazing. A general conceptual model of algal succession under different grazing scenarios was presented.

**CRCP, AG, J**

Succession, grazing, algae, sediments, Malindi, Watamu, Vipingo, Diani, marine park, marine reserve

197

**McClanahan TR (1997) Dynamics of *Drupella cornus* populations on Kenyan reefs. Proceedings of the 8<sup>th</sup> International Coral Reef Symposium 1:633-638.**

*Drupella cornus* is a carnivorous snail that preys on coral in tropical reefs. This paper detailed the increase in the population of *D. cornus* on Kenyan reefs based on surveys carried out between 1987 and 1995 (McClanahan 1994 above). Results showed that the previously rare *D. cornus* increased from the mid 1980's to become one of the most common snails by 1995. The largest population increases were recorded where the branching coral *Porites nigrescens* was abundant but where fishing and a loss of predators such as triggerfish had occurred. The author concluded that the population dynamics of *D. cornus* was dependent on a combination of factors including environmental conditions conducive for successful settlement, the presence of preferred prey, and an absence of predators and competitors.

**CRCP, MOL, P**

Population dynamics, predation, *Drupella cornus*, Kisite, Malindi, Watamu, Mombasa, Mpunguti, Diani, Kanamai, Vipingo, marine park, marine reserve.

198

**McClanahan TR (1997) Effects of fishing and reef structure on East African coral reefs. Proceedings of the 8<sup>th</sup> International Coral Reef Symposium 2:1533-1538.**

Fishing is considered to be amongst the main factors affecting coral reef health but how fishing interacts with other factors such as reef structure is little studied. This paper presents a study that compared the finfish community in shallow fringing and patch reefs in southern Kenya (Kisite/Mpunguti MPA) and northern Tanzania. The density and biomass of finfish and the benthic community including coral, algae and sea urchins were estimated between 1994 and 1996 using visual census and line-transect techniques. Results showed that protected Kenyan fringing reefs had significantly higher biomass of finfish than the fished reef and that there was a 50% reduction in species diversity suggesting a severe impact of fishing on these fished fringing reefs. In contrast, the biomass of fish in the patch reefs did not differ significantly between protected and fished reefs suggesting little impact of fishing. Results also showed that the abundance of the sea urchin *Echinometra mathaei* was higher in fished reefs regardless of the reef type and the author suggests that this was due to lower predation and fewer triggerfish in fished reefs. The author concluded that fishing affects fish and other assemblages but the impact maybe moderated by other factors such as reef structure.

**CRCP, COREEF, P**

Coral, fish, Malindi, Watamu, Kisite, Vipingo, Kanamai, Diani, Ras Iwatine, marine reserve, marine park

199

**McClanahan TR (1997) Recovery of fish populations from heavy fishing: Does time heal? Proceedings of the 8th International Coral Reef Symposium 2:2033-2038.**

Marine protected areas are promoted as a fisheries management tool in coral reefs yet the recovery of finfish populations is dependent on factors such as benthic, fish and urchin community structure. This study evaluated the factors that affected the finfish recovery rates

within the Mombasa marine park that was established in 1986 and received full protection in 1990. Parameters including fish and urchin abundances and diversity, benthic substrate cover and predation were estimated between 1992 and 1996. The results showed that overall, the biomass of fish increased 5-fold and the urchin population decreased by 60% while coral cover increased from ~8% to 45%. Recovery of the fish populations was slowest at sites with high densities of the urchins *Echinothrix diadema* and *Diadema savignyi*. The author recommended that since the rate of fish recovery was affected by factors such as the densities of some species of sea urchins, restoration programs that reduced these urchin species could speed up recovery of fish populations.

**CRCP, FIS, J**

Recovery, finfish, overfishing, sea urchin reduction, Mombasa, *Echinothrix diadema*, *t*, marine park, marine reserve.

200

**McClanahan TR, Obura D (1997) Sedimentation effects on shallow coral communities in Kenya. Journal of Experimental Marine Biology and Ecology 209:103 – 122.**

Increased turbidity due to influx of land-based sources of sediments has been of concern in the reefs of the Malindi-Watamu marine protected area. This study aimed to assess the health of coral reefs along a gradient of sediment influence from Watamu to Malindi. Line transect surveys were conducted between 1984 and 1988. Results showed that total algal cover increased in the low sediment reefs (Watamu), soft coral and sponge cover were higher at increasing levels of sediment influence, and coral cover increased in the intermediate reefs over the course of the study. The community of hard corals showed a pattern of dominance of sediment tolerant species at high sediment reefs. The authors concluded that despite the observed changes in individual benthic substrate categories, the overall change in diversity and ecological health was minimal.

**CRCP, COREEF, J**

Sediments, coral community, Watamu, Malindi, marine park, marine reserve.

201

**McClanahan TR, Glaesel H, Rubens J, Kiambo R (1997) The effects of traditional fisheries management on fisheries yields on the coral-reef ecosystems of southern Kenya. Environmental Conservation 24(2):105-120.**

This study expands on the work on the effect of 'traditional management' on fisheries yield and on the ecological condition of reefs in the Diani marine reserve detailed above (McClanahan et al 1996). The results showed that neither the traditional nor the contemporary methods of fisheries management were effective in managing the fisheries of the area. The authors concluded that the lack of enforcement of the use of illegal and destructive gear (beach seines), resource use conflicts and mistrust of authority emphasised the need to increase dialogue between fishers, local and national natural resource and conservation authorities in order to develop mutually-acceptable policies that enhance compliance.

**CRCP, MGT, FIS, J**

Traditional fisheries management, common property resource, coral reef ecology, human ecology, Diani, marine reserve.

202

**McClanahan TR (1998) Predation and the distribution and abundance of sea urchin populations. *Journal of Experimental Marine Biology and Ecology* 221:231-255.**

Sea urchins are an important component of coral reefs but little is known about the factors controlling the distribution of different species in East Africa. Data on the abundance, distribution, diversity and predation of the nine common urchin species found in reefs in Kenya was collected at sites in Malindi, Mombasa, Vipingo, Kanamai and Diani over a 7-year period. The abundances of predators was estimated through visual fish censuses and the interaction with reef complexity by the line transect method. Results showed that there was a high variation in urchin biomass in space and time for all species except the most abundant and competitively dominant, *Echinometra mathaei*. The spatial variation was highest when predation was high and species dominance was low but at low to intermediate predation however, *E. mathaei*, *Tripneustes gratilla* and *Diadema setosum* partitioned refuge space. In contrast, *D. savignyi*, *Echinothrix diadema*, *T. pileolus* and *Stomopneustes variolaris* densities peaked at the highest predation levels. The author concluded that refuge was important for increasing species diversity and number of species since these variables showed strong association with refuge and had unimodal curves.

**CRCP, SU, J**

Coral reefs, diversity, echinoids, species diversity, predation, sea urchins, Malindi, Mombasa, Vipingo, Kanamai, Diani marine park, marine reserve.

203

**McClanahan TR, Hendrick V, Rodrigues MJ, Polunin NVC (1999) Varying responses of herbivorous and invertebrate-feeding fishes to macroalgal reduction on a coral reef. *Coral Reefs* 18:195-203.**

Coral reefs worldwide have undergone phase shifts to algal dominance and interest is growing on how to restore these reefs. One method, the reduction of macroalgae was tested in the Watamu marine park where macroalgal cover had shown an increase over a nine-year period. Data on fish family abundances, fish behavior, herbivory and predation were collected in four experimental and four control plots in 1997. Results showed that all fish groups increased in abundance in the reduction plots except for wrasses and parrotfishes. Herbivory assays using the algae *Sargassum* and seagrass *Thalassia* also showed higher rates of herbivory in the algal reduction plots one month after algal removal. The foraging intensity of the surgeonfishes *Acanthurus leucosternon* and *A. nigrofuscus* also increased in the reduction plots. Predation rates did not differ between control and experimental plots despite a significant increase in triggerfish densities in experimental plots relative to control plots. The authors concluded that algal dominance in these reefs not only appeared to reduce the abundance of herbivorous fishes but also affected their rates of herbivory and densities of other fish families including predators of invertebrates (triggerfishes, butterflyfishes and angelfishes).

**CRCP, FIS, J**

Macroalgal reduction, *Acanthurus leucosternon*, *A. nigrofuscus*, Watamu, marine park, *Sargassum*, *Thalassia*.

204

**McClanahan TR (2000) Recovery of a coral reef keystone predator, *Balistapus undulatus* in East African marine parks. *Biological Conservation* 94:191-198.**

The red-lined triggerfish *Balistapus undulatus* is reported to be the dominant predator of sea

urchins in reefs in East Africa. The reduction in the densities of this and other predatory species has resulted in population explosion of sea urchins. The factors that affect the recovery of this species was investigated by comparing the recovery of *B. undulatus* within reefs in five fully closed areas (Malindi, Watamu, Mombasa, Kisite, Chumbe) which differed in age of protection spanning 30 years and four fished reefs (Vipingo, Kanamai, Ras Iwatine, Diani). Results showed *B. undulatus* dominance and predation rates on *Echinometra mathaei* took 5 – 10 years to recover. It also took about 10 years for sea urchin densities to decrease below 1000 kg/ha. The data also showed that ~30 years were needed for *B. undulatus* densities to reach full recovery. Behavioral experiments showed that *B. undulatus* dominated the wrasse predator *Cheilinus trilobatus* at baited sites, but was out competed by the triggerfish *Balistoides viridescens* in direct interactions. The author concluded that although closures of 10 years may result in recovery of some fish species and improvements in reef ecology, other ecologically important species require much longer-term or permanent closures.

**CRCP, FIS, J**

Predation, sea urchins, triggerfish, *Balistapus undulatus*, *Balistoides viridescens*, *Cheilinus trilobatus*, *Echinometra mathaei*, predation, Malindi, Watamu, Mombasa, Kisite, Chumbe, Vipingo, Kanamai, Ras Iwatine, Diani, marine park, marine reserve.

205

**McClanahan TR, Mangi S (2000) Spillover of exploitable fishes from a marine park and its effects on the adjacent fishery. *Ecological Applications* 10 (6): 1792-1805.**

An important benefit of closures is the potential spillover of fishes into the adjacent fished areas. This study is the first to investigate spillover of fishes from the Mombasa marine park into the adjacent marine reserve. The study was undertaken over a seven-year period when the park's border changed and beach seines were eliminated. Spillover was measured by laying baited traps at different distances from the northern and southern boundaries of the park. Results showed that fish wet weight, mean size and number of fish species caught per trap decreased away from the park boundaries on the managed but not the unmanaged side of the park. Results also indicated that fishers on the managed side took advantage of the closures by laying more traps per fisher. Traps laid close to the deeper reef edge also caught more fish suggesting an effect of reef morphology interacting with tidal patterns rather than management. Spillover was evident for the common fishery species including the Siganidae, Lethrinidae, and Acanthuridae. The authors suggested that closed areas of 10 - 15% of the total fishing grounds had the potential to enhance fisheries dominated by rabbitfish, emperors, and surgeonfish.

**CRCP, FIS, J**

Fisheries, management, spillover, Lethrinidae, Siganidae, Acanthuridae, marine park, marine reserve.

206

**McClanahan TR, Sheppard CS, Obura D (eds) (2000). *Coral Reefs of the Indian Ocean: Their Ecology and Conservation*. Oxford University Press, New York.**

This book was published as a contribution to the International Year of the Reef- 1997 activity for the Indian Ocean. The book provides a comprehensive review of Indian Ocean coral reefs including their geomorphology, physical environment and climate, the distribution of reefs, ecological processes and how these have been affected by human activities including over fishing destructive fishing and global warming. The book also contains case studies

describing management interventions and other coral reef initiatives in the region. The material is targeted to a broad range of readers including resource managers, scientists, students and decision makers and forms an important reference document for the coral reefs of the region.

**CRCP, CORDIO, COREEF, B**

Coral reefs, Indian Ocean, distribution, threats, management

207

**McClanahan TR, Arthur R, Kaunda-Arara B, Kiambo R, Machanos H, Mangi S, Muthiga N, Rodrigues M (2000). Sea urchin reduction as a new restoration technique in new marine park. *Proceedings of the 9<sup>th</sup> International Coral Reef Symposium 2*; 947 – 953.**

Sea urchin explosions are a common response of reefs that have been heavily impacted by fishing. Their increased numbers can cause degradation of coral reefs increasing erosion and damage to corals. This study evaluated sea urchin removal as a potential technique in the restoration of coral reefs by carrying out experimental removals in large (100/100m) and small plots (50/ 50m) in a newly established marine park in Mombasa. Algae increased in both large and small plots as well as wet weights and biomass of finfish especially parrotfish in both plots after the removals. The changes in finfish weights were greater in the smaller than the larger plots and hard coral cover increased in the larger but not the smaller plots. The authors noted that although removal produced variable results the technique combined with fishing restrictions could be used to promote coral reef recovery.

**CRCP, COREEF, P**

Sea urchin removal, Mombasa, Marine Park

208

**McClanahan TR, Mangi S (2001) The effect of closed area and beach seine exclusion on coral reef fish catches. *Fisheries Management and Ecology 8*(2):107-121.**

Concerns about overfishing have led to the search for management interventions that meet the needs of fishers and fisheries management in Kenya. This study undertook to compare the impacts of MPAs and gears types on adjacent fisheries in the Mombasa marine park and the Diani-Chale marine reserve from 1995 to 1999. Results showed that although the number of fishers and boats at landing sites in the marine reserves remained relatively constant over the study period, the total catch and the catch per unit effort (CPUE) declined regardless of beach seine exclusion or use of different gear types. Sites differed if data were analysed on a catch per area basis which the authors interpreted as evidence for a compensatory reduction in the number of fishers as catches declined. The highest catches were recorded at the landing site next to the Mombasa marine park where beach seines had been excluded despite having the highest density of fishermen. The authors concluded that habitat degradation, use of destructive gears, overfishing and closed areas all influence shallow reef fisheries in Kenya and recommended incentives that reduce effort and co-management of fishing areas between fishers, MPA and fisheries authorities.

**CRCP, FIS, J**

Coral reef, fisheries, gear, Mombasa, Diani-Chale, marine parks, marine reserves.

209

**McClanahan TR, Arthur R (2001) The effect of marine reserves and habitat on populations of east African coral reef fishes. *Ecological Applications 11*(2):559-569.**

Evidence suggests that full closures protect fish populations, especially large individuals but

few studies have taken into account a large spatial and temporal scale, differences in habitat and reef features or age of protection. This paper details a review that was undertaken of a 400km stretch of the East African coast that encompassed 22 patch and fringing reefs including Kenyan MPAs. The population density, species richness, and rarity for 127 species of coral reef fish, sea urchin densities and benthic substrate cover were estimated in these reefs. The age of the protected areas ranged from less than 10 to more than 25 years. Although results showed that fish diversity was positively correlated with hard coral and coralline algal cover, and negatively correlated with sea urchin and algal turf abundance, protection from fishing was the strongest factor affecting fish abundance and diversity. The authors suggested that the observed relationships between fish and habitat variables were probably due to direct and indirect effects of fishing on reef ecology. The authors concluded that because older reserves had more and rarer species than younger reserves or fished reefs, there was a need to protect reserves for more than 10 years in order to retain a high local diversity of fishes.

**CRCP, FIS, J**

Community structure, coral reef, fish, sea urchins, marine park, marine reserve.

210

**McClanahan TR, Muthiga NA, Mangi S (2001) Coral and algal changes after the 1998 coral bleaching: interaction with reef management and herbivores on Kenyan reefs. *Coral Reefs* 19:380-391.**

Widespread coral bleaching was recorded across the western Indian Ocean during the 1998 El Niño. This study determined the responses after bleaching and mortality and interactions with other factors such as herbivory and protection. The progression of the bleaching response was followed by direct observations of coloration of coral colonies along a gradient from normal to fully bleached in fished (Vipingo, Kanamai, Tiwi and Diani), restricted-fishing (Canon Pt, Ras Iwatine, Nyali) and fully protected (Mombasa, Kisite) reefs between March at the beginning of bleaching and September 1998 (159 days). Results showed that mainly branching hard corals bleached rapidly and died while predominantly massive genera showed mild paling and no significant mortality. Measurements of benthic coral cover taken before and 6 to 13 months after bleaching showed large decreases (>85%) in the susceptible coral genera. Despite increased fleshy algal cover at all sites, the high spatial variability in the response resulted in no statistically significant differences between protected and fished sites. In some of the sites, herbivory estimates were a good predictor of the change in fleshy algal cover over the 1-year post-bleaching period. The study concluded that coral bleaching leading to mortality could induce the increase in fleshy algae in tropical reefs that had not been previously impacted by nutrient input or fishing.

**CRCP, COR, AG, J**

Coral reef, algae, El Niño, bleaching, Vipingo, Kanamai, Tiwi, Diani, Canon Pt, Ras Iwatine, Nyali, Mombasa, Kisite, marine park, marine reserve.

211

**McClanahan TR (2002) The near future of coral reefs. *Environmental Conservation* 29(4):460-483.**

This paper reviews the predicted changes that will occur in the ecology of reefs to the year 2025, the research that is needed and suggestions of the management interventions that will mitigate the damage to reefs. The paper details the main disturbances to coral reefs including warming of seawater due to global warming, changes in seawater chemistry

including changes in aragonite saturation, increases in diseases, near extinctions of species and food web alterations. The author predicts a major reorganization of reef ecology including reduction in calcifying and zooxanthellate organisms and species at higher trophic levels, a dominance of algae of low productivity, and explosions of non-commercial invertebrates including sea urchins, starfish and coral eating snails. These changes are predicted to cause reduction in benthic and fisheries productivity and increased bioerosion reducing reef topographic complexity, species diversity and the loss of shoreline protection. The author concluded that management at the global, regional and national levels will be required to reduce greenhouse gases, regulate global trade, regulate resource management including restrictions on resource extraction and run-off and waste management.

**CRCP, COR, J**

Coral reefs, climate change, resource extraction, ecological changes.

212

**McClanahan TR (2002) A comparison of the ecology of shallow subtidal gastropods between Western Indian Ocean and Caribbean coral reefs. *Coral Reefs* 21:399-406.**

This paper compares populations of sea snails (gastropods) surveyed at protected and unprotected reef sites in the western Indian Ocean (Kenya and Madagascar) and in the Caribbean basin (Florida Keys and Belize). Data on abundance, body size, feeding mode, and number and species diversity were compared between these sites. Results showed that the Caribbean region had fewer species and a greater abundance of herbivorous and detritivorous species compared to the Western Indian Ocean. There were no significant differences in body size when species or abundances were compared between the regions. The author suggested that although data on trophic level, dominance and species richness may reflect species that are influenced by environmental stress in the Caribbean fauna, body size data complicated this pattern. The author suggested that the differences in the snail fauna between the two regions was probably due to a combination of low levels of origination and higher levels of extinction in the Caribbean fauna leading to fewer species.

**CRCP, MOL, J**

Gastropods, Caribbean, Western Indian Ocean, extinction, marine park, marine reserve.

213

**McClanahan TR (2002) The effects of time, habitat and fisheries management on Kenyan coral reef associated gastropods. *Ecological Application* 12(5):1485-1495.**

Shell collection is a licensed fishing activity in Kenya yet the long-term impacts of fishing on snail populations were not known. This paper details the results of surveys of gastropods, the dominant sea snails in East Africa, at sites that differed in the level of fishing over a 13-year period in Kenyan reefs including the older marine parks (Malindi, Watamu and Kisite), the newly protected MPA in Mombasa, a site in the Mpunguti reserve, and sites at three fished reefs (Vipingo, Kanamai, Diani). At each site surveys were conducted in the reef lagoon and reef flat habitats using timed searches. Results showed that the snail abundances were relatively low especially the commercial large-bodied species such as *Cassis cornuta*, *Charonia tritonis*, *Lambis truncata* and did not show large fluctuations over time, and that commercial species were more stable than non-commercial species. The density of non-commercial snails increased with time in all reef lagoons and showed the greatest increase in the fished sites indicating fishing effects. Results also showed that snail densities were more variable in the reef lagoons than in the reef flats and that lagoons in the marine parks had the

lowest densities of snails while reef flats in the protected areas had the highest densities of commercial species. The author concluded that a combination of factors including collection and snail body size could cause the low observed population densities.

**CRCP, MOL, J**

Gastropods, coral reefs, environmental stress, fishing, marine park, marine reserve, Malindi, Watamu, Kisite, Mombasa, Mpunguti reserve, Vipingo, Kanamai, Diani, *Cassia cornuta*, *Charonia tritonis*, *Lambis truncata*

214

**McClanahan TR, Uku JN, Hag M (2002) Effect of macroalgal reduction on coral reef fish in the Watamu marine national park, Kenya. Marine and Freshwater Research 53(2):223-231.**

This paper details additional measurements on reef fish and benthic substrate in algal removal plots established in the Watamu marine park (McClanahan et al. 1999 above). Results showed that fleshy algae had not recovered one year after algal removal and that the calcareous algae *Halimeda*, recovered and became the dominant algae in the experimental plots. Algal reduction influenced the fish assemblage and although increases occurred in the density of some herbivores such as surgeonfish and parrotfish, invertivores such as angelfish, butterflyfish, emperors snappers, wrasses and triggerfish, three damsel and wrasses decreased in abundance. The total fish abundance and biomass and the average sizes of parrotfish and snappers was also higher in the algal reduction plots over the year. The authors concluded that the slow recovery of fleshy algae was due to increased herbivory combined with the switch in dominance towards *Halimeda*.

**CRCP, FIS, J**

Algal removal, herbivory, phase shifts, reef degradation, Watamu, *Halimeda*, marine park.

215

**McClanahan TR, Maina J, Pet-Soede L (2002) Effects of the 1998 coral mortality event on Kenyan coral reefs and fisheries. Ambio 31:543-550.**

Coral loss due to bleaching could result in: increased space for turf algae, increased productivity and increased herbivores and fisheries production; decreased reef complexity, reduced habitat for fish and decreased fish production or; open space for colonization by fleshy algae. These hypothesis were tested on reefs in Malindi, Watamu marine parks and Vipingo, Kanamai and Diani (fished reefs) by comparing benthic substrate cover, sea urchin and fish abundances three years before and after the 1998 bleaching event. Results showed that hard and soft corals decreased, coralline algae increased in fished and protected reefs while turf algae increased in marine parks and sponge and fleshy algae increased in the fished reefs. The biomass of sea urchins did not change during the study period. The changes in fish were variable depending on fish family and fishing effort (17%) and demersal catch and catch per man declined (8% and 21% respectively) after 1998 in the adjacent fishing grounds. The authors concluded that the reduction in the total catch and CPUE combined with the increase in effort suggested an overexploited fishery which complicated the ability to distinguish changes caused by coral mortality due to bleaching or fishing pressure.

**CRCP, COR, J**

Coral mortality, bleaching, reef, fisheries, Malindi, Watamu, Vipingo, Kanamai, Diani, marine park, marine reserve.

216

**McClanahan TR (2003) Disturbance, recovery and restoration of Kenyan coral reefs. In: Hoorweg J, Muthiga N (eds) Recent advances in coastal ecology: Studies from Kenya. African Studies Center Research Report 70:21-31.**

There is abundant evidence for the degradation of Kenyan coral reefs but the tools to restore and manage them are less well understood. Degraded reefs present two terminal states: reefs that are dominated by large fleshy algae or by explosions of sea urchins. The results of two restoration experiments where either sea urchins or fleshy algae were reduced are presented in this paper. Results showed that reduction of sea urchins or fleshy algae were most effective where fishing was also regulated. The author concluded that there is a need to increase restoration activities since many reefs had low coral cover due to coral bleaching and mortality that occurred on Kenyan reefs in 1998.

**CRCP, COR, P**

Disturbance, recovery, restoration, coral reefs, fleshy algae, sea urchins.

217

**McClanahan TR, Maina J (2003) Response of coral assemblages to the interaction between natural temperature variation and rare warm-water events. Ecosystems 6:551-563.**

This study undertook to determine how coral assemblages respond to warming seawater temperature. Line-transect data of hard coral assemblages in Vipingo, Kanamai, Mombasa and Diani back-reef lagoons from three years before and after the 1998 El Niño southern oscillation (ENSO) bleaching event were compared. The studied reefs differed significantly in the standard deviations of seawater temperatures but showed only minor differences in mean temperatures. Results showed that the reefs with the highest temperature variations (*eurythermal*) had fewer changes in coral cover and community similarity than reefs with low temperature variation (*stenothermal*). The *eurythermal* assemblages maintained the basic community structure but lost taxonomic richness, whereas the opposite was true for *stenothermal* reefs that showed some taxonomic convergence towards the *eurythermal* reefs. Across the 1998 event there was a general reduction in branching forms including the genera *Porites*, *Pavona* and *Stylophora* and a relative increase in massive *Porites* and *Favia*. The authors concluded that temperature variation may allow some adaptation by corals that could increase resilience to rare disturbances such as ENSO events, but this may also entail a loss in taxonomic richness.

**CRCP, COR, CLI, J**

Bleaching, coral, diversity, El Niño southern oscillation, climate change, Vipingo, Kanamai, Mombasa, Diani, marine park, marine reserve.

218

**McClanahan TR, Mangi S (2003) The effect of a marine protected area and the exclusion of beach seines on coral reef fisheries. In: Hoorweg J, Muthiga N (eds) Recent advances in coastal ecology: Studies from Kenya. African Studies Center Research Report 70:171-182.**

Artisanal fishing is the most common form of fishing on the Kenyan coast. This paper summarized the results of catch data at landing sites adjacent to the Mombasa marine park and seven sites in Diani between 1995 to 1999 in order to determine the influence of the park and removal of the destructive beach seine gear on artisanal fisheries catches. Results showed a large initial increase in the total catch as beach seines were removed and then a decline over time but catches were still above those before the management intervention.

The authors concluded that the continued decline in the catches and catch per man over time reflected not only an over-exploitation of preferred species and degradation of the ecosystem resulting from the use of destructive fishing methods but also indicated that the nearshore coral reef fishery was at or near full exploitation.

**CRCP, FIS, P**

Marine protected areas, beach seine exclusion, fisheries, Mombasa, Diani, marine park, marine reserve.

219

**McClanahan TR (2004) The relationship between bleaching and mortality of common corals. Marine Biology 144:1239-1245**

Warm water anomalies such as those brought on by the 1998 El Niño southern oscillation (ENSO) that caused wide spread bleaching of corals across the western Indian ocean could result in a number of responses by reef corals ranging from bleaching to various degrees and low mortality to bleaching and dying. In this study, the frequency of coral colony responses was recorded for 18 common coral genera across the 1998 ENSO in the Mombasa marine park from November 1997 to September 1998. Results showed that there was no clear relationship between bleaching and mortality for the 18 taxa. Mortality was generally higher in the branching and encrusting corals than in the massive and submassive forms. Although most corals responded by bleaching and dying exceptions included; *Pavona* which did not lose color or die, *Cyphastrea* and *Millipora* that showed mild bleaching but died and *Astreopora*, *Favia*, *Favites*, *Goniopora* and *Leptoria* that bleached but did not die. There was also variability in mortality estimates depending on whether data were collected by direct observation or measured from line transect. The author concluded that although there was a range of responses, the loss of color was most frequently a sign of morbidity, particularly for branching and encrusting taxa.

**CRCP, COR, J**

Bleaching, mortality, corals, ENSO, *Pavona*, *Cyphastrea*, *Millipora*, *Astreopora*, *Favia*, *Favites*, *Goniopora*, *Leptoria*, marine park.

220

**McClanahan TR, Mangi S (2004) Gear-based management of a tropical artisanal fishery based on species selectivity and capture size. Fisheries Management and Ecology 11:51-60.**

Fishing gears select fish according to the size and species and the most effective management strategy is to use gears that are able to catch many different species at sizes that maintain reproductive populations. This study assessed the catches in a multi-species and multi-gear fishery along a 50 km stretch from Marina adjacent to the Mombasa MPA to Chale in the Diani-Chale marine reserve on the Kenyan coast. The species richness, diversity, size and mean trophic level of the catches for each gear type were recorded at nine landing beaches. A total of 163 reef and reef-associated species from 37 families were recorded in the catch. Results showed that the smallest size fish and the highest number of fish landed were caught with beach seines and small traps. Beach seines landed up to 14 species per day in contrast to other gears that landed an average of four to five species per day. Beach seine selectivity overlapped most with large traps and gill nets. Results also showed that large traps, hand lines and spears caught the largest fish, and the species composition of the catch from these gears differed sufficiently to reduce overlap. The authors recommended that a mix of large traps, hand lines and spears as well as the elimination or reduction of beach seines and small

traps, could achieve the best management outcome.

**CRCP, FIS, J**

Gear management, beach seines, traps, gill nets, Mombasa, Diani, marine reserve.

