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Climate Change and Coastal Resources in Tanzania

Studies on Socio-Ecological Systems' Vulnerability, Resilience and Governance

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Preface

The Centre for Climate Change Studies (CCCS) is implementing a 5-year (2014–2018) Norwegian Programme for Capacity Development in Higher Education and Research for Development (NORHED) supported by the Norwegian Agency for Development (NORAD). The project title is "*Vulnerability, Resilience, Rights and Responsibilities: Capacity Building on Climate Change in Relation to Coastal Resources, Gender and Governance in Coastal Tanzania and Zanzibar*." The overall project goal is to promote adaptation to climate change and resilient livelihoods among coastal communities in mainland Tanzania and Zanzibar through capacity development in higher education and research. Key collaborators for the project implementation are the State University of Zanzibar (SUZA) and the Norwegian University of Life Sciences (NMBU). The project sites are along the coastal areas of Pangani, Mafia, Kilwa, Lindi, Mtwara and Zanzibar.

The project aims at building the capacity faculty members of the University of Dar es Salaam and the State University of Zanzibar (SUZA) through research (including publications of scientific journal articles) and education (MSc and PhD). Capacity building is mainly focused on newly established and existing research and educational centres in collaborating institutions on issues pertaining to addressing climate change issues and natural resources governance and management. Robust research methodologies are emphasized in the research process in order to produce findings for publication in monographs and peer-reviewed journals, inform policy- and decision-making processes as well as engage the wider general public through the media, community meetings and short courses for stakeholders across scales and levels. PhD students and faculty have been pursuing their studies in four major thematic areas:

1. Impacts of the changing climate (climatic factors) on coastal resource governance and communities' vulnerability and livelihoods including access to coastal resources, rights and responsibilities
2. Institutional and legal framework for coastal resource governance and management and their implications on community vulnerability and livelihoods,

including how gender roles affect decision-making and access and control of coastal resources, community rights and responsibilities and ecosystem integrity
3. Social systems (non-climatic processes, e.g. poverty levels, access to resources, gender roles and participation in decision-making processes) and their interlinkages with communities' vulnerability to climate change impacts and coastal ecosystems integrity
4. Community responses (coping and adaptation options) to climate change impacts and their implications on coastal resource use, governance and management including participation in decision-making processes, gender roles, legal framework and sustainability of coastal resources and social systems

In the process, these studies have been framed around a rather complex systems theory which offers a more sophisticated understanding of the structure and dynamics of both social and ecological systems than the normal scientific discourses. There are several properties of SES that are operative in these systems. They are normally nonlinearly behaving as a system; they are also mutually hierarchical and hinged upon multiple scales of interests. Due to their self-organization, they always exhibit an internal causality with a dynamic stability. The complexity of a system is thus a result of the interaction among a great deal of components that cause new, emergent and unexpected properties. The analysis of these systems points to the possibility for a sustainable development that will depend on changing the perception and the way of thinking of social actors, moving their attention from "increasing productive capacity to increasing of adaptive capacity...", hence the necessity to turn social actors' attention to a view where "society and nature are co-evolving in the biosphere" (Petrosillo et al. (2015), Socioecological Systems, University of Salento, Lecce, Italy).

All along, the project has been concerned with the environmental and climate sustainability of the landscapes on which rural people depend. Ultimately rural communities, at present the least prepared, are likely to be some of the most severely impacted groups as a result of climate change. Focusing some of this research effort will support a better understanding of how rural communities can be both better prepared and more empowered to manage the vagaries of climate change. There is no simple "silver bullet" for coastal resource management, and the programme also assesses existing approaches and tools being used. However, learning from the equitable participation of local, often marginalized, stakeholders is expected to provide a better understanding of rights and a greater understanding of equity, power and institutional issues and how this can all contribute to enhance ecosystem integrity needed in the face of global climate change. Of key importance to this project has been the link between the social and biodiversity of aspects in conservation, whereby both livelihoods are improving and coastal resources are more sustainably managed in a "win-win" situation.

Key milestones of the project have been to ensure that appropriate recommended adaptation strategies are practised and adopted by local communities, institutional coordination and partnerships are enhanced and climate information is shared between and among local communities, research organizations and government institutions. In this project, special emphasis has been put in promoting integration of climate change adaptation strategies in sectors' policies, plans and programmes taking into consideration the appropriate options for different social groups, including women.

This project is being implemented in line with a number of national environmental and development programmes such as Tanzania Vision 2025, National Strategy for the Reduction of Poverty, National Plan of Action (NAPA), the National Climate Change Strategy and the National Environmental Policy (1997). A majority of these programmes and policies are geared to ensure climate compatible development and focus on achieving sustainable development, promoting climate change awareness, training and education at all levels; building capacity through institutional and human resources development; and fostering research on climate change impacts, adaptation and mitigation of climate change.

Collaborative research activities engaged by faculty and PhD students are generating valuable information which need to be shared among collaborating institutions. Information need to be disseminated to the governments at the local, regional, national and international scales, including communities and other key players. Research findings are also needed to contribute to the development of curricula and/or materials for various courses which engage faculty members from the partner institutions, NGOs, private sector and policy- and decision-makers across scales. Both information generated through research and the development courses are needed to create benchmarks for developing recommendable adaptation options for strengthening resilience of local communities and promoting integration of recommendable adaptation strategies and legal frameworks. This monograph aims to function as a depository for such knowledge for the benefit of the present and the future generations of coastal resource governors and management experts.

The potential negative impacts associated with climate change raise a number of concerns on development of reliable coping mechanisms. Development of such adaptation needs well-qualified experts, high research capacity and good governance mechanisms such as policy and bylaws. Unfortunately, Zanzibar has a huge research capacity gap on climate change, environment and natural resources management. As such, there is dire need of developing research capacity and infrastructure to tackle challenges to environment and natural resources emanated from climate change.

Climate change is negatively affecting key natural resources such as land and water and thus resulting into dwindling of these vital resources for communities' livelihoods. This is increasingly leading to resource users conflicts. Adaptation options to be identified are expected to contribute to the development of resolution mechanisms to such conflicts. Furthermore, in handling the anticipated conflicts in the project area, legal and governance issues will be taken on board through stakeholders' involvement across levels so as to ensure a win-win solution among conflicting resource users. The project also looks forward to integrate lessons learnt and collaborate with other conservation initiatives such as REDD+, the Integrated Coastal Zone Management Program (ICZMP) and the Marine and Coastal

Environmental Management Program (MACEMP) that have been implemented or related to ongoing activities across the project areas.

Rights-based approaches to coastal resource management and global climate change are becoming increasingly important to understand, address and integrate. Rights are of various types and may relate to ownership (land and property) and use, rights to information and respecting the rights of minority and less powerful groups. Rights are a particularly important issue for the livelihood security of people living in coastal Tanzania. Therefore, rights-based approaches are necessary not just for conservation but also for accountability, equitable economic returns and ensuring that those who are most affected and have the most interest in coastal resources are the ones who have the rights to make decisions and choices. New policies and projects will always introduce new biases or divisions within society—with potential winners and losers. Hence, the process of improving equity in representation and access to benefits is integral to this project for long-term sustainability. This book which is the first output of research done by faculty members of the University of Dar es Salaam and the State University of Zanzibar (SUZA) aims to collate and disseminate the findings from research themes that seek to ensure that coastal communities in Tanzania can become more effective in asserting their rights to negotiate and implement decisions about issues related to coastal resource management in the context of global climate change.

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Ås, Norway — Ian Bryceson
Zanzibar, Tanzania — Haji Mwevura
Dar es Salaam, Tanzania — Claude Gasper Mung'ong'o

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Pius Zebhe Yanda is a Research Professor at the Institute of Resource Assessment, University of Dar es Salaam. He is also the Director of the Institute of Resource Assessment as well as the Centre for Climate Change Studies of the University of Dar es Salaam and is coordinating several programmes and projects including Africa Climate Change Fellowship Programme. He has served as a Regional Director for Pan African START Secretariat and National REDD+ Secretariat and conducted a number of climate change-related studies. Key focus areas have been on climate change impacts, mitigation and adaptation. He has been involved in the supervision of postgraduate researches including PhDs within the University of Dar es Salaam faculties and units as well as External Examiner to other universities in Tanzania, Germany and beyond. He teaches courses on biodiversity conservation, science of climate change, vulnerability to impacts of climate change, responses to climate change, physical geography, remote sensing and GIS and integrated research methodologies.

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Claude Gasper Mung'ong'o is currently an Associate Research Professor at the Institute of Resource Assessment, University of Dar es Salaam. He holds a PhD degree in human geography from Stockholm University, Sweden, and has more than 20 years of research experience in environmental sociology (including climate change), pastoral livelihood analysis and food security and general rural development. He has been involved in numerous socio-economic studies as a member of various natural resource use studies. He teaches several postgraduate courses at the University of Dar es Salaam, including the *political ecology of natural resource management*, *integrated social survey methods*, *impacts of climate change on human and ecosystems* and *pastoralism and climate change governance.* He has published widely in his areas of research interest, including editing such books as *Geophysical and Socio-political Dynamics of Environmental Degradation and Conservation in Kondoa District, Tanzania*, *People's Perceptions and Community Response to Climate Change and Variability: Selected Cases from Tanzania*, etc.

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Part I
Introduction

Researching Climate Change and Socio-ecological Systems' Vulnerability in the Coastal Areas of Tanzania: Some Theoretical Perspectives

Pius Zebhe Yanda and Claude Gasper Mung'ong'o

Abstract Most coastal communities are located directly adjacent to the sea and are exposed to climate change through various impacts which go beyond those that are purely geophysical and economic and include the impacts on spiritual and cultural connections to the sea as well. Understanding the interdependency of these subsystems has, however, remained rather superficial. Although a good number of socio-ecological systems (SES) studies have emerged from recent scholarship, there is still a disconnection between generating SES scientific studies and providing decision-relevant information to policy makers. On the other hand, classical studies focused on one or two disciplines are still most common, leading to incremental growth in knowledge about the natural or social system, but rarely both. The dearth of social data relating to human-nature interactions in this particular context is now seen as an omission which can often erode the efficacy of any resource management or conservation action. To address these shortcomings, this book collates eight case studies done in the coastal areas of Tanzania. The conceptual frameworks, applied models, and indices used to highlight the complex nature of SES and the dynamics that can inform environmental policy, conservation, and management of coastal resources in Tanzania are also synthesized.

Background

The coastline of mainland Tanzania runs approximately in a north-south direction and is over 800 km in length, extending from 4° 49' S at the border with Kenya to 10° 28' S at the border with Mozambique (Shao et al 2003). The coastal topography is characterized by a narrow 8–10-km-wide continental shelf that expands to a width of 40 km around the islands of Mafia and Zanzibar (Francis et al. 2002). The total area of the continental shelf is estimated to be 17,900 km^2 surrounded by a

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territorial sea of approximately 64,000 km^2 (Sobo 2012). The Tanzanian coast is also characterized by rivers and estuaries such as Pangani, Rufiji, Mbwemkuru, and Ruvuma rivers. There are also sandy beaches, seagrass beds, and coral reefs that support various types of fisheries that play important local and national economic roles (Elst et al. 2005).

The vegetation which include lush mangrove forests have been well described by Burgess et al. (2004) and Godoy et al. (2011). It contains over 4000 plant species within more than 1000 plant genera, of which around 1750 plant species and 27 genera are endemic. Lowland forest contains at least 554 forest-dependent endemic plant species, with 17 endemic genera. A substantial proportion of the endemic plant species are confined to a single forest, such as Rondo and Litipo forests in southern Tanzania with at least 60 and 30 endemics, respectively. The coastal forest patches are also important in terms of vertebrate diversity and endemism, with 14 endemic species of birds, 14 endemic mammals, 132 endemic or near-endemic reptiles, and 7 endemic amphibians (Burgess et al. 2004).

The remaining fragments of coastal forest of Tanzania are found within a matrix of miombo woodland, plantation, and agricultural habitats. They are threatened by clearing for farmland, selective logging for timber, and burning for charcoal. Charcoal is the major cooking fuel for urban Tanzanians, especially in Dar es Salaam (Burgess et al. 2004). Within the Dar es Salaam and Pwani regions, forest disturbance and degradation are highly correlated to distance to Dar es Salaam City (Ahrends et al. 2010).

Currently the administrative setup of the mainland coast of Tanzania comprises five regions. From the north, these include Tanga, Pwani (Coast), Dar es Salaam, Lindi, and Mtwara. These regions occupy nearly 15% of the total area of Tanzania (ASCLME, 2012 as quoted in Katikiro 2014). The population increase in the coastal regions has been rapid. Table 1, for example, shows that there was an average growth rate of 3.4% between the 2 census years of 2002 and 2012.

Most rural coastal communities are very poor with rates of illiteracy, low schooling, and low health status measuring relatively high compared to other regions of the country (see Mung'ong'o and Moshy and Misana and Tirumanywa in this book).

Table 1 Population increase in the coastal regions of Tanzania, 2002–2012

S/N	Regions	Census years 2002	2012	Average annual change (%)
1	Tanga	1,635,664	2,045,205	2.2
2	Dar es Salaam	2,460,347	4,364,541	5.7
3	Pwani (coast)	870,276	1,098,668	2.3
4	Lindi	787,093	864,652	0.9
5	Mtwara	1,122,145	1,270,854	1.2
6	Zanzibar	956,069	1,303,569	3.1
Total		7,831,594	10,947,489	3.4

Source: coastal profile for Tanzania 2014 – map and tables volume iii: investment prioritization for resilient livelihoods and ecosystems in coastal zones of Tanzania. World Bank – Africa region, Tanzania

Nevertheless, these coastal residents have many connections with the sea, both economically and socioculturally. Except for cities and major towns like Tanga, Dar es Salaam, Lindi, and Mtwara which sprawl far inland, most coastal communities are located directly adjacent to the sea and are exposed to climate change through various impacts such as sea level rise, changes in the fishery productivity, and damage to infrastructure. Climate change impacts go beyond those that are purely economic and include the impacts on spiritual and cultural connections to the sea (see Mung'ong'o and Moshy in this book).

However, we still lack an understanding of the mechanisms by which local impacts can manifest and flow through a coastal community (Barnett et al. 2014). Related to this lack of knowledge is the prevalence of the perception that climate change is after all a long-term risk that can be dealt with in the future when more information and resources are available. And hence the impacts of climate change are also perceived as a remote risk, very much removed from direct personal experience here and now, which potentially reduces the incentive to act (Metcalf et al. 2015; Clark 2015).

At another level, resource users have also been adapting the ways that they use the resources in response to management measures that aim to make these resources more resilient to the impacts of climate change, e.g., the creation of marine reserves that prohibit fishing. Thus, questions of critical importance to resource managers, stakeholders, and scientists alike are as follows: how are coastal resource-dependent societies being affected by climate change, how have they been responding, and, above all, what capacity do they have to adapt to climate change impacts?

However, the relationship between human social systems and coastal resources is by nature also highly complex, involving more than just the fishers alone. According to Katikiro et al. (2013), a fishery system is defined as a combination of sub-systems – comprising those that are human, the natural resources themselves, and their management. These sub-systems interact dynamically and are influenced by both external and internal factors such as climate change and governance. Understanding the interdependency of these sub-systems, particularly with regard to the social implications on the surrounding communities, has, however, remained rather superficial. Although a set of "good practices" about what constitutes a good SES study have emerged from recent scholarship, there is still a disconnection between generating SES scientific studies and providing decision-relevant information to policymakers. Classical studies focused by one or two disciplines are "still most common, leading to incremental growth in knowledge about the natural or social system, but rarely both" (Leenhardt et al. 2015; Moshy et al. 2015; Moshy 2016). These are among the issues that researchers in this book are trying to grapple with.

Concepts, Frameworks, and Indices Adopted by Researchers

The recognition of human dimensions is a key aspect of successful planning and implementation in natural resource management, ecosystem-based management, fisheries management, and marine conservation. However, the dearth of social data relating to human-nature interactions in this particular context is now seen as an omission which can often erode the efficacy of any resource management or conservation action (Leenhardt et al. 2015). To address this shortcoming, the present book collates case studies done in the coastal areas of Tanzania. The conceptual frameworks, applied modeling approaches, and indices to highlight the complex nature of social-ecological systems (SES) and the dynamics that can inform environmental policy, conservation, and management of coastal resources in Tanzania are synthesized in the following sections.

Assessing Vulnerability

Research on social vulnerability to disasters, global environmental change, famine, and poverty has a long history in social science disciplines (Adger 1999, 2006; Cutter 1996; Kelly and Adger 2000), yet few studies have examined social vulnerability in the context of changes specific to coastal ecosystems. Although definitions vary, vulnerability is generally considered to be the degree to which a system is susceptible to, and unable to cope with, the adverse effects of a chronic or stochastic disturbance (Cinner, et al. 2011). Vulnerability to environmental change varies across spatial and temporal scales and for different people within society (Bene 2009).

According to Bennett et al. (2016), there have been several dominant ways of conceptualizing vulnerability. The first has been to view vulnerability as an *outcome*, by focusing on the impacts of a hazard like climate change, and the ability of a system, be it ecological or social, to respond to such impacts. The purpose of such an end point vulnerability analysis is to estimate and reduce costs of hazards. A second perspective has emphasized vulnerability as the *starting point* and continued focus on the historical factors or current characteristics of individuals, households, communities, sectors, or nations that determine their differential susceptibility to harm. A more comprehensive view has considered vulnerability to be the *result of the interaction between exposure, sensitivity and adaptive capacity* as advocated by Turner et al. (2003), Smit and Wandel (2006), and Perry et al. (2010).

Exposure refers to the degree to which trends and scalar shocks are experienced by a region, resource, or group of people. Sensitivity is the susceptibility of an entity or system to the effects of an exposure. Historical, social, political, economic, and environmental preconditions determine a system's sensitivity. Watts and Bohle (1993) have elaborated this definition by arguing that resource distribution, political power and voice, rights, and access to institutions mediate sensitivity. Hence a combination of exposure and sensitivity defines the potential impacts of a change, be it climatic or non-climatic. Nevertheless, it is also noted by O'Brien and Leichenko (2000) that impacts of a change can be unevenly experienced by various similarly exposed groups, be it genders, age groups, classes, livelihood portfolios, et cetera, based on differential sensitivities.

Exposure, in the context of coastal ecosystems, varies depending on factors such as oceanographic conditions, prevailing winds, and latitude. These factors determine tidal range, relative sea level trends, sediment supply, and drier climate which increase the likelihood of being impacted by events such as cyclones or desalinization.

Sensitivity, in the context of environmental change, is the state of susceptibility to harm from perturbations or long-term trends. Sensitivity factors in mangrove ecosystems include forest condition and growth, seaward edge retreat, reduction in mangrove area, elevations within mangroves, sedimentation rates, adjacent ecosystem resilience, and strength of protection legislation (Ellison 2012). Sensitivity can also be affected by levels of dependence on natural resources and the technologies used to harvest resources such as fisheries.

Finally, Bennett et al. (2016) define *adaptive capacity* as the ability to respond to challenges through learning, managing risk and impacts, developing new knowledge, and devising effective responses. Adaptive capacity remains a latent potential until it is applied in response to a change. Adaptive capacity is determined by access to livelihood assets (human, social, physical, financial, and natural), capacity to organize, leadership, learning and knowledge, imaginative resources, and capacity to self-organize (Mung'ong'o and Moshy, in this book). In this view of vulnerability, the relationship between the three components of vulnerability might be simplified to an equation: $V = E + S - \mathrm{AC}$—whereby vulnerability (V) is determined by exposure (E) plus sensitivity (S) minus adaptive capacity (AC), as suggested by Adger (2006).

In the context of coastal communities, understanding the potential impacts of climate change and society's capacity to adapt to these changes requires analyzing a combination of conditions (economic, environmental, and social) that contribute to vulnerability and characterizing locations and segments of society that are most vulnerable. In this respect, adaptive capacity factors will include available migration areas inland from mangroves, community management capacity, and degree of stakeholder involvement in resource management (Ellison 2012). It is thus that several different research frameworks have been proposed to examine how vulnerable socio-ecological systems are to environmental change. Popular frameworks include those by Cutter (1996), Yohe and Tol (2002), Adger and Vincent (2005), Brooks et al. (2005), and Bene (2009).

Methodological Approaches

The application of various research frameworks in the analysis of the vulnerability of coastal resources to climate change has necessitated studies to often focus on natural resources and less on the dynamics of human and ecological processes and even less on non-climatic environmental and socioeconomic changes (Nicholls et al. 2007). Such studies employ an integrated analysis of vulnerability to climate change and variability as well as adaptive capacity and their implications to resilience. Climate change data from meteorological agencies are also obtained in order to complement the observations from the field.

Socioeconomic data have normally been collected from selected communities in the coastal areas and islands with sites selected within the relevant districts to provide a spectrum of social and ecological conditions. For each site/community, data are obtained on exposure, sensitivity, and adaptive capacity of chosen resources such as mangroves, coral reefs, etc.

For *exposure* past resource degradation data and associated oceanographic conditions across the sites/communities are normally used to produce a predictive model of susceptibility of the resource to thermal stress and associated resource degradation throughout the coastal area and the islands (Maina et al. 2008). Such vulnerability assessments are often prefaced by literature/documentary review of existing information that guide the other components of the analyses, including:

- Recent spatial changes of the coverage of the resource
- Relative sea level trends
- Historical rainfall trends; observed trends in coastal river flows and historic rainfall patterns in catchments of rivers flowing into the coastal areas
- Compilation of local community knowledge about mangroves and fishery dynamics
- Reviews of environmental legislation that protects wetlands and mangroves
- Information compiled on mangrove resource usage, such as government records of fishing licenses, fish catches, and forestry

As far as *sensitivity* is concerned, metrics of sensitivity based on the level of dependence on fisheries and mangrove harvesting have been developed in consistence with other studies and protocols (e.g., Marshall et al. 2010). This indicator is developed based on household surveys, focus group discussions, and key informant interviews where all livelihood activities that bring in food or income to the household are listed and ranked in order of importance. Occupations are grouped into categories of fishing, selling marine products, tourism, and farming of cash crops, salaried employment, petty business, et cetera. To better understand sensitivity to the impacts of temperature events on fisheries, fishing and fish trading are lumped together as the "fisheries" sector and all other categories as the "non-fisheries" sector. This grouping has parallels in agricultural economics where activities are classified as "farm" and "nonfarm."

The metric of sensitivity incorporates the proportion of households engaged in fisheries and mangrove harvesting, whether these households also engage in other non-fishery occupations (i.e., "linkages" between sectors), and the directionality of these linkages, i.e., whether respondents ranked fisheries as more important than other activities. The aim is to capture the ratio of fishery to non-fishery-related occupations. Second is to capture the extent to which households dependent on fisheries also engage in non-fishery livelihood activities, including mangrove harvesting. This approach decreases the level of sensitivity when many households are engaged in both occupational categories. Third is to capture the directional of linkages between fisheries and non-fisheries such that communities are seen as more sensitive when households engage in fishery and non-fishery occupations consistently ranking the fisheries and mangrove-harvesting sectors as more important than other livelihood activities.

In order to assess *social adaptive capacity*, researchers often employ a social adaptive capacity index developed by McClanahan et al. (2008). Basing on household surveys and key informant interviews, the following eight indicators of adaptive capacity are derived:

- Recognition of causal agents impacting marine resources (measured by content organizing responses to open-ended questions about what could impact the number of fish in the sea)
- Capacity to anticipate change and to develop strategies to respond (measured by content organizing responses to open-ended questions relating to a hypothetical 50% decline in fish catch)
- Occupational mobility (indicated as whether the respondent changed jobs in the past 5 years and preferred their current occupation)
- Occupational multiplicity (the total number of person-jobs in the household)
- Social capital (measured as the total number of community groups the respondent belonged to)
- Material assets (a material style of life indicator measured by factor analyzing whether respondents had 15 material possessions such as a vehicle, electricity, and the type of house walls, roof, and floor)
- Technology (measured as the diversity of fishing gears used)
- Infrastructure (measured by factor analysis of infrastructure items such as hard top road, medical clinic, schools, etc.)

The indicator of occupational multiplicity is fundamentally different from the measure of sensitivity since it builds on the households' complete portfolios of occupations and is, therefore, able to capture a household's general ability to adapt to change. The sensitivity measure, in contrast, only focuses on the extent to which households are engaged in fishery versus non-fishery-related occupations, including mangrove harvesting and how they rank their relative importance.

Structure of the Book

After this introductory chapter, the rest of the book is structured in two parts. Part II which comprises seven chapters provides the individual case studies. In chapter "The Impact of Climate Variability and Change on Communities' Access to and Utilization of Coastal Resources in Pangani District, Tanzania", D.A. Mwiturubani investigates local communities and their activities in the coastal areas of Pangani District in Tanga Region. These communities have already felt and are vulnerable to the impacts of climate variability and change. A random sample of 60 respondents was selected from 3 villages in the district to investigate the effects of climate variability and change on access to and utilization of coastal resources.

In chapter "Vulnerability and Adaptation Strategies of Coastal Communities to the Associated Impacts of Sea Level Rise and Coastal Flooding", Makame O. Makame and Haji Mwevura from Zanzibar present a case study from Micheweni and Mkoani districts in Pemba Island where they analyze the vulnerability and adaptation strategies of coastal communities to the associated impacts of sea level rise and coastal flooding. This study specifically aims at understanding the livelihoods and infrastructures at risk along the coastal areas and examines the perception of local communities on the occurrence and impact of coastal flooding to their well-being. In the process the researchers also examine the adaptive capacity and different adaptation strategies to coastal flooding.

In chapter "Seaweed (*Mwani*) Farming as an Adaptation Strategy to Impacts of Climate Change and Variability in Zanzibar", I.H. Hassan and W.J. Othman provide the case of seaweed (Mwani) cultivation in four coastal villages of Unguja Island in Zanzibar. The study attempts to provide an analysis and a deeper understanding of the adaptation strategies adopted by the coastal communities to counteract the barriers of carrying out the production of Mwani in a situation of rising sea surface temperatures due to climate change that has led to die-offs and declining production of the crop along the coast of Tanzania, including Zanzibar.

In chapter "Poverty Levels and Vulnerability to Climate Change of Inshore Fisher-Mangrove Dependent Communities of the Rufiji Delta, Tanzania", C.G. Mung'ong'o and V.H. Moshy investigate the poverty levels and vulnerability to climate change of inshore fisher-mangrove-dependent communities of the Rufiji Delta in southern Tanzania. The chapter sets out to answer the questions of critical importance to resource managers, stakeholders, and scientists alike, i.e., of how fisher-mangrove-dependent societies such as those of the Rufiji Delta are being affected by and what capacity do they have to adapt to climate change impacts that are occurring in the area. The chapter is not only aimed at "improving linkages between the practice of community-level assessments and efforts to develop and implement vulnerability-reducing interventions," but it is also an attempt to address the critique offered by McDowell et al. (2016) about the need of a more integrative, community-engaged assessments in vulnerability scholarship.

In chapter "Ecological Impact of Thermal Stress in Reefs of Zanzibar Following 2016 Elevated Higher Sea Surface Temperatures", A. M. Ussi and colleagues present their research on the ecological impact of thermal stress in the coral reefs of Zanzibar following the 2016 elevated sea surface temperatures. This study assesses the characteristics of the reef community so as to describe the community change that takes place following a severe threat. The study also seeks pathways to adaptively manage coral reefs in response to the 2016 and future bleaching events.

In chapter "An Assessment of the Vulnerability and Response of Coastal Communities to Climate Change Impact in Lindi Region, Southern Tanzania", Salome B. Misana and Verdiana Tilumanywa provide an assessment of the vulnerability and response of coastal communities to climate change impact in Lindi Region, southern Tanzania. In this study, the researchers attempt to provide an understanding of how the coastal communities are changing in their vulnerability to climate change and how the livelihood systems are adapting to the change and the implications on coastal resource use, governance, and management. The motivation for this work came from the fact that there is considerable uncertainty about how future climatic changes will affect coastal areas and how the socioeconomic systems will likely adapt to these climate futures.

In chapter "Coastal Communities' Perceptions on Climate Change Impacts and Implications for Adaptation Strategies in Mtwara, Southern Tanzania", E.T. Liwenga and colleagues present a case from Mtwara in southern Tanzania where they assessed coastal communities' perceptions on climate change impacts and implications for adaptation strategies. The study aimed at identifying pathways to reducing vulnerability and enhancing resilience and livelihoods of coastal communities.

In chapter "The Human Rights Dimensions of Conservation and Climate Change Initiatives in Coastal Tanzania: Examples of Villagers' Successful Struggles for their Rights", Betsy Beymer-Farris, Ian Bryceson, and Chris Maina Peter examine the human rights dimensions of conservation and climate change initiatives in Africa's first and largest marine protected area, the Mafia Island Marine Park, and a proposed carbon forestry climate change initiative in the Rufiji Delta mangrove forest in coastal Tanzania. Despite "rights-based" rhetoric of climate change and conservation policies, severe human rights abuses took place in these resource-rich areas. The chapter demonstrates the power of villagers to draw upon their human rights as provided by the Bills of Rights in the Tanzanian Constitution to challenge *and* change ill-conceived conservation and climate change policies. The chapter provides a deeper understanding and greater recognition of human rights that can result in fairer and wiser governance of Tanzania's coastal areas and resources.

And lastly, in chapter "Climate Change and Socio-Ecological Systems' Vulnerability in the Coastal Areas of Tanzania: A Synthesis", C.G. Mung'ong'o and Haji Mwevura conclude the case study presentations by synthesizing and making sense of the arguments and conclusions provided by each of the nine cases.

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Part II
Case Studies

The Impact of Climate Variability and Change on Communities' Access to and Utilization of Coastal Resources in Pangani District, Tanzania

Donald Anthony Mwiturubani

Abstract The main objective of this study was to understand the impacts of climate variability and change on coastal resource governance, communities' vulnerability and livelihoods security in the district. Specifically, the study aimed to assess the effects of rainfall and temperature variability and change on coastal resource distribution and management, to examine the vulnerabilities of socio-economic activities along the coastal areas to the impacts of climate variability and change and to establish the adaptive measures that the community and other stakeholders adapted to address the impacts of climate change and variability. The research was conducted in three purposively selected villages in Pangani District. A random sample of 60 respondents participated in the study. The study employed a mixture of quantitative and qualitative methods. Findings from this study demonstrate that climate change has happened and is still happening in the study area. The notable impacts of climate change include decrease of rainfall and change of rainfall seasons and patterns, emergence of new crop diseases and pests, decrease of fish catch, intrusion of salinity in the rivers and inland and general decline of crop productivity. The findings reveal that the impacts of climate change have been increasing over time between 1980 and 2014.

Introduction

Although climate change and variability are a global phenomenon, their impacts are mainly locally specific. Local communities and their activities in the coastal areas of Tanzania have already felt and are feeling vulnerable to the impacts of climate change and variability (Mahenge et al. 2013). Since the last two decades or so, the coastal region of Tanzania has been hit by the recurrence of droughts and floods with severe negative consequences to the lives of the population and socio-economic activities and the ecosystems (Mckela 2016; Semesi et al. 2000). This predicament presents challenges and questions to the research and development communities on how to minimize the short-term and long-term effects of climate change and variability.

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The coastal area of Pangani, for example, constitutes a variety of ecosystems, both on land and sea. These ecosystems, in their totality, form and furnish the basic foundation of the local culture, economy and people's social well-being (Pangani District Council 2013; Mahenge et al. 2012, 2013). These ecosystems are categorized into coral reefs, sea grass fields and algae, mangroves and sand beaches (Miththapala 2008; Mkama et al. 2013). Coral reefs, for example, are very important to Tanzania, both ecologically and socio-economically, as major fishing grounds and tourism attractions (Darwall and Guard 2000; Wagner 2004). They have high productivity and biodiversity and are regarded as keystone ecosystems in that they provide important ecological services that extend far beyond their area of coverage.

Due to climate change and variability, such coastal resources are increasingly facing degradation and management threats. As a result, the livelihoods of the coastal people in Pangani District are increasingly becoming vulnerable to the impacts of climate change (Mahenge et al. 2012, 2013; Sigalla et al. 2011) and hence also to general livelihood insecurity which in turn tends to shape the way people and institutions interact in accessing and utilizing coastal resources. The dynamics of fisheries, for example, are driven primarily by climate change and variability, and both the ecosystems and the livelihoods of fisher folk living along the coast are highly affected by the extensive fluctuations in sea level and depth, extent of flood plains and changes in aquatic productivity (URT 2006). These conditions have negative impacts on both the livelihood security of the fishermen and the integrity of the coastal ecosystems.

Despite the fact that communities in the coast of Pangani District have lived over decades under such environments and hence have through experiential adaptive systems to climate-related events, exacerbated climate change is expected to make the situation much worse and hence unmanageable under traditional knowledge-based systems (Mwiturubani 2010). This called for a better understanding of the available adaptive systems to climate change in Pangani District, by analysing them and recommending for their improvement backed by policies and legislation. The main objective of this research was, therefore, to understand the impacts of climate variability and change on coastal resource governance, communities' vulnerability and livelihoods security in the district. Specifically, the study aimed to assess the effects of rainfall and temperature variability and change on coastal resources distribution and management, to examine the vulnerabilities of socio-economic activities along the coastal areas to the impacts of climate variability and change and to establish the adaptive measures that the community and other stakeholders adapted to address the impacts of climate change and variability.

Methods and Materials

The research was conducted in three villages in Pangani District, namely, Bweni, Msaraza and Pangani Mashariki (Fig. 1). The selection of the three villages was purposefully done based on socio-economic activities which determined vulnerability to

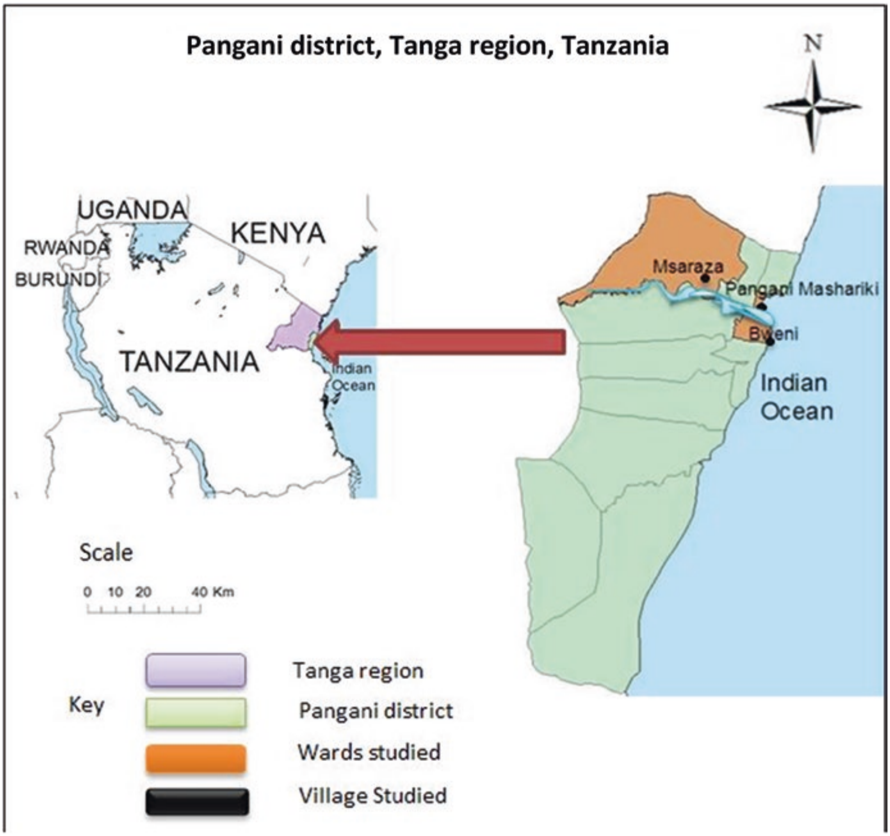


Fig. 1 Location of the study area. (Source: Modified from shape files by the aid of GIS arc map software, URT 2013a)

the impact of climate variability and change (Kothari 2004). Purposive sampling was also employed in order to achieve representation from different agroecological zones and to avoid having villages with more or less similar characteristics (Adam 2008), such as constraints on coastal resource use as determined by location in relation to the Indian Ocean and Pangani River.

Msaraza village, for example, is located further inland along the northern bank of Pangani River and is dominated by horticulture and coconut production. Pangani Mashariki village is located along the coast of the Indian Ocean on the northern side of the mouth of Pangani River. Being located at the mouth of the river, mangrove forests are a dominant feature in the village. The main economic activities there include fishing and fish-related businesses, as well as other petty businesses. Pangani Mashariki village is also located at the vicinity of Pangani town; hence it is more urbanized than the other two villages. On the other hand, Bweni village is located on the southern bank of the river, along the coast of the Indian Ocean. Bweni is dominated by fishing and cashew nut production. The village is famous for its horticultural production. It also practices some livestock husbandry with goats as the dominant species.

After determining the study villages, random sampling was employed to select one sub-village from each village for the study. The sampling procedure was implemented as variously suggested by Babbie (1992) and Kothari (2004). Names of the sub-villages in each village were written in separate pieces of paper. The pieces of paper were put into a bucket and mixed up, and one villager was asked to pick one piece of paper from the bucket. The same process was done in each of the three villages selected for the study. The three sub-villages selected were Kikokwe from Bweni village, Matakani from Msaraza village and Funguni from Pangani Mashariki village.

Random sampling method was further employed to obtain respondent households for the study. The sampling frames used were lists of names of heads of households of the selected sub-villages compiled by Village Executive Officers (VEOs) in each of the study villages. The names of heads of household of the selected sub-villages were written in separate pieces of papers and mixed in a bucket as done in the case of sub-village selections. One villager in each study village was then asked to pick one paper at a time without replacement until the nth number was obtained. The process treated female- and male-headed households differently in order to accommodate gender representation in views and perceptions (Bryman and Bell 2007). The sample households comprised 17.1% of the total households in the study villages. Thus 60 respondents (39 males and 21 females) filled the questionnaires, and 10 key informants were interviewed.

The study employed a mixture of quantitative and qualitative methods in order to overcome any weaknesses which might have arisen as a result of using either method separately in data generation and analysis as suggested by Basten (2010) and Flick (1998). The instruments of data collection included questionnaires which were distributed to the 60 randomly selected respondents in the study sub-villages. Key informant interviews which were conducted with village chairpersons; Village Executive Officers (VEOs); Ward Executive Officers (WEOs); the District Fisheries Officer (DFsO); the District Agricultural, Irrigation and Cooperatives Officer (DAICO); the District Forestry Officer (DFO); the District Statistician; and the cashew nut production coordinator were done with the help of checklists.

Other methods of data collection were focus group discussions (FGDs) and on-site observation. An FGD is any discussion done by a group of people provided that the researcher is actively involved in encouraging of, and being attentive to, the group interaction (Barbour and Kitzinger 1999). Nine, ten and twelve people formed the FGDs in Pangani Mashariki, Msaraza and Bweni villages, respectively. This technique was used to verify some data and information collected through interviews, questionnaires and observation methods (Boateng 2014; Flick 1998).

Observation entailed the systematic recording of events, behaviours and artefacts in social settings as advised by Marshall and Rossman (1995). Under the observation method, we accompanied some members in the study villages as they carried out their daily responsibilities to observe and record events, their practices and behaviours which affected coastal resources utilization and/or development. Direct observation was also made on the nature of coastal resources (such as characteristics of river deltas, coastal plains, wetlands, beaches and dunes, reefs, mangrove forests, crops, et cetera). The aim was to gain on the spot understanding of the constraints and opportunities for coastal resource management. Direct observation was a continuous process throughout the fieldwork. Some quantitative data, particularly rainfall and temperature data trends over time, were acquired from the Tanzania Meteorological Agency and some documentary reviews.

Data from questionnaires were analysed using SPSS version 18 which was found to be convenient and easy to use as commented upon by Marczyk et al. (2005). Some quantitative data, particularly rainfall and temperature data over time, were simulated by the aid of Microsoft Excel. Qualitative data were transcribed to develop themes and specific lines of understanding issues followed by classification and interpretation of the data in order to understand relationships and associations between the different variables (Kitchin and Tate 2000).

Results and Discussion

Local People's Perceptions on Climate Change and Variability

Respondents in the study area demonstrated a reasonably good understanding of what climate change meant, even though they did not provide a concise definition. Rather they gave a clear description of what constituted climate variability and change from their own perspectives. Their understanding of climate change was based on accumulated knowledge they had over time and space about their surrounding environments – water systems, rainfall amounts and patterns, occurrence/disappearance of specific type of vegetation and wild animal species. Respondents revealed that they had developed some indicators which provided evidence for the change in rainfall and severe droughts. The indicators, therefore, included elements of weather such as temperature and rainfall, disappearance and/or emergence of some plant species and new crop and animal diseases. Other indicators included increased salinity in inland water sources, extended growth of mangroves along the Pangani River away from the river mouth, the disappearance of prawns at the mouth of the river, drying up of coconut trees and decreased production of honey (Table 1). Most of these indicators were more or less similar across the study villages.

Increase in temperature tended to increase evapotranspiration of soil moisture and reduced access to water, which are the main drivers of crop growth and productivity (Mwiturubani 2010). Temperature rise could also lead to increase in crop pests and diseases, hence reduced crop yields (IPCC 2014). On the other hand, the decrease in rainfall and change of rainfall patterns significantly affected both crop and livestock productivity. In this study, respondents revealed that there had been significant changes in rainfall patterns. While in the 1980–1990 decade, there were consistently three rainfall seasons in a year (Table 2), since the 2000s the pattern had changed to either one or at most two rainfall seasons a year.

Table 1 Indicators/signs of climate change as per respondents in the study area

Indicator	Sign	Meaning/explanations
Extended drought	Decrease of rainfall and soil moisture	Prolonged drought indicates that climate of the area has changed
Frequent floods	Change of rainfall intensity	A single storm produces floods in the rivers
Emergence of new plant species	Emergence of cactus/euphorbia plants	Presence of cactus/euphorbia plant species indicates consistent decrease of rainfall over long period
Wild fruits and plant flowering	Flowering, fruiting and shading of leaves of wild trees	When some trees stop flowering and fruiting, it indicates consistent drought. Change of time (months) of shading leaves from August/September to other months indicates change of rainfall intensity and patterns
Mangrove forests	Growing of mangroves inland	Growing of mangroves along Pangani River away from the mouth of the river. This signifies salinity intrusion inland
Prawn fish	Disappearance/decrease	Disappearance/decrease of prawn fish at the mouth of Pangani River. This signifies decrease of rainfall inland and increase of salinity intrusion
Dry up of coconut trees	Increase of diseases and pests	Climate change is believed to have led to increase of diseases and pests which affect coconut trees
Honey production	Decrease	Decrease of flowering of tress due to decrease of rainfall leads to the decrease of honey production
Rivers and natural wells	Permanently dried up	These water surface sources, which used to be permanent in the past, are currently seasonal and sometimes dried up permanently
Depth of rivers	Depth of rivers reduced due to siltation	Due to increased run-off coupled with land degradation, there is an increase of siltation in rivers
Rainfall seasons	Number of rainfall seasons in a year	Number of rainfall seasons changed from three prior to 2000s to two in the 2000s onwards
Crop production	Changes of planting dates	When rainfall patterns change and dates for onset and end of rainfall change, planting dates also change
Salinity intrusion in fresh water sources	Decrease of water in the rivers and natural wells	Due to rainfall decrease, water flow in the rivers decreases, and hence during high tides, sea water moves inland. Decrease of water table increases salinity intrusion in the natural wells

Table 2 Number of rainfall seasons in the 1980s and 1990s to date in the study area

	1980s		1990s to date	
Season	Frequency	Percent	Frequency	Percent
One	–	–	4	6.7
Two	2	3.3	56	93.3
Three	58	96.7	–	–
Total	60	100	60	100

This observation was fairly well elaborated during an FGD in Pangani Mashariki village where one elderly participant had this to say:

> In the 1980s and 1990s we experienced rainfall almost throughout the year except in August and December. However, currently we are experiencing rainfall for five months only (March to May for long season commonly known as **masika** and October to November for short season commonly known as **vuli**).

He further postulated that:

> …the kind of drought we are experiencing now is not like that of the past. The drought experienced in recent years is the worst.

Rainfall and temperature patterns that the respondents described echo very well with the data from the TMA, which show that Pangani District and Tanga Region in general have been experiencing rainfall changes and variations over time for the last 35 years. Data on Fig. 2, for example, reveal that since the 2000s, rainfall had decreased as compared to the 1980s and 1990s. Similarly, data on temperature shows a slight increase of both maximum and minimum annual temperatures since the 2000s as opposed to the 1980s and 1990s (Fig. 3).

With regard to decrease in crop productivity, one participant in the FGD in Msaraza village said:

> In the 1980s and 1990s we were able to get over 10 sacks each with 100 kg in one acre plot of maize; but currently we get only 3 to 5 sacks of 100kg each in one acre plot of maize.

Some participants in the FGDs, however, indicated that there was an increase in production of some drought-resistant crops such as cassava. It was, nevertheless, also revealed that cassava diseases and pests such as cassava mill burg had also emerged in the wake of intensified climate change and variability. Furthermore, disappearance of natural vegetation and occurrence of some invasive species in the

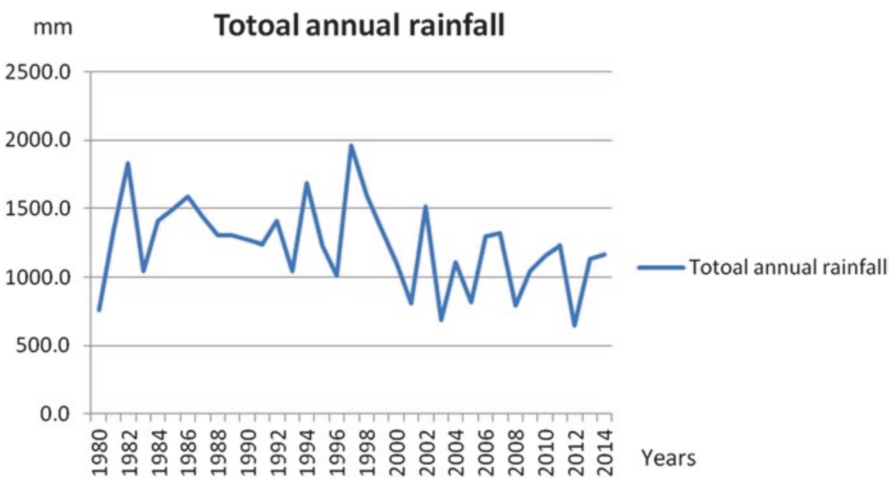


Fig. 2 Total annual rainfall in Tanga Region, 1980–2013. (Source: TMA, 2015)

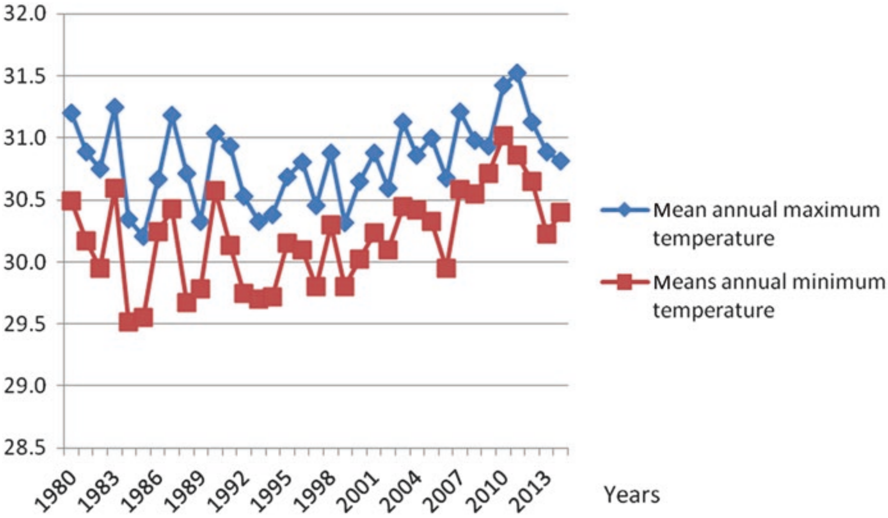


Fig. 3 Maximum and minimum annual temperature in Tanga Region, 1980 to 2013. (Source: TMA, 2015)

Table 3 Sources of knowledge about climate change in the study area (%)

Source of knowledge	Frequency	Percentage
Accumulated knowledge (Indigenous knowledge)	44	73
Seminars, NGOs	16	27
Total	60	100

study area was cited as other indicators of climate change. Respondents pointed out that there was an increased invasion of new breeds of weeds in the area which never existed before.