221

**McClanahan TR, Baird AH, Marshall PA, Toscano MA (2004) Comparing bleaching and mortality responses of hard corals between southern Kenya and the Great Barrier Reef, Australia. *Marine Pollution Bulletin* 48:327-335.**

The warm water anomaly caused by the 1998 El Niño southern oscillation (ENSO) resulted in wide spread bleaching of corals across the Indian Ocean. This paper determines how corals responded depending on the depth, location and regions. The bleaching and mortality responses (BMI) of 19 common scleractinian corals sampled at the Great Barrier Reef in Australia (Magnetic Island, Palm Islands) and in Kenya (Watamu, Mombasa marine parks) were compared. Results showed that corals in the Mombasa Park had the highest BMI, which was attributed to the larger temperature anomaly in Mombasa. The results also showed some variability with depth; corals sampled at 2 m in Kenya and 6 m in Australia showed a high correlation between BMI and depth, but corals sampled at 2 m in Australia showed no correlation between BMI and depth. The responses of individual coral genera were similar in the two regions with the exception *Acropora* and branching *Porites* that showed moderate BMI in Australia but very high BMI in Kenya while the opposite occurred for *Pavona*. The authors concluded that the results suggested phylogenetic constraints indicating that coral physiology or morphology probably play a role in the response to thermal stress.

**CRCP, COR, CLI, J**

Bleaching, climate change, coral, El Niño, temperature, *Acropora*, *Pavona*, *Porites*, Watamu, Malindi, Mombasa, marine park.

222

**McClanahan TR, McLaughlin SM, Davy JE, Wilson HW, Peters CE, Price LK, Maina J (2004) Observations of a new source of coral mortality along the Kenyan coast. *Hydrobiologia* 530/531:469-479.**

Although coral diseases have been reported in Caribbean reefs for many decades, few incidences have been reported in the western Indian Ocean. This is the first study of coral disease in the region. The study was based on visual observation in the field, histological and scanning electron microscope (SEM) observations, benthic line transects, and water temperature measurement taken at seven sites on the Kenyan coast (Malindi, Watamu, Mombasa, Ras Iwatine, Vipingo, Kanamai, Diani) between January and February 2002. Results showed that the coral genera *Astreopora*, *Echinopora* and *Montipora* showed a high level of mortality with death occurring within two weeks; *Montipora* was almost eliminated from Kenyan reefs. Although the disease also affected colonies of *Acropora*, *Platygyra*, *Goniopora* and massive *Porites*, *Goniopora* and *Porites* showed high levels of recovery. Microscopic examination of the skeletons of affected corals revealed invasion by fungi, which was interpreted, as post-invasion after weakening by an unidentified pathogen. The results of this study showed the complexity of coral diseases and the author recommended the use of field assessments as well as laboratory analyses for these types of studies.

**CRCP, COR, J**

Coral disease, fungi, *Astreopora*, *Echinopora*, *Montipora*, Malindi, Watamu, Mombasa, Ras Iwatine, Vipingo, Kanamai, Diani, marine park, marine reserve.

223

**McClanahan TR, Graham NAJ (2005) Recovery trajectories of coral reef fish assemblages within Kenyan marine protected areas. *Marine Ecology Progress Series* 294:241-248.**

The rate of recovery of fish in marine protected areas is a function of several factors including the age of protection. This study compared the size, density and biomass of coral reef fish in Kenyan marine parks (Malindi, Watamu, Kisite and Mombasa) of differing ages over a 17 yr period to determine recovery trajectories. Data were collected by visual census and the benthic community was sampled using the line intercept method. Results showed that, both the size structure and the biomass against time graphs were convex polynomials with a maximum biomass of 1200kg/ha at 22 years; much longer than generally believed for full recovery of abundance and biomass of fish. The results also showed a slight loss in biomass after 25 years indicating a reduction in net primary production. The authors suggest that this loss could be due to increased abundance of calcifying algae due to intense grazing. The authors concluded that it was difficult to make predictions about the equilibrium coral reef fish size structure because the changes in fish size showed a high level of variability probably as a response to local environmental conditions.

**CRCP, FIS, J**

Fish biomass, recovery, calcifying algae, fish size, Malindi, Watamu, Kisite, Mombasa, marine park.

224

**McClanahan TR, Maina J, Davies J (2005) Perceptions of resource users and managers towards fisheries management options in Kenyan coral reefs. *Fisheries Management and Ecology* 12:105-112.**

Fisheries management interventions work most effectively when the needs of users and management are balanced. Acceptance of different management interventions however is often dependent on how managers and fishers view these interventions. This study measured the perceptions of Kenyan resource users and managers towards gear and area management to determine which interventions were acceptable and which were not and to compare these with actual compliance. Interviews were completed at sites in Malindi, Mombasa and Diani (15 landing sites) between 2002 and 2003. Results showed that most groups and traditional leaders were in agreement about the banned gears especially beach seines and spear gun indicating agreement between the national legislation and traditions. However, the level of compliance was low; two-thirds of fishers used these illegal gears. The results also showed that Fisheries officers and MPA managers scored area management especially closed area management benefits higher than fishers and compliance was also higher in the protected areas. The authors recommended that because shared perceptions between managers and users were not sufficient to achieve high compliance, enforcement of regulations, enabling interventions and continued dialogue with fishers about the benefits of sustainable fisheries management was required.

**CRCP, MGT, FIS, J**

Area management, artisanal fishery, gear management, Malindi, Mombasa, Diani, marine park, marine reserve.

225

**McClanahan TR, Davies J, Maina J (2005) Factors influencing resource users and managers' perceptions towards marine protected area management in Kenya. *Environmental Conservation* 32(1):42-49.**

In many tropical countries, marine protected areas were established for ecological and economic purposes but levels of non-compliance are high. For this reason there is a need to determine the factors that encourage compliance. This paper undertook to determine whether the length of protection of the MPA, socioeconomic condition, age, history of community participation and length of employment of respondents affected the attitudes towards MPAs. Data from interviews carried out in Diani, Mombasa and Malindi between May 2002 and November 2003 (detailed in McClanahan et al. 2005 above) were compared. The results showed that employed respondents and those educated to the secondary level had the most positive attitudes towards MPAs but that increased wealth or community participation did not improve perceptions. In addition, although all groups agreed that MPAs benefited the nation, fishers had significantly less positive perceptions towards MPAs than government managers. Proximity to the oldest MPAs also improved perceptions. The authors concluded patience was needed in expecting changes in resource users' perceptions and that managers should improve communication with resource users to increase awareness about the benefits of MPAs.

CRCP, FIS, J

Attitudes, park-people conflicts, perceived benefits, resource users, MPA, Diani, Mombasa, Malindi, marine park, marine reserve.

226

**McClanahan TR, Mwaguni S, Muthiga NA (2005) Management of the Kenyan coast. *Ocean and Coastal Management* 48: 901 – 931.**

The management of the coastal resources of Kenya has undergone many institutional changes over the last decades from traditional management to marine protected areas to piloting integrated coastal zone management. The process of change in governance, the challenges experienced and the lessons learned are reviewed in this paper. Despite many challenges the authors concluded that there was overall sustained progress in managing coastal resources on the Kenyan coast.

CRCP, MGT, J

Coastal management, MPAs, Integrated Coastal Management

227

**McClanahan TR, Verheij E, Maina J (2005) Comparing the management effectiveness of a marine and multiple-use collaborative fisheries management area in East Africa. *Aquatic Conservation: Marine and Freshwater Ecosystems* 16: 147 – 165.**

The effectiveness of management of marine ecosystems can vary depending on institutional, political and social systems of governance. This paper compares the health of coral reefs in Tanga (Tanzania) and Shimoni (Kenya) that are under different systems of governance, a government managed MPA (Kisite Mpunguti) and collaborative fisheries area (Tanga coastal zone). Results showed that the Kenya no-take MPA maintained high coral cover, low sea urchin abundances, high levels of herbivory and predation on sea urchins and high finfish biomass despite a bleaching event during the study period. The collaborative fisheries area showed increased fish biomass but was not effective in maintaining high fish biodiversity

or high predation rates. The authors concluded that when combined these two systems of management could achieve the multiple needs of fisheries management while conserving ecosystem processes.

**CRCP, COR, MGT, J**

Fisheries management, collaborative management, MPA, coral reefs, Kisite-Mpunguti, marine park, marine reserve

228

**McClanahan TR, Maina J, Starger CJ, Herron-Perez P, Dusek E (2005) Detriments to post-bleaching recovery of corals. *Coral Reefs* 24:230-246.**

The rate of recovery of coral reefs after bleaching is dependent on various factors including the temperature regime, coral predator abundances and benthic substrate. This study used coral transplants to test the factors that determine recovery in three marine parks (Malindi, Watamu, Mombasa) and three fished reefs (Vipingo, Kanamai, Ras Iwatine). Data on coral genera response, fragment size response, acclimation period, benthic cover components, predators and tourists, on the survival of the coral fragments were collected. Results showed that fragments transplanted to marine parks showed the lowest survival which as due to predation and not tourist damage with the highest predation occurring in the Malindi park. Stepwise multiple regression analysis of all variables showed that coralline algal cover was positively, and turf algal cover negatively associated with coral mortality; all other variables were statistically insignificant. The authors suggest that the presence of alternate food resources and predator choices were more important in determining coral survival than predator biomass and cautioned that large predatory fish in areas dominated by coralline algae could interfere with recovery of corals that tolerate a wide range of temperature (eurythermal).

**CRCP, COR, J**

Coral, mortality, predation, acclimation, Malindi, Watamu, Mombasa Vipingo, Kanamai, Ras Iwatine, marine park, marine reserve.

229

**McClanahan TR (2006) Interactions between fisheries management and a coral bleaching disturbance on coral reef fish in Kenya. *Proceedings of the 10th International Coral Reef Symposium* 1:688-695.**

Large-scale ecological changes were predicted after the mass bleaching event that occurred in 1998, but the temporal and ecological dynamics of these changes on coral fish assemblages are poorly understood. This paper details the changes that occurred in the finfish populations of reefs in southern Kenya ~5 years before and after the 1998 bleaching event. Data on 129 individual species and the density and biomass of nine families were collected at Malindi, Watamu and Kisite marine parks and fished reefs at Vipingo, Kanamai, Kikambala, and Diani. Results showed a reduction in the density of wrasse and parrotfish families and an increase in two damselfish species in the fished reefs, while surgeonfish, parrotfish, and triggerfish families increased in the protected reefs. Results also showed higher species richness in the parks than in fished reefs and little effect of the climate disturbance. The author concluded that although it was difficult to distinguish the influence of fishing and recovery from fishing from the effects of climate change, the increase in herbivorous fish abundance restricted to the damselfish in fished reefs, and parrotfish and surgeonfish families in unfished reefs was likely due to the effect of the 1998 climate disturbance on the reefs.

**CRCP, FIS, J**

Bleaching, fishing, fish families, climate disturbance, diversity, Malindi, Watamu, Kisite, Vipingo, Kanamai, Kikambala, Diani, marine park, marine reserve.

230

**McClanahan TR (2007) Achieving sustainability in East African coral reefs. Journal of Marine Science and Environment No. C5: 1-4.**

Tropical fisheries are difficult to management due to lack of targets, the diversity of fish assemblages and low-income fishing communities. This study undertook to provide a fisheries management target by estimating 'pristine' biomass using data from several reefs in East Africa including the Mombasa marine reserve. The results showed that pristine biomass was 1200kg/ha or an estimated maximum sustained yield (MSY) of 500-600kg/ha. Although most fish biodiversity was present at this MSY, there was a sharp decline in species below this level and some species were not represented. The author noted the lack capacity to manage fisheries at the local level and recommended national programs that improved enforcement of unsustainable gears especially illegal seine nets.

**CRCP, FIS, J**

Maximum sustained yield (MSY), pristine biomass, gear restrictions, Mombasa, marine reserve

231

**McClanahan TR, Graham AJN, Calnan MJ, Macneil AM (2007) Toward pristine biomass: Reef fish recovery in coral reef marine protected areas in Kenya. Ecological Applications 17(4):1055-1067.**

Marine protected areas that are manage as no-take areas are often designed without knowledge of ecological processes including the rates of recovery of key communities such as finfish. This study compared the recovery of coral reef fish in four marine parks (Malindi, Watamu, Mombasa, Kisite) that varied in size and length of protection in Kenya over a 37-year period. The results showed a rapid increase in species richness to an asymptote at ten years. Although there was variability in the recovery trends of various fish families, there appeared to be an ecological succession starting with a rapid increase of labrids and scarids followed by a slower increase of balistids and acanthurids, a reduction in sea urchins and an increase and dominance of calcifying algae. The equilibrium biomass of the fish assemblage >10 cm was 1100-1200 kg/ha, but the authors noted that the size of the parks was relatively small (<10 km<sup>2</sup> and would likely underestimate rare taxa and large apex predators such as sharks.

**CRCP, COREEF, J**

Ecological succession, marine parks, Malindi, Watamu, Mombasa, Kisite

232

**McClanahan TR, Ateweberhan M, Muhando CA, Maina J, Mohammed SM (2007) Effects of climate and seawater temperature variation on coral bleaching and mortality. Ecological Monographs 77(4): 503-525.**

Corals are susceptible to thermal stress and respond through bleaching that could lead to coral mortality. The level of stress could be mediated by different thermal and physicochemical factors that vary geographically. This study examined the thermal history over a 52-year period and the pattern of bleaching at 29 sites (including Malindi, Watamu Mombasa, Kisite marine parks) across the western Indian Ocean during the thermal stress events of 1998

and 2005. The results showed variability in bleaching and mortality and the temperature regimes at the sites. The rate of temperature rise was less important in causing bleaching and mortality than the variability in the background temperature including the standard deviation and kurtosis. The results also showed that water flow correlated better with bleaching during the 2005 event than temperature variation. The authors argued that the results indicated current effects that combined to create environments that allowed corals to adapt to environmental variation and temperature anomalies. The authors recommended that since these sites were potential refugia against future thermal anomalies, they should be prioritized for conservation.

**CRCP, COREEF, J**

Acclimation/adaptation, coral bleaching, degree-heating months (DHM), marine parks, Malindi, Watamu Mombasa, Kisite

233

**McClanahan TR, Graham N, AJ Maina J, Chabanet P, Bruggemann JH, Polunin NVC (2007) Influence of instantaneous variation on estimates of coral reef fish populations and communities. *Marine Ecology Progress Series* 340: 221-234.**

Reliable information on changes to fish abundances is crucial to the management of fisheries and marine protected areas. Changes in fish abundance are difficult to estimate however because species differ in their detectability and the inherent variability in the abundance of species. This study evaluated an important component of variability the 'instantaneous' change in fish by conducting visual censuses of damselfish, surgeonfish and parrotfish at sites in the Mombasa marine park and reserve and comparing these with counts in 1992 and 2003. Results showed that within-sites and 'instantaneous' variation were the greatest source of variation. Comparison with previous censuses resulted in estimates that were twice as high as from an indirect method where the 'instantaneous' component was subtracted from the total variation. The authors argued that given that the high variability made it difficult to detect changes, then sampling designs using random sampling and that have greater statistical power should be used for detecting change. The use of aggregate parameters such as numbers of species, density at the family, community and functional group level that are more reliable in detecting change were also recommended.

**CRCP, FIS, COREEF, J**

Population variation, fish, marine park, marine reserve, Mombasa, Ras Iwatiné

234

**McClanahan TR, Ateweberhan M, Sebastian CR, Graham NAJ, Wilson SK, Bruggemann JH, Guillaume MMM (2007) Predictability of coral bleaching from synoptic satellite and in situ temperature observations. *Coral Reefs* 26:695-701**

The prediction of climate induced seawater temperature anomalies, bleaching and coral mortality have been made easier by satellite and in situ observations of sea surface temperatures. The application of these techniques were tested in this study of coral bleaching that spanned eight countries across ~35° of latitude in the Western Indian Ocean including Kenya, at or shortly after the peak water-temperature anomalies in 2005. A single, simple and cost-effective system for monitoring bleaching was used to test accuracy of synoptic satellite and shipboard temperature data in detecting and predicting bleaching during 2005. The results showed that the bleaching predictability of degree heating weeks data was moderate, but could be enhanced when past temperature anomalies and coral

community susceptibility data were included in the analysis. The results also showed that ~50% of the bleaching response was due to the temperature anomaly and ~50% due to coral taxa and community level acclimation or adaptation. The authors recommended that since temperature anomalies sometimes over or underestimated bleaching intensity; field observations were needed especially in cases where previous bleaching events may have caused reorganization of the coral community.

**CRCP, CLI, J**

Bleaching, degree heating weeks (DHW), 1998 ENSO, seawater temperature, Western Indian Ocean.

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**McClanahan TR, Ateweberhan M, Graham NAJ, Wilson SK, Sebastian CR, Guillaume MMM, Bruggemann JH (2007) Western Indian Ocean coral communities: bleaching responses and susceptibility to extinction. *Marine Ecology Progress Series* 337:1-13.**

Despite the large scale bleaching events in the recent past in the western Indian Ocean, studies have been limited in spatial scope and the number of coral taxa. This large-scale study combined coral bleaching and coral community structure data from 8 countries spanning ~35° of latitude in 2005 and previous studies in southern Kenya, northeast Madagascar in 1998 and Mauritius in 2004 (McClanahan et al. 2007 above). A total of 37,675 coral colonies, 49 taxa, and 91 reef sites were included in the analysis. Results of cluster analysis identified 8 distinct coral communities: 2 in northern South Africa and central Mozambique; 1 in the central atolls of the Maldives; 5 along a swath from southern Kenya to Mauritius, including Tanzania, the granitic islands of the Seychelles, northeast Madagascar, and Réunion. The coral genera that were the most vulnerable to extinction included *Gyrosmlia interrupta*, *Plesiastrea versipora*, *Plerogyra sinuosa*, and *Physogyra lichtensteini* that belonged to genera with low diversity and narrow environmental ranges. The authors recommended an area from southern Kenya to Tanzania that had the least disturbed and highest diversity reefs as a regional priority area for management.

**CRCP, COR, J**

Coral biodiversity, climate change, degree heating weeks, seawater temperature, *Gyrosmlia interrupta*, *Plesiastrea versipora*, *Plerogyra sinuosa*, *Physogyra lichtensteini*.

236

**McClanahan TR (2008) Response of the coral reef benthos and herbivory to fishery closure management and the 1998 ENSO disturbance. *Oecologia* 155(1):169-177.**

Herbivory plays a key role in coral reef recovery after bleaching. This study tested the hypothesis that herbivory would be higher in fully protected areas and would enhance the rate of recovery of hard coral communities to pre-disturbance conditions. Herbivory was estimated inside protected (Malindi, Watamu, Mombasa) and unprotected reef (Vipingo, Kanamai, Ras Iwatine, Diani) after the 1998 El Niño Southern Oscillation bleaching event. Data were collected using an herbivory assay and biomass methods as well as line-transects for measurements of benthic substrate. Higher rates of herbivory were recorded in fully protected sites than in fished sites and hard and soft coral cover dominance was temporarily replaced by a dominance of turf and erect algae. The substratum showed less changes in fished reefs but the cover of turf and erect algae, and sponge increased shortly after the disturbance. The authors noted that although increased herbivory decreased erect algae and created space for coral recruitment in the protected sites, the annual rates of coral recovery

were still very low (2%) and did not differ between the fished and protected reefs suggesting that post-settlement processes may have reduced the rates of recovery on protected reefs.

**CRCP, COREEF, J**

Herbivory, bleaching, climate change, recovery, ENSO, Malindi, Watamu, Mombasa, Vipingo, Kanamai, Ras Iwatine, Diani, marine park, marine reserve.

237

**McClanahan TR, Ateweberhan M, Omukoto J (2008) Long-term changes in coral colony size distributions on Kenyan reefs under different management regimes and across the 1998 bleaching event. *Marine Biology* 153:755-768.**

The body size of individual organisms has ecological implications because it is often related to reproductive success and hence can affect recovery rates of populations. The sizes of 21,000 coral colonies from 26 common coral taxa were analyzed from line transect data collected annually between 1992 and 2006 in protected (Malindi, Watamu, Mombasa) and unprotected (Vipingo, Kanamai, Ras Iwatine, Diani) reef lagoons. During the period of collection, a major coral bleaching and mortality event occurred in 1998 affecting all studied sites. The results showed that 17 coral taxa had statistically smaller sizes in fished versus protected sites; only *Pavona* colonies were larger in the fished reefs. Results also showed that for 11 coral genera, colonies were significantly smaller after the 1998-bleaching event. On average, the mean sizes of corals did not correlate with mortality across 1998, indicating different responses depending on taxa. The authors concluded that overall, no coral taxa were tolerant of both fishing and bleaching disturbances and that the combined effect was to reduce the size of all corals. This effect of small colony size could result in reduced reproductive output and hence poorer recovery from disturbances.

**CRCP, COR, J**

Coral colonies, bleaching, colony size, reproductive success, Malindi, Watamu, Mombasa, Vipingo, Kanamai, Ras Iwatine, Diani, *Pavona*, marine park, marine reserve.

238

**McClanahan TR, Hicks C, Darling ES (2008) Malthusian overfishing and efforts to overcome it on Kenyan coral reefs. *Ecological Applications* 18:1516-1529.**

The Malthusian view of fishing predicts increases in fishing effort and use of competitive/ destructive fishing gears with increasing human population. This hypothesis was tested in Kenya by examining catch trends over a 10-year period in an artisanal coral reef fishery along a gradient of fishing intensity. Results showed that as fishing pressure increased, total annual catch and catch variability increased but catch per unit effort (CPUE), mean trophic level, the functional diversity of fish, and the diversity of gear declined as predicted. A few highly productive herbivorous fish species maintained the high but variable yield. Fishing within 5km of the Mombasa marine park resulted in a lower total catch and CPUE but more stable yields while exclusion of the illegal beach seine resulted in increased total catch and CPUE. The results also showed a strong interaction between closure and management of destructive gear, which indicated that the ability of closures to increase catch relied on improved gear management around the boundaries of the closures. The authors concluded that the potential to increase the functional and trophic diversity and per-person productivity of the fishery could be enhanced by reduction of effort and removal of the most competitive gear.

**CRCP, FIS, J**

Artisanal fisheries, population, gear use, fisheries closures, fisheries yields, Mombasa, resource competition, social-ecological systems.

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**McClanahan TR, Ruiz Sebastian C, Cinner JC, Maina J, Wilson S, Graham N, (2008) Managing fishing gear to encourage ecosystem-based management of coral reef fisheries. Proceedings of the 11th International Coral Reef Symposium, p,1012-1016.**

The use of proven management interventions such as large closures is limited in coastal areas where socioeconomic conditions are poor. The management of gears that are easily adaptable by local communities and that maximize ecological conditions is an alternative approach, but information on the effects of different types of gear is scarce. This study compared catches at landing sites in heavily fished coral reef sties in Kenya (including Mombasa and Diani marine reserves) with moderately fished sites in Papua New Guinea (PNG). The results showed that different gears caught different species and functional groups. Hook and line captured more top carnivores and piscivores and non-coral dependent species, while traps, drag nets and spear guns primarily caught herbivores, omnivores and species moderately dependent on corals. The authors concluded that although the study increased understanding on the effects of different gears, data from a wider geographical range would be needed to enhance the efficacy of adaptive gear management interventions in coral reefs predicted to be affected by climate change.

**CRCP, FIS, J**

Coral reefs, fisheries, climate change, gears, herbivory, Mombasa, Diani, marine reserve

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**McClanahan TR, Cinner JE, Maina JM, Graham NAJ, Daw TM, Stead SM, Wamukota A, Brown K, Ateweberhan M, Venus V, Polunin NVC (2008) Conservation action in a changing climate. Conservation Letters 1(2):53-59.**

Climate change is threatening societies, ecosystems and species and the challenges posed by these threats require practical solutions that are informed by knowledge of how vulnerable areas are to climate change and the capability of societies to adapt. This paper outlines a framework for priority setting in the Western Indian Ocean that was tested on data from 5 countries (including data from MPAs in Kenya) whose coral reefs had been impacted by the 1998 El Niño Southern Oscillation bleaching event, and where the social adaptive capacity differed. Results showed that given the projected stress to coral reefs and the capacity of people to adapt in the studied countries, the current conservation strategies that emphasize government control and the creation of no-take areas did not adequately prepare these countries for the impacts of climate change on their coral reefs. The authors concluded that since most of the effectively managed MPAs occurred in nations with high climate stress, there was a need to rethink conservation policies to incorporate social adaptive capacity that could cope with the complexities of climate change.

**CRCP, CON, J**

Adaptive capacity, social-ecological systems, climate change, environmental susceptibility, coral bleaching, marine parks, marine reserves.

241

**McClanahan TR, Weil E, Maina J (2009) Strong relationship between coral bleaching and growth anomalies in *massive Porites*. *Global Change Biology* 15:1804-1816.**

Environmental factors that are often associated with climate change such as elevated seawater temperatures are reported to cause increased incidences of scleractinian coral diseases. This study examined a growth anomaly in the *massive coral Porites* that is common on reefs in the western Indian Ocean, the frequency of the anomaly and the possible cause of this anomaly. Data on 16 variables including benthic cover, water temperature, bleaching intensity and growth anomalies were collected at 12 locations including in Kisite, Malindi and Mombasa MPAs in 2005 which was a mild sea water temperature anomaly year. Results showed that 8 of the 16 environmental variables were significantly associated with the growth anomaly but bleaching intensity showed the strongest association. The authors hypothesized that bleaching increased susceptibility of corals to pathogens that caused changes in skeletal porosity and anomalous growth. The authors concluded that growth anomaly frequency would be expected to increase with increasing coral bleaching.

**CRCP, COR, J**

Coral, disease, bleaching, growth anomaly, Kisite, Malindi, Mombasa, marine park, marine reserve, *Porites*.

242

**McClanahan TR, Castilla JC, White A, Defeo O (2009) Healing small-scale fisheries by facilitating complex social-ecological systems. *Reviews in Fish Biology and Fisheries* 19:33-47.**

Numerous studies have shown that small-scale marine fisheries are in decline, which is especially a challenge in developing countries where the dependence on marine fisheries is high and socioeconomic conditions poor. The success of common management tools including spatial and temporal closures and gear restrictions are dependent on their acceptance by fishers. The authors evaluate management interventions from 15 small-scale fisheries worldwide including in Kenyan reserves. Results showed that management interventions were driven by problems and were based on a trial and error process. The analysis also showed that although there was a high level of social organisation in the fisheries, there was poor ecosystem recovery. The authors argue that a focus on the socio-ecological context was needed and that facilitation of local-level compliance rather than promotion of highly technical and qualitative tools were more likely to produce results.

**CRCP, FIS, J**

Small-scale fisheries, coral reefs, socio-ecological, ecological benefits, marine reserves

243

**McClanahan TR, Graham NAJ, Wilson SK, Letourneur Y, Fisher R (2009) Effects of fisheries closure size, age, and history of compliance effects on coral reef fish communities in the western Indian Ocean. *Marine Ecology Progress Series* 396:99-109.**

Marine protected areas are a popular tool for biodiversity protection and fisheries management in the western Indian Ocean. Results from studies primarily on Kenyan reefs have shown that protection has a large impact on fish communities. However, the effects of design factors such as size and spacing and effects of local, geographical, ecological factors and type of management can only be deduced from large-scale comparisons. This study evaluated the effects of management compliance and the variability in spatial and temporal closure at 20 coral reef fisheries closures in 6 countries including Kenya in the western Indian

Ocean. Results showed that geographic location and size of closure only weakly predicted fish community variables while compliance level strongly affected these variables. In addition, none of the different management types (community, government and private closures) were consistently effective in enhancing compliance or increasing fish biomass. The authors concluded that a combination of geography, habitat, fishing, socioeconomics and management type interact with closure design to affect fish communities but that compliance level had the strongest impact.

**CRCP, FIS, J**

Marine protected areas, coral reef fisheries, Malindi, Mombasa, Watamu, Kisite, fish biomass, marine park, marine reserve.

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**McClanahan TR, Cinner JE, Graham NAJ, Daw TM, Maina J, Stead SM, Wamukota A, Brown K, Venus V, Polunin NVC (2009) Identifying reefs of hope and hopeful actions: Contextualizing environmental, ecological, and social parameters to respond effectively to climate change. *Conservation Biology* 23:662-671.**

Coral reefs are amongst the most susceptible marine ecosystems to climate change and their conservation will depend on the interaction between the ability of reefs to recover, the susceptibility to climate change and the capacity of societies to adapt. This paper describes and tests a model with data from 24 coastal communities in 5 countries of the western Indian Ocean. Data on environmental susceptibility based on oceanographic and coral mortality data; social adaptive capacity based on socioeconomic data; and reef pristineness based on abundance and diversity of fishes and corals were compared. Results showed countries differed in these factors and Kenyan marine parks had the highest index of pristineness. The authors recommended that in order to achieve any measure of success, predicted changes in ecological and environmental factors as well as socioeconomic factors must be taken into consideration while planning management interventions in coral reefs in the region.