Some participants also indicated that there was a decrease in honey production due to low rainfall which reduced flowering in the useful trees. This was because rainfall either came in very late or ceased very early in the production period. In the 1980s and 1990s, honey was abundant in Pangani District because rainfall amounts were enough throughout the year.

Some adaptation strategies incorporate indigenous knowledge developed over long history of interaction with the surrounding environment and natural resources therein. The incorporation of indigenous knowledge in developing adaptation strategies to the impacts of climate change is due to the fact that local people are well knowledgeable with their surrounding environment (Yeaman 2015). As far as sources of knowledge about climate change in the study area was concerned, some respondents revealed that apart from the knowledge that they accumulated over time through interaction with their surrounding environments, they also learnt about climate change and its impacts through seminars, workshops and non-governmental organizations (NGOs) that operated in their locality (Table 3).

Impact of Climate Change on Economic Activities and Coastal Resources

According to this study, the main impacts of climate change on coastal resources and socio-economic activities in Pangani District have included decreased crop productivity, emergence of new crop diseases and pests (80%) and the decrease of honey production (80%). Other impacts have been decrease and variations in rainfall, prolonged drought and change of rainfall seasons (and hence also change of planting seasons) (100%). Others have included salinity intrusion (53.3%), increase in oceanic tides (53.3%) and decrease of fish catches and disappearance of some fish species (76.7%), which in their totality have led to increase of the price of fishes and hence also increase in the cost of living (88.3%) of the community (Table 4).

In the key informant interviews, officials from Pangani District Council (including the District Statistician and Coordinator for cashew production, the DAICO) revealed that climate change and variability had tremendous effects on the economic and coastal resource development in the study area. Changes in rainfall seasons and patterns had had effects on the productivity of crops such as maize, paddy, sugar cane, coconuts and horticulture. They also had effects on livestock and honey production, where productivity had decreased due to decrease of soil moisture, lessened pasture and tree flowering, respectively. Crops and livestock had also been affected by the emergence of new pests and diseases. Elsewhere, coconut trees had dried up (Plate 1a) partly because of the increase of salinity but also due to emergence of pests and diseases. On the other hand, there was increase of cashew nut and cassava production which were introduced in the 1990s as a strategy to increase food and cash crop production (Plate 1b). Cashew nuts and cassava were drought-resistant crops.

Similarly, sea level rise due to climate change leads to saline intrusion in fresh water into the rivers that discharge their waters into the sea and natural wells. This was evidenced in the Pangani River and natural wells in Msaraza village. Moreover, the impacts of climate change and variations tend to alter the ecological zones and ecosystems leading into the disappearance and/or emergence of some new species of both flora and fauna as observed by Gelcich et al. (2010) and Kilot and Shmueli (2015). In this study this has resulted into increase of mangrove forests along the Pangani River and decline of coconut and banana trees as observed above.

Table 4 Impact of climate change in the study area (%)

S/No.	Impact of climate change	Frequency[a]	Percent[a]
1	Rainfall decrease and variations, prolonged drought	60	100.0
2	Decrease of crop production, increase of crop diseases and pests	48	80.0
3	Decrease of honey production	48	80.0
4	Increase of salinity intrusion	32	53.3
5	Increase in oceanic tides	32	53.3
6	Decrease in fish catch, disappearance of some fish species	46	76.7
7	Increase of the price of fishes, increase cost of living	53	88.3

Key: [a]There were multiple responses for the questions

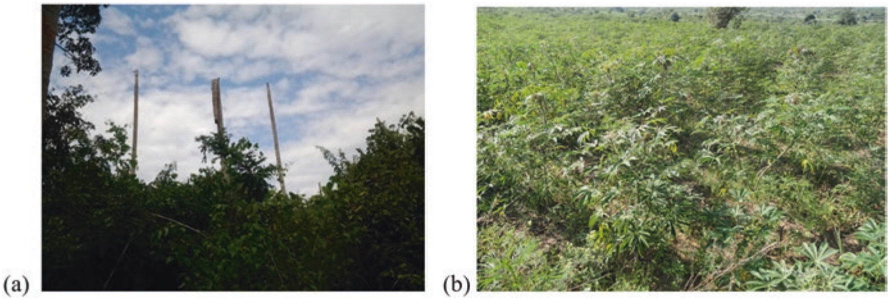


Plate 1 (**a**) Abandoned coconut farm after drying up; (**b**) cassava farm in the study area

Table 5 Impact of increase of oceanic tides in the study area

S/N	Impact of oceanic tides	Frequency	Percent
1	Coastal erosion	60	100
2	Salinity intrusion	60	100
3	Decrease of fish catch	37	62

In general, however, the effects of climate change and variability on access to coastal resources seem to be threefold. First, there may be increase of availability of some coastal resources and hence also increase in production of some economic activities. Second, there may be decrease in the availability of coastal resources and hence also decrease in the productivity of some economic activities due to limited accessibility and utilization of coastal resources. For instance, as echoed by Howden et al. (2007), salinity intrusion challenges the availability of arable land and access to and utilization of fresh water to the coastal communities.

As noted by the DAICO, for example, before the late 1990s, smallholder farmers used to grow crops without using any fertilizers, pesticides or insecticides. However, currently these inputs were increasingly getting en-vogue as agricultural inputs without which farmers would get very low productivity per acre. It should, however, also be noted that the increase in use of fertilizers and pesticides could be a result of non-climatic factors such as decrease in soil fertility due to mismanagement of farms.

Decline in coconut production had led to abandonment of coconut farms and smallholder farmers shifting to engage in other productive economic activities such as fishing and horticulture farming. According to the DAICO, the cause for the decline of coconut production was not only an impact of climate change and variability but also due to mismanagement of farms including insufficient guidance on proper farming technologies from agricultural extension officers.

To a large extent, data from this study shows that the increase of high oceanic tides had had several impacts on coastal landscape and resources. These had included coastal erosion (100%), increase of salinity intrusion (100%) and decline of fish catch (61.7%) (Table 5). Coastal erosion and the widening of the Pangani River banks as observed, for instance, along Pangadeco area (Plate 2a) had increased

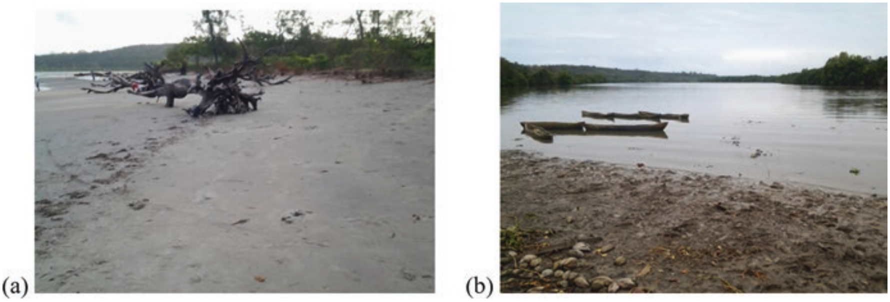


Plate 2 (**a**) Eroded trees along the coast; (**b**) widened Pangani River

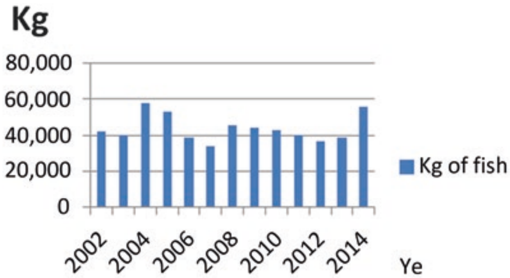


Fig. 4 Amount of fish catch in Pangani District 2002–2014. (Source: Fisheries Department, Pangani District Council, 2015)

the effects of high and low tides. In this respect, respondents in Pangani Mashariki village revealed that more than 30 metres of land along the coastline had been occupied by water between the 1980s and 2015 reducing arable land and other floral and faunal habitats. On the other hand, respondents in Msaraza village recalled that in the 1970s, they used to cross the river on foot, especially during low tides, which was currently not possible because of the widening of the river and increased frequency of high tides (Plate 2b).

Fishing is the predominant economic activity among the Pangani coastal community. The trend of fishing over 12 years (2002–2014) is shown by Fig. 4 which indicates that the maximum amount of fish catch was 68,000 kg in 2004, while the least amount of fish catch was 32,500 kg in 2007. The trends of fish catch in the district reveal that between 2008 and 2013, the amount of fish caught had been decreasing over time due to decrease of rainfall and hence low river flows and increase in high tides and intrusion of salinity. Both the respondents to this study and officials from Pangani District Council linked the decline and disappearance of fishes to the impact of climate change. As observed elsewhere Brooks et al. (2006) and Yohanna et al. (2012) they indicated that when temperature was low, fish breeding was high, while breeding of fish was low when temperatures were high. On the other hand, increase of salinity into Pangani and other rivers led to the disappearance of some fish species.

Increase of salinity intrusion into the inland/offshore has affected the availability and development of some coastal resources. Salinity intrusion into fresh water in the

Plate 3 Abandoned borehole due to increase of salinity in Msaraza village

natural wells and Pangani River had reduced fresh water availability for different uses. It was observed for instance that some boreholes (drilled wells) in the study area had been abandoned because of saline water intrusion into them (Plate 3). Members of the FGDs revealed that salinity levels had risen up in the study area such that drilled wells were no longer productive; hence people had to buy water for domestic purposes or walk long distances over 3–4 km looking for fresh water. They further noted that salinity levels had increased in the Pangani River for several kilometres (up to 7 km) from the mouth of the river which made the problem of fresh water supply worse. As observed by Joubert (2013) elsewhere, salinity intrusion tended to increase in terms of extent and coverage towards the river mouth as it decreased upstream.

Governance and Access to Coastal Resources

Salinity intrusion challenges the availability, access to and utilization of fresh water and other resources to the coastal communities, leading into imposing strict rules on access to and utilization of coastal resources, rules that would enhance their management as evidenced by fishing and mangrove-harvesting permits. However, in some coastal zones, access to and utilization of coastal resources are highly affected by the economic status of the coastal communities themselves and their behaviour in accessing and utilization of coastal resources (Lawson et al. 2010). For instance, practices such as illegal fishing and destruction of mangrove forests made the coastal communities victims and vulnerable to the impact of climate change. Hence, different

Table 6 Measures to govern coastal resources in the study area

S/N	Measures	Frequency	Percent
1	Planting mangroves	22	36.7
2	Harvesting permits for mangroves	15	25.0
3	Fishing permits	5	8.3
4	Build embankments/walls	18	30.0
Total		60	100.0

initiatives have been taken elsewhere to manage the coastal resources such as restricting use of forests like mangroves along the beaches and prohibiting quarrying of corals (Rana 2010).

It was noted in this study that the local government and the public at large had introduced several measures to govern coastal resources in Pangani District. The measures included replanting of mangroves in order to control coastal and river bank erosion (36.7%), introducing and imposing harvesting permits for mangroves (25%), enforcing fishing regulations (8.3%) and building embankments/walls along the beaches to control coastal and river bank erosion (30%) (Table 6).

Participants in the FGDs revealed that planting and replanting of mangroves along the river and along the coast were done by the government, NGOs, government-private cooperation such as in Beach Management Units (BMUs) and community-based organizations. BMUs used participatory approaches where the central government, local government, NGOs, CBOs and the public at large joined hands in the management of coastal resources.

The importance of mangroves cannot be overemphasized. They are highly productive areas acting as nursery grounds for fish and stabilizing sediments on the shoreline and sea bottom. Mangroves support aquatic life, and damage to them, sometimes as a result of overharvesting, can cause a loss of biodiversity and damage to the coastal environment. The Pangani District Forests Officer revealed that in the 1960s mangrove forests were cleared to plant crops such as coconuts along the Pangani River. However, with the increase of salinity and change of rainfall and temperature, production of crops declined in the 1990s which resulted into planting and replanting of mangroves to replace farms that became unproductive. In order to reduce overharvesting of mangroves, the District Forests Department introduced and imposed mangrove-harvesting permits. Local people are now required to apply for permits showing amounts in cubic metres to be harvested and the intended uses. Respondents revealed that the main uses of mangroves which were permitted included harvesting for building poles and firewood.

Similarly, the Department of Fisheries in the district issues fishing permits to fisher folks. The permits indicate the amount of fish to be harvested in tons and the date of expiry of each permit. However, some respondents noted that fishing permits were violated and there was inadequate enforcement from the local and central government officials. They linked inadequate enforcement with alleged corruption between law enforcement officials and fisher folks. This was, however, not confirmed in the current study.

Table 7 Challenges to the implementation of measures to govern coastal resources

S/N	Challenges	Frequency	Percent
1	Non-compliance	18	30
2	Corruption	24	40
3	Inadequate law enforcement	18	30
Total		60	100

Plate 4 Embankment/wall built along the mouth of Pangani River

Generally, Table 7 shows the challenges faced by the various stakeholders in the implementation of measures to govern coastal resources. The survey respondents in this case revealed that the main challenges in the implementation of measures to manage coastal resources included corruption (40%), non-compliance (30%) and inadequate law enforcement (30%). The respondents noted that people, particularly government officials who are entrusted with powers to manage coastal resources, either colluded with environmental criminals or did not deliberately enforce the law properly leading to both unsustainable harvesting of mangroves and other coastal resources. Non-compliance was further linked with corruption whereby law enforcers colluded with violators of rules and regulations governing the access to and utilization of coastal resources. On the other hand, inadequate law enforcement was linked to inadequate capacity among law enforcement agencies and officials and lack of coordination between different law enforcement agencies and officials.

To control erosion the District Council tried to build embankments/walls along the coastline (Plate 4). However, officials in the district indicated that building walls was very expensive as compared to planting mangroves.

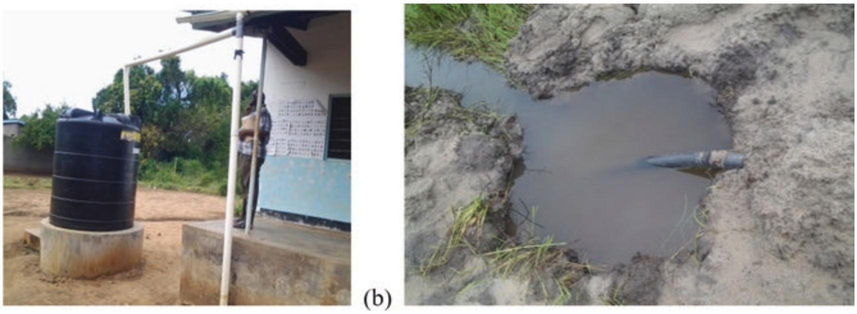
Adaptation Strategies to the Impact of Climate Change and Variability

Adaptation strategies differ in terms of effectiveness depending on the adaptive capacity of the community, organisms and social economic factors (VPO 2013; URT 2013b). Climate change poses a threat to every aspect of human and ecological systems challenging access to and the utilization of different coastal resources such as fresh water, fishes and mangrove forests to the community along the coast. Coastal communities in Pangani District are rational in accessing and utilizing the surrounding coastal resources. They have been designing and implementing different strategies to halt the impact of climate change in their areas. The main strategies which were revealed during the interviews and FGDs are shown in Table 8. They included planting mangroves (36.7%), planting drought-tolerant crops (23.3%) and diversification of economic activities (16.7%). Others were planting early-maturing maize seeds (15%) and rainwater harvesting (8.3%).

Participants of the FGDs variously revealed that due to a decrease of rainfall and changes of rainfall seasons and patterns, some people engaged in horticulture production, where they applied small-scale irrigation. Such diversification of agriculture increased production at the household level. Apart from horticulture, local community members also engaged in off-farm and non-fishing activities such as charcoal making, gravel quarrying and masonry work. Rainwater harvesting was also an adaptation strategy used against the decrease of fresh water due to increased salinity and decrease of rainfall. Rainwater is harvested from the roofs with corrugated iron sheets (Plate 5a)

Table 8 Adaptation strategies to the impact of climate change and variability (%)

S/N	Adaptation strategies	Frequency	Percent
1	Diversification of economic activities	10	16.7
2	Planting mangrove forests	22	36.7
3	Rainwater harvesting	5	8.3
4	Planting drought-resistant crops	14	23.3
5	Planting early-maturing maize seeds	9	15.0
Total		60	100.0



(a) (b)

Plate 5 (**a**) System for harvesting rainwater from the roof in Bweni ward offices; (**b**) micro-dam constructed for horticulture irrigation and from run-off water into micro-dams (Plate 5b). However, some respondents pointed out that rainwater was used for just a few days after the rain season and was mainly used for domestic purposes and for horticulture irrigation.

The use of early-maturing seeds and planting of new or improved seeds of maize were other adaptation strategies to the impact of climate change and variability intended to utilize late beginning and early cessation of rainfall seasons. These types of seed took between 60 and 90 days to mature; hence it was possible to maximize utilization of the scarce rainfall. Furthermore, respondents indicated that due to scarcity of rainfall, they also planted drought-tolerant crops such as cassava and sorghum.

Conclusion and Recommendations

Findings from this study have demonstrated that climate change has happened and is still happening in the study area. There are several notable impacts of climate change including decrease of rainfall and change of rainfall seasons and patterns, emergence of crop diseases and pests, decrease of fish catch, intrusion of salinity in the rivers and inland and general decline of crop productivity. The findings revealed that the impacts of climate change have been increasing over time between 1980 and 2014.

Climate change has both negative and positive impacts on the availability and distribution of coastal resources. While fresh water and fish resources have decreased, mangrove forests have increased in the study area. The increase of the coverage of mangrove forests is partly because of the strict rules on access and utilization but also due to increase of salinity in the Pangani River which create favourable conditions for mangroves growing. Thus changes in climate have shaped the way coastal communities access and utilize coastal resources.

The negative impacts of climate change on the livelihoods of coastal communities are likely to continue in the future. It is recommended that the governments, non-governmental organizations (NGOs), community-based organizations (CBOs) and local people join their efforts to design and implement strategies and measures to address the effects and hence help communities to attain various sustainable futures.

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Vulnerability and Adaptation Strategies of Coastal Communities to the Associated Impacts of Sea Level Rise and Coastal Flooding

Makame O. Makame and Haji Mwevura

Abstract This study aimed to assess the vulnerability of selected communities of the island to the impacts of sea level rise and associated coastal flooding, to examine the perception of local communities of North and South Regions of Pemba Island on the occurrence and impact of coastal flooding to their wellbeing and, lastly, to evaluate the adaptive capacity and different adaptation strategies adopted by the local communities in response to coastal flooding in the two administrative regions of Pemba Island. Within each district, three rice-growing areas were purposely selected for the study. Data collection techniques used included interviews, FGDs and physical observation. A total of 140 individuals were interviewed. Findings show that rice farmers in Pemba were highly exposed to sea level rise and coastal floods. As rice farming in the island is entirely rainfed, the rice-growing areas were sensitive to both declining rainfall and coastal flooding. Poor economic conditions and high levels of poverty exacerbated the low capacity of these communities to respond to the impacts of these stressors. Their vulnerability was manifested in overdependence on fishing, seaweed farming and subsistence crop farming which are highly impacted by sea level rise and associated coastal flooding. The observed building of seawalls was contributing to ameliorations of the impacts of coastal floods. There was a need to extend these walls to other villages for a similar purpose. Adaptation options such as the introduction of alternative sources of income or changing the use of the affected rice farms could also help to build resilience amongst rice farmers and thus reducing vulnerability to impacts of climate change.

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Background

Developing countries depend highly on natural resources that are climate reliant for their livelihoods. Unfortunately, these resources are vulnerable to climate change impacts. The extent of vulnerability is more compounded by the growing environmental degradation which is accelerated by absolute poverty and high population growth rate. Studies show that both physical and biological systems are highly at risk to the impacts of climate change, sea level rise and associated coastal flooding (Pandey et al. 2003; Mimura et al. 2007; Nicholls et al. 2007; Allison et al. 2009). The IPCC in its Fifth Assessment Report (AR5) argued that biological system-based livelihood activities such as agriculture, fishing, aquaculture and tourism are already vulnerable to the impacts of climate change and sea level rise over the continents and small islands (IPCC 2014).

Apparently, the impacts of climate variability and change and sea level rise (SLR) are increasingly threatening the existence and wellbeing of the world's Small Islands Developing States (SIDS) (IPCC 2013). Their vulnerability is influenced by their characteristically small size, remoteness and their small economy (Ghina 2003; IPCC 2007). The Fourth and Fifth Assessment Report (AR4 & 5) reported that coastal systems and low-lying areas especially those in the islands are highly vulnerable to sea level rise, extreme weather events and coastal flooding (Nicholls et al. 2007; IPCC 2013). For instance, farming is already competing with other land uses such as urban expansion all over small island states (Ghina 2003), and studies suggest that the predicted sea level rise and coastal flooding could lead to a further reduction in size and loss of land surface in many of these islands (Mimura et al. 2007; IPCC 2013). For example, 0.5–2 meters increase of sea level would inundate low-lying coastal areas and wetlands, erode beaches, exacerbate coastal flooding and increase salt water intrusion (IPCC 2007; IPCC 2014; Nicholls 2004).

For the past two decades, Zanzibar, like any other SIDs in the Western India Ocean region, has experienced a number of extreme events and coastal flooding (Makame 2013). Coastal flooding in urban Unguja in 2007 (Mustelin et al. 2010) and coastal flooding in arable land in Pemba in 2010–2011 (Sultan 2011) are just a few examples. The observed seawater floods over arable land and salt water intrusion into wells during 2009–2011, particularly in the North and South Regions of Pemba (Sultan 2011), are probably associated with the recent observed instability in sea levels in Zanzibar as a whole (Makame 2013). In emphasis the study by Brown et al. (2011) revealed a high probability that sea level rises could increase in the near future and would thus also increase flooding, particularly on the coasts of East Africa, including Zanzibar.

These coastal floods in Pemba Island are likely to affect crops, underground water, the quality of the arable land and infrastructure. However, there is no study to date that has attempted to investigate the vulnerability of the coastal people in these two administrative regions to sea level rise and associated coastal flooding.

This study, therefore, aimed at understanding the livelihoods and infrastructures at risk from the associated impacts of sea level rise and coastal flooding along the coastal areas of the North and South Regions of Pemba Island. Specifically, the study sought to assess the vulnerability of selected communities of the island to the impacts of sea level rise and associated coastal flooding, to examine the perception of local communities of the island on the occurrence and impact of coastal flooding to their wellbeing, and lastly, the study intended to evaluate the adaptive capacity and different adaptation strategies adopted by the local communities in response to coastal flooding in the two administrative regions of Pemba Island.

Methods and Materials

Description of Study Areas

The study was conducted in Micheweni District in North Region and Mkoani District in South Region of Pemba Island (Fig. 1). The areas are considered to be vulnerable to climate extreme events and other environmental risks such as coastal erosion and flooding (Watkiss et al. 2012). Within each district, three rice-growing areas were purposely selected for the study. These areas were Mapape, Koowe and Sebleni in Micheweni District and Michenzani, Chokocho and Kangani in Mkoani District.

Data used in this study came from various sources for the purposes of triangulation. The data collection techniques used for primary data included interviews, focus group discussions (FGDs) and observation. With regard to the social survey, a total of 140 individuals were interviewed, drawing 70 rice farmers from each district. The survey sought to obtain information related to livelihood portfolios, livelihood activities and natural resources at risk. It was also related to perception of sea level rise and associated coastal flooding, perception on impact of coastal floods to livelihoods and their urgency to adapt to this stressor. The responses were analysed using the SPSS, and the data are presented in this chapter using tables and figures.

With regard to qualitative data, two FGDs were conducted one from each district. Each group comprised five participants. The formation of the groups was heterogeneous with a gender consideration as participants were drawn from different social groups in the community. The data obtained using this method was analysed using content analysis. With regard to secondary data, various important documents related to the study were reviewed, including the analysis of the collected and analysed observed data for rainfall and sea level rise trends and seasonality. Rainfall data were purchased from the Tanzania Meteorological Agency (TMA), Zanzibar office.

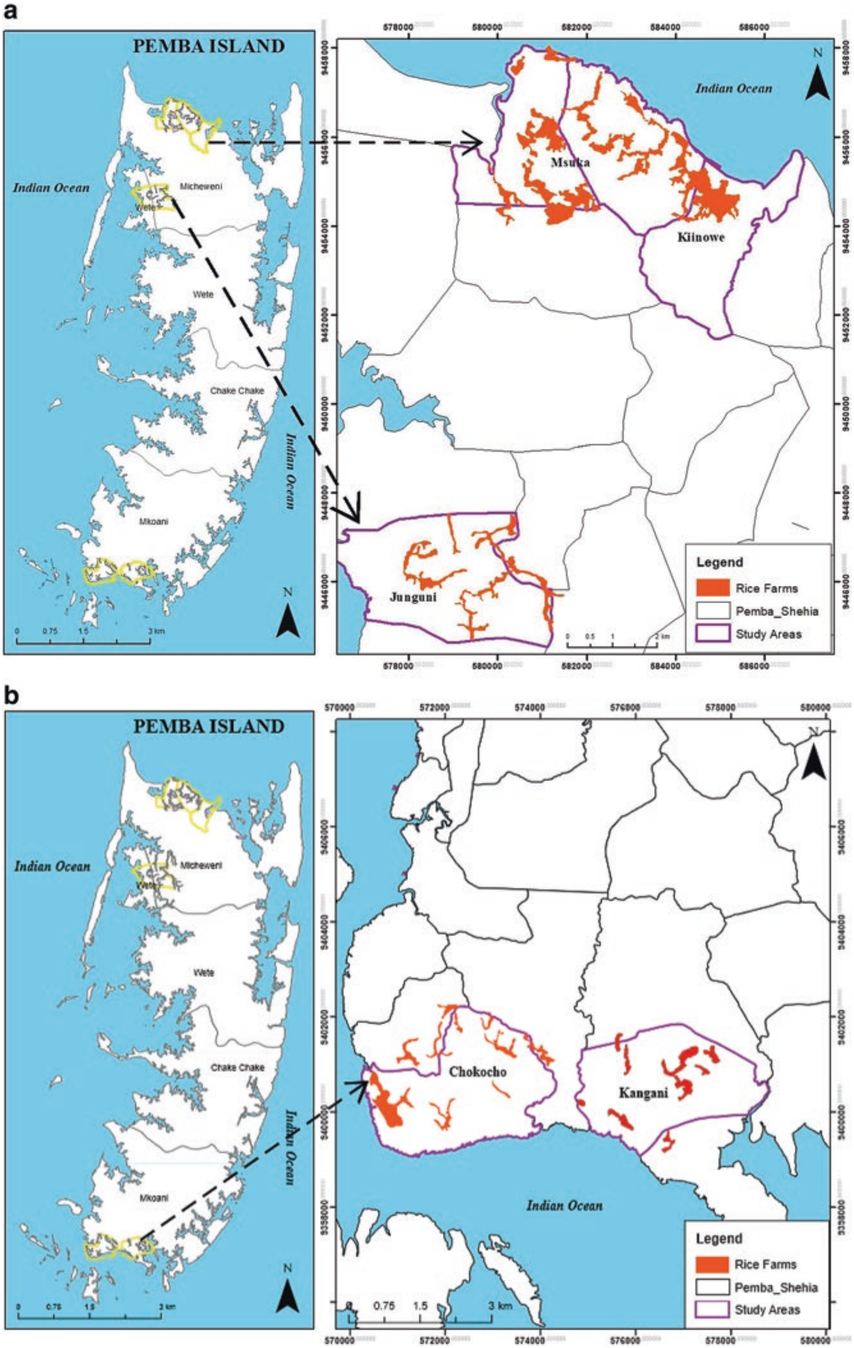

Fig. 1 (**a**) Study areas in Micheweni District, Pemba (**b**) Study areas in Mkoani District, Pemba

Results and Discussion

Perception of Local Farmers on Climate Change and Variability

The results of the study showed that majority of the local farmers perceived variability in rainfall and increasing of temperature over time. Zanzibar experiences four main seasons in a year: a relatively dry *Kiangazi* period (January–March), the long rainy *Masika* season (March–May), a mildly cool and windy period locally known as *Mchoo* in Pemba or *Pupwe* in Unguja (June–August/September) and the short rainy season (*Vuli*) coming in in October and December (Makame 2013). Rainfall occurs in all four seasons, but most is received in the long rainy season followed by the short rainy season. Farmers reported declining incidences of rainfall in both long and short rain seasons, and they branded these seasons as "unreliable". *Kiangazi* and *Mchoo* in Pemba or *Pupwe* in Unguja were reported to be warmer than normal.

In one of the FGDs, an elderly local farmer underlined these incidences and expressed his concern as highlighted in the comment below:

> In those early years rainfall was good, this is because during this harvesting period normally we used to harvest with rain falling but recently most of the time we harvest with dry spells…**Mchoo** seasons have changed tremendously over time, we used to receive wet seasons in those early years but nowadays **Mchoo** is completely dry.

The comments above highlight the variability of rainfall not only during the rain seasons (*Vuli* and *Masika*) but also during the other seasons. The average rainfall received per year might remain similar or a little bit less over time, but the problem is probably the way it is distributed and the variation in the onset of the rain seasons over the last decade or so. This argument was highlighted by the farmers in the study areas who claimed that rainfall during *Masika* poured heavily in 4 or 5 days and then declined throughout the season.

The analysis of rainfall data recorded at the Chake-Chake Airport weather station (Figs. 2, 3, 4, and 5) demonstrates the fact that distribution of rain has varied over time and the amount of rainfall received at this particular station had also declined as perceived by the rice farmers in the study areas. For example, the analysis of graphs for anomalies in Figs. 2 and 4 suggests that rainfall deficit is apparent since 2000.

Figure 2 shows that from 2000 to 2015, only 4 years experienced rainfall above average, while 11 years experienced below normal rainfall during *Masika* season. Similar trends are observed for the short rain season (Fig. 4). Figures 3 and 5, on the other hand, revealed variations in terms of distribution of rainfall in both *Masika* and *Vuli* seasons. For example, the rainfall amount received in March was much variable compared with that of April and May in the long rain season (Fig. 3). Similarly, Fig. 5 shows variation in rainfall received during the *Vuli* months. The future prediction of rainfall is also alarming. The predictions of rainfall in both seasons obtained from the climate change portal of the University of Cape Town (see Makame 2013) show that rainfall is likely to decline in both seasons.

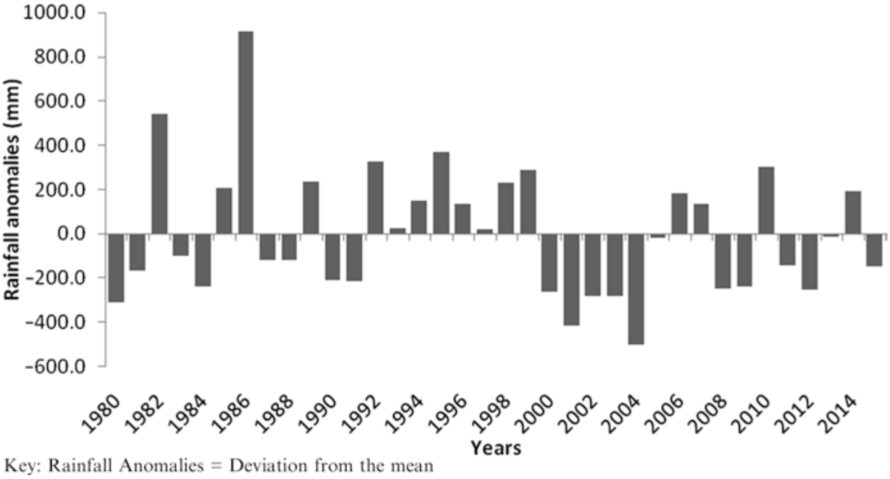

Fig. 2 Interannual variability of the long Masika (March–May)

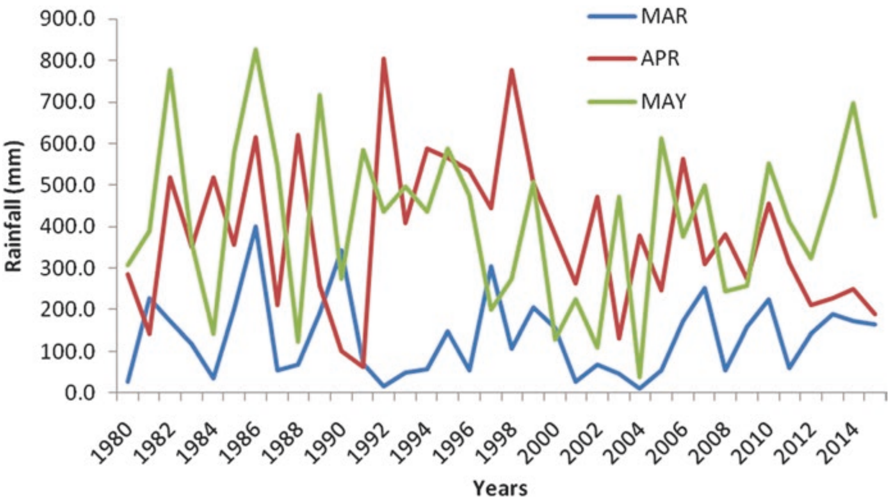

Fig. 3 Interannual variability of the rainfall received during March, April and May from 1980 to 2015

The livelihood portfolio of the communities in the area of study shows that, although they had diversified their livelihoods, they still depended on traditional activities such as farming, fishing and seaweed farming which are vulnerable to current and future changes in climate. Rice farming which is the mainstay of the communities in the area under study is either influenced or controlled by the climate. For example, majority of the rice-producing farmers adopted 6 months

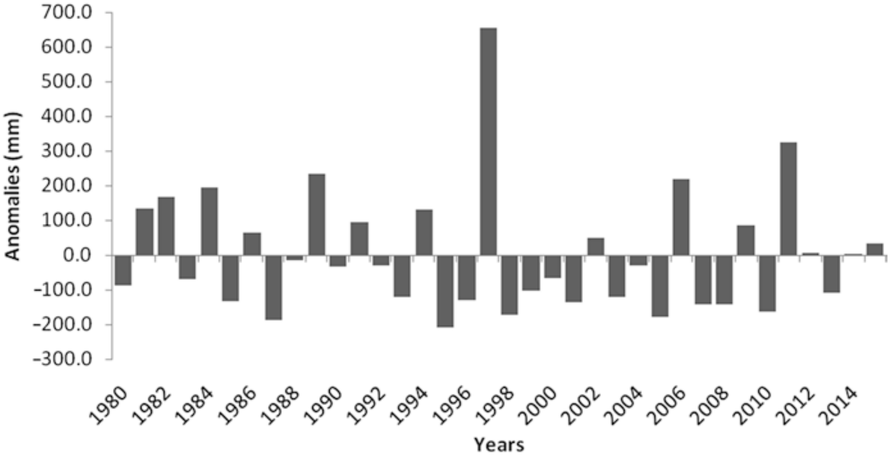

Fig. 4 Interannual variability of rainfall during short rain season/Vuli (October–December) from 1980 to 2015

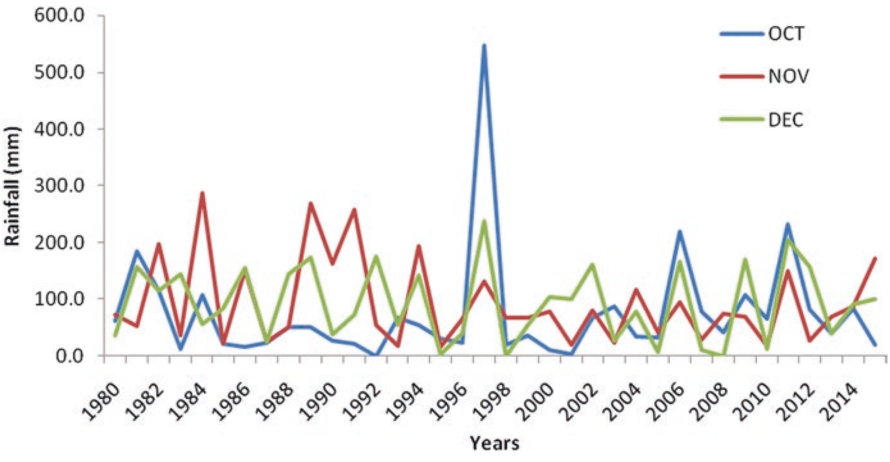

Fig. 5 Interannual variability of rainfall received during October, November and December from 1980 to 2015

maturing seeds, and the fact that each climate season lasts for 3 months, the success of the rice crop would depend on the stability of the two seasons through which the rice would grow and be harvested. If rice was planted during *Masika* (March–May), farmers would need normal *Mchoo* (June–August/September) seasons for them to harvest large amounts of rice. Generally, the results show that majority of the farmers are aware of the impacts of climate change on rice and other crops resulting from variability in rainfall and temperature.

This was demonstrated by the following quotes from two farmers in two separate FGDs:

> We are too worried with this unreliability in rainfall as this season every one didn't harvest much due to poor rainfall received during **Masika** and **Mchoo.**
> and
> I have two plots of cassava but a large part of it dried due to the abnormality of the season; I harvested very little.

Perception of Local Farmers on Sea Level Rise and Coastal Flooding

Seasonal coastal flooding on the farmlands which are very close to the shore is common in Pemba. However, at the beginning of this decade (2010s), increased incidences of coastal flooding on the farmlands have been widely reported in the media (Sultan 2011). This has probably been due to increasing frequency of these floods and increasing severity of their impacts on rice and other coastal resources as well as infrastructure. Since many respondents believed that the trend of coastal flooding and sea level had changed over time, they were asked to explain the nature of this change. The results in Table 1 show that a majority of the respondents (98%) reported on an increasing incidence of coastal flooding now compared with the previous years. Similarly, a majority of the respondents (94%) reported on the rising of sea levels.

Similar to the perception regarding variation in rainfall and temperature, local farmers' perception on sea level and coastal flooding was highly influenced by their experiences and local knowledge (Manyatsi et al. 2010; Vedwan 2006). Their interactions with the environment over time had contributed to their awareness on the observed variability and changes of the various phenomena on the environment. This is mainly because their activities, such as rice farming, had long been interacting with seasonal coastal flooding as their rice farms are located very close to the high tide zone or in areas which were previously covered by mangroves.

Respondents were also asked to comment on the frequency of coastal flooding and its severity over time. The results in Table 2 show that a majority of the respondents (78%) believed that coastal flooding occurred more frequently now compared to previous years. Majority of the respondents also believed that coastal flooding was severely affecting their rice farms now than before. This was also highlighted by additional comments provided by the respondents in FGDs and during the field visits:

Table 1 Perceptions on changes of coastal flooding and sea level

Oceanic parameters	Increase	Decrease	Stayed the same
Coastal flooding	132 (98%)	0	(2) 2%
Sea level	118 (94%)	(4) 3%	(4) 3%

Table 2 Frequency and severity of the coastal flooding as perceived by respondents

Frequency of the events	Frequency	Percent
More frequent	103	78
Same	2	1
Less frequent	29	22
Severity	Frequency	Percent
Severe	126	96
Same	4	3
Less severe	1	1

Long time ago, like 15 years back, we never experienced coastal flooding in our rice farms. In 2010 up to 2014 sea water has slowly started to invade my farm. In 2015 and this year (2016) my farm was completely covered by sea water and consequently destroyed whatever little I had in the farm.

We normally experience coastal flooding in our areas but this year (2016) and last year (2015) the floods were in extreme…

This year (2016) alone in a gap of six months my farm has been flooded 5 times and caused a huge damage…

The in-depth interviews with some of the respondents revealed that coastal flooding on rice farms normally occurred during the spring tide, particularly when the moon was full. This period is about 5 or 6 days. During this period, the high tide watermark is extended towards the shore. According to the farmers, spring tides were more powerful and usually invaded large areas during the north-easterly monsoons, locally known as *kaskazi*, which blow between December and March. For them as *kaskazi* blows towards the shore, it carries large amounts of water in that direction, and thus all low-lying rice farms close to the shore and fresh water streams are invaded by salty seawater. Unfortunately, the *kaskazi* phenomenon which, according to the farmers, is associated with coastal flooding coincides with the rice planting season that begins in the month of February, just before *Masika.* As such, coastal flooding inflicts heavy losses on farmers during the planting period.

Further to this submission, the research team wanted to establish further on the reasons of the perceptions that farmers experienced high frequency of coastal flooding now than before. The responses given were very complex and diverse. Based on the above explanation, some farmers linked the coastal flooding with increasing strength of *kaskazi* winds that could be attributed to climate variability and change. Degradation of environment through sand mining and mangrove deforestation could lower the shore and reduce barriers and thus force the seawater to invade the low-lying streams and associated rice farms (Sultan 2011).

Furthermore, the variability of the sea level rise can also be attributed to coastal flooding and coastal inundation (Brown et al. 2011; Boko et al. 2007; Nicholls 2004). For instance, a study by Nicholls (2004) concluded that future projections of the sea level rise were likely to increase coastal flooding all over the low-lying areas of the globe. However, while respondents perceived change in sea levels (see Table 1), the analysis of the sea level data done by Makame (2013) revealed minor fluctuations on the trends of the sea level rise in Zanzibar over time (Fig. 3).

This state of affairs would seem to prove Alex Evans and David Steven's contention that the history of climate change is not just about facts, evidence and argument (Evans and Steven 2007). It is about *images* that we are constantly shown – of melting glaciers, of Kilimanjaro's receding snow, et cetera. It is about *relationships* between researchers and related scientists, some of whom could be alarmists just like Walter Sullivan or Al Gore in the USA. Or it could also be about v*alues*, *beliefs* and *myths* societies tell themselves about perceived phenomena like climate change and its impacts.

Nevertheless, a coastal flooding in urban Unguja in 2007 (Mustelin et al. 2010) and on arable land in Pemba in 2010–2011 (Sultan 2011) have correlated with significant fluctuations of sea levels in Zanzibar. Figure 6, for example, highlights the interannual variability of the sea level over time which is highly influenced by the warming incidents such as ENSO within the Western Indian Ocean (Ngwali and Reason 2007). For instance, the relationship between sea level variability and ENSO events was also highlighted in other parts of the world (Rong et al. 2007; Tiwari et al. 2004; Sreenivas et al. 2012).

In ensuring that clarity and understanding of the interactions between issues under discussion are sought, respondents were also asked about the causes of coastal flooding in their areas. Results in Fig. 7 show that 46% of the respondents believed that cutting of mangrove forests was a likely cause of coastal flooding in their area. Other causes pointed out included coastal erosion (7%), human activities such as salt farming (11%) and shortage of rainfall (9%). It is also worth noting that 1% of the respondents believed that Boxing Day tsunami which occurred on Sunday, 26 December 2004, triggered by the Sumatra-Andaman earthquakes which shook the whole region of the Indian Ocean, including Zanzibar, was a cause for the occurrence of the coastal flooding in their areas.

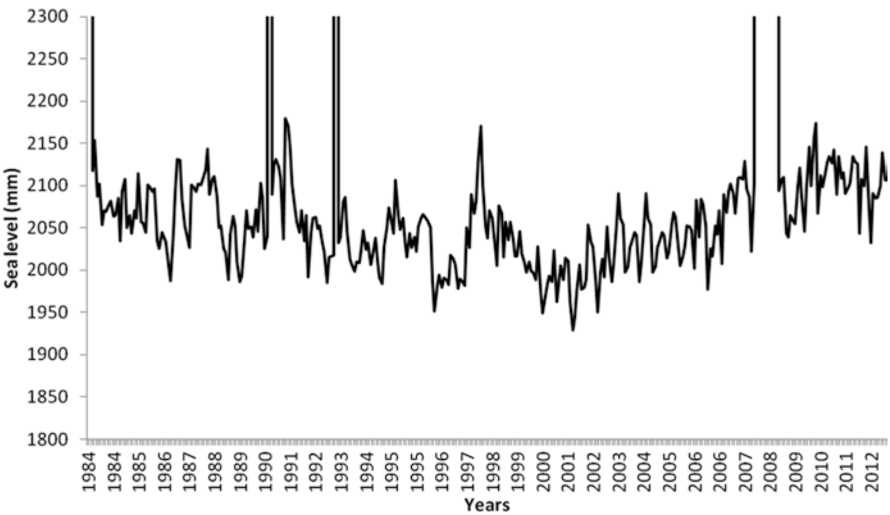

Fig. 6 Time series of sea level measurement at Zanzibar Harbour, 1984–2013. (Source: Adopted from Makame 2013)

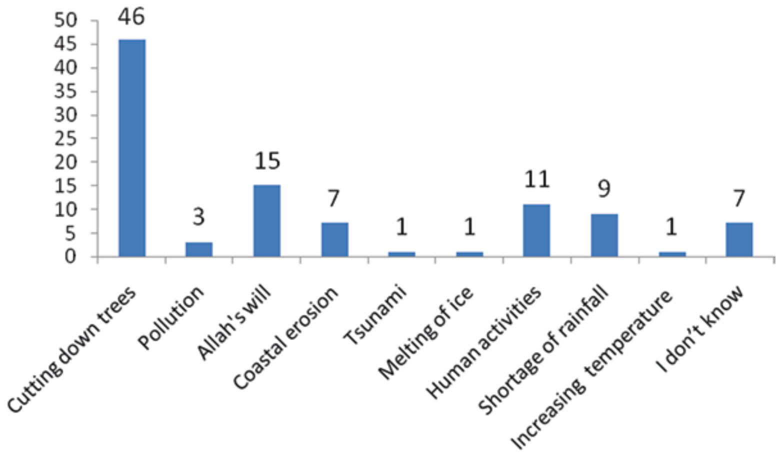

Fig. 7 Perceived causes of coastal flooding

However, contrary to the previous studies in Africa where climate change and sea level rise are linked with religious power, spiritual beliefs and taboos (Manyatsi et al. 2010; Apata et al. 2009), in this study, many respondents believed the causes were rational and were rooted in the science of climate change. This underscores the fact that awareness on climate change issues amongst rural communities has been increasing over time, probably due to the ongoing outreach and awareness creation programs through media and various participatory and learning activities going on amongst these communities by the academia, Civil Society Organizations (CSOs), governments and the private sector as advocated by Evans and Steven (2007).

Local Farmers' Perceived Impacts of Coastal Flooding

Results in Fig. 8 show that 46% of the respondents were engaged in farming activities, with rice production being dominant and the mainstay of agricultural production. Other economic activities included fishing, seafood collection, seaweed farming and livestock keeping. The figure also shows that livelihood activities outside the natural resource base, such as formal employment, were not common in the areas, probably due to low levels of literacy and lack of opportunities. Although the livelihood diversity was observed within the households, the difference was only linked to the diversity within the natural resource-based activities. The situation appears to be common to the whole of Pemba Island and some parts of Unguja Island (Makame et al. 2015).

These findings highlight the fact that the economies of these local communities depend on the livelihood activities that are highly influenced by climate; hence climate change risks such as sea level rise are capable of crippling farming and fishing in many ways as observed by studies such as Allison et al. (2005), Allison et al. (2009)

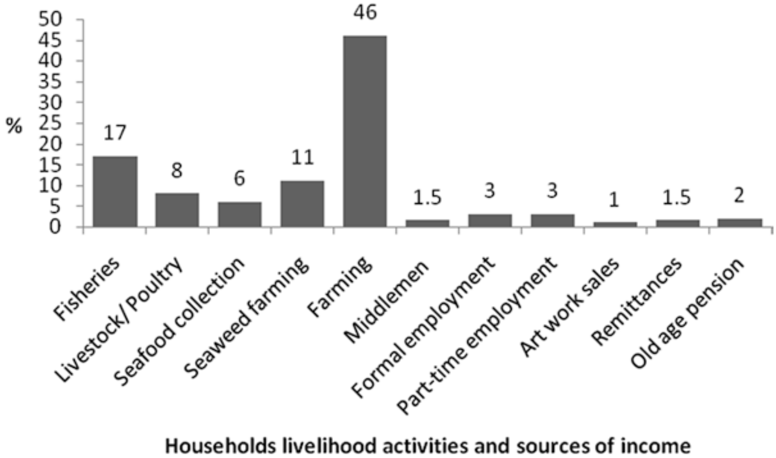

Fig. 8 Coastal livelihood strategies

Table 3 Perceived impacts of coastal flooding

Impacts	Farmland	Crops	Beaches	Houses	Underground water
High impact	98 (85%)	115 (91%)	15 (20%)	3 (5%)	9 (13%)
Moderate impact	15 (13%)	11 (9%)	29 (38%)	2 (3%)	7 (10%)
Low impact	0	0	28 (37%)	31 (50%)	35 (52%)
No impact	2 (2%)	0	4 (5%)	26 (42%)	16 (24%)
Total	115 (100%)	126 (100%)	76 (100%)	62 (100%)	67 (100%)

and Barnett (2011). This makes the two main economic and livelihood stays of these communities sensitive and vulnerable to climate change and variability, leading to entrenched poverty and underdevelopment.