**CRCP, MGT, J**

Adaptive management, coral reefs, social adaptive capacity, climate change, marine protected areas, Malindi, Mombasa, Ras Iwatine, Watamu.

245

**McClanahan TR (2010) Effects of fisheries closures and gear restrictions on fishing income in a Kenyan coral reef. *Conservation Biology* DOI:10.1111/j.1523-1739.2010.01530.x.**

Management interventions such as fisheries closures and gear restrictions that limit effort maybe resisted due to a lack of understanding of their economic benefits. In this study, individual and area income in locations on the Kenyan coast (including Mombasa and Diani-Chale marine reserves) with varying levels of fishing and gear restrictions were evaluated over a 12-year period. Results showed that fishing yields increased when small mesh size seine nets were removed and that the daily income of fishers fishing close to closed areas was higher than for fishers where seine nets were removed. The author concluded that the larger fish and fish of a higher market value caught next to the closed area resulted in the increased income. Gear restrictions were also beneficial by reducing the costs of fishing and increasing self-employment of fishers. The author concluded that empirical evidence of benefits of closures to local incomes may serve to increase the acceptability of closures in the tropics.

**CRCP, FIS, MPA, J**

Coral reefs, economic incentives, spill-over Mombasa, Diani-Chale marine reserves, marine parks

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**McClanahan TR, Kaunda-Arara B, Omukoto JO (2010) Composition and diversity of fish and fish catches in closures and open-access fisheries of Kenya. *Fisheries Management and Ecology* 17:63-76.**

The most common methods used to assess the success of MPAs are fisheries independent methods such as visual fish censuses, however these methods have several limitations. This study addressed this problem by comparing data from fisheries dependent and independent methods collected from Kenyan reefs under varying levels of fishing pressure. Visual fish census, coral reef habitat survey and experimental fishing data were compiled for 9 coral reef sites including in the Malindi, Watamu and Kisite marine parks, the Diani and Mombasa marine reserves and unprotected reefs. Results showed that catch composition was less variable between the fished sites suggesting that fishing had transformed the catch composition. When catch and visual fish census data were compared, the cumulative number of species was higher in fished than in protected sites, which the authors suggested, could be due to the larger area covered by fishers while fishing. The authors concluded that the small differences shown by the fisheries dependent methods need attention because they equate to large effects on the processes and structure of the reef ecosystem.

**CRCP, FIS, J**

Coral reefs, fisheries, sampling, Malindi, Watamu, Kisite, Diani, marine reserve, marine park.

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**McGuinness K (2007) Effects of the beach seine fishery on populations of seagrass-associated *Leptoscarus vaigiensis* and *Siganus sutor*. MSc. University of York. United Kingdom. 30p**

The beach seine was banned in Kenya in 2001, yet this destructive gear is widely used along the Kenyan coast. This study focused on the impacts of beach seines on the commercially valuable parrotfish *Leptoscarus vaigiensis* and rabbitfish *Siganus sutor* fishery. The abundance and sizes of these species were estimated at sites where beach seines were restricted (Kenyatta, Kijangwani, Kuruwitu) and where beach seines dominated (Marina, Reef, Msanakani, Nyali) in 2007. Herbivory was also estimated using a seagrass herbivory assay. Results showed that beach seines landed the highest proportion of *L. vaigiensis* and *S. sutor*, of which 63 % and 77 % (respectively) were sexually immature juveniles. Results of the herbivory assay showed higher densities of larger fish at protected sites and where beach seines had been restricted for a long time. The author concluded that evidence of the decline of the CPUE over the last decade combined with high juvenile mortality indicated that the reproductive stock was under severe pressure limiting the sustainability of the fishery and recommended improved fisheries management.

**CRCP, FIS, T**

Artisanal fishing, fisheries management, parrotfish, rabbitfish, overfishing, *Leptoscarus vaigiensis*, *Siganus sutor*, Kenyatta, Kijangwani, Kuruwitu, Marina, Reef, Msanakani, Nyali, marine reserve

248

**Mdodo RM (1999) Environmental factors and coral bleaching in Kenya. MSc. thesis, Moi University, Kenya 67 pp.**

The El Niño Southern Oscillation (ENSO) caused mass coral bleaching along the coast of Kenya in 1998. This MSc. research study was carried out in order to determine how the symbiotic algal (zooxanthellae) population in different corals changed as a response to bleaching. The study was carried out on reefs at Malindi and Mombasa marine parks and at Kanamai a fished reef between September 1997 and April 1998. The extent of bleaching and mortality was estimated and coral fragments were collected to quantify zooxanthellae densities and chlorophyll concentrations. Results showed that bleaching and mortality was highest at Kanamai a relatively shallow reef and at Malindi marine park which was under the influence of sediments. Bleached corals had 1-35% of the chlorophyll-a concentration and 2-4% of the density of zooxanthellae of normal corals. The coral *Porites nigrescens*, *Porites lutea*, *Acropora spp*, *Pocillopora spp*, and *Stylophora pistillata* were the most susceptible to bleaching and mortality. The author concluded that coral bleaching and consequent mortality was caused by two sets of stressors: sediment/rainfall stress in Kanamai and Malindi in 1997, and elevated sea temperatures in all the sites in March/April 1998. The use of zooxanthellae counts and chlorophyll-a concentration measurements for monitoring bleaching was recommended.

**CRCP, COR, T**

Coral bleaching, temperature, mortality, *Porites nigrescens*, *Porites lutea*, *Acropora*, *Pocillopora*, *Stylophora pistillata*, Malindi, Mombasa, Kanamai, marine park.

249

**Mdodo RM, Tole MP, Obura DO, Muthiga N (2003) Environmental factors in coral bleaching: The 1997/98 El Niño in Kenya. In: Hoorweg J, Muthiga N (eds) Recent advances in coastal ecology: Studies from Kenya. African Studies Center Research Report 70:35-50.**

This paper details the results of an MSc. research study that was carried out on reefs at Malindi and Mombasa marine parks and at Kanamai, an unprotected reef by Mdodo in 1997 to 1998 (detailed in Mdodo 1999 above).

**CRCP, COR, W**

Coral bleaching, temperature, mortality, *Porites nigrescens*, *Porites lutea*, *Acropora*, *Pocillopora*, *Stylophora pistillata*, Malindi, Mombasa, Kanamai, marine park.

250

**Micheli F, Gheradi F, Vannini M (1991) Feeding and burrowing ecology of two East African mangrove crabs. Marine Biology 111: 247-254.**

Crabs play an important role in nutrient cycling and energy flow through their burrowing and feeding activity in mangrove forests. This study investigated the feeding and burrowing behaviours of two common crab species *Sesarma meinerti* and *Cardisoma carnifex* at Mida creek. Observations were carried out along transects from October to November 1988. Results showed that the species overlapped in their zonation and were restricted to the upper intertidal, and showed no particular preference for feeding on the leaves of particular mangrove species. Both species were most active at dusk and dawn but differed in their burrowing with *C. carnifex* being mainly diurnal and *S. meinerti* being mainly nocturnal. From the amount of litter consumed by these crab species the authors concluded that the crabs played a major role in the ecology of the mangroves of Mida Creek.

**KMFRI, CRCP, MAN, CRU, J**

Crabs, mangroves, feeding, burrowing, Mida Creek, marine reserve

251

**Montano S, Seveso D, Galli P, Obura DO (2010) Assessing coral bleaching and recovery with a colour reference card in Watamu Marine Park, Kenya. Hydrobiologia DOI: 10.1007/s10750-010-0407-4.**

Bleaching of coral and other zooxanthellate organisms is projected to increase as a consequence of increased seawater temperature due to climate change. This study assessed the performance of the Coral Watch card in the Watamu marine park in 2007. The study was carried out for eleven months including during the temperature maxima period when bleaching risk was highest. Seven coral colonies of different genera were observed for differences during the bleaching and post-bleaching period. Results showed that 50% of coral bleached and a high percentage of those that bleached (75%) also died. There was variability in the bleaching and mortality rates in the different genera but in general, branching species were more susceptible than sub-massive or massive genera. The authors concluded that the card was a cost effective and practical method of monitoring bleaching.

**CORDIO, MON, J**

Coral reef card, bleaching, monitoring, Watamu, marine park.

252

**Moorjani SA (1970). Seasonal changes in the marine algal flora of the Kenya Coast, University of Nairobi. 19 pp.**

Marine algae are widely distributed in shallow marine habitats along the Kenyan coast and the factors that control their distribution a little understood. This PhD. study assessed the seasonal changes in algal distribution at four intertidal reef platforms (Kanamai, Likoni, Tiwi, Msambweni) between May 1973 and April 1974. Data on abundance, biomass and species composition were collected in 50 by 50cm quadrates placed at 5m intervals along replicate belt transects laid perpendicular to shore. Results showed that algal density, biomass and species diversity was highest towards the end of the southeast monsoon period (September-October) and lowest towards the end of the northeast monsoon period (February to March). Results also showed a seasonal differentiation in algal families; the green algae (Chlorophyceae) were abundant in March to April, the brown algae (Phaeophyceae) were abundant from August to October and the red algae (Rhodophyceae) were abundant from March to April and September to August. The author concluded that the distribution and abundance of algae was related to the seasonal environmental changes that occur during the monsoons in the Western Indian Ocean.

**CRCP, AG, R**

Marine algal flora, Chlorophyceae, Phaeophyceae, Rhodophyceae, Kanamai, Likoni, Tiwi, Msambweni

253

**Moorjani SA (1977) The ecology of marine algae of the Kenya coast. PhD. dissertation, University of Nairobi, 285pp.**

Marine algae have received little attention on the Kenyan coast. This PhD. dissertation focused on the distribution and abundance of marine algae predominantly in southern Kenyan shallow lagoons and builds on the report (Moorjani 1970 above). Results showed

spatial and temporal variability in abundance and variability in dominance amongst the algal groups.

**KMFRI, AG, T**

Marine algal flora, Chlorophyta, Rhodophyta, Cyanophyta, Phaeophyta.

254

**Mörk E (2004) Effects of nutrient availability and herbivory on the reproductive capacity of tropical green macroalgae *Halimeda macroloba* and *Halimeda renschii* on Kenyan coral reefs. MSc. Thesis, Stockholm University, Sweden 21 pp.**

Grazing pressure and nutrient input play a role in controlling the productivity and reproduction of marine algae but the impacts of these factors on reefs in Kenya are poorly understood. This MSc. research study investigated how nutrient concentration and reduced herbivory affected the productivity and reproductive capacity of the common calcareous algae *Halimeda macroloba* and *H. renschii* at reefs that differed in herbivore abundance and nutrient input (Ras Iwatine, Coral Gardens, Kanamai and Malindi). Results showed that *H. macroloba* were larger where nutrient loads were high irrespective of grazing pressure. Tissue nitrogen differed however depending on grazing pressure and nutrient load; at high nutrient load but low grazing pressure sites, the tissue nitrogen concentration was high, while at sites where both grazing pressure and nutrient loads were high, the tissue nitrogen content was low. *Halimeda renschii* responses differed being larger and tissue nitrogen content higher where herbivore fish densities were higher. The author concluded that both nutrient availability and herbivory were important in controlling the reproductive capacity of the two studied algal species.

**CRCP, AG, T**

Herbivory, *Halimeda macroloba*, *H. renschii*, nutrient loads, sea urchins, fish, Ras Iwatine, Coral Gardens, Kanamai, Malindi, marine park, marine reserve.

255

**Mörk E, Sjöö GL, Kautsky NL, McClanahan TR (2009) Top-down and bottom-up regulation of macroalgal community structure on a Kenyan reef. *Estuarine, Coastal and Shelf Science* 84:331-336.**

This paper was based on the MSc. thesis of Mörk (2004 above). The study evaluated how grazing pressure (top-down) and nutrient input (bottom-up) factors regulated macroalgal communities on Kenyan reefs.

**CRCP, AG, J**

Herbivory, *Halimeda macroloba*, *H. renschii*, nutrient loads, herbivore, sea urchins, fish, Ras Iwatine, Coral Gardens, Kanamai, Malindi, marine park, marine reserve.

256

**Munga CN (2008) Ecological and socio-economic assessment of Mombasa marine park and reserve, Kenya. MSc. thesis, Vrije Universiteit Brussel (VUB) 103 pp.**

This MSc. thesis reviews ecological characteristics and socio-economic aspects of the Mombasa marine protected area (MPA) in Kenya. Socio-economic data was collected using interviews of resource users and ecological data was compiled from the KWS monitoring program from 2004 to 2007. Results of the ecological monitoring showed higher coral cover, higher abundances of fish and sea cucumbers and lower abundances of sea urchins in the park than the reserve. Results also showed significant differences amongst the resource

users in terms of gender, perception of park benefits, education level and socio-economic conditions. Overall, fishers had the oldest mean age and associated with the MPA for the longest period while boat operators had the highest mean income from the MPA. The author suggested the establishment of a program to monitor the socio-economic conditions of key MPA stakeholders to inform appropriate community development interventions.

**KMFRI, CRCP, MGT, T**

Socio-economic condition, ecological condition, park, reserve, marine park, marine reserve.

257

**Munga D, Yobe AC, Owili M, Mwanguni SM (1993) Assessment of land-based sources of marine pollution along the Kenyan coast. Kenya Marine and Fisheries Research Institute, Mombasa, Kenya. 60 pp.**

This paper reviews the sources and contribution of urbanization to pollution in the marine environment in Kenya. The review showed that 80% of pollution entering the ocean was land-based coming primarily from liquid and solid waste generated in coastal urban centers. The largest city Mombasa, which produced 60% of the industrial effluent, had a non-functioning and poorly designed sewage system and most of the other towns were ill equipped to handle solid or liquid waste. Other sources of land-based pollution included storm water runoff and domestic waste that had the potential to impact nearshore coastal and marine habitats. The report recommended joint efforts between the government and the private sector to address this challenge.

**KMFRI, POL, R**

Pollution, solid and liquid waste, sewage, Mombasa.

258

**Muohi A, Onyari JM, Omondi JG, Mavuti KM (2003) Heavy metals in sediments from Makupa and Port-Reitz creek systems: Kenyan Coast. Environment International 28:639-647.**

The Makupa and Port-Reitz creek system are adjacent to the most developed industrial center on the Kenyan coast; the Mombasa port, Airport, refinery and many heavy industries and the municipal dumpsite are located in the area. The creek system is fringed by mangroves and is an important fishing ground for artisanal fishers. This study undertook to establish whether heavy metal concentrations in the creek system were higher than internationally recommended standards. Sediment samples were collected from Makupa (11 stations) and Port Reitz Creek (13 stations) using an Eckman grab sampler and analyzed for copper, zinc, lead and cadmium concentrations using atomic absorption spectrophotometric and energy dispersive X-ray fluorescence techniques. Results showed higher concentrations of these metals than expected in the creeks, and concentrations were higher in sediments collected from Makupa than from Port Reitz sediments. The authors concluded that industrial activities and the nearby municipal dumpsite contributed to the higher concentrations of metals especially in the Makupa creek sediments.

**CRCP, POL, J**

Pollution, sediments, heavy metals, Makupa creek, Port Reitz creek, Mombasa.

259

**Muthama CM, Uku JN (2003) Macrofaunal assemblages of littoral seagrass communities. In: Hoorweg J, Muthiga N (eds) Recent advances in coastal ecology: Studies from Kenya. African Studies Center Research Report 70:51-63.**

Seagrass habitats are diverse and highly productive ecosystems that are widely distributed throughout the Kenyan coast. This study compared the community of macrofauna found in vegetated seagrass areas and unvegetated areas at Nyali in the Mombasa MPA in order to evaluate the contribution of seagrass beds to macrofaunal abundance. Data were collected during both the north and southeast monsoon periods on assemblages of seagrasses. Results showed a slightly higher abundance of macrofauna in vegetated compared to the unvegetated sites. At both sites, the abundance of macrofauna was higher during the northeast monsoon period. The authors suggested that organisms derived a variety of benefits from vegetated areas including shelter in the roots and leaf blades from physical stress and predators, and food mainly from detrital matter. The authors concluded that the largest impact occurred due to seasonal disturbances from the southeast monsoon winds that resulted in a greater change in macrofaunal abundance than the increase in seagrass biomass.

**KMFRI, CRCP, SG, J**

Macrofauna, seagrass, Mombasa, Nyali, marine reserve.

260

**Muthiga NA, McClanahan TR (1987) Population changes of a sea urchin (*Echinometra mathaei*) on an exploited fringing reef. *African Journal of Ecology* 25:1-8.**

The sea urchin *Echinometra mathaei* is the mostly widely distributed urchin in shallow habitats in the western Indian Ocean. This paper described the population structure and dynamics of *E. mathaei* at Diani, Kenya and compared with data from a previous study undertaken 15 years earlier (Khamala 1971, above). Results showed that *E. mathaei* densities and average sizes (test length) were significantly higher in the inner reef lagoon than the reef flat and had increased significantly in the inner reef lagoon but not the reef flat in 15 years. The distribution of *E. mathaei* was positively correlated with the percentage of hard substrate (dead coral and coral rubble) in the lagoon but not on the outer reef. The authors suggested that the increase in *E. mathaei* was probably driven by fishing pressure removing the competitors and predators of this sea urchin in Diani and that the lack of an increase in the outer reef was due to the stressful physical conditions that limited both the urchin population and fishing and shelling activities.

**CRCP, SU, J**

*Echinometra mathaei*, population, Diani, reef lagoon, reef flat, marine reserve.

261

**Muthiga NA (1996) The role of early life history strategies on the population dynamics of the sea urchin *Echinometra mathaei* (*de Blainville*) reefs in Kenya. PhD. dissertation, University of Nairobi, Kenya. 252 pp.**

The population of the sea urchin *Echinometra mathaei* was shown to be increasing on Kenya's fished reefs and the prevailing hypothesis was that this was due to a reduction in the numbers of its predators and competitors due to overfishing. Other factors that affect population densities were poorly studied. This PhD. research focused on life history strategies of *E. mathaei* including reproduction, recruitment and growth and the factors affecting these

strategies. Results showed that on Kenyan reefs (Diani, Vipingo and Kanamai), *E. mathaei* had a seasonal reproductive pattern that correlated with temperature, light and chlorophyll-a concentrations and spawning coincided with the phytoplankton peak. The density of *E. mathaei* was related to growth and reproduction; individuals were smaller, achieved sexual maturity earlier, and had relatively larger gonads in the densest population, in Diani. Recruitment however was not affected by population density. The author concluded that the study increased knowledge of the biology and ecology of this widely distributed echinoid, and on the effect of seasonality on the reproduction and recruitment of marine benthic invertebrates in the tropics.

**CRCP, SU, T**

Sea urchin, *Echinometra mathaei*, life history, reproduction, recruitment, growth, Diani, Vipingo, Kanamai, marine reserve.

262

**Muthiga NA (1996) A survey of the coral reef habitats of the Mombasa marine park and reserve with a review of the existing boundary. Kenya Wildlife Service, Mombasa, Kenya. 11 pp.**

This report presented the findings of a coral reef survey of sites in the park and in the reserve carried out in 1996 prior to a boundary review. Benthic substrate cover and invertebrate densities were estimated using line-transect and quadrat methods. Results showed higher coral cover and lower fleshy algae and sea urchin densities in the marine park sites than in the reserve sites. Sites adjacent to the Mtwapa creek on the northern boundary of the MPA had higher soft coral cover. The study recommended spatial planning and regulations to control users to minimize conflicts within the protected area.

**CRCP, COREEF, R**

Ecology, closed area, Mombasa, Mtwapa, marine park, marine reserve.

263

**Muthiga NA (1997) Coral reefs of Kenya: research activities and priorities. In: Annala JH (ed) Fisheries and aquaculture research planning needs for Africa and West Asia. Proceedings of the ICLARM Conference 50:15-17.**

Coral reefs are amongst the most diverse and productive marine ecosystems on the Kenyan coast. They provide goods and services for millions of people living and working at the coast. However, coral reefs are also highly vulnerable to overexploitation, destructive exploitation, sedimentation and climate change. This paper reviewed the past, ongoing and planned coral reef research activities in Kenya. Research included studies on reef ecology and structure, coral and fish communities, effects of human impacts and other disturbances to reef ecosystems, the effects of marine protected areas and restoration measures. The report recommended the development of monitoring programs and data management systems that could enhance the capacity of managers to mitigate impacts on reefs.

**CRCP, COREEF, P**

Coral reef, research, monitoring, data management.

264

**Muthiga NA, McClanahan TR (1997) The effect of visitor use on the hard coral communities of the Kisite marine park, Kenya. Proceedings of the 8th International Coral Reef Symposium 2:1879-1882.**

Marine protected areas are mainly established for biodiversity protection and tourism

in Kenya, yet there is a potential conflict between the needs of the tourism industry and biodiversity protection. This study investigated whether recreational activities were causing more damage to the coral community in the back-reef slopes in the Kisite marine park than natural disturbances. Results showed no significant difference in coral cover at experimental and control sites although there was more damage from tourists in the experimental plots and more damage from fish bites in the controls plots. Greater damage was measured in shallow than deep sites suggesting that snorkelling may have caused more damage than SCUBA diving although this could also be due to differences in coral sizes; larger more robust corals occurred in deeper waters. The authors concluded that visitor use did not result in higher damage to coral colonies than natural disturbances and recommended maintenance of the present visitor numbers as well as visitor education to minimize coral breakage, and monitoring to estimate future carrying capacity of the reef.

**CRCP, TOU, P**

Tourism, corals, Kisite, marine park, visitor use, marine park.

265

**Muthiga NA (1998) National perspective of marine protected area management in Kenya. In: Salm VR, Tessema Y (eds) Partnership for conservation. Report of the regional workshop on marine protected areas, tourism and communities. IUCN Eastern Africa Regional Programme. 28-32 pp.**

This paper was a contribution to a regional workshop on the marine protected areas of Eastern Africa. The paper summarized the objectives, management and biodiversity within the marine protected areas (MPAs) of Kenya and described the distribution of marine habitats, endangered species and the threats to these species and habitats. The paper also described the legislative framework governing the management of the MPAs and the challenges in balancing biodiversity protection and economic development and recommended the establishment of formalized collaborative mechanisms between sectors and communities utilizing the MPAs and the MPA management authority.

**CRCP, MPA, MGT, P**

Coral reefs, marine protected area, management, marine park, marine reserve.

266

**Muthiga NA, Ndirangu S (2000) Village based larviculture and stock enhancement of sea cucumbers (*Echinodermata: Holothuroidea*) on the Kenyan coast. Biodiversity Support Fund Report No. 422000.**

Sea cucumbers (holothurians) have been harvested and exported from Kenya for hundreds of years yet little was known about the status of the fishery. This report summarized the first widespread study of sea cucumbers on the Kenyan coast. Different aspects including the diversity and distribution of holothurians, a preliminary assessment of the reproductive patterns of two commercial species (*Holothuria fuscogilva* and *H. scabra*) and, the effectiveness of management interventions and socio-economic conditions of fishers were investigated. The results showed that the fishery was severely over-exploited and that the poor socio-economic conditions of the fishers encouraged continued fishing despite low economic returns. The report recommended urgent measures including the enforcement of a ban on the use of SCUBA and development of mariculture for restocking and for community based ranching.

**CRCP, SC, R**

Sea cucumbers, holothurians, fishery, *Holothuria fuscogilva*, *H. scabra*.

267

**Muthiga NA, Riedmiller S, Carter E, Rudy van der Elst, Lang-man J, Horrill C, McClanahan TR (2000) Management status and case studies. In: McClanahan TR, Sheppard CRC, Obura DO (eds) Coral reef of the Indian Ocean, their ecology and conservation. Oxford University Press. 473-505 pp.**

This book chapter was a contribution to a book on the coral reefs of the Indian Ocean that was an activity of the 'Year of the Reef 2000' programs in the western Indian Ocean. The chapter described case studies of the management of coral reefs and associated fisheries in East Africa including the national marine protected area system of Kenya. The case studies traced the history, justification and objectives of management, described the origin of the specific management challenges and provided recommendations for future management interventions.

**CRCP, MGT, J**

Management, coral reefs, fisheries, MPA, Kenya, Zanzibar, South Africa, Tanzania.

268

**Muthiga NA, Mwangi SN, Kirugara D, McClanahan TR, Uku J, Ndirangu S, Gwada P, Pakia M, Moragwa G, Kioko S (2001) The biophysical and ecological profile of Diani-Chale. Kenya Marine Fisheries Research Institute. 15 pp.**

The Diani-Chale marine protected area was gazetted in 1995. The process of consultation prior to establishment of this MPA was fraught with conflict primarily between the MPA management authority and the fishing community. A pilot integrated management project was initiated in the area to try and resolve these conflicts. This report details a biophysical profile of the MPA as a contribution towards development of an integrated management plan for the area. The main marine and coastal ecosystems from river Mwachema on the northern boundary to Gazi Bay on the southern boundary of the MPA were mapped and the habitats and species were recorded. Marine and coastal ecosystems consisted primarily of fringing coral reefs, seagrass beds in the lagoons, mangrove forests along Gazi Bay and fragments of coastal forest. The report provided a detailed bibliography of research carried out in Diani-Chale MPA and identified gaps in the knowledge of the area.

**CRCP, BIOD, R**

Diani-Chale, coral reefs, mangrove, coastal forests, seagrass beds, integrated coastal management marine reserve.

269

**Muthiga NA (2003) Coexistence and reproductive isolation of the sympatric echinoids *Diadema savignyi* (Michelin) and *Diadema setosum* (Leske) on Kenyan coral reefs. Marine Biology 143:669-677.**

The sea urchins *Diadema savignyi* and *D. setosum* are sympatric species that inhabit shallow reef lagoons throughout the western Indian Ocean. This study investigated whether the reproductive strategies of these sea urchins played a role in maintaining the coexistence of these closely related species. The seasonal and lunar reproductive periodicity of these species at Vipingo, Kanamai and Diani reef lagoons were determined by gonad index, histological and spawning induction methods. Results showed that both species had

continuous reproduction throughout the year. Gonad indices in *D. savignyi* peaked during the northeast monsoon period when light and temperatures were highest while *D. setosum* showed less of a seasonal trend and gonad indices peaked when temperatures were lower. Both species exhibited synchronized lunar spawning patterns with *D. setosum* spawning a few days before the full moon and *D. savignyi* spawning after the full moon. The author concluded that temporal reproductive isolation during the lunar spawning period reinforced by seasonal differences in reproductive effort maintained the coexistence of these closely related species.

**CRCP, SU, J**

Coexistence, reproductive isolation, sea urchins, *D. savignyi*, *D. setosum*, Vipingo, Kanamai, Diani, marine reserve.

270

**Muthiga NA, Njue R (2004) Implementing ICRAN activities at the Malindi-Watamu MPA complex demonstration site, Kenya. In: People and reefs: Successes and challenges in the management of coral reef marine protected areas. UNEP regional seas report and studies No 176. UNEP: 52-57.**

In 2001, the Malindi-Watamu MPA complex, one of the oldest MPAs in Africa was selected as a Demonstration site under the International Coral Reef Action Network (ICRAN) East African project component. Subsequently, in 2002, an ICRAN project was initiated through the United Nations Environment Program (UNEP) with the objective of profiling the MPA complex, developing small-scale infrastructural developments to enhance management, and reviewing socio-economic issues of stakeholders. This report outlined the key management challenges encountered in the MPA complex, detailed implementation of the demonstration project activities and summarized the lessons learned during the implementation of the project. The authors recommended the establishment of a stakeholder advisory committee to assist in the management of the area.

**CRCP, MPA, R**

Malindi, Watamu, International Coral Reef Action Network (ICRAN), MPA.

271

**Muthiga NA (2005) Testing for the effects of seasonal and lunar periodicity on the reproduction of the edible sea urchin *Tripneustes gratilla* (L) in Kenyan coral reef lagoons. Hydrobiologia 549:57-64.**

The sea urchin *Tripneustes gratilla* is widely distributed in the western Indian Ocean and gonads (roe) of this urchin are collected for subsistence and commercial purposes in some countries. This paper details the findings of a study on the reproduction of *T. gratilla* in Kenya a prerequisite for mariculture. Standard gonad index and histological techniques were used on individuals collected monthly at Kanamai from 1987 to 1988. Results showed that although gonad growth commenced in the northeast monsoons and peaked in the southeast monsoons, reproduction was continuous throughout the year. Results also showed that *T. gratilla* exhibited lunar periodicity; spawning although not perfectly synchronized, mainly occurred in the second and third quarters of the moon. The author concluded that despite *T. gratilla* having gonads throughout the year, a high proportion of individuals had low quality roe ('runny' gonads), which indicated that the urchin was not a suitable candidate for wild harvest. There was a need to develop techniques to improve roe quality before this urchin could be considered for mariculture.

CRCP, SU, J

Continuous reproduction, lunar periodicity, *Tripneustes gratilla*, sea urchin fishery, mariculture.