In addition, the respondents were asked to list and rank the impacts of coastal flooding on some of the coastal resources, including their home structures. Results in Table 3 show that a majority of the respondents believed that coastal flooding was affecting both farm lands as it increased the salinity content in the soil and to the crops, notably rice. Detailed discussion with the respondents during the FGDs revealed that rice was more affected by coastal flooding when it coincided with declining rainfall. According to them, if coastal flooding was followed by very good rains, rice farms would not be affected much as rainwater would dilute and reduce the amount of salinity brought in by the floods. But when the farms were exposed both to coastal flooding and drought, the impact was huge (Plate 1). This reality was demonstrated by the following quote from a participant of one of the FGDs:

> In those early days' coastal flooding normally accompanied by rainfall or that occurred few days before the rainfall season would wash away the salinity brought by the tidal waves. These days our farms are flooded by sea water and there is no rain to clean our farms and thus rice is highly affected.

Plate 1 Rice fields affected by coastal flooding in the study areas. (Source: Photos by the Authors, 2015)

Results in Figs. 2 and 4 show that, by the time of the study, coastal flooding had increased its frequency over the last 5 years, while rainfall had become more unreliable. Hence, the observed double impacts of exposure would likely affect the local economy and livelihoods of the coastal communities in the study areas. In fact, coastal flooding would generally affect the household's food security and the general economic development in the study areas, including the capacity of households to save money. The FGDs also reported that rice farming in the areas which is essentially small scale in nature could only enable a well to do family to produce rice that would be consumed by the household members for a month or two. Thus, when the harvest was too low or no production could be realized due to coastal flooding and unreliable rainfall, farmers were forced to buy food from the shops which had an implication on the household's food security and savings.

Strategies Adopted by Farmers to Cope with Coastal Flooding

Both the government and local farmers had started embarking on using various adaptation strategies/options at both community and household levels to the associated impacts of climate change, such as sea level rise and coastal flooding. Table 4 shows the various adaptation strategies/options employed by the farmers to cope with increasing frequency of coastal flooding and associated impacts of climate change. At the farm level, farmers were building ridges to protect their rice plots

Table 4 Adaptation options employed by the rice farmers in study areas

Farm-level adaptation	Household-level adaptation
Building ridges	Small business
Planting trees	Daily pay working
Shifting to other farms	Middlemen
Cultivating other types of crops in upland areas	Remittances

from coastal flooding, shifting from affected plots to others and planting trees as the main adaptation options. Although farmers preferred ridges as the most effective adaptation measure that could reduce the impacts of seawater flooding into their farms, the capacity to put well-built ridges was very low. It was only at two study areas where "professional" ridges were built with the help of the central government through the Ministry of Agriculture.

However, some local farmers believed that even the ridges built by the government were not effective enough to protect them from serious coastal flooding (Plate 2). Generally, it was observed that low adaptive capacity of the community was mainly attributable to low technology and poor financial portfolios that provided bottlenecks towards effective adaptation to the associated impacts of climate change. For instance, the study revealed that the building cost of the trench at Wingwi was estimated at Tsh. 300 million. This amount could not be easily contributed by farmers without external support.

As far as mangrove stands were concerned, the surveyed communities seemed to be very much aware that they acted as wind breakers and played major roles in reducing coastal erosion. Therefore, the respondents believed that the root cause of sea level rise and coastal flooding was cutting and uprooting of such mangrove stands. Based on this knowledge, planting of trees, especially the mangroves, was singled out as the most potential adaptation strategy to minimize coastal flooding. During one study visit, for example, it was noted that the communities at Kinowe in Micheweni District had invested in and dedicated efforts to plant mangroves. Consequently the abandoned rice farms were rapidly being colonized by mangrove stands.

With regard to saltwater intrusion, it was noted that farmers in both study areas were highly affected by such intrusions. The situation was worse during severe drought. However, the farmers' ability to address salt intrusion was rather low, and there were no strategies in place to address this challenge. Although breeding technology had been used elsewhere to adapt to salt intrusion, there was no direct solution to the problem in the study areas. For instance, in Bangladesh where coastal flooding is also a common phenomenon, farmers managed to adopt salt-tolerant rice varieties in salt-affected areas or converted the farms into aquaculture and/or shrimp culture ponds (Hoque and Haque 2016).

At household level, the strategies adopted by community members in the study areas included change of their occupations and engagement into other livelihood activities such as fishing, small businesses and petty day working slots. Thus many residents from the study areas whose source of livelihoods had once depended on natural resources such as farming and fishing diversified their means of livelihoods.

Plate 2 Professionally made ridges at Wingwi which were built by the help of the central government to protect rice farms from coastal flooding. (Source: Photos by the Authors, 2015)

It was also noted that most of them were engaged in multiple activities as a strategy to boost their income and livelihood options. This change in occupation had obviously reduced the contribution of subsistence farming to support food security and in turn had increased dependency on imported food. Farmers were, for example, found buying more food from the stores using the earnings accrued from nonagricultural activities as the most sustainable option to their survival.

Conclusion and Recommendations

This study aimed to provide an understanding of the livelihoods and infrastructures at risk from the associated impacts of sea level rise and coastal flooding along the coastal areas of the North and South Regions of Pemba Island. Specifically, the study sought to assess the vulnerability of selected communities of the island to the impacts of sea level rise and associated coastal flooding, to examine the perception of local communities of the island on the occurrence and impact of coastal flooding to their wellbeing and to evaluate the adaptive capacity and different strategies adopted by the local communities in response to coastal flooding in the two administrative regions of Pemba Island.

In general, the study has found that rice farmers in Pemba Island are highly exposed to the impacts of climate change and variability sea level rise and its accompanied coastal floods. As rice farming in the island is entirely rainfed, the rice-growing lowland areas are sensitive to both declining rainfall and coastal flooding as observed and reported by the farmers themselves. Furthermore, poor economic conditions and high levels of poverty amongst the farmers exacerbated the low capacity of these communities in adapting to the impacts of these stressors. In fact their vulnerability was characterized by overdependence on fishing activities, seaweed farming and subsistence crop farming which were highly influenced by sea level rise and associated coastal flooding.

Thus since planned adaptation such as building of seawalls that were found in some villages was contributing to ameliorations of the impacts of coastal floods, there was a need to build or extend these walls to other villages for a similar purpose. Similarly, other adaptation options such as the introduction of alternative sources of income or changing the use of the affected rice farms could also help to build resilience amongst rice farmers and thus reducing vulnerability to impacts of climate change.

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Seaweed (*Mwani*) Farming as an Adaptation Strategy to Impacts of Climate Change and Variability in Zanzibar

Iddi H. Hassan and W. J. Othman

Abstract This study aimed at identifying climatic factors affecting seaweed (*Mwani*) farming, its associated impacts and adaptation strategies employed by seaweed farmers to cope with the impacts of climate variability and change along the coast of Unguja Island. The study was carried out in four coastal villages of the Island. The villages were chosen because a majority of communities were engaged in the production of *Mwani*. Household surveys were conducted to collect quantitative data, whereas FGDs and observation were employed to collect qualitative information. A total of 476 households engaged in seaweed farming were used as a sampling frame in the study, where 25% of them (119 households) were randomly selected to participate in the interviews. Results reveal that *Mwani* production has been widely practised by women (92.4%) and mostly by married people (87.2%). The labour force for seaweed farming fell within the age group 31–49 years (60.3%). About 77.6% and 70% of the respondents were specific *Mwani* producers and literate, respectively. Despite the challenges *Mwani* production was the most popular alternative livelihood performed by many rural populations in Zanzibar. Seaweed farmers perceived that seaweed growing in Unguja had been affected by changes in climate factors and non-climatic stressors over the last 20 years. Climatic variables that have affected seaweed included increasing surface water temperatures, wind speed, sea waves, irregular rainfall patterns and salinity. *Mwani* production had generally declined over the last 5 years. Despite a number of strategies taken by *Mwani* growers to cope and adapt to the impact of changing climate, new research is needed to develop new adaptation technologies that will help farmers to counteract the effect of desiccation and associated diseases aggravated by climatic variables in the field.

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Background

Climate change in developing countries is no longer a myth. It is a real phenomenon which touches important economic and livelihood activities for many local communities. Climate change threatens the ability of coastal resource-dependent communities to maintain sustainable livelihoods and achieve development goals. Farmers, livestock keepers, fishermen and seaweed farmers have been struggling hard to produce in the face of climate change. However, many of them have been getting lower yields due to unexpected weather changes in the eastern region of Africa. For example, prolonged droughts, temperature rises and shift of precipitation patterns have, for decades, become persistent, thus affecting ecosystem-dependent livelihoods (Amri and Arifin 2016). Comparing extreme drought events and shift of precipitation patterns along the coastal zone of Tanzania, both Unguja Island and Kisarawe District have been reported to be affected by extreme drought events and change of precipitation patterns (Hassan et al. 2014).

Despite the high exposure of these coastal ecosystems to weather extremes, the marine ecosystem underpins economic activities accounting for 30% of the GDP (Lange and Jiddawi 2009). Key livelihood activities within the marine social-ecological systems (SES) include artisanal fishing and aquaculture, especially the production of seaweed *Mwani*. The commercial production of *Mwani* was introduced in Zanzibar in the late 1980s which brings foreign currency and gives coastal people, especially women, an opportunity to earn an income for themselves and their families (Msuya 2012). However, climate change has been considered a key threat not only to coral reefs (Hughes et al. 2003) and marine fisheries but also a major threat to the production of *Mwani* (Allison et al. 2009; Cheung et al. 2010) to Zanzibar and other nearby coastal ecosystems.

There have been reports of die-offs of *Mwani* along the coast of Tanzania, including Zanzibar, and rise in sea surface temperature has mostly been taken to be the likely cause (RGZ 2012). Since mitigation of such impacts to climate change is out of the way for many communities, adaptation remains the only feasible strategy which can be implemented within the capacity of the rural poor population. Understanding the adaptation strategies engaged by coastal communities to counteract the impact climate change in carrying out the production of *Mwani* is inevitable. The adaptation strategies need to be identified and acted upon. This study aimed at identifying climatic factors affecting seaweed farming, its associated impacts and adaptation strategies employed by seaweed farmers to cope with the impacts of climate variability and change along the coast of Unguja Island.

Materials and Methods

Study Area

The study was carried out in four coastal villages of Unguja Island in Zanzibar which are Bwejuu, Bwereu, Matemwe and Unguja Ukuu (Fig. 1). These villages were chosen because of a majority of communities were greatly engaged in the production of *Mwani* and thus practising a wide range of adaptation measures.

Approaches to Data Collection

Two broad approaches to data collection were employed in this study. The first approach focused on secondary data collection and desk review, while the second approach was focused on primary data collection from the coastal communities who regularly practised seaweed farming. Both quantitative and qualitative approaches of data collection were employed for collection of the primary data. Household interviews using a semi-structured questionnaire were conducted to collect quantitative data, whereas focus group discussions (FGDs) and observation were employed to collect qualitative information deemed necessary for this study.

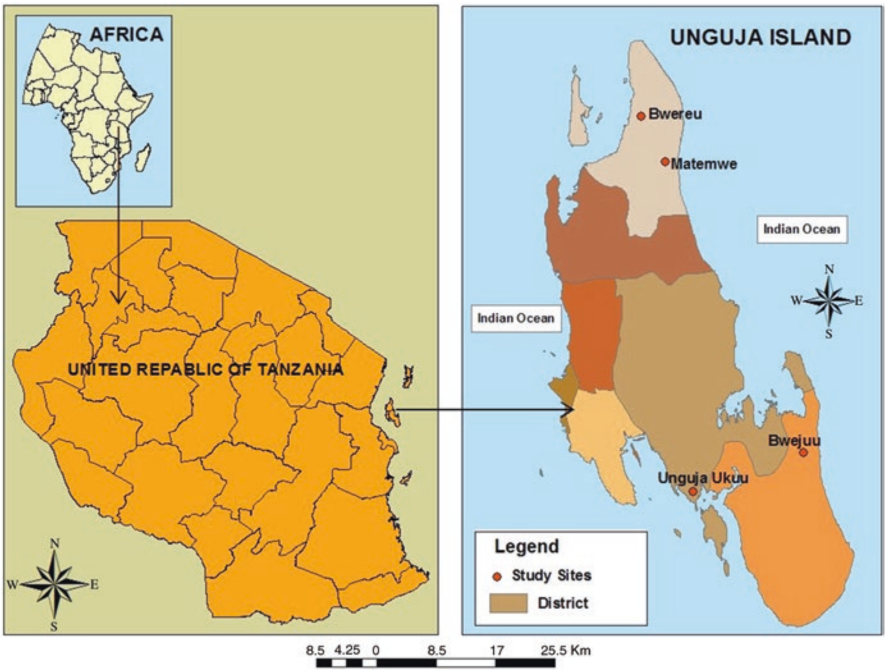

Fig. 1 Locations of the study site

Table 1 Sampling of respondents in seaweed farming

S/N	Village	Respondents by gender		Sampled households (25%)	
		Males	Females	Males	Females
1	Bwejuu	4	149	1	37
2	Matemwe	9	59	2	15
3	Unguja Ukuu	4	152	4	38
4	Bwereu	8	81	2	20
TOTAL		35	441	9	110

Household Interviews

Face-to-face household interviews using a semi-structured questionnaire were used to collect most of the quantitative data on seaweed farming and household socio-economic conditions, including the households' portfolio of livelihood activities which have direct linkage to the seaweed farming activities in each of the study sites. In addition to the structured questions used in this questionnaire, a few open-ended questions were administered to generate detailed and contextual discussion on the adaptation strategies to climate variability and change in seaweed farming. The qualitative questions of the household interview were organized using the Likert scale since it is a valid and powerful approach to scaling or rating responses in qualitative survey as suggested by Wuensch (2005), with particular focus on assessing adaptation strategies to climate variability and change in the production of *Mwani*.

Sampling Procedure and Sample Size

A cross-sectional study design was used to collect diverse categories of data at specific period of time. In each study site, a list of households and their economic activities including household engaged in seaweed farming was prepared under the assistance of Shehia leaders or key informants who are familiar to household activities in the village. Thus a total of 476 households engaged in seaweed farming in all study area and used as sampling frame in the study, whereas 25% of them (119 households) were randomly selected to participate in the interviews. Table 1 gives the total number of respondents involved in the study from each village. The targeted respondents during these interviews were the household heads. However, when the head of household was absent, any other knowledgeable household member participated in the interview.

This survey also employed focus group discussions (FGDs) to explore the meanings behind the household interview data and to collect detailed information that were not possible to be collected during the interviews. Krueger (1994) puts emphasis on the use of FGDs as a robust tool to gain more knowledge, perceptions, opinions, beliefs and attitudes towards specific issues that arose during face-to-face interviews. Thus a total of eight FGDs (two from each study site) with an average of five people per FGD were held in the all study sites. Selection of a group was based on capacity to speak, experience in seaweed farming, gender consideration and intellectual capability. To encourage inclusiveness and ensure plurality of voices, FGDs considered gender representation as well.

Direct observation of various activities performed by *Mwani* growers was also used to clarify discrepancies and information gaps that occurred during data collection using the former methods. Literature review from different research reports and publications from various projects and institutions that had worked in the area in more or less similar issues was done to add value to the primary data that were collected from respondents.

Data Analysis

Qualitative data obtained through seaweed farmers and observations was summarized into meaningful themes using content analysis. Quantitative data obtained through the household questionnaire survey was entered into the SPSS software for storage and subsequent analyses to generate descriptive statistics.

Results and Discussion

Socio-economic Characteristics of the Respondents

Results reveal that *Mwani* production has been widely practised by women (92.4%) and mostly by married people (87.2%). The labour force for seaweed farming fell within the age group 31–49 years (60.3%). About 77.6% and 70% of the respondents were specific *Mwani* producers and literate, respectively (Table 2). Despite of vivid challenges facing *Mwani* production, it was found to be the most popular alternative livelihood performed by many rural populations in Zanzibar, especially female farmers, compared to other climate sensitive sectors. For example, agriculture sectors in Zanzibar support only 81% of female (FAO 2013). This result is in consensus with the findings reported by others who noted that the *Mwani* growing activity is only performed by women, which indicate that men are no longer

Table 2 Socio-economic characteristics of the respondents

Sex %		Marital status %		Age group %		Education level %		Occupation %	
Male	Female	Married	87.2	18–30	10.3	Primary	35.9	Seaweed farmer	77.6
7.4	92.6	Divorced	9.0	>50	29.5	A level	1.3	Fishing	2.6
		Widowed	1.3			Adult education	2.6	Trade	2.6
		Single	2.6			No education	29.5	Firewood collector and seller	2.6
								Tourism worker	1.3

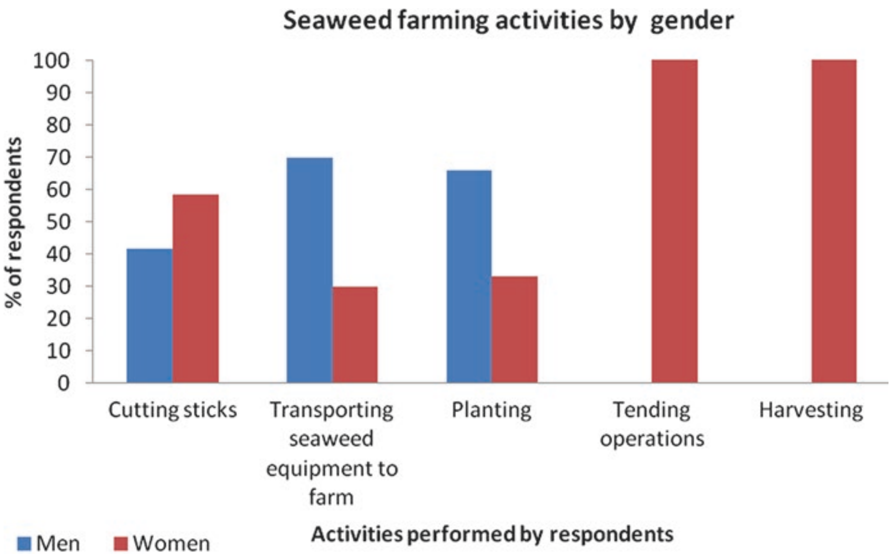

Fig. 2 Seaweed farming activities by gender

considering this business as their livelihood activity (Msuya 2012). While majority of *Mwani* growers are women, men in the house also indirectly involved themselves in the *Mwani* value chain production. Men are mostly hired to cut seaweed sticks and transport seaweed equipment up to *Mwani* farming areas using boats and were also employed during planting (Fig. 2).

The study found that seaweed farming is conducted as a family business, meaning that daughters or sons are likely to follow their parents into the industry. It was commonly reported during FGDs that a group of *Mwani* growers may include a grandmother, a mother, children and sisters-in-law all farming together. However, because education levels have risen since the 1980s, this family chain was starting to break engaging more older people in *Mwani* farming. For example, Shechambo et al. (1996) reported that farmers were generally older, aged 40 years and above, with the majority over 50 years. However, the current study observed that many young people, including school children, especially in Matemwe village still grew *Mwani*, indicating limited availability of reliable alternative livelihood activities that could generate funds to meet daily household needs by a majority of community in the area.

Mwani *Growing and Planting Seasons*

Majority of the *Mwani* farmers owned very small plot of land, ranging between 0.25 acre (42.3%) and 0.5 acre (30.8%). This indicates that *Mwani* farmers had low capacity to manage large plot sizes in Unguja Islands. Only 6.4% of the farmers managed to hold above 1 acre of seaweed plots (Fig. 3). The size of *Mwani* plots reflects the load that a farmer has to take in the process up to marketing phase of the product. *Mwani* growing consists of number of activities that *Mwani* grower's must engage in order to realize the product. It ranges from initial preparation and demarcation of the plot, fixing seaweed sticks for buoyancy, planting, tending the *Mwani*, hand harvesting and carrying it to the drying sites, drying for several days, packaging, storing and selling. Thus leaving women alone in *Mwani* production becomes a more difficult task. For example, at Kidoti (close to Bwereu), the number of women *Mwani* farmers had decreased because some men who used to give additional workforce to women in seaweed production had stopped farming (Msuya 2012).

The results show that a large group of farmers (61%) reported that the south-east monsoon winds (*Kusi*) between June and September was the preferable season for planting *Mwani b*ecause the relatively low temperatures of the period were favourable to the initial growth of seaweed plants. The farmers further reported that the north-east monsoon winds (*Kaskazi*) period was the worst time to initiate *Mwani* planting in Unguja (Table 3). However, some farmers (26%) acknowledged that

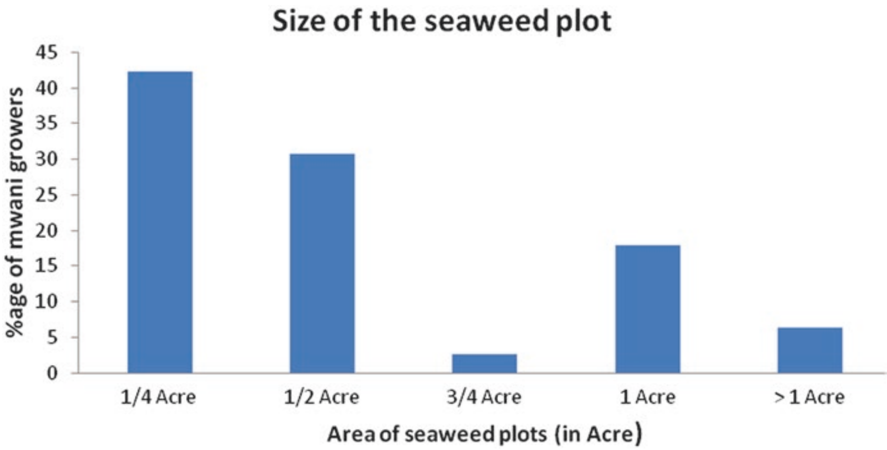

Fig. 3 Size of the seaweed farm plots

Table 3 Preferred seasons for seaweed plating in Zanzibar

S/N	Seasons	Period	% of responses
1	South-east monsoon winds (*Kusi*)	June–September	61.0
2	Calm period (*Leleji*)	September/October–February/ March	4.1
3	North-east monsoon winds (*Kaskazi*)	October–February	1.3
4	Rainy season (*Masika*)	March–May	7.6
5	Any time	All year round	26.0

planting of seaweed could be done at any time in the year, indicating that planting season for the crop depended on where one was geographically and on the intensity of climate variation in a particular year.

Status of Mwani *Production*

Majority of respondents (98.7%) acknowledged that there is a change of seaweed production over the last 5 years and that this change follows a decreasing trend. The main reported causes of the decline of mwani production is contributed to changing of weather and climates (76%), market fluctuations (16%) and emergence of new seaweed diseases (8%) (Table 4). Recent changes in the world market and in the farming environment are threatening this industry in Zanzibar to the extent that men are leaving seaweed farming, while others, mostly women, are carrying on with lower expectations (Msuya 2012). It has also been reported that good *Mwani* species which most farmers preferred and perceived to fetch good market prices are not well thriving in Zanzibar. For example, *E. cottonii* – the most profitable seaweed species – is now failing to grow in areas where it used to, due to changes in environmental conditions (Msuya 2012). These changes include the rise in seawater temperatures, epiphytism and fouling (Mmochi et al. 2005; Msuya 2007).

A large proportion of *Mwani* growers (97%) agreed that there have been changes in weather and seasonal patterns over the last 20 years in Unguja Island. In particular, temperatures had been observed to be higher than normal (94%). Rainfall had been in a decrease and irregular (79%), while wind speed had been in increase (73%). Meanwhile, the seasons had become unpredictable such that the hot season (*Kaskazi*) had come to resemble the cool dry season (*Vuli*) (Table 5).

These changes in weather patterns and seasons had affected the livelihood activities of the local communities, including seaweed farming. This situation had led to confusion to seaweed farmers as they have come to find it difficult in taking decisions as to when to start planting *Mwani* and so on. From the FGDs, for example, it was pointed out that some women had been discouraged from farming because of increasing climate change challenges.