272

**Muthiga NA, Jaccarini V (2005) Effects of seasonality and population density on the reproduction of the Indo-Pacific echinoid *Echinometra mathaei* in Kenyan coral reef lagoons. *Marine Biology* 146:445-453.**

This paper summarizes the findings of a study of the reproductive biology of the widely distributed tropical sea urchin *Echinometra mathaei* that was part of dissertation research by Muthiga (1996 above). The results showed that *E. mathaei* exhibited an annual reproductive pattern that was synchronized between males and females and that did not exhibit a lunar periodicity in spawning. The findings contributed to the growing body of literature showing that the seasonality of the east African coast plays a role in controlling reproductive patterns in marine invertebrates in the region.

CRCP, SU, J

Seasonality, reproduction, *Echinometra mathaei*, gametogenesis, spawning, Vipingo, Kanamai, Diani, marine reserve.

273

**Muthiga NA, McClanahan TR (2006) Ecology of *Diadema*. In: Lawrence JM (ed) Edible sea urchins: biology and ecology (2<sup>nd</sup> Edition). Elsevier Amsterdam. Pp 205-225.**

Sea urchins of the genus *Diadema* are some of the most widely distributed, abundant and ecologically important sea urchins in tropical oceans. This book chapter reviews the taxonomy, biogeography, population biology and ecology, and ecosystem effects of the genus across the world's oceans including examples from studies carried out on Kenyan MPAs.

CRCP, SU, B

Sea urchins, *Diadema*, biology, ecology, marine protected areas.

274

**Muthiga NA (2006) Assessing the effectiveness of management in marine protected areas in Kenya: Experiences from the Mombasa marine park and reserve. *Proceedings of the 10<sup>th</sup> International Coral Reef Symposium*: 1231-1242.**

The Mombasa marine protected area is the youngest MPA in Kenya however, it is adjacent to the most highly developed beach on the Kenyan coast. This paper evaluates the success of this MPA by assessing management capacity and actions, against the stated objectives of the MPA. Biophysical, socioeconomic and governance indicators were selected and used to evaluate each of the objectives of the MPA. Results showed that the marine park was meeting the objective of biodiversity conservation but the marine reserve where the regulation of fishing activities was less effective was not adequately meeting the objective of sustainable fishing. The author concluded that although the governance framework was sound, jurisdictional conflicts with other management authorities reduced the ability of the MPA to meet its overall objectives. The author recommended; administrative actions to ensure the stability of the managers, actions to resolve conflicts of mandate, revision of the legislation, enhanced collaboration between management authorities, and actions to improve the socioeconomic conditions of MPA users, minimize conflict and enhance compliance.

**CRCP, MAN, J**

Management effectiveness, Mombasa, marine park, marine reserve.

275

**Muthiga NA (2006) The reproductive biology of a new species of sea cucumber, *Holothuria (Mertensiothuria) arenacava* in a Kenyan marine protected area: the possible role of light and temperature on gametogenesis and spawning. *Marine Biology* 149 (3):585-593.**

During surveys of sea cucumbers on the Kenyan coast in 1997, a new species *Holothuria (Mertensiothuria) arenacava* was discovered in the Mombasa marine reserve (Samyn et al 2001 below). Subsequently, studies on the reproductive biology of this species were initiated. The gonad index and microscopic methods were used on *H. arenacava* individuals collected over a 13-month period. Results showed that the reproductive cycle of *H. arenacava* was annual; gametogenesis started in July during the southeast monsoon period and spawning occurred between March and May during the northeast monsoon. Gonad indices showed a higher correlation with light than with temperature suggesting that changes in light probably cued the onset of gametogenesis in this species. Results also showed tight synchrony between females and males and no lunar periodicity in spawning. The author suggested that these life history strategies including synchronous spawning, more and larger females, and spawning just prior to the most favorable time for larval development served to increase the reproductive success of this sea cucumber.

**CRCP, SC, J**

Sea cucumber, annual reproduction, *Holothuria (Mertensiothuria) arenacava*, Mombasa, marine reserve.

276

**Muthiga NA, Ochiewo J, Kawaka J (2007) Sea cucumbers in Kenya. In Conand, C and Muthiga, N (eds) *Commercial Sea Cucumbers: A review for the Western Indian Ocean WIOMSA Book Series No. 5*, 9-21 pp.**

This chapter is part of a review on the sea cucumbers (holothurians) of the western Indian Ocean focusing on the current state of knowledge on sea cucumbers in Kenya. Details on the ecology, biology and socioeconomic aspects of the fishery are summarized from previous studies and surveys including studies carried out in Kenyan marine protected areas. The chapter includes a comprehensive reference section and recommendations for management.

**CRCP, SC, BK**

Sea cucumbers, holothurians, fisheries management, marine park, marine reserve.

277

**Muthiga NA, Kawaka J (2008). The effects of temperature and light on the gametogenesis and spawning of four sea urchin and one sea cucumber species on coral reefs in Kenya. *Proceedings of the 11<sup>th</sup> International Coral Reef Symposium, Fort Lauderdale, Florida* : 356-360**

Tropical marine invertebrates are often assumed to have continuous reproduction since environmental variability is lower in the tropics. This paper reviews the reproductive cycles of five echinoderm species on Kenyan reefs studied at various times between 1987 and 1998. Samples were collected in Mombasa marine reserve and Kanamai and processed using standard gonad index, macroscopic and microscopic methods. Results showed that

the sea urchin *Echinometra mathaei* and the sea cucumber *Holothuria arenacava* had tightly synchronized spawning and an annual cycle of reproduction that correlated significantly with temperature and light. In contrast the sympatric sea urchins *Diadema savignyi* and *D. setosum* had continuous reproduction but with monthly spawning at different phases of the moon; *D. savignyi* spawned at full moon and *D. setosum* spawned in the last quarter. These urchins also showed reproductive peaks in different monsoon seasons. The authors concluded that the reproductive strategies of these invertebrates not only ensured reproductive isolation in the sympatric species but also sexual synchrony and spawning when food was abundant for the larvae.

**CRCP, SC, SU, P**

Sea cucumber, sea urchin, reproduction, seasonality, *Holothuria arenacava*, *Echinometra mathaei*, *Diadema savignyi*, *D. setosum*, Mombasa, Kanamai, marine reserve.

278

**Muthiga N, Costa A, Motta H, Muhando C, Mwaipopo R, Schleyer M (2008) Status of coral reefs in East Africa: Kenya, Tanzania, Mozambique and South Africa. In: Wilkinson C (eds) Status of coral reefs of the world: 2008. Global Coral Reef Monitoring Network and Reef and Rainforest Research Centre, Townsville, Australia. Pp 91-104.**

The 'Status of the Worlds Coral Reefs' report is produced every four years through the Global Coral Reef Monitoring Network (GCRMN). This chapter is a contribution to the report summarizing the status of reefs in Kenya, Tanzania, Mozambique and South Africa since 2004. The reefs of these countries mostly showed good recovery from the 1998 El Niño Southern Oscillation bleaching event especially in areas where local stressors such as fishing and crown of thorns outbreaks were managed. In general, the governance and management of many MPAs in the region was improving but more resources including trained personnel, and resources for operational and administrative, and research purposes were needed.

**CRCP, COREEF, B**

Coral reefs, East Africa, MPAs, Kenya.

279

**Muthiga NA (2009) Evaluating the effectiveness of management of the Malindi-Watamu marine protected area complex in Kenya. Ocean and Coastal Management 52:417-423.**

Marine protected areas have typically been assessed through studies of trends in biophysical changes yet effectiveness also depends on the capacity for management. In 2005, an initiative to introduce the concept and train managers and researchers on Management Effectiveness Assessment (MEA) was conducted in Kenya, Seychelles and Tanzania. Subsequently, the first MEA of the oldest MPA in Kenya, the Malindi-Watamu MPA was conducted. This paper summarized the findings of the MEA. Results from biophysical, socioeconomic and governance indicators showed that the marine parks (Malindi and Watamu) where full protection was enforced were making progress especially in conserving biodiversity but that the marine reserve where fishing activities were poorly regulated lagged behind in meeting the objective of sustainable fishing. The author concluded that inefficiencies due to overlapping mandates, financial and administrative constraints, external factors such as climate change and civil unrest, and inadequate stakeholder consultation and participation contributed to reducing the effectiveness of the MPA.

**CRCP, MGT, J**

Management effectiveness assessment, MEA, Malindi, Watamu, marine park, marine reserve.

280

**Muthiga NA (2009) Evaluating the effectiveness of management of the Kisite – Mpunguti marine protected area. In: Hoorweg J, Muthiga N (eds) Advances in coastal ecology: People, processes and ecosystems in Kenya. African Studies Centre, African Studies Collection Vol 20:178-191.**

Managers of marine protected areas are faced with many demands and often do not have the opportunity to reflect on the results of their actions. Management evaluations allow managers to learn and improve through time. This paper details the first assessment of the management effectiveness of Kisite-Mpunguti MPA. Biophysical, socioeconomic and governance indicators were selected and using existing information evaluated against actions towards meeting the goals of the MPA. Results indicated that the Kisite-Mpunguti MPA showed progress in biodiversity protection. Less progress was shown in stakeholder participation, sustaining fisheries, and financial stability of the MPA. Weaknesses in the management plan and conflicts due to overlapping mandates with other natural resource management authorities further reduced the effectiveness of management actions while, external factors such as coral bleaching and terrorism had a negative impact on biodiversity and the financial sustainability of the MPAs respectively. The author recommended; revision of the MPA plan, creation of formalized communication mechanisms, improved financing of MPA operations and systematization of monitoring data to inform management.

**CRCP, MGT, P**

Management effectiveness assessment, Kisite, Mpunguti, marine park, marine reserve.

281

**Muthiga NA, Kawaka J (2009) The breeding pattern and variations in timing and reproductive output of the commercial sea cucumber *Holothuria fuscogilva* in Kenya. Western Indian Ocean Journal of Marine Science 8 (2):183-192.**

The sea cucumber *Holothuria fuscogilva*, one of the most commercially valuable species worldwide is widely distributed throughout the western Indian Ocean. However, little is known about the reproductive biology of this species in the region, information that is crucial for management. This study examined the reproductive pattern of *H. fuscogilva* collected by SCUBA on a monthly basis in the Shimoni area including in the Mpunguti marine reserve. Results showed that *H. fuscogilva* exhibited an annual pattern of reproduction with a high level of synchrony between sexes. Gametogenesis commenced in May and spawning occurred monthly over an extended period. The gonad index correlated significantly with water temperature but not with light. The findings fail to support the hypothesis that reproduction of marine invertebrates would show no sexual synchrony and would be continuous at the equator. The authors argued that the change in sex ratio from unity towards more males implies a negative impact of fishing that could result in a reduction in the overall reproductive success of the *H. fuscogilva* population in Shimoni.

**CRCP, SC, J**

Sea cucumber, reproduction, sexual synchrony, seasonality, *H. fuscogilva*, Mpunguti, marine reserve.

282

**Muthini M, Tole PM, Otieno D (2003) Solid waste pollution loads in beach hotels on the Kenyan south coast. In: Hoorweg J, Muthiga N (eds) Recent advances in coastal ecology: Studies from Kenya. African Studies Center Research Report 70:153-167.**

The beaches along the coastlines of Mombasa and Diani are the most highly developed tourist beaches along the Kenyan coast. The management of solid waste along this coastline has been a source of some concern. This study assessed the types and quantity of solid waste generated by six of the largest beach hotels in Mombasa and Diani during the high tourist season from September 1996 to February 1997. Results showed that an average of 1.90kg/person/day was generated and food waste comprised the highest component (7.9%). The municipal waste management facilities were inadequate and only a few hotels recycled and composted waste. The authors recommended in-house separation of solid waste to ensure high quality waste components that would encourage recycling and reduce waste disposal costs, minimize health risks and improve the quality of the environment.

**CRCP, POL, P**

Solid waste, hotels, Mombasa, Diani, marine reserve.

283

**Mwadzaya H, Ndung'u M, Simba D (1995) Knowledge, attitudes and practice assessment concerning community conservation and participatory rural appraisal in areas that neighbour the Kisite/Mpunguti marine park and reserve, Kenya. 69 pp.**

In many cases, marine protected areas (MPAs) are established in areas that were historically utilized by local communities. Failure to adequately engage these communities has often resulted in conflicts that reduce the success of the MPA. This paper reviews the knowledge, attitudes and conservation practices of the local community neighbouring the Kisite/Mpunguti MPA that was established in 1978. The review focused on the traditional methods of resource use and conservation, the socioeconomic conditions of the local community, the areas of conflict and the working relationship between the management of the MPAs and the communities. Results indicated that despite the age of the MPA, a sense of alienation and resource use conflicts especially between the fishers and MPA users continued. The report recommended enhanced involvement of the local community in the management of the MPA and better articulation of the benefits of the MPA for community livelihoods.

**KWS, COM, R**

Management, MPA, conflicts, attitudes, Kisite, Mpunguti, marine park, marine reserve.

284

**Mwakumanya AM (1998) The impact of sea waves on beach morphology: A case study on Nyali and Bamburi beaches in Mombasa, Kenya. MPhil thesis, Moi University, Kenya. 167 pp**

Some key tourist beaches on the Kenyan coast are experiencing shoreline retreat and beach erosion yet the rates of erosion and interactions of hydrodynamic and morphological characteristics is poorly understood. This study evaluated the hydrodynamics and morphological factors of beaches along the northern coast of Kenya. Results showed that beaches at Nyali had a gentle slope and were composed mainly of fine sand and that surging waves contributed 83.0 % to the beach slope and sediment characteristics. Bamburi beach on the other hand had a relatively steep sloping and narrow beach and wave energy contributed over 74.2% in slope changes and sediment characteristics. Human activities including the construction of beach walls aggravated shoreline instability and beach erosion especially along the Bamburi shoreline. The study recommended that coastal erosion mitigation measures must take into account site-specific morphological and hydrodynamic processes and that the physical planning units in the municipality should have knowledge of, and enforces appropriate construction on shorelines.

**CORDIO, CE, T**

Coastal erosion, hydrodynamics, beach morphology, Bamburi, Nyali, marine reserve

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**Mwakumanya AM, Tole PM (2003) Coastal erosion at Mombasa beaches hydrodynamic and morphological interactions. In: Hoorweg J, Muthiga N (eds) Recent advances in coastal ecology: Studies from Kenya. African Studies Center Research Report 70:133-143.**

This paper summarizes the findings of the MPhil thesis research of Mwakumanya (1998 above). The study was carried out along the Nyali-Bamburi shoreline and assessed the contribution of beach morphological characteristics and hydrodynamics to the rates of erosion.

**CRCP, CE, P**

Coastal erosion, hydrodynamics, beach morphology, Bamburi, Nyali, marine reserve.

286

**Mwaluma JM (2002) Pen culture of the mud crab *Scylla serrata* in Mtwapa mangrove system Kenya. Western Indian Ocean journal of Marine Science 1(2):127-133.**

Mariculture is increasingly being evaluated as a means to resolve the problem of diminishing food security and livelihoods of coastal communities, however very little research has been done on mariculture in Kenya. This study investigated the pen culture method for rearing the mud crab *Scylla serrata*, which is the most commercially valuable crab in East Africa. An experimental pen was established in an intertidal area in a mangrove in Mtwapa creek adjacent to the Mombasa MPA in 2000. Results showed that the temperature, salinity and dissolved oxygen in the pen were suitable for rearing and crabs reached harvest size within four months. Since there was a relatively poor recovery rate at harvest due to the crabs boring behaviour and cannibalism, the author recommended experiments with other methods such as cage culture. The author concluded that pen culture was a viable method provided careful selection of locations and recommended polyculture using crabs, finfish such as milkfish and prawns since these species were also retrieved during harvest.

**KMFRI, MAR, J**

Mariculture, crabs, *Scylla serrata*, Mtwapa, mangrove.

287

**Mwaluma JM, Osore M, Kamau J, Wawiye P (2003) Composition, abundance and seasonality of zooplankton in Mida Creek, Kenya. Western Indian Ocean Journal of Marine Science 2 (2): 147 – 155.**

Plankton play an important role in the productivity of marine ecosystems yet the types and abundance of plankton in tropical marine ecosystems has received little attention. In this study, the seasonality and abundance of plankton is investigated at four stations in Mida Creek from May 1996 to April 1997. Results showed that phytoplankton abundance peaked in May after the long rains and in January after the short rains on the Kenyan coast. Zooplankton abundances followed the peaks in phytoplankton and copepods dominated the zooplankton comprising 60% of the total. The highest abundance of zooplankton occurred at the station at the mouth of the creek, which the authors concluded was influenced by the input of high salinity waters.

**KMFRI, PK, J**

Phytoplankton, zooplankton, abundance, diversity, Mida Creek, marine reserve

288

**Mwaluma JM, Paula J (2004) Composition, abundance and distribution of brachyuran larvae in Mida Creek, Kenya. Western Indian Ocean Journal of Marine Science 3 (2):143-150.**

Brachyura or crabs have a global distribution and can be found in a diversity of marine environments. This study focused on the composition, abundance and distribution of brachyuran larvae in Mida creek in the Watamu marine reserve. Samples were collected from plankton hauls at four stations from May 1996 to April 1997 and simultaneous measurements of temperature and salinity were made. Results showed that nine major families of larvae were present in the plankton and the most abundant belonged to the *Ocypodidae*, *Grapsidae* and *Xanthidae* families. The highest abundance of larvae occurred in February at the temperature maxima and correlated significantly with total zooplankton abundance and salinity. The authors concluded that the seasonal pattern of brachyuran larval abundance in Mida Creek was associated with both biotic and abiotic factors, most significantly salinity and zooplankton abundance.

**KMFRI, CRCP, PK, J**

Plankton, abundance, distribution, brachyuran larvae, Mida Creek, *Ocypodidae*, *Grapsidae*, *Xanthidae*, marine reserve.

289

**Mwangi SN, Kirugara D, Osore M, Njoya N, Yobe A, Dzeha T (2001) Status of marine pollution in Mombasa marine national park and reserve and Mtwapa Creek, Kenya. Kenya Wildlife Service Report, Mombasa Kenya. 9 pp.**

The most popular and highly developed beaches on the Kenyan coast, Nyali-Bamburi-Shanzu, are also adjacent to the Mombasa marine park. Most hotels located along this coastline dispose of liquid waste in soakage pits. Consequently, there has been concern about contamination of the waters adjacent to these hotels. This report summarized the main findings of a two-year pollution assessment study conducted in the Nyali-Bamburi-Shanzu lagoon, and Mtwapa creek on the northern boundary of the Mombasa marine park from August 1995 to July 1997. Results indicated that the lagoon was well flushed and concentrations of nutrients and chlorophyll-a, organic loading and bacteriological contamination were low and not considered eutrophic by international standards. Results from Mtwapa creek on the other hand, indicated eutrophication and high bacterial contamination. The authors concluded that the seasonal river discharge, surface water runoff and point sources of raw sewage disposal especially in the vicinity of Shimo la Tewa prison were responsible for the poor water quality in Mtwapa creek.

**CRCP, POL, R**

Marine pollution, Mombasa, marine park, Nyali, Shanzu, Mtwapa Creek.

290

**Mwashote BM (2003) Levels of cadmium and lead in water, sediments and selected fish species in Mombasa, Kenya. Western Indian Ocean journal of Marine Science 2(1): 25-34.**

Inputs of heavy metals into the marine environment from anthropogenic sources are a concern especially since these metals can bioaccumulate to lethal levels in the marine food chain. This study investigated the levels of cadmium (Cd) and lead (Pb) in Makupa and Tudor creek adjacent to Mombasa Island; the most populated center on the Kenyan coast, and at Mida creek and Gazi Bay that are relatively low population sites. Samples of fish, water and sediments were collected at these sites in the dry and wet season in 1987 to 1998 and analyzed

using flame absorption spectrophotometry. Results showed that Cd and Pb concentrations were relatively lower in the water column in Makupa and Tudor creek but similar and higher in the sediments and tissues especially during the rainy season. The concentrations of both heavy metals were significantly lower in Gazi and Mida creek and generally higher in Makupa creek than Tudor creek and were within internationally recommended limits of concentration.

**CRCP, POL, J**

Pollution, lead cadmium, Mombasa, Mida, Gazi, marine reserve.

291

**Mwashote BM, Ohowa BO, Wawiye PO (2005) Spatial and temporal distribution of dissolved inorganic nutrients and phytoplankton in Mida Creek, Kenya. *Wetlands Ecology and Management* 13 (6): 599 -641.**

Mida Creek is an important wetland on the Kenyan coast yet little is known about the physico-chemical characteristics of the Creek. In this study, the dissolved inorganic nutrients of Mida Creek and in boreholes and wells in the areas surrounding the creek as well as the phytoplankton composition were investigated from May 1996 to April 1997. Results showed that inorganic nutrients were generally much higher in the wet than dry season and in boreholes and wells than in the creek waters. More than 295 species of phytoplankton in 78 genera were identified dominated by *Chaetoceros spp*, *Chroococcus limneticus* and *Oscillatoria spp*. The authors concluded that the groundwater outflow and surface runoff were the main contributors to nutrients in the creeks waters.

**KMFRI, NUT, J**

Nutrients, phytoplankton, *Chaetoceros*, *Chroococcus limneticus*, *Oscillatoria*, Mida Creek, marine reserve

292

**Mwatha GK, Fondo E, Uku J, Kitheka JM (1998) Biodiversity of Mida Creek, Kenya. *Kenya Marine and Fisheries Research Institute and Kenya Wildlife Service, Mombasa, Kenya.* 197 pp.**

Mida creek within the Watamu marine reserve is an important fishing, recreation and tourist destination on the northern coast of Kenya. This report summarized an assessment of the biodiversity of Mida creek that was commissioned by the Kenya Wildlife Service in 1998 prior to drafting the management plan of the MPA. Results of the survey indicated that the creek supported a wide range of marine and coastal ecosystems including mangroves, coral reef assemblages, seagrass beds, sandy beaches and rock cliffs, and associated fauna including fish, crustaceans, marine invertebrates, cetaceans, marine turtles and shorebirds. Species distribution, abundance and diversity were associated with environmental conditions, the tidal regime and the ocean currents. The report documented anthropogenic pressure as the major threat to the productivity of the marine ecosystems within the creek. The authors recommended a coordinated effort by management authorities and the local community to help address the problem.

**KMFRI, BIOD, R**

Mida Creek, coral reefs, mangroves, Watamu, marine reserve.

293

**Mwaura J, Grimsditch G, Kilonzo J, Amiyo N, Obura D (2009) Zooxanthellae densities are highest in summer months in equatorial corals in Kenya. *Western Indian Ocean Journal of Marine***

**Science 8 (2): 193 – 202.**

When corals bleach the relationship between the coral and symbiotic algae is disrupted leading to loss of zooxanthellae. However, zooxanthellae densities are known to fluctuate on a seasonal basis. This response was investigated in this study that was carried out at the Mombasa marine park. Results showed that densities were highest during the northeast monsoons during periods of peak temperature and light and fluctuated amongst species. The authors noted that the response differed from corals at higher latitudes and emphasized the variability in responses in corals between sites and locations.

**CORDIO, COR, J**

Zooxanthellae, coral bleaching, Mombasa, marine park

294

**Ngugi I (1998) Economic impacts of marine protected areas: a case study of Mombasa marine park. MSc. thesis, University of Nairobi, Kenya. 71 pp.**

Marine protected areas have been proven to enhance biodiversity but the impacts on the fisher community that are alienated from previous fishing grounds limits the success of many MPAs. This MSc. research focused on the economic implications of the Mombasa marine park on local fishers. Catch related variables i.e. CPUE, number of fishermen, and the levels of revenue from fish sales were collected for fishers fishing in the marine reserve (Bamburi and Nyali) and outside the MPA (Marina). Fishers and MPA users and stakeholders were also interviewed using structured questionnaires. Results indicated that there was a high level of negative attitudes by fishers towards the establishment of the park due to a loss of access to previous fishing grounds. The author recommended integration of existing traditional systems of marine resource use into spatial planning prior to establishment of MPAs to reduce conflict.

**CRCP, MPA, T**

Marine protected areas, resource conservation, Mombasa, Marina, Bamburi, Nyali, marine park.

295

**Nordemar I, Sjö GL, Mörk E, McClanahan TR (2006) Effects of estimated herbivory on the reproductive potential of four East African algal species – a mechanism behind ecosystem shifts on coral reefs? *Hydrobiologia* 575(1):57-68.**

Herbivory is an important process in coral reefs controlling the distribution and abundance of benthic fauna and flora. The effects of herbivory on reproductive processes of algae however, are little known. This study investigated the effects of fish and sea urchin herbivory on the reproductive potential of four species of macroalgae; *Halimeda macroloba*, *H. renschii*, *Turbinaria ornata* and *Padina boergesenii*, that are common in East African reefs. Field studies were carried out at Ras Iwatine a restricted fishing area, Mombasa marine park that is fully protected and Kanamai that is unprotected between January and March 2004. Results showed fecundity was higher and individuals grew larger in areas where the estimated fish herbivory was lower for *T. ornata* and the two *Halimeda* species. The brown algae *P. boergesenii*, however, responded ambiguously to herbivory. The authors concluded that although herbivory increased size and reproductive output in some species of algae it was not possible to generalize about the effects of overfishing on algal fecundity because of the variability in responses at protected and unprotected sites.

**CRCP, AG, J**

Macroalgae, herbivory, reproduction, coral reefs, *Halimeda macroloba*, *H. renschii*, *Turbinaria ornata*, *Padina boergesenii*, marine park, marine reserve.

296

**Ntiba M, Jaccarini V (1992) The effect of oocytic atresia on fecundity estimates of the rabbit fish *Siganus sutor* (Pisces: Siganidae) of Kenyan marine inshore waters. *Hydrobiologia* 247:215-222.**

The rabbitfish *Siganus sutor* is an important component of the artisanal catch on the Kenyan coast but little is known on its reproduction. This study focused on the reproduction of this species in Mombasa. Sampling was carried out using traps laid fortnightly around neap tides in 1985. Standard histological techniques as well as categorization of gonads into maturity stages were used to evaluate the reproductive stages of the species. Results showed that *S. sutor* had a strongly bimodal size frequency distribution of late stage oocytes, which supported other evidence that indicated that this species spawned twice in a year. Results also showed that about 5% of oocytes were removed by atresia before spawning. The authors concluded that the presence of atresia in both pre and post-spawning oocytes made it difficult to conclude that their main function was primarily to remove non-functional oocytes.

**CRCP, FIS, J**

Fecundity, *Siganus sutor*, reproduction, Mombasa.

297

**Nyang'wara AO (2002) Catch assessment on the artisanal fisheries of Mpunguti marine reserve, Shimoni and Funzi bay, South Coast, Kenya. MSc. thesis, University of Nairobi, Kenya. 139 pp.**

The waters around Shimoni and Funzi bay are important fishing grounds for artisanal fishers on the south coast of Kenya. This MSc. research study focused on a catch assessment survey of the artisanal fisheries of Mpunguti marine reserve and Funzi bay from January to August 2001. A total of 1,596 fish were caught through experimental fishing dominated by species of the families *Scaridae*, *Siganidae*, *Lethrinidae*, *Labridae*, *Acanthuridae*, *Chaetodontidae*, *Pomacentridae* and *Balistidae*. Results showed variability in the catch but no clear seasonal pattern and significantly higher abundance in most fish families and more fishers in Mpunguti than in Funzi bay. The study also estimated that the total catch per landing site and catch per fisherman were declining. The author recommended the introduction of a closed season in Funzi bay, a ban on destructive gears and improved enforcement on the use of illegal fishing methods.

**CRCP, FIS, T**

Artisanal fishing, MPA, Mpunguti, Funzi bay, fishing gear, marine reserve, marine park.

298

**Nyunja JA, Mavuti KM, Wakwabi EO (2002) Trophic ecology of *Sardinella gibbosa* (Pisces: Clupeidae) and *Atherinomorous lacunosus* (Pisces: Atherinidae) in Mtwapa creek and Wasini channel, Kenya. *Western Indian Ocean Journal of Marine Science* 1(2):181-189**

The availability of food is a major factor regulating growth, reproduction, abundance and movement patterns of fish and ultimately fisheries production. This paper detailed a comparative study of the stomach contents of the common planktivorous fishes *Sardinella*

*gibbosa* and *Atherinomorous lacunosus* in Mtwapa creek adjacent to the Mombasa MPA and Wasini channel adjacent to the Kisite-Mpunguti MPA. Fish were sampled monthly using a cast net and simultaneous measurements of temperature, salinity and pH were made at each site in 2001. Results showed that the two locations differed in their physicochemical characteristics, which the author attributes partly to the increased input of nutrients into the Mtwapa creek. The two species also differed in their diets; *S. gibbosa* mainly fed on copepods regardless of monsoons, *A. lacunosus* fed mainly on nematodes in the northeast monsoons and a mixture of copepods and phytoplankton in the southeast monsoons. The author concluded that the two species were able to utilize different food resources despite occupying similar microhabitats.

**KMFRI, FIS, J**

Trophic ecology, planktivorous fishes, seasonality, Mtwapa, Wasini, *Sardinella gibbosa*, *Atherinomorous lacunosus*.

299

**Nzuki S (2004) Integral use of remote sensing and GIS techniques in the management of mangroves in a tropical marine protected area. Lamu, Archipelago, Kenya. MSc. thesis, Moi University, Kenya. 125 pp.**

This MSc. thesis research focused on a comparative assessment of the mangroves of Kiunga marine reserve using remote sensing and GIS techniques. The results showed changes in the areal extent and community structure of the mangroves of Kiunga which the author attributed to mangrove cutting for export, for building, for fuel, lime and tannin production, and medicinal uses. The author noted that previous studies focused on mangrove wetland inventories and concluded that the study increased knowledge of the interaction between utilization and changes in mangrove community structure in Kiunga.

**CRCP, MAN, T**

Remote sensing, GIS, mangroves, Kiunga, marine reserve.

300

**Obura DO, McClanahan TR, Muthiga NA, Mutere J (1994) Status of Malindi marine park: Study of the 1991 and 1992 Sabaki River sediment discharge on the park's coral community. Coral Reef Conservation Project, Mombasa 22 pp.**

Increased discharge of terrigenous sediments, due to changing land use practices along the Sabaki River catchment basin, has been a cause of concern about the ecological health of coral reefs in Malindi. This report detailed a comparative study of the impacts of sedimentation on shallow coral communities in the Malindi and Watamu marine parks. Benthic substrate and mean colony size was measured using line transects, and the secchi disc to estimate sedimentation. Results showed that algal cover increased in the control reef (Watamu marine park) while soft coral and sponge cover increased in the intermediate reef (Coral gardens in Malindi marine park). No differences were recorded in coral genera richness, diversity and dominance amongst the reefs but the average colony size increased for 'sediment-tolerant' genera and decreased for 'sediment-intolerant' genera in the high sediment reef. The authors concluded that the lack of a strong sediment effect was probably due to the active protection of the Malindi marine park and recommended management of other factors that contributed to degradation including tourist damage, pollution and varying extractive uses in the MPAs.

**CRCP, MPA, SED, R**

Sedimentation, coral reef, marine park, Sabaki river, Malindi, Watamu.

**301**

**Obura DO (1995) Differential bleaching and mortality of eastern Africa corals. In: Richmond MD, Francis J (eds) Marine Science Development in Tanzania and Eastern Africa, Western Indian Ocean Marine Science Association. 301-317 pp**

Bleaching responses differ due several factors including exposure, species and the level environmental stress in hard corals. This study examined interspecific patterns of bleaching, mortality and recovery of corals on reefs in Kenya (including in MPAs), Tanzania, Mozambique and Madagascar for one year after 1997-1998 El Niño southern oscillation. Results showed that 50-80% of corals bleached and died. Coral tissue condition (normal, pale, bleached and dead) recorded for up to one year after the onset of bleaching showed three major response groups characterized by (a) severe bleaching and 100% mortality (*Acropora spp*, *Pocillopora spp*, *Galaxea astreata*), (b) graduated bleaching with low to moderate mortality (*Porites lutea*, *Echinopora gemmacea*, *Hydnophora exesa*), and (c) moderate persistent bleaching with moderate recovery (*Pavona varians*, *Montipora tuberculosa*). These species groups were consistent with coral life history strategies. The study recommended continuous monitoring and assessment of coral reefs to facilitate the design and implementation of effective conservation strategies.

**CORDIO, CRCP, COR, P**

Bleaching, mortality, corals,

**302**

**Obura DO (1995) Environmental stress and life history strategies, a case study of corals and river sediment from Malindi, Kenya, PhD. thesis, University of Miami, USA. 326 pp.**

Sediments can have detrimental effects on corals through smothering or by increasing the turbidity of seawater, which has a negative effect on coral physiology. The Sabaki River discharges tonnes of sediments annually into Malindi bay. This PhD. research assessed the impacts of sedimentation on reefs from Malindi to Watamu that varied in sediment inputs. Results showed that overall terrigenous sediments reduced coral growth and survival in shallow reef habitats on these reefs. The extent of the impact however, was mediated by the interaction between water energy, tidal and climatic variables, sediment supply, and monsoon seasonal variation. Results also showed that although water visibility was low in Malindi, the degree of sediment smothering was low due to high resuspension of sediments. Further experimental studies of growth and survivorship in three common coral species (*Acropora cerealis*, *Pocillopora damicornis* and *Porites lutea*) showed moderate sediment influence. The author concluded that patterns of coral species distributions along this coast were probably influenced by adaptation to environmental stress induced by continuous sedimentation.

**CORDIO, CRCP, COR, SED, T**

Environmental stress, corals, sediments, Sabaki, Malindi, Watamu, MPA, *Acropora cerealis*, *Pocillopora damicornis*, *Porites lutea*, marine park, marine reserve.

303

**Obura DO, Mwadzaya H, Wekesa E, Muthiga NA (1998) Rapid assessment of coral reef biophysical and socio-economic conditions in the Kiunga marine national reserve. UNEP/FAO Report 56 pp.**

The ecological status of the coral reefs of Kiunga, their importance for biodiversity conservation and their economic contribution to local communities have received little attention. This report details a rapid ecological and socioeconomic assessment that was carried out in March 1998 as part of a UNEP regional seas initiative. Forty sites in and adjacent to the MPA were surveyed. Results showed high diversity of species including: Kui channel (corals and fish), Mlango Bomani (corals), Bomo (fish), Rubu channel (fish) and the deep reef ledges (corals and fish). Results of the socioeconomic assessment showed that fishing was the main subsistence and commercial activity of communities living in and around the MPA and an increasing trend in fishing effort. The authors recommended zoning of the reserve to delineate areas of high conservation concern and areas important for fishing in collaboration with the local community to address the growing problems of resource supply and fishing impacts.

**CRCP, COREEF, R**

Assessment, biophysical, socioeconomic, coral reefs, Kiunga, marine reserve.

304

**Obura DO, Visrams S (2000) Transplantations of coral fragments. In: Souter D, Obura D, Olof L (eds) Coral reef degradation in the Indian Ocean Status Report 2000, 180-184 pp.**

Rehabilitation of coral reefs through coral transplants is hampered by the lack of sufficient information about which coral genera are most suitable in the field. This study was carried out in Mombasa marine park, to evaluate the ability of different genera that differed in growth rates and life history strategies in rehabilitation of degraded reefs. Fragments from the common species *Porites lutea*, *Pavona cactus*, *Montipora spongodes*, *Echinopora gemmacea*, *Acropora sp.* (*F. corymbosa*), *Hydnopora microconus* and *Goniopora sp.* were cemented onto natural reef substrate or elevated cement racks. Results showed that the sub-massive corals had a higher survival rate on elevated racks while branching species survived better on natural substrate. The authors suggest that survival of the sub-massive species was probably influenced by algal competition and sediment accumulation at the coral tissue margins and algal overgrowth, which suppressed the growth of these corals. The authors recommended further studies using larger sized fragments to determine if growth was a function of size.

**CORDIO, COR, R**

Transplantation, corals, Mombasa, marine park, *Porites lutea*, *Pavona cactus*, *Montipora spongodes*, *Echinopora gemmacea*, *Acropora sp.*, *Hydnopora microconus*, *Goniopora sp.*

305

**Obura D, Muthiga NA, Watson M (2000) Kenya. In: McClanahan TR, Sheppard CS, Obura D (eds). Coral Reefs of the Indian Ocean: Their Ecology and Conservation. Oxford University Press, New York, p, 199-229.**

This book chapter details the ecology, oceanography, geography, fisheries, conservation and management of coral reefs in Kenya. The marine protected areas of Kenya and their history are also provided. The chapter forms a comprehensive reference for coral reefs in Kenya prior to 2000.

**CRCP, CORDIO, COREEF, B**

Coral reefs, threats, fisheries, MPAs.

306

**Obura DO, Uku JN, Wawiye O, Mwachireya SA, Mdodo R (2000) Kenya, reef status and ecology. In: Souter D, Obura D, Linden O. Coral reef degradation in the Indian Ocean: Status Report 2000, 25-34 pp.**

The 1998 El Niño southern oscillation caused the most extensive and severe bleaching of Kenyan coral reefs in recent record. This report summarized findings of studies of coral bleaching, mortality and effects on benthic community structure on reefs in Kenya collated from a number of studies including in MPAs. Results showed that most of Kenya's southern fringing reefs in shallow water experienced high mortality of live corals, and reefs in deeper water experienced lower mortality possibly due to exposure to lower water temperatures. In addition, the reefs in Kiunga on the northern border of Kenya showed less mortality probably due to exposure to the cooler waters of the Somali current system. Changes in other reef components such as algae, invertebrates and fish were also reported. The authors concluded that the low recruitment rates of corals coupled with changes in reef community structure due to overfishing were causing delays in coral and reef recovery.

**CORDIO, COR, R**

Coral reefs, bleaching, mortality, temperature, El Niño southern oscillation, overfishing, Kiunga, marine reserve,

307

**Obura DO (2001) Participatory monitoring of shallow tropical marine fisheries by artisanal fishers in Diani, Kenya. Bulletin of Marine Science 69 (2):777-791.**

Community participation has increasingly been acknowledged as a tool to enhance the understanding of socioeconomic and ecological conditions experienced by fisher communities. This paper details the findings of an eco-anthropological study to document and map the resource and spatial knowledge of the fisher community in the coral reefs of Diani, Kenya. Results showed that fishing was the main livelihood activity of this community and that fishers were able to assess trends in the fishery and showed a high awareness of the issues involved with fishing. Fishers were also relatively competent in mapping, recording catch data, and analysis of the information. The author recommended use of participatory methods for assessing local use patterns but noted the limitation that the older fishers with the most knowledge of the community lacked skills due to the low level of literacy.

**CORDIO, MON, J**

Participatory monitoring, fisheries, coral reefs, Diani, marine reserve.

308

**Obura DO (2001) Can differential bleaching and mortality among coral species offer useful indicators for assessment and management of reefs under stress? Bulletin of Marine Science 69 (2):421-442.**

Coral bleaching and other disturbances are increasing on reefs, as is the need to develop tools to monitor and assess the effects of these disturbances. This paper details the evaluation of coral colony tissue condition (normal, pale, bleached and dead) on reefs in Kenya, Madagascar, Mozambique and Tanzania up to a year after the start of the 1997-98 El Niño bleaching event. Results showed that more than 50% of coral colonies bleached

and died but the response was species dependent; one group severely bleached and had 100% mortality, another group gradually bleached and had low to moderate mortality and one species (*Montipora tuberculosa*) showed extended bleaching. The author noted that each group generally showed similarities in life history strategies and that this relatively simple method of observing coral condition in the field could provide a reliable technique for monitoring.

**CORDIO, MON, J**

Coral bleaching, El Niño, coral tissue condition, monitoring, marine reserve.

309

**Obura DO, Mwaura JM (2001) Overlap of tourism and fisheries sites in the Diani-Chale coral reef. Opportunities for multiple use zonation. Coral reef degradation in the Indian Ocean Report 10 pp.**

The Diani-Chale marine reserve is a multiple-use MPA that is primarily utilized by artisanal fishers and tourism operators. The activities of these users have opposing interests and access to the beach, on-water and reef areas are the cause of major conflicts in the area. Zoning within the MPA for the different uses could minimize this user conflict. This study used GIS, field surveys and information gathered through informal interviews and participant observation techniques to generate a map of user zones in the area. Results showed that although fishing was conducted at many sites, covering large contiguous areas of the reefs, the income value obtained from individual sites was higher for tourism than fishing. The authors recommended conflict resolution interventions at a few key sites where the fishing versus tourism interaction was highest and adopting a fishing-centered management context since fishers were the most vocal and resistant to the establishment of the MPA.

**CORDIO, FIS, TOU, R**

Diani-Chale, MPA, marine reserve, tourism, fishing, coral reef, zoning, mapping.

310

**Obura DO (2002) Status of Coral reefs in Kiunga marine reserve in Kenya. In: Linden O, Souter D, Wilhelmson D, Obura D (eds) Coral reef degradation in the Indian Ocean: Status Report 2002. 47-54 pp.**

The coral reefs of the Kiunga marine reserve have been monitored periodically from 1998 to 2002. This report detailed the main findings of benthic cover, coral population information, fish diversity and abundance data and compares this with data from reefs monitored in southern Kenya. Results showed that coral cover was significantly lower in Kiunga reefs than in southern Kenyan reefs. Hard coral cover averaged 15% before the El Niño Southern Oscillation bleaching event of 1998. While reefs in the south showed increases in coral cover to 2001, half of the monitored sites in Kiunga showed coral cover declines and coral recruitment was below detectable levels. Estimates of fish densities also showed a strong decline with increasing latitude. The author noted that the monitoring indicates that fishing was the strongest factor in controlling the fish assemblage; fish abundances increased away from populated areas. The author recommended additional monitoring in different reef zones that could be achieved by involving other stakeholders including dive operators.

**CORDIO, MON, COREEF, R**

Bleaching, coral recovery, Kiunga, Diani, marine reserve.

311

**Obura DO Celliers L, Machano H, Mangubhai S, Mohamed SM, Motta H, Muhando C, Muthiga N, Pereira M, Schleyer M (2002) Status of coral reefs in eastern Africa: Kenya, Tanzania, Mozambique and South Africa. In: Wilkinson C (ed) Status of coral reefs of the world. Pp 63-73.**

The 'Status of the Worlds Coral Reefs' report is produced every four years through the Global Coral Reef Monitoring Network (GCRMN). This chapter was a contribution to the report summarizing the status of reefs in Kenya, Tanzania, Mozambique and South Africa upto 2002. The 1998 El Niño Southern Oscillation bleaching event caused variable mortality from very low (South Africa <1%) to very high (80%, northern Tanzania and Kenya) and recovery had been poor to moderate. Additional stressors included floods in Mozambique, a fungal disease in Kenya and northern Tanzania and continued anthropogenic pressures from over fishing, destructive fishing, sedimentation, and pollution. The review also showed that management of MPAs in the region had improved, additional MPAs were established, co-management programs, monitoring programs including socioeconomic and community programs were initiated.

**CORDIO, COREEF, MGT, R**

Coral reefs, management, monitoring

312

**Obura DO, Wanyonyi I, Mwaura JM (2002) Participatory monitoring of artisanal fisheries in Kenya. In: Linden O, Souter D, Wilhelmson D, Obura D (eds) Coral reef degradation in the Indian Ocean: Status Report 2002. 70-82.**

This report summarizes additional findings from the participatory monitoring by fishers in Diani detailed in Obura (2001 above). Variables including catch, underwater visual census of fish, and socio-economic factors were monitored. Results showed that the use of spear guns increased over the monitoring period. The authors note that this could be due to the relatively low cost, ease of use and slightly higher catch compared to other gears of similar and moderate cost. The authors predicted an increase in conflict between spear gun fishers and the Fisheries department due to the ban of spear guns in 2001 and argue that participatory monitoring could serve to empower fishers in negotiating interventions that would be beneficial to livelihoods and fisheries management.

**CORDIO, MON, R**

Artisanal fishery, Diani, participatory monitoring, marine reserve.

313

**Obura DO, Wells S, Church J, Horrill C (2002) Monitoring of fish and fish catches by local fishermen in Kenya and Tanzania. Marine Freshwater Research 53: 215–222.**

There is increasing interest in the involvement of fisher communities in monitoring their fisheries. The common understanding is that this approach will empower fishers by increasing their knowledge of the resources their livelihoods depend on. This study compares fisher monitoring using similar protocols at several sites in the Kiunga and Diani-Chale marine reserves in Kenya, and in Tanga on the northern coast of Tanzania. The sites were ecologically similar but culturally and socially different. The main challenges encountered included the use of different names for the same species and the low literacy level of the fishermen. Nonetheless, the authors argue that the benefits of participatory monitoring outweighed the disadvantages namely that enhanced local involvement and participation by fishing communities in the monitoring of their resources could lead to the application of more effective management approaches.

**CORDIO, FIS, J**

Participatory monitoring, Kiunga, Diani-Chale, marine reserve, Tanga.

314

**Obura DO (2005) Resilience and climate change: Lessons from coral reefs and bleaching in the Western Indian Ocean. *Estuarine Coastal and Shelf Science* 63 (3):353-372.**

Coral reefs in the western Indian Ocean are under stress from several factors including thermal stress induced coral bleaching. This paper reviews the hypothesis about the ability of coral reefs to withstand these stresses against evidence from reefs in the western Indian Ocean and suggests that reefs in the region may have characteristics that allow 'resistance and resilience to bleaching'. The paper details several properties including coral-zooxanthellae relationships, physical factors that allow for tolerance to thermal stress, or ecological and other processes that create conditions that reduce bleaching induced mortality. The author concluded that an overarching framework of spatial resilience theory could allow the interaction of scientific and management questions related to global and future impacts on coral reefs.

**CORDIO, COREEF, J**

Coral bleaching, resilience, thermal stress.

315

**Obura DO, Furaha J, Mwaura J (2005) Coral settlement patterns in the Mombasa marine park. In: Souter D, Linden O (eds) *Coral reef degradation in the Indian Ocean: Status report 2005*, 167-173 pp.**

The rates and coral species that recruit onto coral reefs in East Africa are poorly studied. This paper summarized findings from coral settlement studies in the coral reef lagoon within the Mombasa marine park from 2001 to 2003. Rates of settlement were estimated on artificial settlement plates that were deployed for 3-month periods. Results showed that between 1 - 38 spat settled per tile. Settlement rates had a high variability and although peaks occurred in November, there was no discernable seasonal cycle. Results also showed that water flow could have influenced settlement; spat numbers were highest at the study site with the higher flow and exchange with the open ocean. Corals of the genera *Pocillopora* had the highest settlement (76%) followed by *Porites* (19%). The authors concluded that although recruitment occurred throughout the year, the peak in September-November each year when water temperatures were increasing the fastest may indicate an environmental cue for settlement.

**CORDIO, COR, R**

Coral recruitment, settlement, *Pocillopora*, *Porites*, Mombasa, marine park.

316

**Obura DO (2006) Impacts of the 26 December 2004 tsunami in Eastern Africa. *Ocean and Coastal Management* 49 (11): 873-888**

The Indian Ocean tsunami of the 26<sup>th</sup> December 2004, was the largest on record in the region. This paper details the progression and damage caused by the tsunami and the consequences of the lack of an early warning system. In Kenya and Tanzania, the waves hit the coastline during low tides and the damage was minimal. The author noted the lack of response by the public despite warnings by government officials in Kenya argued for the development of an early warning system based on satellite television and mobile telephones.

**CORDIO, MON, J**

Tsunami, early warning system.

317

**Obura DO, Chuang Y, Olendo M, Amiyo N, Church J, Chen AC (2007) Relict *Siderastrea savignyana* (Scleractinia: Siderastreidae) in the Kiunga marine national reserve. *Animal Miraculum* 1pp.**

This report provides the first taxonomic description of the coral *Siderastrea savignyana* in the Kiunga marine reserve in Northern Kenya. Two populations were discovered on sheltered shallow patch reefs in channels leading into mangroves at 0-3m depth. The colonies varied in size from <10cm diameter mounds to large 2m massive micro-atoll colonies. The colony morphology and corallite structure of *S. savignyana* in the Kiunga reserve were similar to those of *S. radians*.

**CRCP, COR, R**

Coral, *Siderastrea savignyana*, *S. radians*, Kiunga, marine reserve,

318

**Ochieng AC, Erftemeijer PLA (1999) Accumulation of seagrass beach cast along the Kenyan coast: a quantitative assessment. *Aquatic Botany* 65:221-238.**

Seagrass beach cast material is considered an eyesore detracting from the beauty of Kenyan beaches. Consequently many beach hotels remove beach cast on their beaches. This paper summarized the results of a study of beach cast accumulation along the beaches of the Mombasa MPA from September 1995 to August 1996. Results showed an estimated total volume of 93,000 kg (dry weight) of beach cast material mainly composed of leaves of the seagrass *Thalassodendron ciliatum* (88%) and the seaweeds *Sargassum sp.* and *Ulva sp.* Significantly more beach cast accumulated during spring tides and during the southeast monsoon (March to October). Results also showed that beach cast influenced beach ecology; the density of fauna increased with the amount of beach cast material. The study estimated that approximately one fifth of the total seagrass productivity in the lagoon was recycled through beach cast. The authors concluded that rather than being a nuisance, beach cast and the subsequent process of decomposition contributed to recycling of nutrients crucial to the health of adjacent seagrass meadows.

**CRCP, SG, J**

Beach cast, seagrass, Mombasa, marine park, marine reserve, seasonality, *Thalassodendron ciliatum*, *Sargassum*, *Ulva*.

319

**Ochieng CA, Uku JN (2001) Seagrass beach cast: The environmental implications of its removal. *Kenya Marine and Fisheries Research Institute*. 12 pp.**

The common view is that beach cast reduces the aesthetic value of beaches and limits enjoyment of the beach by users, hence beach cast removal is a common activity on Kenyan beaches. This report details a study that complimented the study by Ochieng and Erftemeijer 1999 (detailed above) that focused on management related factors. Interview results showed that most tourists were more concerned about harassment by beach operators than by the supposedly unsightly beach cast. The authors recommended that beach cast removal activities should be discouraged because they interfered with recycling of nutrients to the adjacent seagrass meadows. Moreover, since beach cast accumulated mainly during the low

tourist season and since beach users were unconcerned about beach cast, the rationale for beach cast removal was flawed.

**KMFRI, SG, R**

Beach cast, seagrass *Thalassodendron ciliatum*, Mombasa, MPA.

320

**Ochiewo J (2004) Changing fisheries practices and their socioeconomic implications in South Coast Kenya Ocean & Coastal Management 47:389-408.**

The socioeconomic factors that control marine resource use and the effects on management have recently started receiving attention on the Kenyan coast. This study evaluated the factors that influenced fishing, assessed changes in fishing practices and their socioeconomic impacts at four key fishing areas (Vanga, Shimoni, Msambweni, Gazi) on the south coast of Kenya. The results showed that changes in fishing practices including type of vessels used, type of fishing gears used including increased use of highly destructive gears, increased involvement of women in fishing activities and migration of fishers to other fishing grounds all indicate a severely over exploited artisanal fishery. Management interventions such as the control of destructive gears, participatory processes and development of alternative livelihoods were recommended.

**KMFRI, FIS, J**

Socioeconomics, overfishing, fishing effort, Shimoni, Vanga, Gazi, Msambweni, marine reserve.

321

**Ohowa BO (1996) Seasonal variations of the nutrient fluxes into the Indian Ocean from the Sabaki River, Kenya. Discovery and Innovations 8 (3):265-274.**

Increased nutrient inputs into the marine environment have been a source of concern in the Sabaki river basin in the recent past. The proximity of the Malindi MPA and the potential deleterious effects of nutrients on coral reefs have been especially troubling. This study evaluated the nutrient concentrations (nitrates, phosphates and silicates) of the water and sediments of the of the Sabaki River estuary during the dry and wet seasons between March 1991 and February 1992. Results showed a strong seasonal component in nutrient concentrations; high nutrient concentrations occurred during rainy seasons and low concentrations during dry spells. The author concluded that the seasonality of the microclimate regimes of the areas traversed by the Sabaki River affected the level of nutrients and sediments, which it discharged into the Indian Ocean.

**KMFRI, NUT, J**

Nutrients, seasonal variations, Sabaki River, Malindi bay, nitrates, phosphates, silicates.

322

**Okello MM, Kiringe J (2004) Threats to biodiversity and their implications in protected and adjacent dispersal areas of Kenya. Journal of Sustainable Tourism 12: 55 – 69.**

Protected areas in Kenya cover approximately 8% of the land area and 8.7 % of the coastal shelf and face various threats that potentially compromise the conservation of biodiversity. In this study, a threats analysis was carried out of all protected areas including MPAs. Interviews of protected area managers indicated ten main threats including poaching, human-wildlife conflict, human population density and encroachment of migration and dispersal corridors. Results showed that most protected areas were impacted by half of the threat factors and that marine protected areas, forest ecosystems and wetlands were the most susceptible and needed urgent conservation action.

**CRCP, MGT, J**

Threats analysis, MPAs, biodiversity conservation.

323

**Okemwa G, Nzuki S, Mueni E (2004) Status and conservation of sea turtles in Kenya. Marine Turtle Network 105: 1-6.**

Five species of sea turtles have been documented in Kenyan waters; the green turtle, the hawksbill turtle, the loggerhead turtle, the olive ridley turtle, and the leatherback turtle. This paper reviews the main threats to sea turtles and provides details of the national and local sea turtle conservation activities in Kenya. The review determined that mortality from fishing practices and poaching of nesting females, egg poaching, and loss of nesting habitat were the main threats to sea turtles on the Kenyan coast. The key nesting beaches included highly developed tourist beaches such as Watamu, Mombasa and Diani and remote beaches of Lamu and Kiunga. Results of nest monitoring programs between 1997 and 2000 indicated 684 nests with green turtles representing 91% of the nests, the rest were hawksbills and olive ridley nests. Conservation activities of the Kenya Sea Turtle Conservation Committee (KESCOM) and collaborating community turtle conservation groups were detailed including nest monitoring, protection of nesting females, awareness programs, beach clean-ups and research activities.

**KMFRI, CRCP, ST, J**

Sea turtles, nests, green turtle, hawksbill turtle, loggerhead turtle, olive ridley turtle, leatherback turtle, Mombasa, Diani, Watamu, Lamu, Kiunga.

324

**Okemwa GM, Muthiga NA, Mueni E (2005) Proceedings of the western Indian Ocean region marine turtle conservation workshop. September 16 - 17, 2004, Mombasa, Kenya. 32pp.**

Sea turtles are distributed throughout the western Indian Ocean inhabiting shallow marine areas where their primary food sources are abundant. Reports that sea turtle population numbers have decreased drastically in countries in the region generated interest in the implementation of national sea turtle conservation programs. However, since sea turtles are migratory and evidence has shown migrations across range states in the region, standardized and coordinated conservation and management actions across the region could potentially improve the success of national sea turtle programs. This report details the proceedings of a regional workshop that reviewed the research, conservation and community turtle programs in Kenya, Madagascar, Mauritius, reunion, Seychelles, South Africa, Tanzania. The establishment of a regional Sea Turtle Task Force under the auspices of the Nairobi Convention and Convention on Migratory Species tasked with harmonizing tagging, research and monitoring programs and encouraging information exchange amongst programs in the region was discussed and endorsed.

**KESCOM, CRCP, ST, P**

Sea turtles, conservation, research, Western Indian Ocean.

325

**Okemwa GM, Fulanda B, Kimani EN, Ochiemo J (2009) Exploitation of marine aquarium reef fisheries at the Kenyan coast. In: Hoorweg J, Muthiga N (eds) Advances in coastal ecology: People, processes and ecosystems in Kenya. African Studies Centre, African Studies Collection Vol 20:28-42.**

Ornamental marine species (corals, invertebrates and fish) are the highest value products that can be harvested from coral reefs and are an important source of income for coastal communities in developing countries. Kenya's marine aquarium fishery was established in the early 1970's but it has received limited attention. This study collated baseline information on the aquarium fishery focusing on the key harvest sites, harvest methods, exploited species, the catch and effort trends and trade links. Results showed a simple supply network from collectors to exporters without involvement of middlemen. The bulk of the catch was harvested in the Shimoni area including the Mpunguti marine reserve and Nyali in the Mombasa marine reserve by snorkelling in shallow areas and SCUBA in deeper areas. Approximately half of the fish landed belonged to 10 species and to species that were difficult to catch or were rare which indicated the intense pressure on these species. The authors recommended prohibitions on collecting fish that had low survival rates, improvement and enforcement of current fisheries regulations and monitoring mechanisms to make the fishery sustainable.

**KMFRI, FIS, P**

Ornamental fish, trade, collectors, exporters, Shimoni, Nyali, Mombasa, marine reserve.

326

**O'Leary, JK. (2009) Effects of fishing and trophic interactions on tropical reef builders: coralline algae and corals. PhD. thesis, University of California Santa Cruz USA, 141 pp.**

Crustose coralline algae (CCA) are major reef builders and produce chemical cues that induce settlement of coral larvae yet few studies have been carried out on CCAs. This PhD. research focused on the effects of grazing (mediated by fisheries management and climate change) on abundance and species composition of CCA using long-term monitoring data, field experimentation, and field surveys on reefs in Kenya. Results showed that sea urchin grazing had a stronger effect than grazing by fishes and an ocean warming event, and depleted CCA in fished reefs did not reduce this impact. There was more inductive CCA in protected than on fished reefs which indicated an effect of fish grazing while hard coral recruitment was strongly correlated with CCA, and especially inductive CCA. The author concluded that fishing changed the distribution and composition of CCA with potentially strong effects on coral settlement.

**CRCP, AG, T**

Coral reef, crustose coralline algae, grazing, marine parks, marine reserves.