> "*We have many problems with climate change while we're farming,*" said Mwanaisha Makame; a Zanzibari woman who had been cultivating *Mwani* for two decades. "*When we are in the ocean, we see the sand is getting too hot and the seaweed is dying. We've been noticing this since 2011.*"

Table 4 Causes of changes in *Mwani* production over the last 5 years

S/N	Causes of the changes	Responses (%)
1	Changing of weather and climate conditions	76
2	Market fluctuations	16
3	Emerging new seaweed diseases	8

Table 5 The trends of changes of weather and seasonal patterns over the last 20 years

S/N	Observed weather parameters	Trend of change Increased	Decreased	Constant
1.	Temperature	94.4 (higher)	5.6 (lower)	–
2.	Rainfall	20.6 (higher)	79.4 (little)	–
3.	Wind	72.9 (high)	14.3 (low)	12.9
4.	Hot season (*Kaskazi*)	25.0 (hot and dry)	37.5 (cold)	37.5
5.	Cool dry season (*Kipupwe*)	63.2 (warmer)	8.8 (colder)	28.1
6.	Rainy season (*Masika*)	4.6 (more rains)	93.8 (less rain)	1.5
7.	Low rain season (*Vuli*)	0.0	93.5 (less rain)	6.5
8.	Southerly winds (*Kusi*)	85.7 (stronger)	6.3 (weaker)	7.9
9.	Northerly winds (*Kaskazi*)	79.0 (stronger)	8.1 (weaker)	12.9

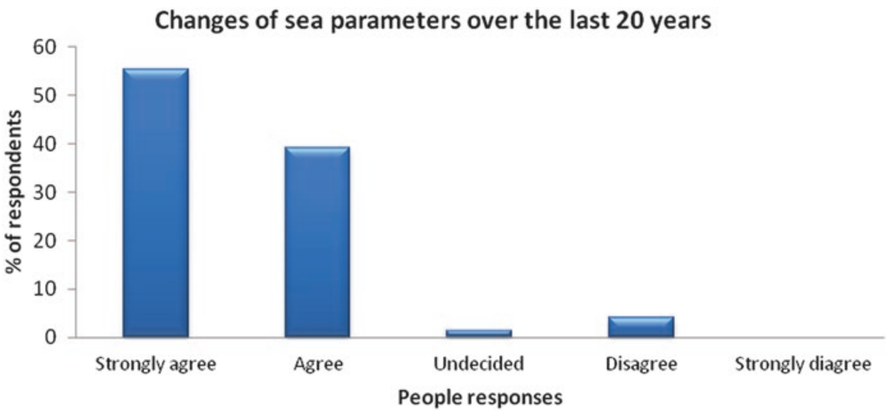

Fig. 4 Changes of sea parameters over the last 20 years

Most of the respondents reported significant changes in sea variables in their coastal areas (Fig. 4). Among the sea variables that had changed over the last 20 years included increasing of water temperatures and sea waves as observed by 94.3% and 97.3% of the respondents, respectively (Table 6).

Furthermore, the communities also noted the shrinking and/or widening of coastline structure over the last 20 years. In FGDs the participants said that the coastline configuration was not fixed such that at certain times and places the beach line became wider (50%) and after some period, let say 2–3 years, became narrow at some places (35.5%) because of beach erosion and sea-level rise. About 79% of the respondents acknowledged that there had been occurrence of sea-level rise over the last 20 years. On the other hand, the northerly and southerly monsoon winds were said to have become stronger than normal and the calm period (*leleji*) had remained constant over the last 20 years (Table 6).

Table 6 Changes of sea parameters and related conditions over the last 20 years

S/N	Observed sea parameters	Trend of change		
		Increased	Decreased	Constant
1.	Waves	94.3 (stronger)	2.9 (lower)	2.9
2.	Water temperature	97.1 (higher)	2.9 (lower)	–
3.	Salinity	42.9 (high)	7.9 (low)	49.2
4.	Coastline (beach) structure	50.0 (wider)	34.5 (narrow)	15.2
5.	Sea level	79.1 (rise)	7.5 (fall)	13.4
6.	Northerly monsoon winds (*Kaskazi*)	81.3 (stronger)	7.8 (weaker)	10.9
7.	Calm period (*Leleji*)	33.3 (longer)	23.8 (shorter)	42.9
8.	Southerly monsoon winds (*Kusi*)	60.7 (stronger)	11.5 (weaker)	27.9

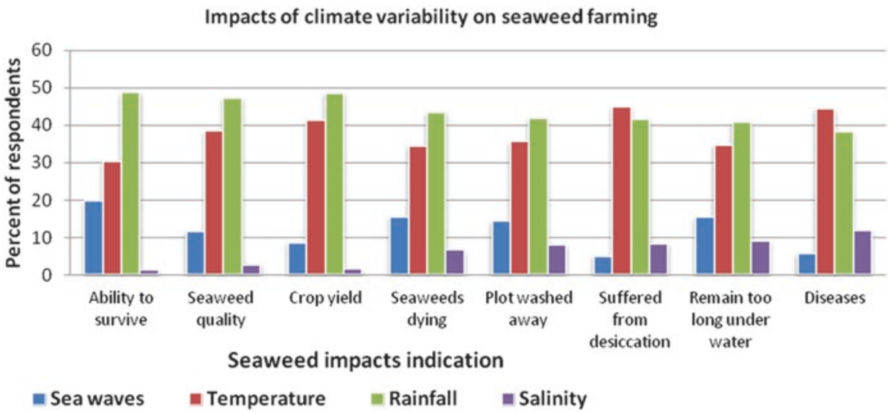

Fig. 5 Impacts of climate variability on seaweed farming

Impacts of Climate Variability on Mwani *Farming*

The community perception on the changes of climate variables was evidenced by persistent decrease and unreliability of rainfall (76%) and the persistence of high temperatures and speedy dry wind in their areas (19% and 4.3%, respectively). Increase in the sea surface temperatures had enormous effects on seaweed farming to the extent that famers experienced low yields of crops during the period (GOZ 2012).

Data from this study revealed, in this respect, that changes in climate factors such as sea waves, temperature, rainfall and salinity have had serious impacts on the seaweed production industry in Zanzibar. Majority of the respondents (98.6%) in the study villages perceived that seaweed farming had been affected by climate change and variability as indicated in Fig. 5. The reported impacts of the changing climatic variables included the inability of seaweed to survive (49%), reduced seaweed quality (47%), decreased crop yield (49%) and washing away of seaweed seedlings (42%) during storms and flooding. Temperature variability was alleged by the local community to have facilitated increases in vulnerability of seaweed to new diseases (44%) and to desiccation (45%). On the other hand, salinity was not seen to cause any major threats to seaweed farming.

These results corroborate the observations made by Msuya (2012) elsewhere that seaweed die-offs caused by persistent rise of temperature along the seaweed farming areas in Zanzibar had caused production to decline since 2001. Msuya (2012) also attributed the production decline to severe cases of epiphyte infestation coupled with high incidence of ice-ice disease that occurs during extremely high water temperature and high light intensity in hot-dry *Kaskazi* season. Recent dramatic decline in production has also been seen in many carrageenophytes (*Kappaphycus*) farming countries (e.g. the Philippines) (Loureiro et al. 2015). Such production deficits were also caused by rising sea temperatures, which caused bleaching of the thallus, making the cultivated individuals more susceptible to viruses and bacteria from the genera *Vibrio*, *Cytophaga*, *Pseudomonas*, *Pseudoalteromonas*, *Halomonas* and *Flavobacterium*, as well as to diseases and epiphyte infestations, such as 'goosebumps' caused by filamentous red algae of the genus *Neosiphonia* spp.

In the FGDs many *Mwani* farmers claimed that seaweed production was dramatically declining as the number of farmers doing seaweed farming had also been falling down. As observed in Fig. 6, while in 2014 about 27% of the *Mwani* farmers were able to produce more than 200 kg per season, only 20%, 14% and 6% of farmers were able to produce Mwani in 2015, 2016 and 2017, respectively. By 2017 a majority of the farmers (60%) produced less than 50 kg per season.

These results show that seaweed farming is no longer an attractive business and only engaged by people who have no alternative reliable incomes in the village.

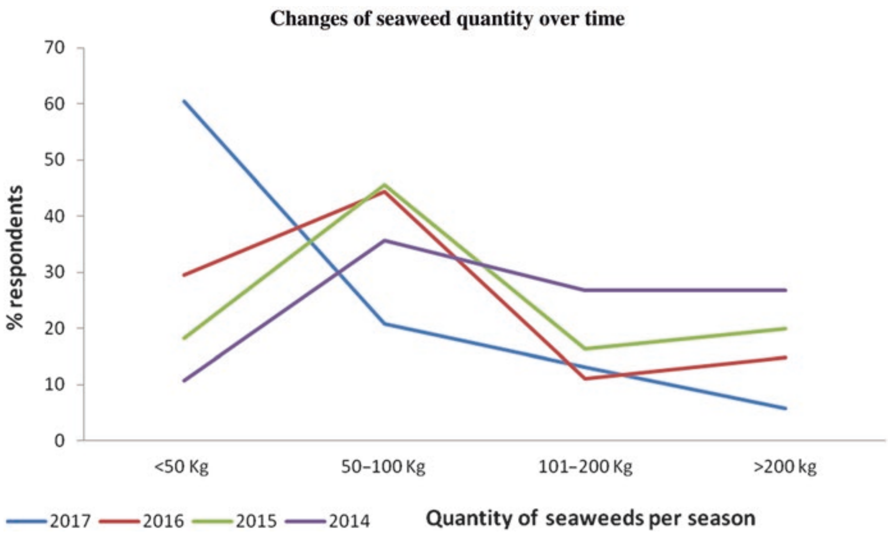

Fig. 6 Changes of seaweed quantity over time period

For example, total *Mwani* production in Paje village shows that between 1989 and 1995, it was 45–50 tons per month, but currently production had decreased to 7–10 tons per month. Similarly, a manager employed by a seaweed company in the Uroa-Matemwe area mentioned that the amount of seaweed purchased had decreased such that about 70–80 tons per month were bought in 2000 compared to 55–60 tons per month in 2003, to 35 tons per month in 2006, and to just 7–13 tons per month in 2010 (Unpublished reports from seaweed office Paje and Matemwe stations). As represented in Fig. 5, the major causes of this decline is due to the impacts of changing the climatic variable specifically temperature, precipitation and sea waves.

During the focus group discussion, it was revealed that the seaweed (*Mwani*) in the name cottonii is declining in terms of growth rates and productivity such that farmers abandoned this seaweed variety. *Cottonii* has been known by its higher prices compared to other variety the *Spinosum* which is currently under cultivation. Changing of weather patterns and other environmental condition has been mentioned as the major factors contributing to the abandonment of *cottonii*. The changing of weather including increasing of seawater temperature has also cause the seaweed diseases like ice-ice and others. But also prevalence of strong waves leads to loss of newly seaweed plants.

Responses of *Mwani* Growers to Climate Change Impacts

While there are several climate change impacts on the growth, survival and production of mwani, villagers have developed diverse adaptation measures to cope with the situation. To improve seaweed growth and survival, majority of mwani growers (59% of respondents) engaged on frequent tending operation in order to immediately identify any climate risks and impacts caused by heavy storms and waves. In preventing the incidence of seaweed being cut from the sticks and being washed away by the strong winds, farmers used strong strings and sticks (5%) and harvest the crops before the onset of strong winds (9%). At the same time, farmers developed mechanisms of fixing stones to strengthen the fixed poles or sticks (23%) which also made in big size to withstand storm surge and protect the mwani plots from being washed away by the strong waves. Planting of mwani in creeks including close to streams or mangroves, sea grasses and enclosed areas (4% of respondents) is also an adaptation mechanism developed by farmers to prevent the young/recent planted mwani from excessive desiccation and remain too long underwater (Fig. 7).

Despite high engagement on these coping strategies, mwani growers reported several other adaptation measures that they think are more appropriate to reduce the impact of high temperature and other climatic stressors and thus improve mwani growth and survival. These include planting of mwani in deep water (41% of respondents), using boats and improved equipment for regular planting and tending operation (25% of respondents) and planting of tolerant seaweed species to desiccation and high salt (34%). However, putting in practice these adaptations measures have become a serious challenge to mwani growers since these practices

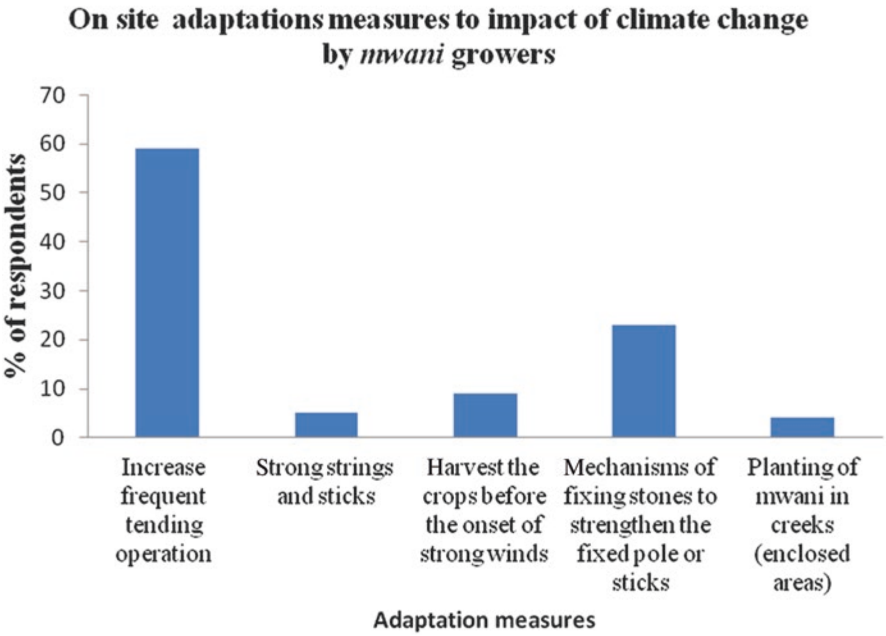

Fig. 7 Adaptations measures towards impact of climate change to *Mwani* growers

Table 7 Coping mechanism over impacts of climate variability on seaweed farming

S/N	Coping mechanisms before harvesting	% of responses	Coping mechanisms after harvesting	% of responses
1.	Move to high water to avoid exposure	41	Diversification of income and other economic activities	30.6
2.	Planting tolerant seaweed species	34	Selling wild seaweed products	5.6
3.	Improved equipment for regular planting and tending operation	25	Adding the value chain of seaweed farming	52.7
4.			Drying seaweed under special constructed shelter for storage and drying.	11.1

have financial and technical support implications which is difficult by majority of mwani growers to achieve.

As the general trend showing declining trend of seaweed productivity and quality, various measures have been taken to reduce the impacts (Table 7). Farmers reported that due to lower productivity of seaweed at a farm level, some farmers (5.6% of respondents) are collecting and selling wild seaweed products since they catch same market price as the planted varieties. Other farmers (30.6%) viewed that diversification of income sources such as small-scale agricultural practices and livestock/poultry production and adding value on the seaweed products (52.7% of the respondents) are the important adaptation mechanisms to supplement for the climate loss resulted by low production of seaweed as they are impacted by climate change. Either large proportion of farmers carried the harvested seaweed to their homes, drying under special constructed shelter and kept in a storage home after drying to improve seaweed quality (11.1% of the respondents).

Whilst there are different impacts of climate change to seaweed production at the farm scale, seaweed desiccation and diseases are major climate problems reported by Mwani growers in the study sites. However the adaptation measure of these reported climate change impacts is not clearly known. Therefore the *Mwani* growers requested the responsible authority to provide appropriate knowledge, practices and disease-tolerant seaweed species that can cope with the existing climate change challenges. This will help to improve the seaweed productivities while improving farmers' income and general life standards of seaweed growers in their areas.

Conclusion and Recommendations

Conclusion

Climate change is one among the key direct drivers to diverse marine ecosystems, especially coral reefs, marine fisheries and *Mwani* productivities. Thus understanding the adaptation strategies to counteract the effect of the coastal communities in carrying out the production of *Mwani* in a changing climate is inevitable affect. Despite the challenges faced by this industry, this study is concluding that *Mwani* growing has become the most popular alternative livelihood activity that is engaged by majority of females than any other climate-sensitive sectors in Unguja Island, especially in families with limited livelihoods. The intervention is run in family basis where female are the leaders with other young close family relatives usually assisting them to perform the activity. *Mwani* growing is a tedious task requiring a huge work force from initial planting to selling points. Consequently a majority of the *Mwani* farmers owned very small plot sizes, ranging between 0.25 acre (42.3%) and 0.5 acre (30.8%) per every farming season. Preferable good seasons for planting seaweed are during the southeasterly winds (*Kusi*) between June and September because relatively low temperatures favour the initial growth of seaweed plants.

Seaweed famers have a wealth of indigenous knowledge related to climate change of their area. They believed that seaweed planting in Unguja is affected by both changes of climate factors over the last 20 years and non-climatic stressors. Important climatic variables that have affected seaweed include increasing of water temperature, wind speed, sea waves and a decrease and irregular in rainfall patterns and salinity. The seasons have become unpredictable such that the hot seasons (*Kaskazi*) resemble the cool dry seasons (*Vuli*) and vice versa.

Other factors include dynamism of coastal line and occurring of sea-level rise. High temperature and unpredictable rains increase vulnerability of seaweed crops to be affected by diseases. Several indicators verified the changes of climate variables including long-lasting high temperature, increasing frequent events of unpredictable rainfalls and winds and wave actions in the areas. These changes in weather patterns and seasons have led confusion among seaweed farmers to continues farming and have affected the livelihood activities of the local communities including seaweed farming.

Changes on climate factors have serious impacts on the seaweed productivity in Unguja. Rainfall was reported by seaweed growers to affect seaweed productivity especially in the ability to survive (49%), reduce seaweed quality (47%), crop yield (49%), dying of seaweed (43%) and washing away newly seaweed plants (42%), while temperature variability increases vulnerability of seaweed diseases (44%) and suffering from desiccation (45%). *Mwani* production has generally changed showing declining trend over the last 5 years. In 2014 about 27% of the *Mwani* farmers were able to produce more than 200 kg per season compared to 2015, 2016 and 2017, where only 20%, 14% and 6% of *Mwani* farmers, respectively, were able to produce more than 200 kg per season. The decline of productivities has consequently discouraged the farmers to engage in these activities in Unguja Island.

Since the seaweed farmers are most vulnerable to the impact of climate change, they develop and number of adaptation strategies to cope and adapt to reduce the impacts of climate. The adaptation measures that are in practice include using heavy stones and poles to fix seaweed and planting of mwani in creeks and enclosed areas to reduce the exposure and impacts of strong winds. To improve mwani productivities under climate change impacts scenario farmers are collecting and selling wild seaweed species to supplement for the lost amount of seaweed caused by rainfall and temperature in the area. Carrying of harvestable mwani to homes and drying under special constructed shelter and kept in a storage home after drying are adaptation measure used by farmers to improve seaweed quality. Since the farmers have little knowledge on the drying and disease incidences that are facing seaweed crops in the farm, they failed to implement any adaptation measure, and this has seriously discouraged many farmers to continue with the business.

Recommendations

Despite number of strategies taken by *Mwani* growers to cope and adapt to the impact of changing climate, new research is needed to develop new adaptation technologies that will help farmers to counteract the effect of desiccation and associated diseases aggravated by climatic variables in the field. In addition these new research areas are also required to address the impacts of non-climatic factors on seaweed production especially the impact of low market prices of mwani which discourage farmer to continue with the intervention. On the other hand, farmers should develop more effective adaptation practices that could avoid some of the potential impacts and enhance resilience to climate change and other non-climatic stressors.

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Poverty Levels and Vulnerability to Climate Change of Inshore Fisher-Mangrove-Dependent Communities of the Rufiji Delta, Tanzania

Claude Gasper Mung'ong'o and Vicky H. Moshy

Abstract This chapter assesses how fisher-mangrove-dependent societies such as those of the Rufiji Delta in Southern Tanzania are being affected by and what is their capacity to adapt to climate change impacts that are occurring in the area. The objective of the study was not only aimed at improving linkages between the practice of community-level assessments and efforts to develop and implement vulnerability-reducing interventions; it was also an attempt to address the critique about the need for a more integrative, community-engaged approach to assessments in vulnerability scholarship. This study aimed to measure three key dimensions of vulnerability, i.e. exposure, sensitivity and adaptive capacity. Socio-economic data was collected from two purposely selected coastal communities in the Rufiji Delta. Sites were selected to provide a spectrum of social and environmental conditions. For each community, data were obtained on exposure, sensitivity and adaptive capacity. Findings show that, despite differences in wealth status, community members of the study villages generally shared similar socio-economic characteristics and were thus anticipated to be impacted in similar magnitudes. What was needed was community education on climate change impacts and the presence of social networks to assist in creating awareness on climate change impacts and livelihood diversification to reduce direct dependence on the fisher-mangrove ecosystem. Such livelihood diversification strategies included provision of capital for small businesses and establishing environmentally friendly activities such as compound-based livestock keeping (zero-grazing) and modern beekeeping.

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Introduction

There is growing consensus among environmental change researchers that treating communities as separate from their ecological contexts can lead to research that overlooks critical socioecological interdependencies and subsequently to recommendations for reducing vulnerability that are not mindful of the effects remedial actions have on various social groups and ecosystems (McDowell et al. 2016). This point is in fact a confirmation of an earlier concern raised by authors such as Adger (2000) who argued that although 'there is a clear link between social and ecological resilience, particularly for social groups or communities that are dependent on ecological and environmental resources for their livelihoods, it is not clear whether resilient ecosystems enable resilient communities in such situations'.

This chapter sets out to answer the questions of critical importance to resource managers, stakeholders and scientists alike, i.e. of how fisher-mangrove-dependent societies such as those of the Rufiji Delta in Southern Tanzania are being affected by and what capacity do they have to adapt to climate change impacts that are occurring in the area. The objective of the chapter is not only aimed at 'improving linkages between the practice of community-level assessments and efforts to develop and implement vulnerability-reducing interventions'; it is also an attempt to address the critique offered by McDowell et al. (2016) about the need of a more integrative, community-engaged assessments in vulnerability scholarship. The data used in this chapter is derived from a socio-economic study done in the Rufiji Delta in May 2016.

Methods and Materials

Study Area

Location

This study was conducted in the mangrove ecosystem in the Rufiji Delta, Southern Tanzania. The delta covers 53,255 ha (Semesi 1992) located between latitudes 7°50′ and 8°03′ S and longitudes 39°15′ and 32°17′ E 7.47° E. Nyamisati and Mchungu villages are found in the northern part of the Rufiji Delta in Rufiji District (Fig. 1). The delta is about 250 km south of Dar es Salaam. Mchungu village which is in Mwambao ward has two hamlets, i.e. Mipekeso and Mititimbo. It has a total number of 392 households.