327

**Oluoch SJ, Obura D, Hussein A (2009) The capacity of fisherfolk to implement beach management units in Diani-Chale. In: Hoorweg J, Muthiga N (eds) Advances in coastal ecology: People, processes and ecosystems in Kenya. African Studies Centre, African Studies Collection Vol 20:162-176.**

Fisheries have historically been managed through a top-down process in Kenya. The establishment of the Beach Management Unit Regulations has legally empowered fishers to manage the resources within their fishing grounds. However, whether fishers have the capacity to manage their fisheries under the framework of the regulation is not known. This study evaluated the capacity of fisher organizations in the Diani-Chale reserve to implement the BMU regulations. The results showed that the capacity of most fisher organizations was very low and that the main challenges were the lack of tenure of landing sites and transparency in financial management. The authors recommended assessments of each

BMU and training of the BMU regulations prior to BMU establishment.

**CORDIO, CRCP, MGT, P**

Beach management unit, fisheries management, Diani-Chale, marine reserve.

328

**Orwa OP (2007) Population aspects of sea cucumbers (Echinodermata: Holothuroidea) in protected and unprotected reefs along the southern Kenyan coast. MSc. thesis, University of Nairobi, Kenya 130 pp.**

Trade of sea cucumbers (Holothurians) has existed for hundreds of years on the Kenyan coast yet little is known about this fishery. This MSc. research study focused on the holothurian fauna and the effects of management, habitat, topographic complexity and substrate cover in shallow reefs in protected and fished sites in Malindi, Watamu, Mombasa, Shimoni on the Kenyan coast. Results showed that sea cucumbers occurred in relatively low densities and that densities were highest in reefs in Mombasa and lowest in Malindi. On average reef lagoons had higher abundances of sea cucumbers than the adjacent reef flats. The overall average abundance of commercial value holothurians was also low. Although abundances, diversity, density and distribution showed significant correlations with both benthic substrate cover and rugosity, protection showed the strongest relationship. The author concluded that the higher densities in protected lagoons were an indication that protection of whole reefs from exploitation might be an effective management option for conservation of holothurian stocks in Kenya.

**CRCP, SC, T**

Sea cucumbers, distribution, abundance, Malindi, Watamu, Mombasa, Shimoni, marine park, marine reserve.

329

**Orwa P, Ntiba J, Muthiga NA, Kawaka J (2009) Holothurian population resource assessment: Mombasa marine national park and nearby unprotected reefs. In: Hoorweg J, Muthiga N (eds) Advances in coastal ecology: People, processes and ecosystems in Kenya. African Studies Centre, African Studies Collection Vol 20:162-176.**

This paper is part of the MSc. research study of Orwa (2007 above). The study focused on a comparative survey of shallow water holothurian fauna to determine patterns of distribution, abundance and diversity, and the factors that affect these patterns. The study showed that although habitat, topographic complexity and substrate cover controlled distribution and abundance of holothurians, reef protection showed the strongest response. The authors concluded that MPAs are an effective tool in the conservation of holothurians.

**CRCP, SC, P**

Sea cucumbers, holothurian, fisheries management, Malindi, Watamu, Mombasa, Shimoni, marine reserve, marine park.

330

**Osore MKW, Fiers F, Daro MH (2004) Distribution and abundance of *Candacia dana*, 1846 and *Paracandacia Grice*, 1963 (*Copepoda calanoida*, *Candaciidae*) off the Kenyan Coast. Western Indian Ocean Journal of Marine Science 3 (2) 189-197.**

The planktonic crustaceans dominate zooplankton biomass and are an important link in the marine food chain. This study investigated zooplankton in several creeks and lagoons on the coast of Kenya including; Makupa, Tudor, Kilifi and Mida creeks, and lagoons in the Mombasa

marine park and reserve and Diani, and Gazi Bay. Results showed that copepod species belonging to the genera *Candacia* and *Parandacia* were widely distributed, occurred at low abundances within the inshore waters, and increased within the shelf waters. Copepod abundance was highest during the southeast monsoons when temperatures were at the seasonal minima. Abundances were also controlled by depth, decreasing with increasing depth. Five new records of *Candacia* for the Kenyan coast; *C. bradyi*, *C. bipinnata*, *C. curta*, *C. tuberculata* and *C. ethiopica* were reported during the study.

**KMFRI, PK, J**

*Candacia*, *Parandacia*, distribution, abundance, Makupa, Tudor, Kilifi, Mida, creeks, lagoons, Mombasa, marine park, marine reserve, Diani, Gazi Bay.

**331**

**Osore MKW, Mwaluma JM, Fiers F, Daro MH (2004) Zooplankton composition and abundance in Mida Creek, Kenya. *Zoological Studies* 43(2):415-424.**

Zooplankton are an important component of the marine food web yet little is known about the factors that control zooplankton productivity in different marine habitats in Kenya. This study assessed the temporal composition, abundance, and distribution of zooplankton within Mida creek in the Watamu marine reserve for one year from May 1996 to April 1997. Results showed that of the 27 major zooplankton taxa collected in monthly plankton hauls, the order Copepoda dominated especially the genera *Acartia*, *Paracalanus*, *Labidocera*, *Temora*, *Centropages* and *Calanopia*. Other common zooplankton taxa included the Medusae, Ctenophora, brachyura larvae, and Chaetognatha. The highest abundances of zooplankton were recorded during the northeast monsoon season (February – March) at the temperature maxima and the lowest during the wet southeast monsoon season (May-July). The authors concluded that a combination of season, vertical migration and tidal cycle controlled zooplankton abundance and diversity in the Mida creek.

**KMFRI, PK, J**

Zooplankton, Mida creek, copepods, seasonality, Watamu, marine reserve, Copepoda, *Acartia*, *Paracalanus*, *Labidocera*, *Temora*, *Centropages*, *Calanopia*, Medusae, Ctenophora, brachyura, Chaetognatha.

**332**

**Pertet F, Thorsell JW (1980) The dugong in Kenya: a preliminary report. Ministry of Tourism and Wildlife, Wildlife Planning Unit. 5 pp.**

This was one of the earliest reports on the status of dugongs within Kenya's waters and the implications for conservation. Records showed that there had been a drastic decline in dugong numbers along the Kenyan coast over the years. The authors argued that of the several factors contributing to the decline of dugongs, harvesting by the coastal community for meat had the largest impact. The authors recommended urgent conservation measures to protect the few remaining individuals.

**KWS, MM, R**

Dugongs, Kenya.

**333**

**Pertet F (1982) Kenya's experience in establishing coastal marine protected areas. In: McNeely JA, Miller KR (eds) National parks, conservation, and development. The role of protected**

areas in sustaining society. **Proceedings of the World Congress on National Parks, 101-108pp.**

Kenya was among the first countries in Africa to launch a Wildlife Conservation Strategy in the early 1980s. This article details the process that was taken and the lessons learnt during the design and implementation of the conservation strategy particularly in the implementation of marine protected areas.

**KWS, MM, P**

Conservation strategy, marine protected areas.

334

**Pollnac R, Christie P, Cinner JE, Dalton T, Daw TM, Forrester G, Graham NA, McClanahan TR (2010) Marine reserves as linked social-ecological systems. Proceedings of the National Academy of Sciences, USA 1-4. [www.pnas.org/cgi/doi/10.1073/pnas.0908266107](http://www.pnas.org/cgi/doi/10.1073/pnas.0908266107)**

The interrelationships between ecological and social interactions are increasingly becoming recognized as crucial to the effective management of marine reserves. This review examined how the ecological performance measured as fish biomass of 56 reserves in the Philippines, Caribbean and Western Indian Ocean (WIO) including in Kenyan MPAs was affected by the design and socioeconomic condition of adjacent communities. Results indicated that human population density and compliance with reserve regulations had the strongest effects on fish biomass. Results were not uniform across regions however with population density showing a negative effect on fish biomass in the Caribbean, a positive effect in the WIO and no measurable effect in the Philippines. The authors surmised that effects could be due to a number of factors including human migration to effective reserves, depletion of fish stocks outside reserves or other social factors that affect population density. The effect of compliance was also variable, and was due more to complex social interactions rather than enforcement, which has implications for how reserves are managed.

**CRCP, MPA, J**

Coral reefs, socioeconomic, social-ecological system, marine protected areas

335

**Ragionieri L, Cannicci S, Schubart CD, Fratini S (2010) Gene flow and demographic history of the mangrove crab *Neosarmatium meinerti*: A case study from the western Indian Ocean. Estuarine Coastal and Shelf Science 86 (2): 179 – 188.**

Animals that possess planktonic stages were thought to be genetically homogenous due to the dispersal ability of larvae. This paper investigated the population genetic structure and demographic characteristics of the mangrove crab *Neosarmatium meinerti* in the western Indian Ocean including samples collected from Gazi Bay, Mida Creek and Lamu. Results showed that the mainland of East Africa and Island state of Seychelles were separated but gene flow along the East African coast was not restricted allowing for the establishment of a single metapopulation.

**CRCP, CRU, J**

Genetic structure, larval dispersal, *Neosarmatium meinerti*, Gazi Bay, Mida Creek, marine reserve

336

**Ransom KP, Mangi SC (2009) Valuing recreational benefits of coral reefs: The case of Mombasa**

**marine national park and reserve, Kenya. Environmental Management. DOI 10.1007/s00267-009-9402-9.**

Park entry fees are a common market tool that is used in financing the costs of managing marine protected areas. However, park entry fees are often implemented without evaluating the willingness of visitors to pay for the services provided. In this study, a contingent valuation analysis was used to estimate the amount adult Kenyan citizens and foreign tourists were willing to pay for park entry and compare this with the costs of management and the proposed increase in the fee. The study was undertaken in October and December 2007. Results showed that the additional amount which visitors were willing to pay was more than twice the total annual operational expenditure of the Mombasa MPA. However, the authors note that any fee increase could raise several concerns including increasing the perception that MPAs were restricted to tourists and affluent Kenyans, and the continued concern by the tourism sector about over-taxation by the government without commensurate provision of services. The authors recommended that the MPA needed to demonstrate that the extra revenue would be used to fund conservation activities that would benefit local communities and the tourism sector.

**CORDIO, MGT, J**

Valuation, tourism, user fees, Mombasa, marine park, marine reserve.

337

**Rodwell DL, Barbier EB, Roberts CM, McClanahan TR (2002) A bioeconomic analysis of tropical marine reserve-fishery linkages: Mombasa marine national park, Kenya. Natural Resource Modelling, 15(4):453-486.**

The benefits of fully protected marine reserves are difficult to justify in developing countries where the socioeconomic conditions drive continued fishing even in overexploited fisheries. The need to demonstrate spillover is therefore key, but spillover is difficult to measure in the field. This study developed a bioeconomic model to determine the contribution of fully protected marine reserves to fishery enhancement. The model analyzed different scenarios of fishing intensity and size of reserve versus fished areas and included both adult migration and larval dispersal and tested against data from the Mombasa marine park, which was 30% of the original fishing grounds. Results showed that the optimal area of a fully protected reserve was 15% to 25% (depending on stock growth rate), if fishing intensity in the adjacent fishery did not exceed 40% of exploitable biomass. Where fishing effort could not be controlled, larger reserves were required to maximize catch. The authors concluded that because fishing effort was difficult to regulate in developing countries, marine reserves should be encouraged as an essential component of management.

**CRCP, MPA, FIS, J**

Bioeconomics, marine reserve, marine park, Mombasa, coral reefs, optimal reserve area.

338

**Rodwell DL, Barbier BE, Roberts CM, McClanahan TR (2003) The importance of habitat quality for marine reserve-fishery linkages. Canadian Journal of Fisheries and Aquatic Sciences 60:171-181.**

Ideally, the establishment of marine protected areas that prohibit fishing should be beneficial to fisheries and biodiversity. This study undertook to determine whether improved habitat quality within a marine reserve contributed to enhancing fisheries using data from the Mombasa marine park and the adjacent fishing area. The study used the model developed

by Rodwell et al 2002 (above). The results of the simulations showed that with the decrease in natural mortality of fish stocks due to improved habitat, fisheries catches increased by up to 2.6 tonnes/km/year and total fish biomass by up to 36 tonnes/km. However, if improved habitat reduced fish movements out of the reserve, catches could fall by up to 0.9 tonnes/km/year. The authors concluded that although habitat protection played a role in enhancing fish productivity, the benefits to adjacent fisheries were dependent on the effects of improved habitat on fish movements.

**CRCP, FIS, MPA, J**

Fisheries, marine reserve, marine park, habitat loss, emigration, Mombasa.

339

**Rubens J (1996) An analysis of the benefit and costs of marine reserve regulations at Diani, Kenya. MSc. thesis, University of Newcastle upon Tyne, UK 156 pp.**

The Diani marine reserve was established in 1995 but has experienced management problems since its inception in particular, the lack of support for the MPA by the fisher community. This MSc. research study attempted to quantify the respective benefits and costs of the MPA to coastal resource stakeholders at Diani. Data included catch information collected at 8 major fish landing sites within the Diani-Chale MPA from September 1995 to May 1996, interviews with fishers and hotel managers and questionnaires, which were administered to the tourist sector. The results showed that despite the higher economic return from the tourism sector compared to artisanal fishing, the conflict between these sectors continued. The author recommended that more attention was needed in improving the welfare of the fishing communities, eliminating the destructive seine nets and enhancing fisheries productivity rather than solely addressing the concerns of the tourism community.

**CRCP, MPA, MGT, T**

Marine reserve, Diani-Chale, cost benefit analysis, resource use conflict.

340

**Ruwa RK (1990) The effects of habitat complexities created by mangroves on macrofaunal composition in brackish water intertidal zones at the Kenyan coast. *Discovery and Innovation* 2:49-55.**

Mangrove ecosystems are highly productive and provide a habitat for many species especially invertebrates. This study compared the benthic invertebrate fauna on beaches and adjacent mangroves at Ngomeni, Malindi, Kanamai, Mombasa (Bamburi and Mkomani) and Gazi, on the Kenyan coast from April 1986 to February 1987. Results showed that the highest number of species of benthic invertebrates was recorded in the creek mangroves and beaches with mangrove peats indicating the contribution of mangroves to benthic diversity and productivity. The author noted that the mangrove forests showed signs of overexploitation especially of the mangroves species *Rhizophora mucronata* and *Sonneratia alba* which were the preferred species for building and fuel wood.

**KMFRI, MAN, J**

Mangroves, diversity, macrofauna, crabs, Ngomeni, Malindi, Kanamai, Mombasa, Gazi, marine reserve.

341

**Samoilys MA (1988) Abundance and species richness of coral reef fish on the Kenyan coast: the effects of protective management and fishing. Proceedings of the 6th International Coral Reef Symposium 12:261-266.**

Several studies have been carried out on the shallow reefs of the Kenyan coast but the reef slopes and reef edges have received less attention. This study focused on the species richness and abundance of coral reef fish on the seaward reef slopes of 19 protected and fished sites between Kiunga in the north and Shimoni reef in the south of the Kenyan coast from November 1987 to March 1988. Results from visual censuses showed that although species richness was highest in fully protected marine park sites, fish abundance and the biomass of commercially important fish did not differ. The author argued that more intense fishing lowered average fish size since sites with higher fishing intensity had lowered standing crops but not lowered abundances. The author concluded that the effects of siltation from the Sabaki River impacted the Malindi marine park while dynamite fishing impacted Mako Kokwe reef within the Kisite MPA, which reduced the overall beneficial impacts of protection.

**CRCP, FIS, P**

Coral reefs, reef slopes, coral reef fish, abundance, species richness, Malindi, Kisite, marine park, marine reserve.

342

**Samyn Y, Berghe VE (2000) Annotated checklist of the echinoderms from the Kiunga marine national reserve, Kenya. Part 1: Echinoidea and Holothuroidea. Journal of East African Natural History 89:1-36.**

Few taxonomic studies have been carried out on the echinoderms of East African marine ecosystems. This article documents the results of a survey of the Holothuroidea (sea cucumbers) and Echinoidea (sea urchins) that was undertaken in the Kiunga marine reserve in 1999. A total of 96 specimens representing eight orders, 13 families, 19 genera and 37 species were recorded and described in an annotated checklist. The study stressed the importance of the Kiunga marine reserve as a sanctuary for these echinoderms.

**CRCP, SU, SC, J**

Holothuroidea, Echinoidea, checklist, Kiunga, marine reserve.

343

**Samyn Y, Massin C, Muthiga NA (2001) A new species of Holothuria (Aspidochirotida, Holothuriidae) from Kenya. Annals Sciences Zoologiques 285: 101-110.**

This article described a new species of sea cucumber that was discovered in the Mombasa marine reserve, Kenya during an echinoderm survey conducted between 1998 and 2000. The species *Holothuria (Mertensiothuria) arenacava* was a sand-burrowing species and the article provides a detailed description of the taxonomy, ecology, distribution and morphology of the species.

**CRCP, SC, J**

Sea cucumber, *Holothuria arenacava*, Mombasa, marine reserve, taxonomy.

344

**Samyn Y (2003) Shallow-water regular echinoids (Echinodermata: Echinoidea) from Kenya. African Zoology 38(2):193-212.**

The taxonomy of the shallow water regular echinoid (sea urchin) fauna of Kenya has received

little attention. This article documents all the species of echinoids recorded during several field trips on coral reefs and seagrass beds on the Kenyan coast, and additional information from the literature. A total of 20 species belonging to 16 genera and 6 families are recorded from the surveys and 2 additional species were reported from the literature. The article provides an annotated checklist of the 22 species.

**CRCP, SU, J**

Sea urchins, echinoids, taxonomy.

345

**Samyn Y (2003) Shallow-water Holothuroidea (Echinodermata) from Kenya and Pemba Island, Tanzania. Coronet Books Inc 158 pp.**

The taxonomy of the shallow water holothurian (sea cucumbers) fauna of East Africa has received little attention. This monograph provides an extensive species list and detailed descriptions of the shallow water Holothuroidea of Kenya and Pemba Island. Sites surveyed in Kenya included; the Kiunga and Diani-Chale marine reserves, Malindi, Watamu, Mombasa and Kisite-Mpunguti marine parks and reserves, and Shariani and Kanamai that are fished reefs. Surveys were carried out in the inner and outer coral reefs and in sea grass beds during three expeditions in 1997, 1998 and 1999 in shallow lagoons to reefs at depths of 40m. A total of 225 specimens from 3 orders, 4 families, 12 genera, 44 species and one variety were described. Nine new records were obtained for Kenya and Pemba Island while *Holothuria timana* was a new record for the western Indian Ocean. The monograph also detailed diagnostic characteristics and descriptions, brief notes on the ecology and a species level identification key.

**CRCP, SC, J**

Sea cucumbers, Holothuroidea, taxonomy, *Holothuria timana*, zoogeography, Kiunga, Diani-Chale, Malindi, Watamu, Mombasa, Kisite-Mpunguti, marine park, marine reserve, Shariani, Kanamai.

346

**Schmitz N, Robert EMR, Verheyden A, Kairo JG, Beeckman H, Koedam N (2007) A patchy growth via successive and simultaneous cambia: Key to success of the most widespread mangrove species *Avicennia marina*? *Annals of Botany* 101: 49 – 58.**

Some plants grow by laying down secondary wood through cambria. This phenomenon was investigated in this study on the mangrove species *Avicennia marina* at Gazi Bay and Dabaso in Mida Creek between 2005 and 2007. Results showed that growth layers were variable and was correlated to the radial growth. The radial increment was not related to salinity but the growth layer width correlate with increasing salinity and decreasing tree height. The authors concluded that a patchy growth mechanism occurred which allowed several growth layers to form simultaneously, which may have severed to optimize growth during different environmental conditions.

**KMFRI, CRCP, MAN, J**

Growth, mangrove, *Avicennia marina*, Gazi Bay Mida Creek, marine reserve

347

**Schubart CD, Cannicci S, Vannini M (2006) Molecular phylogeny of grapsoid crabs (Decapoda, Brachyura) and allies based on two mitochondrial genes and a proposal for refraining from current superfamily classification. *Journal of Zoological Systematics and Evolutionary***

**Research 44(3): 193 - 199.**

Crabs of the grapsoid and ocy podoid families play an important role as primary and secondary consumers in mangrove forests and the resolution of the taxonomy of these groups would therefore assist in their identification. In this study, the phylogenetics of these crabs was investigated based on DNA sequences of mainly East African specimen including individuals collected from Mida Creek and Gazi Bay. The authors recommend that the Grapsoidea and Ocy podoidea should not be classified as monophyletic superfamilies but should be treated as separate families.

**CRCP, CRU, J**

Systematics, mangrove crabs, Gazi Bay, Mida Creek, marine reserve

348

**Serra L (2001), Duration of primary moult affects primary quality in Grey Plovers *Pluvialis squatarola*. *Journal of Avian Biology* 32: 377 - 380.**

The Grey Plover *Pluvialis squatarola* is a circumpolar breeding wader that overwinters at Mida Creek. This study compares Plovers from different geographical locations including Kenya (Mida Creek), South Africa and Australia in order to determine factors that controlled rates of feather wear between moults. Results showed that variability between populations was mainly driven by rates of annual moult duration and migration distance. The authors suggested that the different modes of moulting including partial and complete moulting in pre-breeding first-year birds and complete biannual moults might evolve due to a combination of migration distance, pigment deposition, feather structure and moult duration.

**CRCP, BD, J**

Moulting, Plover, *Pluvialis squatarola*, Mida Creek, marine reserve

349

**Seys J, Moragwa G, Boera P, Ngoa M (1995) Distribution and abundance of birds in tidal creeks and estuaries of the Kenyan coast between the Sabaki River and Gazi Bay. *Scopus* 19: 47-60**

Birds are not only recognized to be reliable indicators of environmental change, they are also the major driver behind the rapidly growing recreational tourism sector of bird watching. Kenya is recognized as a key bird watching tourism destination yet little was known about the birds of the coast prior to this survey. This paper describes the results of the first comprehensive survey of the birds of the major creeks of Kenya including Mida creek in the Watamu marine reserve and Mtwapa creek that drains into the Mombasa marine park. The number of birds ranged between 10500 and 15,000 in February to September of 1994. A total of 60 species were reported and Palaearctic shorebirds formed the majority (61%) followed by terns and gulls (28 % and 15% respectively) while large wading birds were the fewest (5%). Mida creek and the Sabaki river mouth had 75% of the total number of birds and 80% of the species reported. The authors recommended a monitoring program within the framework of the International Wetlands and Waterfowl Research Bureau.

**CRCP, BD, MON, J**

Birds, Mida creek, Mtwapa creek, Sabaki River, marine reserve, Palaearctic shorebirds, gull, terns, waders

350

**Sindiga I (1995) Wildlife-based tourism in Kenya: Land use conflicts and government compensation policies over protected areas. *The Journal of Tourism Studies* 6 (2): 45-55.**

This paper reviews the management of protected areas in Kenya, human-wildlife conflicts and the compensation policies related to land-use, and for loss injury due to wildlife. Although communities in land-based protected areas receive various types of compensation, no commensurate compensation for loss and injury from protected species is provided for in marine protected areas. The author concluded that although human-wildlife conflicts can be minimised a harmonised regulatory framework to address conflicts between people and wildlife is urgently needed.

**CRCP, MAN, J**

Human-wildlife conflicts, compensation policies, protected areas, MPAs

351

**Sjöö GL (2004) Effects of varying nutrient load and grazing intensity on size and fecundity of the brown macroalgae *Turbinaria ornata* and *Padina gymnospora* on the coast of Kenya. MSc. thesis, Stockholm University, Sweden. 25 pp.**

Fleshy brown algae are an important component of the food web of coral reef ecosystems providing food for fish and other grazers. These algae however, also pose a threat in their ability to overgrow corals. This MSc. research study was carried out to investigate whether nutrients affected the fecundity and size of the brown algae *Turbinaria ornata* and *Padina gymnospora* and whether this response was mediated by grazing intensity. The study was carried out from February to May 2004 at sites in the Mombasa marine park (Coral garden), marine reserve (Ras Iwatine) and at a fished reef (Vipingo) with varying levels of nutrient load and grazing intensity. Results showed that *T. ornata* exhibited a variable response to differences in nutrient load, but showed increased size and fecundity, at low herbivore abundance sites. *Padina gymnospora* also showed variable response to a higher nutrient load, but increased in size and had a higher fecundity at the high herbivore abundance site. The author concluded that since grazing intensity either limited or enhanced the growth of these species, grazing might be an important factor in controlling the size and reproductive capacity of these fleshy brown macroalgae.

**CRCP, AG, R**

Fleshy algae, *Turbinaria ornata*, *Padina gymnospora*, nutrients, grazing intensity, Mombasa, Ras Iwatine, Vipingo, marine park, marine reserve

352

**Sjöö GL, Mörk E (2009) Tissue nutrient content in *Ulva* spp. (Chlorophyceae) as bioindicator for nutrient loading along the coast of East Africa. *The Open Environmental and Biological Monitoring Journal* 2:11-17.**

Nutrient loading can result in eutrophication that causes detrimental changes in benthic communities in marine and coastal waters. Sampling of nutrients in the water column is the most common method used in monitoring nutrient loading, however, changes in tissue nutrient in macroalgae is increasingly being used as an alternate method. This paper details a study that evaluated the use of macroalgal tissue in *Ulva* spp. as a bioindicator of nutrient loading at coral reef sties in Kenya (Mombasa and Mpunguti marine reserve and Wasini, Is.) and Tanzania. Results showed that tissue nitrogen (N) concentrations was 90% higher at sites close to high population centers (Dar-es-salaam and Mombasa) compared to areas

with low human population. The authors argue that tissue nitrogen reflects the nitrogen concentration in the surrounding waters and can be used to complement water column monitoring.

**CRCP, AG, MON, J**

Macroalgae, eutrophication, *Ulva*, nutrients, monitoring, Mpunguti, Mombasa, Ras Iwatine, marine reserve.

353

**Skov MW, Vanini M, Shunula JP, Hartnoll RG (2002) Quantifying the density of mangrove crabs: Ocypodidae and Grapsidae. Marine Biology 141:725-732.**

Crabs have a key role to play in mangrove systems feeding on detrital material and contributing to nutrient turnover. However, in order to measure their contribution to mangrove systems, reliable estimates of abundance are needed yet methods of estimating population densities of crabs are scarce. This study evaluated the accuracy of relatively fast non-invasive methods for estimating the population density of three species of mangrove crabs in East Africa: *Uca annulipes*, *Sesarma guttatum* and *Neosarmatium meinerti*. A combination of visual counts of active individuals, counts of burrows, counts of evacuated individuals and counts of marked individuals was used for the different species depending on their behaviour and habitat in Mida creek Kenya and Inhaca Island Mozambique. Results showed that different methods had varying levels of reliability and the authors concluded that visual and burrow count techniques had advantages and disadvantages that needed to be taken into consideration when planning surveys of crabs in mangrove systems.

**CRCP, CRU, J**

Crabs, mangroves, abundances, *Uca annulipes* *Sesarma guttatum*, *Neosarmatium meinerti*, Mida Creek, Inhaca island.

354

**Souter P (2009) Hidden genetic diversity in a key model species of coral. Marine Biology 157: 875-885.**

The scleractinian coral *Pocillopora damicornis* is widely distributed throughout the Indo-Pacific but there are several unresolved morphological and molecular questions about the species. This study was part of a larger research program on the phylogeny and phylogeography of the genus *Pocillopora*. Forty-three colonies of *P. damicornis* sampled from reefs in the western Indian Ocean including in Kenyan MPAs (Mombasa, Malindi, Kisite, Diani) were characterized using genetic techniques. The results showed two clusters suggesting two cryptic species of *P. damicornis* in these reefs. Comparison with previously published genetic sequences of *P. damicornis* showed that the western Indian Ocean types remained in separate clusters further supporting the author's suggestion that these types were separate species.

**CORDIO, CRCP, COR, J**

Genetic structure, morphology, *Pocillopora damicornis*, Malindi, Mombasa, Kisite, Diani, marine park, marine reserve.

355

**Souter P, Henriksson O, Olsson N, Grahn M (2009) Patterns of genetic structuring in the coral *Pocillopora damicornis* on reefs in east Africa. BioMed Central Ecology 9 Article no. 19, 13pp.**

Genetic studies are increasingly being used to determine the population structure of

broadcasting marine invertebrates and connectivity between populations. This can lead to an understanding of the dispersal patterns of larvae and the potential for recovery of populations as well as providing crucial information for planning marine protected areas. This study focused on the population genetic structure of a common hard coral species *Pocillopora damicornis* on 26 reefs in east Africa including reefs in the Mombasa, Malindi and Kisite MPAs. The results showed that a high degree of geographical and ecological variability occurred between populations and that populations could only be differentiated at small-scale distance of <10km, at 100km mixing between populations could not be statistically rejected. The authors concluded that the levels of dispersal were consistent with findings from other coral species that have reported gene flow over distances of 100s of kilometers and that there was some evidence of genetically isolated reefs including sites in the Malindi MPA.

**CORDIO, CRCP, COR, J**

Population genetics, *Pocillopora damicornis*, Malindi, Mombasa, Kisite, marine park, marine reserve.

356

**Speybroeck D (1992) Regeneration strategy of mangroves along the Kenya coast: a first approach. *Hydrobiologia*: 247: 243-251.**

Mangrove reforestation interventions are promoted as an effective tool for restoring degraded mangroves. This study investigated the natural regeneration patterns of mangrove seedlings in order to provide information useful for reforestation activities in Kenya. Mangrove seedling data were collected in a total of 449 quadrats sampled along 35 line transects in 4 mangrove forests in June 1990 at Gazi Bay and Mida Creek. Results showed that mangrove seedlings recruited close to parent trees and their distribution was limited to well-defined species-specific zones that correlated with the mean low water level at spring tide. A comparison between propagule dispersal modes showed that the self-planting mode dominated in undisturbed mangrove forests, whilst the stranding mode dominated in over-exploited and cleared mangrove forests. The author concluded that reforestation of mangrove seedlings in the intertidal zone would be most successful when the seedlings were planted in their species-specific zones.

**KMFRI, CRCP, MAN, J**

Regeneration, mangrove, seedlings, zonation, Mida creek, marine reserve, Gazi Bay.

357

**Starger JC (2001) Coral reef restoration after a global bleaching event. MSc. thesis, Columbia University, USA, 76 pp.**

Interest in coral transplantation as a management tool to restore reefs increased after the El Niño Southern Oscillation 1998 bleaching event in East Africa. However, in order for transplantation to be successful, information on the survivorship of corals under different ecological and environmental conditions is needed. This MSc. research study explored the feasibility of using coral transplants of massive *Porites*, *Pocillopora damicornis* and *Pavona decussata* that are common on Kenyan reefs. Fragments of these corals were transplanted in the Malindi marine park and at Ras Iwatine a fished reserve after size and live coral cover estimates were made. Subsequently, size measurements were taken every few days for up to 25 days. Results showed that coral fragments transplanted to the Malindi marine park had significantly lower survivorship than corals transplanted to Ras Iwatine in the

Mombasa marine reserve. The author concluded that although coral transplants have the potential to enhance reef restoration, the success of transplants depended on ecological and environmental factors including predation and sedimentation.

**CRCP, COR, T**

Restoration, coral reefs, bleaching, Malindi, Mombasa, Ras Iwatine marine park, marine reserve.

358

**Tamelaender J (2002) Coral recruitment following a mass mortality event. *Ambio* 31(7-8):551-557.**

Recovery of corals after a disturbance may depend on rates of coral growth and recruitment. However, even on healthy reefs, recruitment may be limited due to ecological and environmental factors resulting in slower recovery. In this study rates and growth of coral recruits were measured on reefs that experienced bleaching during the 1998 El Niño in Kenya. Estimates of size, density and growth of recruits were recorded at 7 sites in the Mombasa, Malindi and Kiunga MPAs. Results showed that of the 31 genera belonging to 13 families recorded in 2001, the Pocilloporidae, Poritidae and Faviidae families dominated. The highest diversity and density of recruits was recorded at sites in the Mombasa marine park and the lowest in the Mombasa and Kiunga marine reserves and Malindi marine park. Results also showed that recruits of massive corals survived better than branching corals, that the diversity of recruits was lower in the post-bleaching population and that there was no significant difference in recruit density between pre and post-bleaching populations. The author concluded that although bleaching did not appear to significantly reduce recruitment, factors such as protection and sedimentation mediated the response.

**CORDIO, CRCP, COR, J**

Coral recruitment, mortality, Pocilloporidae, Poritidae, Faviidae, Mombasa, Malindi, Kiunga, marine park, marine reserve.

359

**Tuda AO (2007) Environmental conflict management in the Mombasa marine national park and reserve, Kenya: a Multi-objective spatial approach. MSc. thesis, University of Plymouth, UK, 56 pp.**

The focus on biodiversity protection at the expense of social benefits has often resulted in non-compliance of MPA regulations and increased conflicts especially from local fisher communities that previously fished the area. This MSc. research study tested a planning approach that takes into consideration both ecological and conflict management objectives in the Mombasa marine park and reserve, Kenya. A spatial multi-criteria decision analysis (SMCDA) framework was used and the impacts of four management scenarios were simulated to look for interactions between the different stakeholder values and predicting potential conflict. The optimal spatial arrangement of MPA use that could maximize ecological benefits and minimize stakeholder conflicts was then mapped. Results showed that although conflicts in the Mombasa MPA were relatively minimal, inadequate and uncoordinated implementation of policies by different management authorities and changes in use patterns could result in increased conflict. The author concluded that the studied approach had the potential to be applied in a number of ways including decision support for MPA planning and environmental regulation.

KWS, CRCP, MGT, T

Planning, resource conflicts, multi-criteria analysis, Mombasa, marine park, marine reserve.

360

**Tunje GJ, Hoorweg J (2003) Awareness of resource degradation among artisanal fishers in Kilifi and Lamu. In: Hoorweg J, Muthiga N (eds) Recent advances in coastal ecology: Studies from Kenya. African Studies Center Research Report 70:185-200.**

The use of destructive gears is a cause of much concern in the management of artisanal fisheries in Kenya. However, the assumption is often made that fisher knowledge of destructive gears may limit their use. This study evaluated whether fishers were aware of destructive gears and whether this factored into their choice of gear. Standard methods of observation and interviews were used to collect data at landing sites in Kilifi, Malindi and Lamu districts including in the Malindi and Kiunga marine reserves. The results showed that the main criteria for gear choice, was experience with a particular gear and high catches and that environmental impacts played no role in gear choice. Traditional forms of marine conservation were scarce and only cultural restrictions relating to personal safety at work, good hygiene and fish handling and religion limited fishing activities. The authors concluded that although knowledge of destructive gears did not limit their use, the willingness of fishers to be involved in conservation initiatives provided an opportunity to increase conservation activities that could also benefit community livelihoods.

**CRCP, FIS, COM, P**

Artisanal fishers, indigenous knowledge, destructive gears, Malindi, Kilifi, Lamu, Kiunga, marine reserve.

361

**Turpie JK, Hockey PAR (1997) Adaptive variation in the foraging behaviour of Grey Plover *Pluvialis squatarola* and Whimbrel *Numenius phaeopus*. IBIS 139: 289 – 298.**

Some shore birds migrate long distances to forage in coastal wetlands such as Mida Creek. In this study, the foraging behaviour and diet of the Grey Plover *Pluvialis squatarola* and the Whimbrel *Numenius phaeopus* were examined at nine temperate and tropical sites including Mida Creek. The birds differed in their foraging behaviour, foraging densities and diets which the authors suggested affected foraging effort and the energy intake of each species. Contrary to expectations, the species with the most versatile foraging behaviour had the more specialized diet

**CRCP, BD, J**

Foraging, grey plover, *Pluvialis squatarola*, Whimbrel *Numenius phaeopus*, Mida creek, marine reserve

362

**Tychesen J (2006) KenSea environmental sensitivity atlas for coastal areas of Kenya. Copenhagen, Geological Survey of Denmark and Greenland, 76 pp.**

Oil spills occur infrequently but their large and sudden impacts complicate the planning of oil spill response. Although the Kenyan coast has experienced relatively few and small oil spills, the lack of spatial information on the susceptibility of different ecosystems and habitats pose challenges for planning oil spill response by the national command center. In addition, the proximity of the Mombasa Port to the Mombasa MPA is of some concern. This atlas was therefore generated to inform the recently developed National Marine Oil Spill

Contingency Plan. The atlas included a GIS electronic component with an environmental data dictionary and GIS datasets on environmental and socioeconomics data of the Kenyan coast.

**KMFRI, CRCP, MAP, R**

Oil spill, response, GIS atlas, environmental sensitivity.

363

**Uku JN (1995) An ecological assessment of littoral seagrass communities in Diani and Galu coastal beaches. MSc. thesis, University of Nairobi, Kenya 310 pp.**

Land based sources of pollution are of major concern for marine and coastal ecosystems. This MSc. research study undertook to estimate the effects of sewage seepage on the flora and fauna of the littoral seagrass community in Diani beach a highly developed tourist resort adjacent to the Diani-Chale marine reserve and Galu Beach, a relatively underdeveloped beach. Seagrass diversity, biomass and physico-chemical parameters were measured during 4 sampling periods in 1993. Results showed that nutrient loading, seagrass biomass, and seagrass epiphytic algal load were higher at Diani than at Galu. The author concluded that although there were signs of nutrient input at Diani, tidal flushing and the capacity of the seagrass beds to absorb the excess nutrients minimized the potential for eutrophication in the Diani lagoon. However, the author recommended the installation of sewage treatment plants to treat increased wastewater from the predicted increased tourism developments in the area.

**KMFRI, CRCP, SG, T**

Seagrass, nutrients, pollution, sewage, Diani, Galu, marine reserve.

364

**Uku JN, Björk M (2001) The productivity of the seagrass *Thalassodendron ciliatum* (forskal) den hartog in nearshore Kenyan seagrass beds: an initial study. Western Indian Ocean Marine Science Association Report. 32 pp.**

The seagrass *Thalassodendron ciliatum* is the dominant and widely distributed seagrass species in shallow lagoons on the Kenyan coast. This study undertook to evaluate the productivity of *T. ciliatum* under varying conditions of nutrients at Nyali in the Mombasa marine reserve and Vipingo on the north coast of Kenya. Results showed that the Vipingo site had significantly lower concentrations of nitrates, ammonia and phosphates in the water column. The Shoot productivity of *T. ciliatum* was also higher at Nyali and the leaves were overgrown by epiphytes that contributed significantly to the productivity of the seagrass beds in the area. The authors concluded that the increased productivity of the seagrass beds at Nyali suggested the input of nutrients and run-off from the adjacent densely developed tourist beach.

**KMFRI, CRCP, SG, R**

Seagrass, *Thalassodendron ciliatum*, productivity, nutrients, Vipingo, Nyali, Mombasa marine reserve.

365

**Uku JN, Kitheka J (2002) The Mida Creek: The physical and biological aspects. Kenya Wildlife Service Technical Series Report. 21 pp.**

Mida Creek in the Watamu marine reserve is fringed by mangroves and provides a habitat for many estuarine species. The Kenya Wildlife Service commissioned a biodiversity survey

of the creek in 1996 to gather scientific information on the fauna and flora of the creek and to assess threats and impacts, both natural and anthropogenic, on the creeks ecosystem. The information was intended for use in the development of the management plan of the MPA. This report summarized the findings from physical and biological surveys and assessments that were conducted between May 1996 and May 1997. The report provided a description of the spatial and temporal variability of planktonic productivity of the creek waters, the species composition and population dynamics of birds that visit the creek, the sedimentary environment and macrofauna of sand flats and the distribution patterns of seagrasses and their associated macroalgae.

**KMFRI, CRCP, BIOD, R**

Mida Creek, biodiversity, plankton, seagrass, shorebirds, Watamu, marine reserve.

366

**Uku, JN (2005) Seagrasses and their epiphytes: Characterization of abundance and productivity in tropical seagrass beds. PhD. dissertation, Stockholm University 107 pp.**

The seagrasses *Thalassodendron ciliatum*, *Thalassia hemprichii* and *Cymodocea rotundata* are widely distributed in shallow lagoons on the Kenyan coast. This PhD. research study was carried out to evaluate whether these species were affected by groundwater nutrient inputs, and to what extent epiphytic algae reflected nutrient inputs. Seagrass productivity was compared at a high nutrient site at Nyali (Mombasa marine reserve), and a low nutrient site at Vipingo. Results showed no differences in productivity between sites in *C. rotundata* and *T. ciliatum*. Within species however, *T. hemprichii* showed higher growth, biomass and more epiphytes at Nyali. Results also showed that the shoots of *C. rotundata* had a higher association with nitrogen fixing cyanobacteria at Vipingo, which the author interpreted as an adaptation to low nutrients in this reef. The author concluded that the high productivity of *T. hemprichii* was an indicator of nutrient input and that the prevalence of 'acid zones' in tropical seagrass species suggested that competition for carbon mediated the association between seagrasses and epiphytes.

**KMFRI, CRCP, SG, T**

Seagrass, productivity, nutrients, cyanobacteria, Nyali, Mombasa Vipingo, marine reserve  
*Thalassodendron ciliatum*, *Thalassia hemprichii*, *Cymodocea rotundata*.

367

**Uku J, Björk M (2005) Productivity aspects of three tropical seagrass species in areas of different nutrient levels in Kenya. Estuarine Coastal and Shelf Science 63(3):407-420.**

This paper summarizes the findings of one aspect of the PhD. research of Uku (2005 above) focusing on the impact of nutrient input on the productivity and growth of the seagrasses *Thalassodendron ciliatum*, *Thalassia hemprichii* and *Cymodocea rotundata* in shallow lagoons on the Kenyan coast. The results suggested that of the three species of seagrass studied, *T. hemprichii* was most affected by nutrient inputs. The increased productivity in *T. hemprichii* as well as increased epiphyte abundance on the stems of *T. ciliatum* reported in Uku and Björk (2001 above) were reliable indicators of the nutrient status of the studied sites.

**CRCP, SG, J**

Seagrass, nutrient, productivity, growth, *Thalassodendron ciliatum*, *Thalassia hemprichii*, *Cymodocea rotundata*, Vipingo, Nyali, Mombasa, marine reserve.

368

**Uku J, Björk M, Bergman B, Diez B (2007) Characterization and comparison of prokaryotic epiphytes associated with three East African seagrasses. *Journal of Phycology* 43(4):768-779.**

Epiphytes associated with seagrasses are thought to play a role in the productivity of seagrass beds. However, very few studies have been carried out on this association in East Africa. This paper detailed a genetic and morphological study of prokaryotic epiphytes growing on three common species of seagrasses, *Thalassodendron ciliatum*, *Thalassia hemprichii*, and *Cymodocea rotundata*. Samples were collected at Nyali (a high-nutrient site) and Vipingo (a low-nutrient site). Results showed that while the abundance of epiphytes was dependent on the site: higher in the high nutrient site, diversity was species dependent. The authors argue that the presence of microorganisms that resembled types from wastewater indicated an influx of land-based pollution into the lagoon. In addition, the presence of cyanobacteria on the leaves of *C. rotundata* especially in the low nutrient site indicated a response to low nitrogen. The authors concluded that there is a distinct epiphytic community growing on seagrasses that varied in composition depending on species and environmental conditions.

**KMFRI, CRCP, SG, J**

Epiphytes, nutrient input, nitrogen fixation, seagrass, *Thalassodendron ciliatum*, *Thalassia hemprichii*, and *Cymodocea rotundata*, Nyali, Vipingo, marine reserve.

369

**UNEP (1998) Eastern Africa atlas of coastal resources: Kenya. UNEP Nairobi, Kenya. 119 pp.**

This atlas provides a comprehensive user-friendly manuscript and maps on the coastal resources of Kenya. The companion booklet detailed the ecological, cultural and economic resources of the Kenyan coast including topics on climate, hydrology and oceanography, agriculture, tourism, fisheries and conservation. The atlas was a product of the East African Database and Atlas project of UNEP that was initiated in 1993.

**CRCP, CR, R**

Coastal resources, Kenya, atlas.

370

**UNEP/FAO/PAP/CDA (2000) Progress in integrated coastal management for sustainable development of Kenya's coast: the case of Nyali-Bamburi-Shanzu area. East African Regional Seas Technical Reports 6. 67 pp.**

The coastal and marine ecosystems and resources of the Kenyan coast are managed through various government institutions. However, the mandates of these institutions are often conflicting and management strategies are not coordinated which results in poor implementation of their objectives. A pilot Integrated Coastal Area Management (ICAM) project was initiated in Kenya in 1993. This report provided an evaluation of the first ICAM pilot project in the Nyali Bamburi-Shanzu area, adjacent to the Mombasa marine park and reserve and the most highly developed tourist beach in Kenya. The report detailed the status of the coastal zone environment and the socioeconomic, institutional and legislative challenges in the area and the process that was followed. The authors concluded that despite the hurdles encountered which included an entrenched sectoral mode of operation, the ICAM pilot project was successful in building partnerships amongst the various stakeholders of the area and increasing an understanding of the benefits of working in an integrated

manner. The authors recommended using the experience developed through the ICAM pilot in other areas along the coast.

**CDA, CRCP, ICAM, R**

Integrated Coastal Area Management, Nyali, Bamburi, Shanzu, Mombasa, marine park, marine reserve.

371

**van Katwijk MM, Meier NF, van Loon R, van Hove EM, Giesen WBJT, van der Velde G, den Hartog C. (1993) Sabaki River sediment load and coral stress: Correlation between sediments and condition of the Malindi-Watamu reefs in Kenya (Indian Ocean). *Marine Biology* 117: 675-684.**

Sediment discharge from rivers has been shown to have a negative impact on coral reef ecosystems. This study evaluated the impacts of the river Sabaki on the coral community of the Malindi-Watamu fringing reef complex. Coral decline was measured using stress indicators along 10m line transects at 42 coral stations between 1982 and 1983. Terrigenous sediment influence was measured by estimating the non-organic and non-calcareous fraction of suspended matter in seawater. Results showed that impacts of terrigenous sediment were strongest in the northern most part of the Malindi reef and in the Watamu area. Results also showed that taken individually, there were no consistent relationships between the coral stress indicators and terrigenous sediment loads but that combining the stress indicators resulted in a positive relationship between increasing coral stress and increasing values of terrigenous sediment loads in both study areas. The authors predicted that reef condition would continue to decline since the silt load of the Sabaki River continued to increase.

**CRCP, SED, J**

Sabaki River, sediment load, coral stress, Malindi, Watamu, marine park, marine reserve.

372

**Vannini M, Ruwa RK (1994) Vertical migrations in the tree crab *Sesarma leptosoma* (Decapoda, Grapsidae). *Marine Biology* 118: 271-278.**

The crab *Sesarma leptosoma* is one of the few species of mangrove crabs that is arboreal living exclusively in Mida creek in 1991 and 1992 to record the pattern of migration up and down mangrove trees and the adaptive significance of this behaviour. Observations showed that the crabs mainly spent their time on the aerial roots of the mangrove trees but migrated up to the leaves twice a day. The authors concluded that the spring-neap tidal cycle, light levels and other climatological cues modulated the migration behaviour of the crab species.

**KMFRI, CRCP, MAN, CRU, J**

Migration pattern, crab, *Sesarma leptosoma*, Mida Creek, marine reserve

373

**Vannini M, Cannicci S, Ruwa RK (1995) Effect of light intensity on vertical migrations of the tree crab, *Sesarma leptosoma* Hilgendorf (Decapoda, Grapsidae). *Journal of Experimental Marine Biology and Ecology* 185: 181-189.**

The tree climbing crab *Sesarma leptosoma* makes daily upward migrations in mangrove trees yet the cue entraining these migrations was not known. This study investigated whether light was a controlling factor by timing the onset of migrations under different light regimes. The light was controlled experimentally through the use of black and white tents draped on the roots of mangrove trees where the crabs spend much of their day. Results showed

a correlation between the delay in the onset of migration and light reduction. The authors concluded that the crabs were entrained to a light threshold that served to synchronise their upward migration.

**KMFRI, CRU, MAN, J**

Grapsidae, light intensity, synchronization, *Sesarma leptosoma*, Mida Creek, marine reserve

374

**Vannini M, Ruwa RK, Cannicci S, (1997) Effect of microclimatic factors and tide on vertical migrations of the mangrove crab *Sesarma leptosoma* (Decapoda: Grapsidae). *Marine Biology* 130: 101 – 108.**

The tree crab *Sesarma leptosoma*, migrates up and down mangrove trunks daily. This study investigated the factors that controlled the timing of these movements. Results showed that morning upward migrations were controlled by light, while morning downward migrations corresponded with temperature increase and humidity decrease. The evening upward migrations were controlled by tides while the evening downward migrations corresponded with a combination of the timing of the upward migration, tides and light levels. The authors note that non-tidal factors have rarely been shown to affect the migratory behaviour of an intertidal species.

**CRCP, KMFRI, CRU, J**

Daily migrations, crabs, *Sesarma leptosoma*, Mida Creek, marine reserve

375

**Vannini M, Cannicci S, Fratini S (2001) Prey selection of *Epixanthus dentatus* (Crustacea: Brachyura: Eriphiidae) as determined by its prey remains. *Journal of the Marine Biological Association of the UK* 81: 455-45.**

The predatory crab *Epixanthus dentatus*, is a nocturnal species that lives in mangrove forests in East Africa. This study investigated the feeding and diet of *E. dentatus* at Mida Creek. Results showed that the crab fed during low and high tides and preyed on 17 different species including gastropods and crabs such as *Uca* and swimming crabs.

**CRCP, CRU, J**

Predatory crab, *Epixanthus dentatus*, Mida Creek, marine reserve

376

**Vannini M, Cannicci S, Berti R, Innocenti G (2003) *Cardisoma carnifex* (Brachyura): Where have all the babies gone? *Journal of Crustacean Biology* 23: 55 – 59.**

Juveniles of the crab *Cardisoma carnifex* are cryptic and difficult to study. This study describes the findings of the young of *C. carnifex* at Mida Creek. The young of this crab were found in the burrows of adults in canals branching off from the main burrow. They had underdeveloped gill structures and lived in the burrows of adults for up to three years.

**CRCP, CRU, J**

Crabs, young, burrows, *Cardisoma carnifex*, Mida Creek, marine reserve

377

**Vannini M, Rorandelli R, Lähteenoja O, Mrabu E, Fratini S (2006) Tree-climbing behaviour of *Cerithidea decollata*, a western Indian Ocean mangrove gastropod (Mollusca: Potamididae). *Journal of marine Biological Association of the United Kingdom* 86 (6): 1429 – 1436.**

The mangrove tree-climbing snail *Cerithidea decollata*, is common throughout the western Indian Ocean. This study investigated the tree climbing behaviour of this gastropod at Mida Creek in 2005. The snail lived mainly on the mangrove species *Avicennia marina*, resting on tree trunks during the high tide and migrating onto the surrounding mud to forage during low tide. Movements were more prominent at spring than at neap tides and during the day than at night and were influenced by the level of the shore with more coordinated daily movements on the lower than upper shore level.

**KMFRI, MOL, J**

Tree climbing, snail, daily migrations, *Cerithidea decollata*, *Avicennia marina*, Mida Creek, marine reserve

378

**Vannini M, Cannicci S, Mrabu E, Rorandelli R (2008) Random walk, zonation and the food searching strategy of *Terebralia palustris* (Mollusca, Potamididae) in Kenya. *Estuarine, Coastal and Shelf Science* 80 (4): 529 – 537.**

The whelk *Terebralia palustris* occurs in dense aggregations in mangroves in the Indo-West Pacific. This study investigated the food searching behaviour of *T. palustris* in Mida Creek to ascertain whether snails used a searching strategy rather than random movement to locate food. The results showed that the snails' movements were not purely random. The distribution of the different size classes of *T. palustris* indicated variable recruitment of juveniles that controlled the eventual spatial pattern of the adults.

**CRCP, KMFRI, MOL, J**

Molluscs, mangroves, *Terebralia palustris*, Mida Creek, marine reserve

379

**Vannini M, Coffa C, Lori E, Fratini S (2008) Vertical migrations of the mangrove snail *Cerithidea decollata* (L.) (Potamididae) through a synodic month. *Estuarine, Coastal and Shelf Science* 78 (4): 644 -648.**

The migration pattern of the mangrove dwelling snail *Cerithidea decollata* was followed over a period of 5 weeks in Mida Creek. Previous studies showed that migrations were daily with snails moving down to the substrate to feed during low tide and up the trees during high tide. A biological clock was suggested to control these daily movements (Vannini et al 2008 below). Results from this study however, showed that migrations varied during the month with periods when snails did not migrate due to the intensity of the tide especially during spring tides. The authors suggested that apart from an internal rhythm, other direct cues played a role in allowing the snail to adjust to the physical conditions of the sea.

**CRCP, KMFRI, MOL, J**

Vertical migrations, biological clock, *Cerithidea decollata*, Mida Creek, marine reserve

380

**Vannini M, Lori E, Coffa C, Fratini S (2008) *Cerithidea decollata*: a snail that can foresee the future? *Animal Behaviour* 76 (3): 983 – 992.**

The mangrove snail *Cerithidea decollata* lives on mangrove trees and migrates downwards to forage on the surrounding sediment at low tide. After foraging the snails aggregate on the base of the tree trunks at a height that is higher than the reach of the high tide. How these snails determine when to stop climbing was investigated in this study. Results from experiments conducted at Mida Creek showed that snails were able to judge the length

to travel upward along the tree trunk to avoid the incoming tide. How snails were able to determine the distance to travel was not known although the authors discounted the use of visual cues and chemical markers in controlling this behaviour.

**CRCP, KMFRI, MOL, J**

Vertical migration, biological clock, *Cerithidea decollata*, Mida Creek, marine reserve

**381**

**Vannini M, Mrabu E, Cannicci S, Rorandelli R, Fratini S (2008) Rhythmic vertical migration of the gastropod *Cerithidea decollata* in a Kenyan mangrove forest. *Marine Biology* 15 (6): 1047 – 1053.**

The snail *Cerithidea decollata* that is widely distributed throughout the mangroves of East Africa is known to occur in the trunks of the mangrove species *Avicennia marina* during high tide and migrate to the substrate to forage during low tide. The migration behaviour of this species was investigated in Mida Creek to ascertain whether migrations were cued by external or internal factors. Results showed that the snail mainly used internal information and the authors suggest that an internal clock controlled the migrations.

**CRCP, KMFRI, MOL, J**

Daily migrations, *Cerithidea decollata*, Mida Creek, marine reserve

**382**

**Verheyden A, Kairo JG, Beeckman H, Koedam N (2004) Growth rings, growth ring formation and age determination in the mangrove *Rhizophora mucronata*. *Annals of Botany* 94: 59 -66.**

In this study, the dark and light brown layers on polished stem discs were investigated to ascertain the presence of growth rings that were previously discounted in the common mangrove species *Rhizophora mucronata*. Results from cambial marking experiments using trees of known age showed distinct annual growth rings. The rings were independent of site environmental factors in forests in Gazi Bay and Mida Creek. Growth rings however were not detectable in trees with low growth rates (>0.5mm per year radial growth). The rings consisted of low vessel density wood that coincided with the long rains and high vessel density wood that coincided with the dry season. This is the first study to confirm annual growth rings in *Rhizophora mucronata* a characteristic that has applications for silviculture.

**CRCP, KMFRI, MAN, J**

Age, annual growth rings, *Rhizophora mucronata*, Mida Creek, marine reserve

**383**

**Versleijen N (2001) An empty sufuria. The effects of a marine national park on the livelihood strategies and income diversification of fisherman households at the Kenya coast. MSc. thesis, Wageningen University, 137 pp.**

Artisanal fishing is the dominant fishing activity in the nearshore habitats of Kenya. The fishery has been reported to be under severe pressure yet until recently few studies had focused on how fisher livelihoods were impacted by increased effort and ecosystem degradation. This MSc. research focused on the activities of artisanal fishers and their households, the livelihood strategies they had, their attitude towards conservation, their indigenous environmental conservation practices and the perceptions about marine parks. Data was collected at Uyombo (Watamu reserve) Takaungu and the Watamu marine park. The results revealed that fishermen were aware of the decline of marine resources and responded by diversifying into small-scale agriculture. Results also showed an increase into the fishery

of people who were traditionally not from fishing communities. This resulted in the influx of fishers from other ethnicities and religions reducing the use and impact of traditional conservation measures. A high percentage of fishers were willing to stop fishing but the lack of employment opportunities prohibited exit from the fishery. The author recommended building fisher capacity by increased basic education and financial assistance to increase and enhance livelihoods.

**CRCP, COM, T**

Artisanal fishers, livelihoods, diversification, Watamu, Takaungu, Uyombo, marine reserve.

**384**

**Versleijen N, Hoorweg J (2008) From farming to fishing: marine resource conservation and a new generation of fishermen. *Western Indian Ocean journal of Marine Science* 7(1):1-14.**

How fishers adapt to changes in their social and ecological conditions is crucial for developing management interventions. This paper that is part of the PhD. research study of Versleijen (2001 above) focused on differences between the new generation of fishers and fishers who were traditionally from fishing communities. The authors recommended economic interventions that would allow fishers to completely exit the fishery.

**CRCP, COM, J**

Artisanal fishers, livelihoods, diversification, Watamu, Takaungu, Uyombo, marine reserve.

**385**

**Versleijen N, Hoorweg J (2009) Marine conservation: The voice of the fishers. In: Hoorweg J, Muthiga N (eds) *Advances in coastal ecology: People, processes and ecosystems. African Studies Centre, African Studies Collection Vol 20:79-98.***

Marine protected areas are often established in areas that were historically utilized by artisanal fishers and the failure to adequately involve them at the initiation of the MPA leads to conflicts in the future. This paper reviewed the attitudes of fishers in two villages towards marine conservation as part of PhD. research by Versleijen (2001 above). The study found that the fishers that utilize the Watamu marine reserve had a more negative attitude towards marine conservation. The authors recommended increased communication between MPA management and fishers and development of livelihood options that could relieve pressure from the resource.