Geology and Soils

According to Semesi (1992), the land in the Rufiji Delta is not stable. Banks are scoured by the river currents and silt deposited again at the convexities of curving water channels. The rain-swollen river deposits its detritus load on reaching the

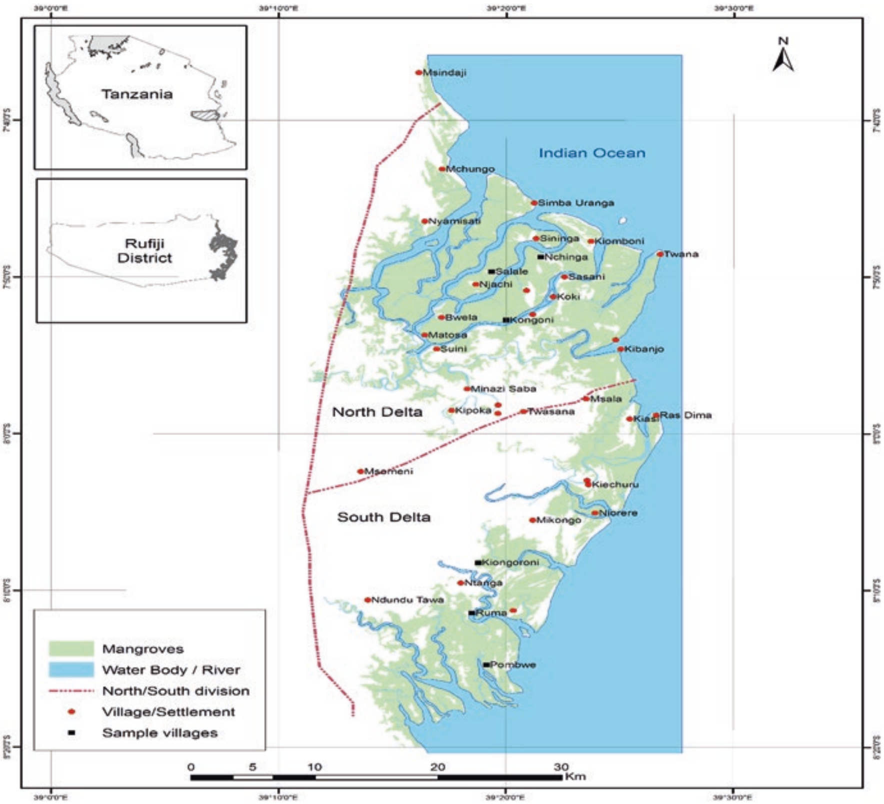

Fig 1 Location of the study area in Rufiji District, Tanzania. (Source: Adopted from Mwansasu 2016)

slack waters in its delta and rapidly builds up new mud banks. According to FGD, for example, in the 1980s, Mchungu village was bordered with a coastal beach. Following increment in the frequency of flooding paralleled with intensive and extensive siltation of Rufiji River in subsequent years caused the diversion of the river, filling the beach with mud and creating favourable conditions for germination of some of mangrove species in the places where there was a beach before (Plate 1).

Rufiji Delta is 23 km wide and 65 km long protruding 15 km into the Mafia channel. It is overlain by superficial alluvial material mainly sand, silt and clay resulting to a large degree from suspended sediments transported from the Rufiji Basin (Semesi 1992). Deposition of sediments at the middle of channels is still increasing; small islands are created and some channels are blocked. The sediments have an impact on transport in the delta because larger vessels can now no longer pass through most channels or passage is only possible during high tides.

Plate 1 Part of the beach at Mchungu impacted by sedimentation. The mangroves' covered area was part of the beach in the 1980s according to the local narratives. (Source: Photo by Anselm Mwajombe, May 2016)

Climate

The study area is characterized by a dry *Kiangazi* period (January to March); the long rainy *Masika* season (March to May); a mild cool and windy period locally known as *Kipupwe* (June to August/September), and the short rainy season (*Vuli*) coming in October and December. The average temperature of the study area varies between 24 °C during the months of June and July and 28 °C during the period of December to February. Temperature in Rufiji District ranges from 25 to 41 °C throughout the year and has two rainy seasons ranging from 750 to 1250 mm: short rains (October to December) and long rains (February to May) (Lupembe 2014; Mwansasu 2016). The population of the district is about 182,000 with the Ndengereko as the largest ethnic group (Mkindi and Meena 2005).

Hydrology

The study area is drained by the Rufiji River. According to Semesi (1992), the Rufiji River is the largest river in Tanzania. It has three main tributaries, i.e. the Great Ruaha, Kilombero and Luwegu rivers. The delta is also influenced by tides which reach about 25 km upriver. The delta is traversed by numerous deltaic branches of the Rufiji River. There are about 43 islands in the delta. The river has a mean flow of approximately 800 m^3/s with a strong seasonal flow pattern with flood peaks around April. Its fertile lower floodplain is up to 20 km wide, and maize and paddy cultivation is dominant. The river developed a delta partially covered by 500 km^2 of mangroves, the largest stand in East Africa (Semesi 1992).

Vegetation

Rufiji District is mainly covered with tropical forest and grassland vegetation types. The Rufiji Delta forms part of the Rufiji River basin which covers an area of 177,000 km^2. The Delta contains the largest area of estuarine mangroves in East Africa and provides nursery grounds for about 80% of Tanzania's prawn fishing industry. Eight of the ten mangrove species occurring in Tanzania are found in the Delta (Wagner and Sallema-Mtui 2010). Common mangrove species in the Rufiji Delta are *Rhizophora mucronata*, *Sonneratia alba*, *Ceriops tagal*, *Avicennia marina* and *Bruguiera gymnorrhiza*. Other species are *Lumnitzera racemosa*, *Heritiera littoralis* and *Xylocarpus granatum*. Mangrove species often occur in more or less pure stands, and where stands are mixed, a single species tends to dominate.

Generally, *Rhizophora mucronata* and *Avicennia marina* are the most common species. The inner, landward zone is frequently occupied by *Avicennia marina* and occasionally by *Ceriops tagal* or *Lumnitzera racemosa*, while the seaward zone is occupied by *Sonneratia alba* or *Avicennia marina* (Semesi 1992).

According to the Rufiji Delta Mangrove Forest Reserve inventory exercise of 2011, the Rufiji Delta is divided into three parts, namely, the northern delta, the central delta and the southern delta. The forested area in the northern delta has changed from 24,555.5 ha in 1991 to the present 17,555.7 ha due to rice farming and mangrove pole cuttings, among others. The central delta has an area of 15,172 ha, while the southern delta has a total area of 13,526.7 ha. The mangrove vegetation of the Rufiji Delta often occurs in more or less pure stands. In situations where stands of mixed species composition occur, a single species still tends to dominate.

The Rufiji Delta Mangrove Forest Reserve was officially gazetted as a forest reserve in 1928. The mangroves have been extending to over 500 km following the flooding of the Rufiji River during the El Niño rains in the 1980s. Flooding of the Rufiji River caused sedimentation due to erosion which created a favourable condition for mangrove growth. The Rufiji Delta Mangrove Forest Reserve is the only reserve in Africa that allows harvesting and occupies over 5000 ha.

Conceptual and Theoretical Framework

This study aimed to measure three key dimensions of vulnerability, i.e. exposure, sensitivity and adaptive capacity, as defined and expounded by Cinner et al. (2011) and Ellison (2012). Socio-economic data was collected from two purposely selected coastal communities in the Rufiji Delta. Sites were selected to provide a spectrum of social and environmental conditions. For each community we obtained data on exposure, sensitivity and adaptive capacity as described below.

Exposure

Past mangrove degradation data and associated oceanographic conditions across the sites/communities were collated from literature and/or documentary review of existing information and were used to produce a predictive model of mangrove susceptibility to thermal stress and associated mangrove as proposed by Malleret-King et al. (2006) and Maina et al. (2008). The variables investigated during this vulnerability assessment had the following components:

- Compilation of local community knowledge about climate change impacts, mangroves and fishery dynamics
- Information on mangrove resource usage and fish catches

Sensitivity

Consistent with other studies and protocols (e.g. Malleret-King et al. 2006; Marshall et al. 2010, etc.), a metric of sensitivity was developed based on the level of dependence on fisheries and mangrove harvesting by wealth groups. This indicator was developed based on *household surveys*. Sampling of households within the communities was based on wealth ranking, followed by a systematic sampling design. We conducted household surveys in the two selected villages, depending on the population of the communities and the available time to conduct interviews per community.

To develop the sensitivity metric, the respondents were asked through *FGDs* and *key informant interviews* to list all livelihood activities that brought in food or income to the household and ranked them in order of importance. Occupations were grouped into the following categories: fishing, selling marine products, tourism, and farming of cash crops, salaried employment, petty business, other, and 'none'. To better understand the sensitivity to the impacts of temperature events on fisheries, we considered fishing and fish trading together as the 'fisheries' sector and all other categories as the 'non-fisheries' sector. This grouping has parallels in agricultural economics where activities are classified as 'farm' and 'nonfarm'.

Our metric of sensitivity incorporated the proportion of households engaged in fisheries and mangrove harvesting by wealth groups, whether these households also engaged in other non-fisheries occupations (i.e. 'linkages' between sectors), and the directionality of these linkages (i.e. whether respondents ranked fisheries as more important than other activities). Firstly, the aim was to capture the ratio of fishery to non-fishery-related occupations. Secondly, it was to capture the extent to which households dependent on fisheries were also engaging in non-fishery livelihood activities, including mangrove harvesting. This approach decreased the level of sensitivity when many households were engaged in both occupational categories. Thirdly, it was meant to capture the directional linkages between fisheries and non-fisheries such that communities were seen as more sensitive when households engaged in fisheries and non-fisheries occupations consistently ranked the fisheries and mangrove harvesting sectors as more important than other livelihood activities.

Social Adaptive Capacity

Here, we employed a social adaptive capacity index developed by McClanahan et al. (2008). Based on both the *household surveys* described above and *key informant interviews*, we derived eight indicators of adaptive capacity as follows:

- Recognition of causal agents impacting marine resources (measured by content organizing responses to open-ended questions about what could impact the number of fish in the sea)
- Capacity to anticipate change and to develop strategies to respond (measured by content organizing responses to open-ended questions relating to a hypothetical 50% decline in fish catch)
- Occupational mobility (indicated as whether the respondent changed jobs in the past 5 years and preferred their current occupation)
- Occupational multiplicity (the total number of person-jobs in the household)
- Social capital (measured as the total number of community groups the respondent belonged to)
- Material assets (a material style of life indicator measured by factor analysing whether respondents had 15 material possessions such as vehicle, electricity and the type of walls, roof and floor)
- Technology (measured as the diversity of fishing gears used)
- Infrastructure (measured by factor analysis of infrastructure items such as hard top roads, medical clinic, schools, etc.)

The indicator of occupational multiplicity is fundamentally different from our measure of sensitivity since it builds on the households' complete portfolios of occupations and is, therefore, able to capture a household's general ability to adapt to change (McClanahan et al. 2008). The sensitivity measure, in contrast, only focuses on the extent to which households are engaged in fishery versus non-fishery-related occupations, including mangrove harvesting and how they rank their relative importance. These eight indicators of adaptive capacity were, therefore, combined into a single metric based on weightings derived from expert opinion as proposed by McClanahan et al. (2008).

Results and Discussion

Identifying Demographically Vulnerable Groups

Different groups in the same community or region may experience different levels of vulnerability to changing climate (Malleret-King et al. 2006). *Demographically vulnerable groups* are those that, because of their particular demographic or social characteristics, are more vulnerable than others in the broader community. Particular demographic characteristics may result in varying levels of exposure to certain types of climate hazards (e.g. location of home, needed resources and infrastructure in relation to hazard-prone areas), how sensitive people are to hazards (age, health condition, occupation, economic status or dependency on impacted resources) and their adaptive capacities (attitudes and knowledge, skills, economic status, social affiliation and willingness and ability to change). Demographic data from this study are presented below.

Livelihood Activities and Social Conditions: An Overview

Approximately 220,000 people live in Rufiji District, the majority in the Rufiji floodplain and the Delta. According to the 2012 National Census, Rufiji District had the lowest population density of any district in Tanzania, namely, 16 persons per km^2 compared to the national average of 50.6 persons per km^2. The level of education was comparatively low. For example, less than 60% of the respondents of a socio-economic survey carried out by Mbiha and Senkondo in 2001 had attended formal education.

According to the FGD and key informant interviews, household income in Rufiji Delta was generally derived from activities such as agriculture, fisheries and forestry. Cultivation occurred at the fringe zones of the mangrove area, and along some of the main rivers, where rain season flooding brought in fresh water to the fields. With time, the soil in the rice fields became too saline. New areas were then cleared for agriculture, while the old fields were abandoned. The location of rice farming demonstrates the natural dynamics of the delta. Contrary to the situation before the major river shift in the 1970s, it was observed during this study that rice farming was now mostly being carried out in the north of the delta where Mchungu village is located. After the river avulsion, the southern delta communities were forced to temporarily migrate to cultivate their rice outside the delta.

Agriculture was the main occupation (93% of the household) in the Rufiji floodplain and the delta. By 2014 the cash crops grown were paddy, cashew nuts and sesame (Lupembe 2014). Different crops were grown with rice as staple foods. These included maize, sweet potatoes and millet (being grown by 76% of the households in the lower Rufiji River Valley (Lupembe 2014)). Fruits such as mangoes, oranges, pineapples, paw paws and jack fruits were also grown for subsistence, with a proportion being sold for cash (Mkindi and Meena 2005).

Fishing was carried out in the upstream of the main Rufiji River, in the delta and in some of the inland oxbow lakes formed by the flooding of the river. To date, the delta waters support one of the richest wild prawn-fishing grounds in Tanzania, providing more than 80% of the country's prawn exports (Mwansasu 2016).

During the time of this study, mangroves in the delta contributed to much of the forest harvesting for timber and logging in the area. The mangrove products were extensively used locally in canoe construction and as building materials. But trading in mangrove poles also occurred outside the delta, including in places like Dar es Salaam and Zanzibar. Although regulated through a system of permits issued by government authorities, poor control and enforcement of laws have occasionally led to some illegal harvesting (Mwansasu 2016).

Plate 2 The road to Mchungu village during the rainy season. It is a hub called 'Fulanguo' connecting the village and the main road that a person must pass through using motorbikes or on foot. (Source: Photo by Anselm Mwajombe, May 2016)

In general, however, trade in fish and other marine products is encumbered by poor infrastructure. Many of the roads in the delta are impassable during the rainy season (Plate 2). In addition, market opportunities are erratic. In the case of fish, electricity is in poor supply, which causes problems with storage facilities (Mbiha and Senkondo 2001).

On the positive side, one study in the area (Lupembe 2014) has shown that, if sustainably managed, the Rufiji Delta mangrove ecosystem could have a high potential as a carbon sink useful for climate change mitigation. The ecosystem was estimated to have 40.5 t ha^{-1} of aboveground carbon, 21.08 t ha^{-1} of belowground carbon (roots) and 98.57 t ha^{-1} of soil organic carbon (Lupembe 2014).

Social Stratification in Nyamisati and Mchungu Villages

Poor people tend to be the most natural resource-dependent communities in many developing countries. They are the most severely affected when the environment around them is struck by a serious hazard like drought, floods or climate change-induced sea level rise or simply degraded '…or their access to the resources is limited or denied' in any way (Ireland et al. 2004).

On the other hand, the coastal communities also have many opportunities to improve their livelihoods if well utilized. To get a clear picture of what the social stratification of the communities looked like, a wealth ranking exercise was done in Mchungu and Nyamisati villages in the Rufiji Delta a la Grandin (1988). The ranking was performed by teams of selected villagers from each village categorized by

Table 1 Percentage distribution of wealth groups in Mchungu and Nyamisati villages (2016)

Wealth group	Villages	
	Mchungu (%)	Nyamisati (%)
Well-off	8.8	25.0
Middle	23.5	34.1
Poor	67.6	40.9
Total	100.0	100.0

age and gender. Lists of assets that were perceived as 'wealth' in the villages were, first of all, compiled.

In both villages these included block/brick houses with iron roofs, cultivable land of four acres and above, country motor vehicles or motorized boats and livestock (mainly goats). The groups were also identified by the nature of businesses they were involved in, such as running shops/kiosks, harvesting and sale of mangrove products, prawns and crabs. The importance of each of these assets as criteria for assessing wealth or social status of villagers was then determined.

Characterizing wealth groups in the two communities was then done by determining the importance of each of the assets mentioned above as criteria for assessing wealth or social status of villagers. This activity was followed by establishing the definition of a 'household' among coastal communities.

After a protracted discussion on the ranking criteria, the ranking teams then ranked all the names of heads of the households. The names were read out aloud from *Vitongoji* (sub-villages – the smallest administrative unit in rural Tanzania; sing. *Kitongoji*) registers developed by the respective *Vitongoji* chairpersons in collaboration with the Village Executive Officers of the two villages. Placing a particular name in a specific group category was based on consensus of all the participants in the ranking exercise. Table 1 illustrates the wealth groups identified and categorized in Mchungu and Nyamisati villages with their different socio-economic characterizations.

The *well-off* group had a variety of the identified assets, including one or two block/brick houses with iron roofs (Plate 3), cultivable land of four acres and above, a car and one or two fishing boats for renting to fishers from the middle and poor groups. A boat and its fishing gear were rented at Tsh 2000 per boat per day. Some of these households had 20 or more goats. The group was also identified by the nature of businesses they were involved in. Some households were running shops selling a variety of household items, while others were involved in harvesting and selling of mangrove products, prawns and crabs.

Households in the *middle group* had fewer and less valuable assets, among them. These included hard wood mud houses with corrugated iron roofs as exemplified by Plate 4, some pieces of cultivable land of 1–2 acres, a motor bike, a bicycle and/or three to five fishing canoes. Some kept between 50 and 100 poultry for sale. The main economic activities of these households in the village were fishing using local canoes (*mitumbwi*) and some subsistence agriculture using the hand hoe.

Many of the households who practised agriculture in this wealth group grew food for household consumption and for sale. The range of productivity was, however,

Plate 3 An iron-roofed brick house for a 'well-off' household in Nyamisati village. Note the TV dish on the roof. (Source: Photo by Anselm Mwajombe, May 2016)

Plate 4 A hard wood mud house with corrugated iron roof OF 'middle wealth group' in Nyamisati village. (Source: Photo by Anselm Mwajombe, May 2016)

relatively low with households harvesting between 40 and 60 bags of paddy per season. By the time of this study, a bag of rice cost about Tshs 40,000.[1] Some of the households that farmed in this group also fished, both for household consumption

[1] The exchange at the time of this study was 1US$ = Tsh 2170.

Plate 5 A twig and mud house with makuti (dried palm fronts) thatched roof in Mchungu village. While such houses are widespread in Mchungu, in Nyamisati, they are commonly seen in the periphery of the village indicating that poverty was much more widely spread in Mchungu than in the latter village. (Source: Photo by Anselm Mwajombe, May 2016)

and for sale. In a good season, those who held fishing permits could earn between Tsh 500,000 and Tsh 700,000.

Generally, households of the *well-off* and *middle wealth groups* were multi-active with the ability to switch between economic activities through livelihood diversification. Households in the *poor* were, characteristically, the least economically endowed. The majority had twig mud houses with *makuti* (dried palm fronds) thatched roofs (Plate 5). Very few of them owned bicycles as a means of transport. Their main economic activities included small-scale fishing, mainly for subsistence by hiring canoes from others. They had no fishing gears or permits as they could not pay for them. Many of the women in this group of households engaged in petty business such as food vending (*mama ntilie*), making mats and other raffia handcrafts, day labouring, fire wood collection and charcoal making for sale.

Social Infrastructure in Mchungu Village

During the time of this study, Mchungu village had only 1 primary school with 5 teachers, (3 women and 2 men) and 300 pupils. The school had only three teachers' houses. The village had no secondary school. A student had to travel some 13 km to Nyamisati where there was a secondary school. The village had one dispensary with only one nurse. They had no ambulance and depended on the government ambulance at Nyamisati dispensary. When needed, a patient had to contribute fuel costs which amounted to Tsh 60,000 (an equivalent of US$ 30) a trip.

Transportation was poor with the village depending only on motor bikes for transportation. Communication was via mobile networks Airtel and Halotel whose connectivity was fairly strong. There was no electricity which negatively impacted fish business, especially for refrigeration. There was no tap water. Some people who had corrugated iron roofs used rain water harvesting techniques and water from shallow wells. Water for drinking and cooking was bought at Tsh 800–Tsh 1000 per 20 L plastic container (*dumu*).

Socio-economic Conditions in Nyamisati Village

Nyamisati village, on the other hand, is in Salale ward. It had three hamlets, i.e. Mjengea, Kihigi-Shule and Pwani, with a total number of 567 households. The total area of the village was 2225 ha. The main economic activities included agriculture, fisheries, businesses and handcrafts. Agriculture was mainly mixed farming comprising of cultivation of cassava and cashew nuts, whereas paddy was a stand-alone crop. On average, 574 acres was under paddy cultivation, whereas cashew nut farming covered almost the same area. Cassava cultivation covered 266 ha. Each household in the 'well-off' and 'middle wealth' groups had an average of two acres of arable land. Agriculture was overwhelmingly characterized by the hand hoe. Hence, productivity was low, with farmers harvesting around ten bags of paddy, six bags of cashew nuts and 1 ton of cassava. Paddy was the main crop used both as a food and cash crop. Data from this study show that a half of the households (i.e. 287 households) grew paddy (Plate 6).

Plate 6 Paddy cultivation within the delta of Rufiji River. Ever since the Rufiji mangrove forest was declared a forest reserve, it has been a legal quagmire, with 'legally established villages' being located in a reserved forest where human habitation is prohibited by law. (Source: Photo by Anselm Mwajombe, May 2016)

Fishing was the second economic activity engaging about 60% of villagers of Nyamisati. As shown above, most of the fishers were from the *middle wealth group.* Types of fish caught included prawns and other species like *chewa*, *kungu*, *papa* (sharks), *hongwe*, *sanje* and *kolekole.* The average number of kilogrammes fished per year was between 25,000 and 30,000. The fishing gear mostly used for fishing included hooks and nets (*mishipi*).

Data from FGD and key informants show that temperature variations in sea water impacted the fish catch. During the rainy season, for example, sea waters were cooler, and fish were often available on the shallow shoreline fishery. Subsequently, fish became plenty and fish catches increased. However, during the dry season when temperatures were high, sea water remained warmer most of the time, and fish migrated to the deep sea to seek favourable temperature conditions. Consequently, the number of fish in the shallow shoreline fishery declined and fish catches decreased.

The data also show that a sizable number of households from the *well-off* and the *middle wealth groups* were also engaged in small businesses selling some mangrove products, running small shops, etc. As shown for Mchungu village, businesses related to natural resources included sale of firewood, timber, traditional medicines, building materials and charcoal making. Timber, building poles and charcoal are mostly derived from mangroves. Some households from the *poor* engaged themselves in handcrafts, especially mat making, mainly for subsistence, although some artefacts were also sold to raise household incomes. Similarly, petty businesses included running of supply kiosks and food vendors (*mama ntilie*).

Dependence on Vulnerable Resources and Services

Dependence on resources and services is a measure of how dependent households are on local resources that are vulnerable to climate impacts for their food security, income, physical protection or other sociocultural aspects (Malleret-King et al. 2006). These resources might be natural, such as ecosystems and their products and services, or man-made infrastructure, such as jetties, coastal roads and other facilities and services, including schools, public health centres and utilities (e.g. power plants and water reservoirs). The man-made resources of the study area have been described in Mbiha and Senkondo (2001). Let us here dwell a little bit on the characteristic behaviour of the main natural resource in the study area, the delta of the Rufiji River.

As already pointed out, paddy was the main crop grown in the study area. Formerly, the crop was grown in upland areas. However, due to climatic variability and land exhaustion, farmers migrated to the delta which offered favourable conditions for paddy. This can be explained as follows: during the rainy season, the Rufiji River floods, and delta areas become occupied with fresh water. The salinity is eventually washed away, and since the plains are naturally fertile due to siltation from the upstream, the conditions so created become favourable for paddy. Conversely, during the dry season, river flow declines, and salty water dominates

Plate 7 Farmers weeding rice farms in Rufiji Delta. Apart from the clearance of the mangrove forests for paddy farms, communities in Rufiji District also rely on the mangrove forest reserve for forestry business through both legal and illegal harvesting. Illegal harvesting and encroachment have contributed to unsustainable clearance of mangroves where large trees are harvested for timber and logging. (Source: Photo adopted from Lupembe 2014)

the flood plains creating saline conditions, which do not support crop growth. Meanwhile, weeds are permanently suppressed from germinating. Farmers are thus attracted to practice paddy farming that entails clearing of mangroves (Plate 7).

Data from the present study show, however, that mangrove utilization by sample households was fairly low. At Mchungu village, for example, only 17.6% of the sample households used mangroves as building material, charcoal and firewood. And among those who used mangroves for such purposes, 11.8% came from the *poor*. In Nyamisati only 6.8% of the households used mangroves for building material, charcoal and firewood. Out of these households, some 4.5% belonged to the *poor*.

Clearance of mangrove forests for agriculture and logging has, nevertheless, affected an important economic activity in the area – fishing. Despite being the major economic activity, fishing was said to be declining due to continued degradation of mangrove fish breeding sites. Agriculture also caused water pollution through fertilizers that farther impacted the integrity of some of the breeding sites.