**CRCP, COM, P**

Artisanal fishers, livelihoods, Watamu, Takaungu, Uyombo, marine reserve.

**386**

**Vezzosi R, Barbaresi S, Anyona D, Vannini M (1995) Activity patterns in *Thalamita crenata* (Portunidae, decapoda): A shaping by the tidal cycles. *Marine and Freshwater Behaviour and Physiology* 24 (4): 207 – 214.**

The portunid crab *Thalamita crenata* is widely distributed in mangroves in East Africa. The activity rhythm of this crab was studied at Mida Creek in 1994. The crab predominantly foraged during high tide at water levels between 10 and 30 cm with activity being limited above and below these water levels. The authors suggested that changes in hydrostatic pressure cued the onset and cessation of activity in this crab.

**KMFRI, CRCP, CRU, J**

Tidal rhythm, feeding, *Thalamita crenata*, Mida Creek, marine reserve

387

**Visram S, Douglas AE (2006) Molecular diversity of symbiotic algae (zooxanthellae) in scleractinian corals of Kenya. *Coral Reefs* 25:172-176.**

The symbionts of corals, zooxanthellae are poorly studied in East Africa. This study investigated the molecular diversity in Kenyan corals using samples collected from reefs in the Mombasa, Malindi, Kiunga, Kisite MPAs and fished reefs (Kanamai). Seven coral species were sampled and analyzed using Restriction Fragment Length Polymorphism (RFLP) and sequencing of a PCR-amplified fragment of the LSU rRNA gene. Results showed that phylotypes A, C and D zooxanthellae were found in the samples. The zooxanthellae phylotypes varied; while all type D zooxanthellae were identical, type C showed some variability. The authors concluded that the data on zooxanthellae diversity in Kenyan corals 3-4 years after the 1998 bleaching event provided baseline information that were useful for comparison in future large-scale bleaching episodes in Kenyan corals.

**CORDIO, CRCP, COR, J**

Coral, zooxanthellae, *Symbiodinium*, bleaching, Kiunga, Malindi, Mombasa, Diani, marine reserve, Kanamai.

388

**Visram S, Mwaura J, Obura DO (2007) Assessing coral community recovery from coral bleaching by recruitment in two reserves in Kenya. *Western Indian Ocean Journal of Marine Science* 6 (2): 199-205.**

Coral reefs ecosystems are exposed to different physico-chemical regimes and the potential for recovery may therefore differ. In this study, recruitment of corals was measured and related to the changes that occurred in reef community structure after the 1997-1998 El Niño Southern Oscillation bleaching event in Kenya. Coral recruits were identified and counted in quadrates placed at similar depths and tidal cycles between 2003 and 2005 in the Mombasa marine park and reserve and the Kiunga marine reserve. A total of 28 coral genera and 12 families were recorded. The genera *Porites*, *Coscinarea* and *Pocillopora* had the highest densities of recruits in Kiunga while *Pocillopora* dominated in Mombasa. Overall recruitment was lower in Kiunga as were recruits of corals that had experienced high bleaching and mortality during the bleaching event. The authors suggested that recruitment in Kiunga may have been affected by isolation from sources of coral reef larvae and the seasonal input of nutrient-rich, cooler water from the Somali Current indicating that reefs in Kiunga are unlikely to recover by natural recruitment making them more vulnerable to environmental disturbances such as coral bleaching.

**CORDIO, COR, J**

Coral, bleaching, recruitment, Mombasa, Kiunga, marine park, marine reserve, recovery.

389

**Wamukota AW (2002) Marine fish marketing in Malindi and Kilifi Districts – Kenya. MPhil. thesis, Moi University, Kenya. 115 pp.**

The economics of artisanal fishing on the Kenyan coast has rarely received any attention yet it is vital to informing any interventions in the management of the fishery. This MPhil. research study undertook to evaluate the marketing system of fish in Malindi and Kilifi districts at fish landing sites at Ngomeni, Takaungu (fished areas) and Mayungu and Uyombo (Malindi-Watamu marine reserve). Data was collected by structured questionnaires, interviews, observation, photography and the use of secondary data from various sources. Results from

logistic analysis showed that the choice of a marketing channel depended on ownership of storage facilities, profit margin and time taken to selling point. The main challenges identified in the marketing system related to infrastructure and socio-economic factors such as ownership of fish storage facilities and household size. The author recommended the revitalization of fisher co-operative societies and investment in fish storage facilities, which would improve access to credit and marketing of fishery products.

**CRCP, FIS, R**

Artisanal fishing, marketing system, fish traders, Malindi, Watamu, Mayungu, Uyombo, Ngomeni, Takaungu, marine reserve.

390

**Wamukota AW (2009) The structure of marine fish marketing in Kenya: The case of Malindi and Kilifi Districts. *Western Indian Ocean Journal of Marine Science* 8(2): 215-224.**

This article is based on the MPhil. research study by Wamukota (2005 detailed above). The study focused on the challenges faced by artisanal fishers in marketing fish at landing sites in Malindi and Kilifi districts. The study recommended revitalization of the fisher co-operative movement, improvement of fish storage facilities.

**CRCP, FIS, R**

Artisanal fishing, marketing system, fish traders, Malindi, Watamu, Mayungu, Uyombo, Ngomeni, Takaungu, marine reserve.

391

**Wamukota AW, Okemwa, G (2009) Perceptions about trends and threats regarding sea turtles in Kenya. In: Hoorweg J, Muthiga N (eds) *Advances in coastal ecology: People, processes and ecosystems. African Studies Centre, African Studies Collection Vol 20:194-205.***

The success of conservation programs depends on several factors including the perceptions of key stakeholder. This paper detailed the trends and status of sea turtles in Kenya and compares these with perceptions of local communities. Perceptions were collected using a participatory rural appraisal approach that included transect walks, observation, resource mapping, problem visualization, resource prevalence trend lines and structured interviews. Sampling was carried out at villages along the coastline from Ngomeni in the north to Vanga in the south. Results showed that respondents had a high degree of agreement that sea turtle numbers had declined from the 1980's and that the main threat to turtles was drowning in fishing nets. There was also a high degree of agreement about the need to conserve sea turtles. The authors concluded however that the level of awareness about the value and decline of marine resources was low and argued for the adoption of integrated and participatory approaches in the conservation and management of sea turtles.

**CRCP, ST, W**

Sea turtles, perceptions, communities, participatory rural appraisal.

392

**Wamukoya GM, Mirangi JM, Ottichillo WK, Cockcroft V, Salm R (1996) *Marine aerial survey; marine mammals, sea turtles, sharks and rays, KWS Technical Series Report 1: 22 pp.***

Marine mammals and other large charismatic species are distributed widely along the Kenya coast but few aerial surveys have been carried out to assess their populations. This report details the first large aerial survey of marine mammals, sea turtles, sharks and rays on the Kenyan coast that was conducted in November 1994. The aim of the aerial survey was to

determine the occurrence, distribution and relative abundance of sea turtles, dugongs, whales and dolphins and to produce distribution maps of these species. Sea turtles were distributed throughout the coast and dolphins were concentrated around the creeks. A total of 443 turtles, 10 dugongs, and 1326 dolphins were sighted but no whales were counted during the survey.

**KWS, CRCP, MM, R**

Marine mammals, aerial survey, dolphins, dugongs, whales sea turtles, sharks, rays.

393

**Wamukoya GM, Kaloki FP, Mbendo JR (1996) Sea turtle recovery action plan for Kenya. Kenya Wildlife Service Technical Report Series 3:105 pp.**

Sea turtles are fully protected under the Wildlife Conservation and Management Act and the Fisheries Act in Kenya. In 1995, a Marine Turtle Conservation Strategy and Action Plan for the Western Indian Ocean was formulated at Sodwana in South Africa at which Kenya participated. The Sodwana agreement called upon countries of the western Indian Ocean to develop country specific action plans for the conservation and management of sea turtles. This report provided comprehensive information on the status and distribution of sea turtles and the threats to their survival and details several actions that can be undertaken to mitigate these threats.

**KWS, KESCOM, ST, R**

Sea turtle, action plan.

394

**Wamukoya GM, Ottichilo WK, Salm RV (1997) Aerial survey of Dugongs (*Dugong dugon*) in Ungwana Bay and the Lamu Archipelago, Kenya. Kenya Wildlife Service Technical Report No. 2, 13 pp.**

The concern about the drastically reduced number of dugong compared to historical data on the Kenyan coast led the Kenya Wildlife Service to commission an aerial survey of dugongs. The survey recorded six dugongs in Ungwana Bay; four individuals were sighted in Siyu channel and two solitary individuals were sighted near Manda Toto Island and one calf was counted. Several clear feeding trails were observed in areas off Faza, Uvondo and Ndau Islands. The authors suggested that factors including increased coastal settlements, beach tourism developments, fishing activities, loss and degradation of habitat, and poaching caused the decline in the dugong population. The authors recommended enhanced surveillance and protection of habitat to save the few remaining dugongs and noted that the success of their protection and conservation would greatly depend on the integration and support of the local communities, fisheries and tourism sectors.

**KWS, CRCP, MM, R**

Dugongs, conservation, Ungwana Bay, *Dugong dugon*, Lamu.

395

**Wamukoya GM, Salm RV (1998) Report of the Western Indian Ocean Turtle Excluder Device (TED) training workshop. IUCN Eastern Africa Regional Office, Nairobi, Kenya. 30 pp.**

One of the major threats to sea turtles is incidental capture, injury and mortality during fishing operations. Previous studies have indicated that sea turtles are caught incidentally in shrimp trawlers in the waters of the western Indian Ocean, however, there was no expertise in the region on mitigating measures such as Turtle Excluder Devices (TEDS). This challenge was addressed during a regional workshop on TEDs that was conducted in Malindi in January

1997. This report details the main discussions of the workshop, the training exercise on TED installation and challenges of implementing TED legislation and enforcement in the region.

**KWS, CRCP, ST, R**

Sea turtles, Turtle Excluder Device (TED), Malindi.

396

**Watson DM (2006) Growth rates of sea turtles in Watamu, Kenya. Earth and Environment 2: 29-53.**

The growth rates of the green turtle *Chelonia mydas* was estimated using a capture-mark-recapture technique at Watamu adjacent to the marine reserve and in Mida Creek from 1999 to 2005. Results showed growth rates averaging 5.2 cm/year, a rate that was fast relative to rates recorded in other geographical locations worldwide. This was the first attempt to measure green turtle growth in Kenya.

**CRCP, ST, J**

Sea turtle, growth, *Chelonia mydas*, Mida Creek, marine reserve

397

**Watson M, Ormond (1994) Effect of an artisanal fishery on the fish and urchin populations of a Kenyan coral reef. Marine Ecology Progress Series 109:115-129.**

The Kisite marine park and adjoining Mpunguti reserve were established in 1978 but implementation of the full closure of the Kisite marine park was reportedly not effective until after 1989. Recovery of the coral reef fish community in Kisite after full closure was the main focus of this study. Data were collected at sites within the Kisite and Mpunguti by replicate visual censuses of fish along 250 by 10 m belt transects in 1992. Results showed that abundances of the dominant commercial reef fish were ~10 times higher in the park than in the reserve, that sizes of most species were larger in the park than in the reserve, and that six Chaetodontid and two Balistid species had higher densities in the park. Only smaller *Cephalopholis* spp. (Serranidae), one species of butterflyfish, and sea urchins were more abundant in the reserve than in the park. The authors concluded that overall, the results contributed to an understanding of how artisanal fishing affects coral reef fish populations and the effectiveness of closure of the Kisite marine park.

**CRCP, FIS, SU, J**

Coral reefs, fisheries, Kisite, Mpunguti, sea urchins, Chaetodontid, Balistid, *Cephalopholis*, marine park, marine reserve.

398

**Watson M (1996) The role of protected areas in the management of Kenyan reef fish stocks. PhD. dissertation, University of York, UK. 206 pp.**

The effects of artisanal fishing on coral reefs may include reduced abundances and sizes of fish and changes in the reef community structure that results in declining stocks and degraded habitats. This PhD. research study focused on a comparison of the coral reef fish community in the Kisite marine park and the Mpunguti marine reserve and aimed to evaluate the effects of artisanal fishing on reefs in the MPA. Visual fish censuses were carried out along replicate belt transects in 1992 and 1995. Results showed that there were significantly more and larger commercial fish in the park than in the reserve but the species diversity of many coral reef fish families were not significantly different between the park and reserve. Estimates of natural fishing mortality from the artisanal catch of the dominant *Lethrinus borbonicus*

suggested that the park played a role in preventing stock collapse through larval supply to the reserve. The author concluded that the coral reef fish population in the Kisite marine park showed marked recovery as a result of more effective enforcement of the fishing ban and enhanced stocks in the Mpunguti marine reserve.

**CRCP, MPA, MGT, T**

Coral reef fish, artisanal fishing, Mpunguti, Kisite, marine park, marine reserve, *Lethrinus borbonicus*.

399

**Watson M, Righton D, Austin T, Ormond R (1996) The effects of fishing on coral reef fish abundance and diversity. *Journal of Marine Biology Association* 76: 229-233.**

This article details results of the PhD. research of Watson (1996 above). The study focused on the effect of artisanal fishing on the abundance and diversity of coral reef fish assemblages in the Kisite-Mpunguti MPA. Results showed that abundances of commercial fish increased due to effective protection in the marine park and that fishing resulted in changes in the community structure of reefs in the marine reserve.

**CRCP, FIS, J**

Coral reef fish, artisanal fishing, Mpunguti, Kisite, MPAs, marine park, marine reserve.

400

**Watson M, Ormond RFG, Holliday L (1997) The role of Kenya's MPAs in artisanal fisheries management. In: Lessios HA, Macintyre IG (eds) *International Coral Reef Symposium 8: 1955-1960*.**

Trends in fish catches compared with records of fish abundances in adjacent closed areas could be used to evaluate the benefits of protection to fisheries management. This study builds on the work by Watson (1996 above) on Kisite-Mpunguti MPA and includes additional work on Malindi-Watamu MPA to assess the impacts of artisanal fishing on coral reef fishes. Results showed that protection enhanced the population of commercial coral reef fish in the Kisite marine park while the artisanal fish catch in the Mpunguti reserve showed a significant improvement since 1989 when the fishing ban in the reserve was effectively enforced. Catch trends in the Malindi marine reserve declined however and consisted mainly of herbivores suggesting that the Malindi reserve did not benefit from the adjacent marine parks (Malindi and Watamu). The authors concluded that effective enforcement of full closures was crucial for the realization of the potential benefits of fisheries enhancement in adjacent reserves.

**CRCP, MPA, P**

Artisanal fishing, coral reef fish, MPAs, Kisite, Mpunguti, Malindi, Watamu, marine park, marine reserve.

401

**Wells S (2004) *Assessment of management effectiveness in selected Marine Protected Areas in the Western Indian Ocean. Final report. IUCN Eastern Africa Programme. 29 pp***

Assessments of marine protected areas have typically been conducted through studies of trends in biophysical changes yet the success of MPAs also depends on the capacity for management. Over the last decades, many MPAs have been established in the western Indian Ocean, however, few have been monitored to track changes of management actions. In recent years, methods for conducting management effectiveness assessments (MEAs) have been developed that evaluate management effort against the stated objectives of

the MPA. This report detailed the process, findings and lessons learned while testing the regional workbook on MEAs at eight pilot sites in Kenya, Tanzania and Seychelles. The author concluded that although there were varying levels of capacity in each of the MPAs, the initiative was beneficial as a learning process for the MPA managers in the region. The author recommended the mainstreaming of MEAs into MPA management.

**CRCP, MGT, R**

Marine Protected Areas, assessment, management effectiveness.

402

**Wells S, Burgess N, Ngusaru A (2007) Towards the 2012 marine protected area targets in Eastern Africa. *Ocean and Coastal Management* 50(1-2):67-83**

Many countries in the western Indian Ocean are signatories to the Convention on Biological Diversity (CBD) and have established marine protected areas. Few countries however, have carried out a comprehensive assessment of the spatial extent of their MPAs and how close they are to the set 1992 CBD targets of 10% of all marine ecological regions by 2012. This paper reviews the efforts made by Kenya, Tanzania and Mozambique in MPA establishment and management and uses the available data to estimate the spatial extent of MPAs. Results showed that Kenya had 8.7%, Tanzania 8.1% and Mozambique 4.0% of their continental shelves under full or partial protection. In many cases, the MPAs were located in areas of high biodiversity coral reefs and Important Bird Areas. Challenges in meeting the MPA targets included lack of information to accurately estimate representation of species and habitats, the small areas under full protection from fishing, and the low capacity for management in some countries. The authors recommended increasing the number of MPAs, improving the management of existing MPAs and establishing monitoring systems that measured management effectiveness and progress towards meeting the CBD targets.

**CRCP, MPA, J**

Marine protected areas, CBD targets, management, Kenya, Mozambique, Tanzania.

403

**Weru SM (1994) Optimum coral reef resource use: a case study of a marine protected area. MSc. thesis, University of Nairobi, Kenya. 85 pp**

Marine protected areas in Kenya were mainly established for biodiversity protection, fisheries and tourism, yet there are potential conflicts between these sectors within an MPA. Spatial planning that maximizes biodiversity protection and optimizes economic returns without adversely affecting the ecosystem has the potential to reduce this conflict. This MSc. research study was conducted between 1992 and 1993 in the Mombasa marine park and reserve and used a Location Analysis to examine the possibilities of maximizing indirect economic rent while ensuring protection of the coral reef. Data included; estimates of spillover from park to reserve using species-area relationship and the quantities of fish landed, estimates of the area used for tourist activities, park fee and other entry charges, perception of tourists about park ecological condition and predation and herbivory trends. The author recommended that the spatial framework of the Mombasa MPA be carefully designed so that it optimized the benefits of the tourism sector without impacting negatively on the reef system.

**CRCP, MGT, T**

MPA design, coral reefs, Mombasa, marine park, marine reserve.

404

- Weru S (1995) Pomacentrids of Kenya: An annotated checklist and cast study of Mombasa marine park and reserve. In: NK (ed) Sustainable Development of Fisheries in Africa. 141p.** Damselfishes are popular for dive tourism and the aquarium trade. There are 45 species in Kenyan coral reef lagoons and two species are endemic. This paper summarized information on the damselfishes of the Mombasa marine park and reserve as part of the MSc. Thesis of Weru (1994 above). Results showed that the damselfishes had a short ranging distance and had higher densities and diversity in the no-take marine park than in the fished reserve. The author makes the argument that the no-take areas are an important refuge for these species.  
**CRCP, MGT, P**  
Damselfish, species diversity, Mombasa, marine park, marine reserve

405

- Weru S (2001) Rapid baseline survey of large marine animals, with special emphasis on humpback whales in Kenya, Kenya Wildlife Service Technical Report Series 14 pp.** Humpback whales are reported to migrate along the Kenyan coast at the beginning of the northeast monsoon season. During the first large aerial survey of marine mammals in Kenya (Wamukoya et al 1995 above) that was conducted in November, no whales were recorded. This report detailed the findings of a follow-up aerial survey that was conducted for three days in September 2001, one month earlier than the previous survey. The survey covered the entire coast from Shimoni to Kiunga and the GPS positions of all large mammals as well as other large marine species that were sighted were recorded. Only one humpback whale with a calf was recorded which the author suggested was an indication that the time of the survey was probably towards the end of the humpback whale migration period in Kenyan waters. Anecdotal evidence also reported humpback whales in Watamu, Shimoni, Kisite, Kiwaiyu and Diani during the survey. There was a large concentration of whale sharks and for the first time, devil rays were documented in the aerial survey.  
**KWS, MM, R**  
Humpback whale, aerial survey, marine reserve.

406

- Weru SM, Amboga GM, Verheij E, Koyo A, Muthiga N, Kavu BK, Kareko JK, Litoro M (2001) Management Plan, Mombasa marine national park and reserve. Kenya Wildlife Service, Mombasa. 121 pp** The marine protected areas of Kenya were established for the purposes of biodiversity conservation and the management of fisheries and tourism activities. These broad goals however cannot be assessed without defined and measurable objectives, which requires that MPAs have plans that guide management. This management plan of the Mombasa marine park and reserve was developed in 2000 through a participatory process in parallel with all the other MPAs in Kenya. The plan detailed; physical, biological and cultural characteristics of the area, legislative and regulatory information, threats and resource use, administrative and financial mechanisms, management challenges and actions to address them. The plan also included a daily management handbook that detailed operational procedures, personnel management, law enforcement procedures, research and monitoring, information management and community outreach.  
**KWS, CRCP, MGT/P, R**  
Management plan, Mombasa, marine park, marine reserve

407

**Weru SM, Kaleha J, Verheij E, Koyo A, Muthiga N, Kavuu BK, Kareko JK, Litoro M (2001) Management Plan, Kisite Mpunguti marine park and reserve. Kenya Wildlife Service, Mombasa, Kenya 117 pp.**

The marine protected areas of Kenya were established for the purposes of biodiversity conservation and the management of fisheries and tourism activities. This plan of the Kisite-Mpunguti marine park and reserve was developed in 2000 through a participatory process in parallel with all the other MPAs in Kenya. The management plan provides details on: the physical, biological and cultural characteristics of the area, legislative and regulatory information, threats and resource use, and administrative and financial mechanisms, management challenges and actions to address them. The plan also included a daily management handbook that details operational procedures, personnel management, law enforcement procedures, research and monitoring, information management and community outreach.

**KWS, CRCP, MGT/P, R**

Management plan, Kisite, Mpunguti, marine park, marine reserve.

408

**Weru SM, Wakaba GM, Macharia D, Mwakau BK, Njue RM, Verheij E, Koyo A, Muthiga N, Kavuu BK, Kareko JK, Litoro M (2001) Management Plan: Malindi and Watamu marine parks and reserves. Kenya Wildlife Service, Mombasa, Kenya. 107 pp**

The marine protected areas of Kenya were established for the purposes of biodiversity conservation and the management of fisheries and tourism activities. This plan of the Malindi-Watamu marine parks and reserves was developed in 2000 through a participatory process in parallel with all the other MPAs in Kenya. The management plan provided details on; the physical, biological and cultural characteristics of the area, legislative and regulatory information, threats and resource use, and administrative and financial mechanisms management challenges and actions to address them. The plan also included a daily management handbook that details; operational procedures, personnel management, law enforcement procedures, research and monitoring, information management and community outreach.

**KWS, CRCP, MGT/P, R**

Management plan, Malindi, Watamu, marine park, marine reserve.

409

**Weru SM, Church J, Lubia I, Nekesa N, Verheij E, Koyo A, Muthiga N, Kavuu BK, Kareko JK, Litoro M (2001) Management Plan: Kiunga marine national reserve (KMNR). Kenya Wildlife Service and Worldwide Fund for Nature, Mombasa, Kenya. 208 pp**

The marine protected areas of Kenya were established for the purposes of biodiversity conservation and the management of fisheries and tourism activities. This plan of the Kiunga marine reserve was developed in 2000 through a participatory process in parallel with all the other MPAs in Kenya. The management plan provided details on; the physical, biological and cultural characteristics of the area, legislative and regulatory information, threats and resource use, and administrative and financial mechanisms, management challenges and actions to address them. The plan also included a daily management handbook that details; operational procedures, personnel management, law enforcement procedures, research and monitoring, information management and community outreach.

KWS, CRCP, MGT/P, R  
Management plan, Kiunga, marine reserve.

410

**Weru SM, Muthiga N (2004) Kenya. In: WWF Eastern African Marine ecoregion: Towards a Western Indian Ocean dugong conservation strategy: The status of dugongs in the Western Indian Ocean and priority conservation actions. Dar es Salaam, Tanzania: WWF. 16-20 pp**

Dugongs are distributed throughout the western Indian Ocean, inhabiting shallow marine areas where their primary food source seagrasses are abundant. However, despite reports that Dugong population numbers have decreased drastically in the region, no large-scale population surveys have been carried out. This review collates information on the status of dugongs in countries of the region including Kenya. In Kenya, information on the status, distribution and threats to dugongs was obtained from a literature review, consultations with researchers and resource managers, interviews with key informants and questionnaires administered in villages on the coast. Results showed that one third of respondents claimed to have seen a dugong live at sea, while another third had seen a dead dugong on the beach or trapped/entangled in a fishing net. Only 5% of respondents did not know what a dugong was. The most important dugong habitats were in the Kiunga marine reserve, Dodori and Mongoni creeks and the Siyu Channel in Lamu district, and around Gazi in Kwale district. The authors recommended the establishment of Dugong sanctuaries in key dugong areas, more detailed surveys and studies on dugongs and improved capacity of government organizations to protect dugongs.

**CRCP, MM, R**

Dugongs, population, Kiunga, Gazi, marine reserve.

411

**Yarish C, Wamukoya GM (1990) Seaweeds of potential economic importance in Kenya: Field survey and future prospects. Hydrobiologia 204:339-346**

Commercial seaweed (marine algae) farms are increasing at a rapid pace in East Africa as fish stocks decline and alternative livelihoods are sought. This paper reviews the potential for seaweed harvest and farming in Kenya. Results of a survey at 15 sites along the coast indicated that seaweeds of the genus *Euchema* that produce high grade carrageenan and *Gracillaria* and *Gelidium* producers of high grade agar were abundant and widely distributed. The authors noted there were suitable physical and chemical conditions for establishment of a pilot *Euchema* farm in the sea in Shimoni and/or a land-based pond cultivation of *Gracillaria*. The authors recommended the development of a national program for seaweed farming and processing in Kenya.

**CRCP, SW, J**

Seaweeds, agar, carrageenan, Shimoni, *Gracillaria*, *Euchema*, *Gelidium*, Shimoni.

412

**Young SE (2004) Artisanal fishers perspective on a "rich man's" fishery, the potential for ring net development in Kenya. MSc. thesis, University of Newcastle upon Tyne, UK. 26 pp**

Artisanal fisheries have been on the decline in the inshore waters of the Kenyan coast for some time and fisheries managers have argued for the provision of fishing gear to encourage fishing in deeper waters. However, the entry of the ring net in Kenya that is intended for use in deeper waters caused severe social conflicts among artisanal fishers, recreational fishers

and tourism operators mainly over resource rights and equity of access to gear. This MSc. research study focused on the ring net fishery in Kilifi and Kwale district (including in marine reserves in these districts) on the Kenyan coast. A qualitative and semi-quantitative approach was used to collect data for evaluating fisher perspectives on development of the ring net fishery from May to July 2004. The results highlighted four key issues that would control the success or failure of the ring net fishery: access to credit and fishing cooperatives, conflict resolution, markets and infrastructure and management issues.

**CRCP, FIS, R**

Artisanal fisheries, ring net, Kilifi, Kwale.

413

**Zanre R (2005) Report on Watamu turtle watch's sea turtle bycatch release programme. Kenya. 95 pp**

Sea turtles are incidentally caught in the nets of artisanal fishers in Kenya and compensatory release programs have been touted as a way to reduce mortality of sea turtles incidentally caught by local fishers. This report evaluated a compensatory release program that was initiated in Watamu in 1998 by the Watamu Turtle Watch. The report reviewed: the context for implementation, the type and quality of research data collected, the programs value as a viable sea turtle conservation activity and implications of sea turtle conservation policy in the region. Results showed that 1422 turtles were released during the period 1998 to 2004. The author concluded that the review provided information about the extent of the bycatch problem in Watamu and allowed an estimation of the minimum size of the local foraging populations. The author recommended research in areas where fishing effort was high, and mapping turtle foraging behaviour to provide information about priority areas for sea turtle conservation efforts.

**CRCP, ST, R**

Sea turtles, bycatch, Watamu, marine reserve.

414

**Zorini LO, Contini C, Jiddawi N, Ochiwo J, Shunula J, Cannicci S (2010) Participatory appraisal for potential community-based mangrove management in East Africa. *Wetlands Ecology and Management* 12 (2): 87 – 102.**

Community based approaches have become quite popular in East Africa but the conditions that encourage successful initiatives have rarely been evaluated prior to inception. In this paper, mangrove management programs are evaluated by comparing socioeconomic and ecological aspects at sites in Tanzania (Kisakasaka), Mozambique (Inhaca Island) and Kenya (Mida Creek). Results showed that mangrove exploitation in Inhaca was primarily for household use and was sustainable but exploitation at Kisakasaka and Mida Creek supplemented livelihoods and was unsustainable. The results were presented to the local communities and possible alternative management options were discussed and a multi-criterion analysis was used to compare the alternatives in relation to social, economic and ecological criteria. The authors concluded that such a process could reveal the most suitable management actions for the management of mangrove forests.

**CRCP, MAN, J**

Mangrove management, community, Mida Creek, marine reserve

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