All these notwithstanding, a recent study by Mwansasu (2016) has shown that no major destruction of mangroves has taken place in the study area and that there is no evidence that prolonged flooding due to, e.g. the 1997–1998 El Niño has permanently damaged the mangrove forest. The results show that mangroves appear to be more or less in a stable equilibrium although the potential of over-exploitation exists. However, another study that analysed land cover change using Landsat images data of 2000 and 2011 (Peter 2013) showed that while the bare land in the delta had increased by 7412.8 ha (2.62%), *Rhizophora* dominance improved by 3076.47 ha (1.09%), *Sonneratia* almost pure stands were enhanced by 1998 ha (0.71%) and *Sonneratia* dominance was amplified by 129.06 ha (0.05%). Elsewhere, *Heritiera* almost pure stands increased by 900.45 ha (0.32%), and their dominance was added by 3872.1 ha (1.37%). On the other hand, *Avicennia* dominance decreased by −1962.9 ha (−0.69%), and it's almost pure stands reduced by −1681.83 ha (−0.59%). A mixture of *Avicennia* and *Ceriops* degraded by −15,222.8 ha (−5.38%), while *Ceriops* dominance dropped by −2302.56 ha (−0.81%) within the period of observation.

Pressures on mangroves in the Rufiji Delta were observed to be mostly human-induced as pointed out above and as argued by Ellison (2015) in another study in the same area. The latter study showed that, though the Rufiji Delta had inherent resilience owing to location on an uplifting coastline with a macro tidal range, the area was vulnerable to human impacts and low local community management capacity. The most critical components to the vulnerability of the area, according to Ellison (2015), were exposure components of relative sea level trends and sediment supply and sensitivity components of forest health, recent spatial changes and net accretion rates.

These findings are corroborated by a reef baseline inventory carried out in 2007 and repeated in 2009 at key coral reef sites offshore of the Rufiji mangrove area (Obura 2010). The inventory found the reefs to be in fairly good condition and on a recovery trajectory from a previous coral bleaching event. The inventory commented on the protective functions that coastal mangroves provided to offshore coral reef health.

Awareness of Household Vulnerability to Climate Hazards

Awareness of household vulnerability of climate hazards measures a household's knowledge of susceptibility to climate hazards and its ability to cope with, recover from or adapt to those hazards (Malleret-King et al. 2006). Households may be at risk for different types of climate-related events. Some may be transient, characterized by rapid onset and identifiable termination (such as storms, floods or droughts). Others may result from a longer-term change in climatic variables resulting in phenomena such as sea level rise, mass coral reef bleaching or ocean acidification.

In this study we investigated the households' awareness to tropical storms, storm surges, beach erosion, beach intrusion and flooding as evidence of the existence and magnitude of these risks. We noted also that different households in the same community may experience each of the factors at a different level and thus have different levels of awareness about their vulnerability to the same types of hazard due to the influence of some socio-economic attributes. So we investigated the household awareness to the five climatic hazards by wealth groups, by educational level and by age groups.

Awareness to Tropical Storms

Generally, only 38.2% reported that they were aware of the occurrence of tropical storms in their villages. Out of those who claimed to be aware of the climatic phenomenon, 29.4% belonged to the *poor*, a majority of whom (23.5%) had primary education and 14.7% had no education at all. Only 8.8% came from the *middle wealth group.* Awareness of tropical storms by age groups for Mchungu Village is shown by Table 2. Again, only 37.5% reported to be aware of the occurrence of tropical storms in their village. A majority of these (18.8%) were from the age cohort 36–55 indicating that tropical storms were very recent phenomena in the study area.

Awareness to Storm Surge, Beach Erosion, Beach Intrusion and Flooding

A similar trend of awareness was observed for storm surge, beach erosion, beach intrusion and flooding in both villages. Relatively few households were aware of the occurrence of these climatic hazards in their villages, again indicating that such occurrences were recent happenings in the study area. Out of those who claimed to be aware of a climatic phenomenon, many came from the *poor*; a majority of whom had primary education and/or no education at all.

Table 2 Awareness of tropical storms by age groups in Mchungu Village (2016)

Age cohort	Responses: Yes	Responses: No	Total
18–25	0.0	6.2	6.2
26–35	6.2	9.4	15.6
36–55	18.8	28.1	46.9
56–65	0.0	9.4	9.4
66+	12.5	9.4	21.9
Total	**37.5**	**62.5**	**100.0**

Access to and Use of Climate-Related Knowledge

Access to and use of climate-related knowledge measures household access to different sources of information related to climate change, climate variability and its impacts and how this information is used (Malleret-King et al. 2006). It also includes access to any type of early warning system and can, therefore, include past experience, traditional or local knowledge of climate patterns and events as well as other sources of education, media and communications. Data from this study shows that access and use of climatic information was through modern conventional sources such as radio, cellular phones and such other information media. In fisheries, climate information from modern sources was often used in deciding to abstain or to continue with fisheries activities depending on official weather forecasts.

Nevertheless, not all the people in the study area could access the climate information they needed. According to the interviews and FGD responses, most of the barriers lay in the lack of efficient early warning systems at the district and local levels. Failure of government institutions at those levels to predict climatic events such as floods, occurrence of storms in the sea, etc. was mostly due to lack of modern devices for accessing the climate information. Also climate information often required clarifications from experts who were not always there.

From the FGDs it was clear that communities conversely used traditional knowledge usually gained through observation of some local indicators. For example, when the sunrise was associated with red skies in the east, there was a strong possibility that strong winds could occur during the day. Similarly, diminishing brightness of stars associated with fast-moving light clouds indicated the occurrence of rain later in the day. Also, during *mwezi mwandamo* (half-moon), sea voyages were said to be safe as the sea waters were normally calm and safety was guaranteed. However, during *mwezi mpeuzi* (crescent moon), sea waters were said to advance towards the coast with powerful crests that normally made sea voyages unsafe. On the other hand, people could also recognize occurrence of high or low tides using the *hijri* calendar and the onset of *hilari kiza* (full moon). *Hilari kiza* normally occurred from the 25th to 30th day of the Islamic month.

Networks Supporting Climate Hazard Reduction and Adaptation

Formal and informal networks are institutional and social networks that support preparedness for climatic hazards and adaptation. Formal institutional networks may include those that are formalized with clear structure and supported by governmental authorities or institutions, such as hazard mitigation networks, health service networks or protected area networks. Informal networks, on the other hand, are often formed through social connections in a group that shares common values, interests, engagement or purpose (Malleret-King et al. 2006). They could be large families, clans, church groups, women's groups or occupational groups. In some communities, such networks may have been in place for a long time but only recently begun to address climate hazards. In other communities, such networks may have already dealt with climate-related hazards that regularly impact the community.

No such networks could be observed in the study area. Those that were available included religious groups, clan groups, women's *vicoba* groups, etc. that did not specifically address climate-related hazards. However, since about 75% were estimated to be impacted by climate hazards owing to their low-income status, these groups could still be useful networks to cushion climate hazard impacts when and if they occurred. What was needed, according to FGD responses, was the presence of social networks to assist in creating awareness on climate change impacts and livelihood diversification to reduce direct dependence on natural resources. Community education on climate change was also mentioned as an important input.

Ability of Communities to Reorganize

The ability of a community to reorganize refers to the degree to which it is able to collectively learn, plan and make necessary changes to their lives to cope with climate-related impacts in such a way that the main functions of the community are sustained (Malleret-King et al. 2006). This may require restructuring organizations, changing plans, shifting priorities, adjusting roles, carrying out activities in a different way or applying lessons from the past to better face a climate hazard. The degree of community reorganization is a critical indicator of resilience to changing climate. The level of community reorganization is a function of factors including cooperation and collaboration among community members, planning for climate change, level of collectivism in the culture, community leadership, shared goals and responsibilities and access to and support from other sources in reorganization.

This study found out that the administrative structure of the study area is fundamentally based on the Village Council system (Commonwealth Local Government Forum 2009). The intended links between the local government and the residents of a given village are the *Vitongoji* (sub-villages; singular: *Kitongoji*) which are designed to mobilize citizens' participation in local development. Priorities for local service delivery and development projects from the *Vitongoji* are brought to the Village Councils (VCs) for discussion before being forwarded to the Ward Development Committees (WDCs). A ward comprises more than three but less than five villages.

The VCs have three standing committees, i.e. for finance and planning, for social services and for defence and security. The VCs also have statutory committees such as HIV/AIDS committees, water committees and animal health committees in pastoral areas. The VCs have discretion to establish further committees, although there is a maximum limit for each type of authority. Committees for particular climate change hazards can be established under this prerogative as the role of such committees is to oversee the work of specific projects in the villages.

Table 3 Village Councils by number of committees, constituent members and gender

Village council	No. of committees	No. of members	No. of women
Nyamisati	3	25	5
Mchungu	3	19	3

VCs must have 25 members consisting of a chairperson elected by the Village Assembly (VA). The VA comprises all adults in the village who are over the age of 18, all chairpersons of the *Vitongoji* within its area and other members elected by the assembly. Women must account for 25% of the council members.

In this study, both the study villages had full-fledged VCs although they differed in the number of constituent members and gender as shown in Table 3.

Governance and Leadership

Governance is a very broad indicator that measures a variety of characteristics that together indicate how process and decisions are made to serve the best interests of the community and stakeholders (Malleret-King et al. 2006). We focus here on leadership and stakeholder participation in management and decision-making. Leadership measures the presence of community leaders or government officials who can mobilize climate change responses and resources to support adaptation and their effectiveness or credibility. This indicator is important because communities with strong, trustworthy, effective leaders will be more able to adapt. Stakeholder participation in management and decision-making is critical to buy-in of any new programme related to climate change.

The most important governance and leadership institutions in this context were the Tanzania Forest Services (TFS) and the Beach Management Units (BMUs). The TFS is a central government agency that has the responsibility to conserve and protect mangrove forests. Collaborating with village natural resources committees, the TFS verifies mangrove reserve boundaries, formulates by-laws for mangrove forest management, conducts patrols and supervises replanting of new mangroves in degraded areas.

The BMUs, on the other hand, are community conservation initiatives whose responsibilities include the collective conservation and management of both coastal and marine resources and approval of the eligibility for issuance of fishing and mangrove forest harvesting permits. An example of such an institution in the study villages is the beach conservation and management initiative for four villages, Mchinga, Mfisini, Mchungu and Nyamisati (MCHIMCHUNYA).

Firstly, according to the FGDs and key informant interviews, stakeholder participation in the management of coastal and marine resources in the study area was facing serious challenges. For instance, issuance of forest harvesting permits is managed by TFS whereby village authorities have no voice even for reserves that fall under areas of their jurisdiction. Thus verification by village authorities of the legitimacy of permits issued is not possible.

Secondly, there is often lack of value for money spent in the implementation of mangrove reforestation projects. Often the amount of money that is quoted to have been spent in a particular project are not translated into quantity and/or quality work in actual project implementation. For example, in 2011, donors granted Tsh 700 m for a mangrove reforestation project in the degraded areas, but such an amount could not be translated into actual project implementation, clearly portraying the tendency of embezzlements of funds allocated for particular projects.

Thirdly, there were clear interferences in duties and responsibilities between stakeholders. For example, BMUs have been mandated to manage both coastal and marine resources. However, in practice they have been working on marine resources only and not on coastal resources because mangroves were said to be government resources. In addition, BMUs are mandated to approve eligibility of granted coastal and marine resources harvesting permits. In practice, however, those permits were issued by government agents without BMU's approval. This tendency by permit-issuing agents demoralized the BMUs from accomplishment of given tasks.

In an effort to improve stakeholder participation, villages have been instructed to prepare management plans, whereby they are required to sign contracts with the TFS so that the illegally harvested mangrove forest products seized and/or confiscated during various management operations shall be handed over to village authorities for village use. Of the revenues collected from the sale of the products, 5% should be given back to the community through the Village Environment Committee. The system was introduced as a benefit-sharing scheme to engage communities in sustainable management of mangroves.

Conclusion and Recommendations

This chapter set out to answer the questions of how fisher-mangrove-dependent societies such as those of the Rufiji Delta in Southern Tanzania were being affected by and what was their capacity to adapt to climate change impacts that were occurring in their area. The objective of the paper was not only aimed at 'improving linkages between the practice of community-level assessments and efforts to develop and implement vulnerability-reducing interventions'; it was also an attempt to address the critique offered by McDowell et al. (2016) about the need for a more integrative, community-engaged approach to assessments in vulnerability scholarship.

Social vulnerability assessment is a process that engages those who are impacted by changing climate to provide input on their strengths, weaknesses, opportunities and limitations in addressing climate events and impacts (Malleret-King et al. 2006). In this study, despite differences in wealth status, in general community members of the study villages shared similar socio-economic characteristics and were thus anticipated to be impacted in similar magnitudes.

What was needed was community education on climate change impacts or what Lance Gunderson calls 'the need for experimentation and learning to build adaptive capacities' (Gunderson 2010) and the presence of social networks to assist in creating awareness on climate change impacts and livelihood diversification to reduce direct dependence on the fisher-mangrove ecosystem. Such livelihood diversification strategies included provision of capital for small businesses and establishing environmentally friendly activities such as compound-based livestock keeping (zero-grazing) and modern beekeeping.

Such capacity building of communities and other relevant stakeholders to effectively respond to climate change impacts in agriculture, fisheries and mangrove conservation sectors envisaged three key outcomes:

- Improved output and income through supported sustainable agriculture and fisheries practices.
- A critical mass of vulnerable communities and other relevant stakeholders are capacitated and equipped and practice low-cost and efficient wood-saving technologies that will reduce significantly the impacts of mangrove deforestation.
- Strengthened institutional capacities to plan, govern and respond to climate change impacts in agriculture, fisheries and mangrove conservation in the study area.

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Ecological Impact of Thermal Stress in Reefs of Zanzibar Following the 2016 Elevated Higher Sea Surface Temperatures

A. M. Ussi, M. Mohammed, C. A. Muhando, and S. A. S. Yahya

Abstract This study has assessed the reef community characteristics so as to describe the community change following a severe threat and adaptively manage coral reefs in response to the 2016 and future bleaching events. The study was conducted in Misali, Bawe, Chumbe, and Mnemba reefs in Zanzibar. Misali reef is located in Pemba Island, whereas the remaining three reefs are located in Unguja Island. The composition of the benthic cover within plots was assessed using the 20-m-long line intercept method. Each site had two plots at least 150 m apart. Four transects were randomly placed within each plot. A total of 63 benthic categories, summarized into 8 major groups, hard corals (49 categories), soft corals, sponges, algae (5 categories), corallimorpharians, hard substrates (4 categories), soft substrate, and others, were monitored. Hard corals were assessed at genus level to improve biodiversity change detection. Coral bleaching levels and coral size class distribution were assessed. A belt transect of 25 m × 1 m was used to sample for coral colonies larger than 10 cm in diameter, whereas sampling for corals smaller than 10 cm, which were considered as recruits, was done using six 1 m^2 quadrats located along the transect, at fixed intervals of 0, 5, 10, 15, 20, and 25 m. Four transects per plot were sampled out. The results showed that prevalence of bleaching among surveyed reefs varied between 74% (Misali) and 88% (Bawe). However, the effect of bleaching to coral cover loss was more pronounced in Bawe (37%) and Chumbe reef (19%). Genus *Acropora* was the most affected coral with higher relative proportions of dead colonies for Misali (85%), Chumbe (63%), and Mnemba (43%) and *Porites* for Bawe (39%). Genus *Porites* at Bawe and *Acropora* at Misali and Mnemba have temporarily lost their dominance to *Echinopora*, *Galaxea*, and *Porites*, respectively. Coral diversity was highest in Misali for both adult and recruit populations and was lowest in Bawe reef. Geographical location, coral community composition, diversity, and reef topography are suggested to be among the determinants of variability in coral bleaching prevalence and impact to coral cover loss.

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Introduction

In Zanzibar, coral reefs are vital in supporting fisheries, tourism industry, and coastal protection (Lange and Jiddawi 2009). Unfortunately, coral reefs in Zanzibar have been suffering from a multitude of threats, leading to severe degradation (Wagner 1999; Muhando 2003). Increased frequency and severity of coral bleaching events due to unusual high sea temperatures is one of the climate change-related phenomena that has shown the greatest threats to coral reefs worldwide (Wilkinson 2008).

Corals optimally thrive in water temperature of between 26 and 27 °C and are mostly restricted to shallow clear water in sunny tropics and subtropics (Wood 1983; Veron 2000), with lower and upper thriving limits of 18 °C and 32 °C, respectively (Coles 1988). Coral reef ecosystems are ecologically very sensitive, i.e., they have a narrow physiological tolerance against climate (human and natural) threats (Pastorock and Bilyard 1985). Prolonged exposure to temperatures of beyond 30 °C has been a common cause of significant mass coral bleaching (Winter et al. 1998). The extent of coral reef damage from coral bleaching mainly depends on factors such as magnitude of lethal temperature and extent to which that lethal temperature will last and on the ability of coral reefs to cope with change (Hoegh-Guldberg 1999; Hoegh-Guldberg et al. 2007). The ability of coral communities to survive in the environment of elevated temperatures is determined by key factors such as resistance and recovery potential (Obura and Grimsdith 2009). Community resistance relates to the ability of individual corals to experience exposure without bleaching and if they bleach to survive, whereas the recovery potential relates to the community's capacity to maintain or recover its structure and function in spite of coral mortality. Community resistance and recovery potentials determine the resilience of communities in the face of elevated sea temperatures.

Mass coral bleaching and mortality in the coral reefs of Zanzibar occurred in 1998 and 2016 when Zanzibar experienced prolonged higher temperatures of beyond 30 °C (Fig. 1). The implications of severe bleaching on reef ecology include coral mortality, shifts in coral community structure, altered habitat composition, and ecosystem flow-on effects (Wilkinson 2000, 2004, 2008). Likewise, severe bleaching in synergy with other natural and anthropogenic threats has direct implications on industries that depend on the reef as well as associated human communities since bleaching can reduce the social or economic value of reef sites important to tourism operations, fishers, and recreational users. The extent of coral damage from the 2016 bleaching event as a result of reported unusual higher sea temperatures (Fig. 1) and associated impacts was not yet known. Thus, in the context of management, it was vital to assess the change that this threat of elevated sea temperatures could bring to the reef community so as to measure the extent of damage and adaptively manage coral reefs in response to bleaching events.

One of the best approaches of assessing the impact of that threat to reef communities is by assessing reef resilience (Donner et al. 2005). Reef resilience can be determined by reef community characteristics which include benthic cover, coral community structure (genera), coral size class distribution, and coral bleaching

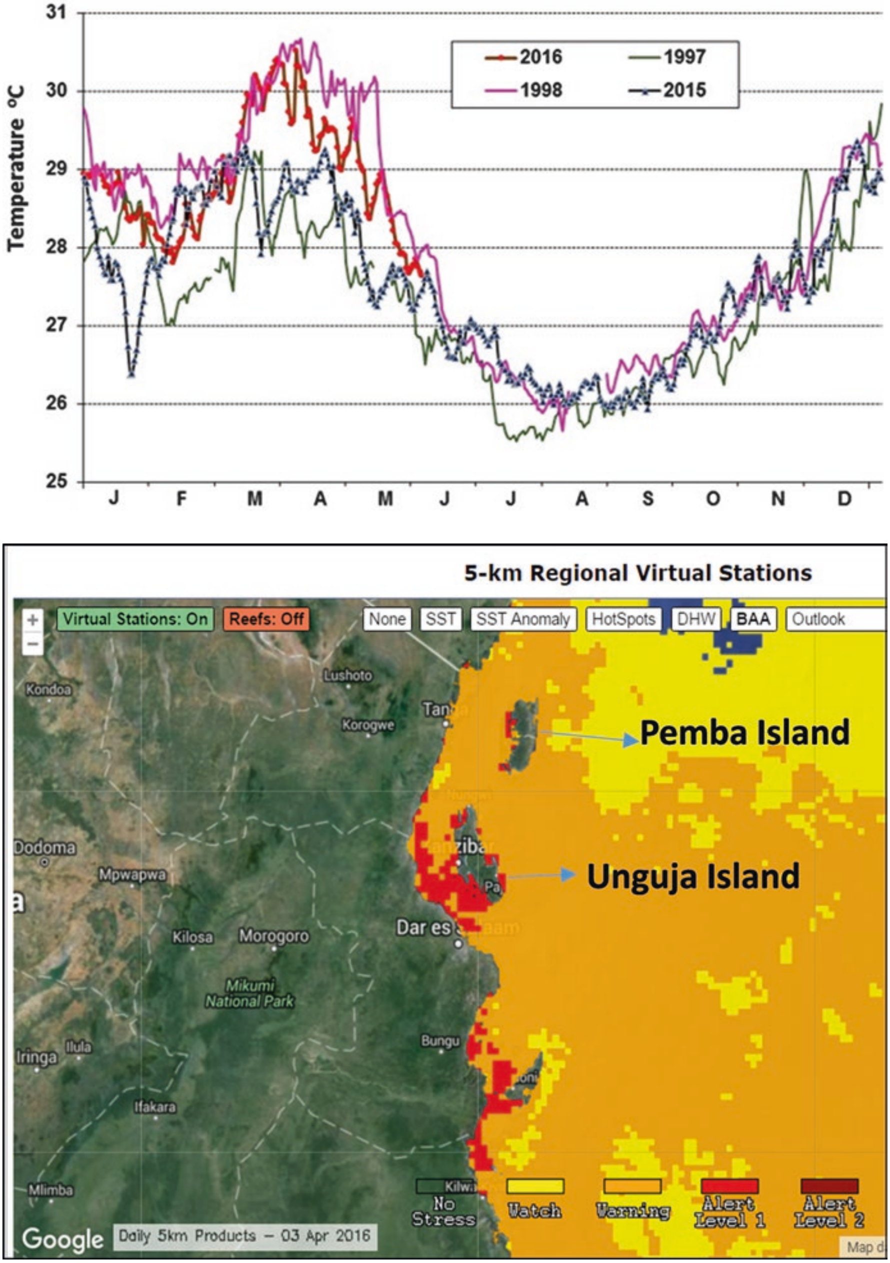

Fig. 1 (**a**) Seawater temperature records at Chumbe coral reef for 1997, 1998, 2015, and 2016. Note the elevated seawater temperatures (higher than 30 °C) that are associated with coral bleaching events in 1998 and 2016. (**b**) Elevated sea surface temperatures in Western coast of Indian Ocean, April 2016. (Source: http://coralreefwatch.noaa.gov/vs/map.php)

condition. In a normal well-functioning coral reef ecosystem, live hard corals are expected to dominate the reef with diverse species and growth forms that increase habitat complexity, which is potential for inhabiting other marine organisms. Thus, any change in live hard coral cover can substantially jeopardize the entire reef community including fishes and sustainability of other sectors that are reef dependent such as fisheries and tourism. This study, therefore, assessed the reef community characteristics so as to describe the community change following a severe threat and adaptively manage coral reefs in response to 2016 and future bleaching events.

Methods and Materials

Study Sites

This assessment study was conducted in Misali, Bawe, Chumbe, and Mnemba reefs in Zanzibar, Tanzania. Misali reef is located in Pemba Island, whereas the remaining three reefs are located in Unguja Island (Fig. 2). Chumbe is located at southernmost tip of the surveyed zone followed by Bawe and Mnemba to the north, whereas Misali reef is at the northernmost tip. Misali, Mnemba, and Chumbe reefs are located within long established (>10 years) marine protected areas, whereas Bawe has only recently (2015) been declared an MPA. With exception to Chumbe reef which is privately managed, Bawe, Mnemba, and Misali are managed by the government. Coral cover prior to bleaching was highest in Bawe (64% in 2015) followed by Chumbe (57% in 2012) and Misali (37% in 2009) and was lowest in Mnemba (29% in 2015) (Ussi 2014; Mohammed 2016). Bawe reef experiences immense fishing pressure. Misali and Mnemba reefs are located along the banks of deep channels of the open oceans, which is not the case for Chumbe and Bawe reefs. Assessment of ecological community characteristics was done in predetermined 70 m × 50 m monitoring plots, where previous coral benthic cover records exist. Sampling was done from May 31, 2016 to July 03, 2016.

Benthic Cover and Coral Community Structure Assessment

The composition of the benthic cover within plots was assessed using the 20-m-long line intercept method (English et al. 1994). Each site had two plots, which were at least 150 m apart. Four transects were randomly placed within each plot. A total of 63 benthic categories, summarized into 8 major groups: hard corals (49 categories), soft corals, sponges, algae (5 categories), corallimorpharians, hard substrates (4 categories), soft substrate and others, were monitored. Hard corals were assessed at genus level to improve biodiversity change detection (Muhando 2008).

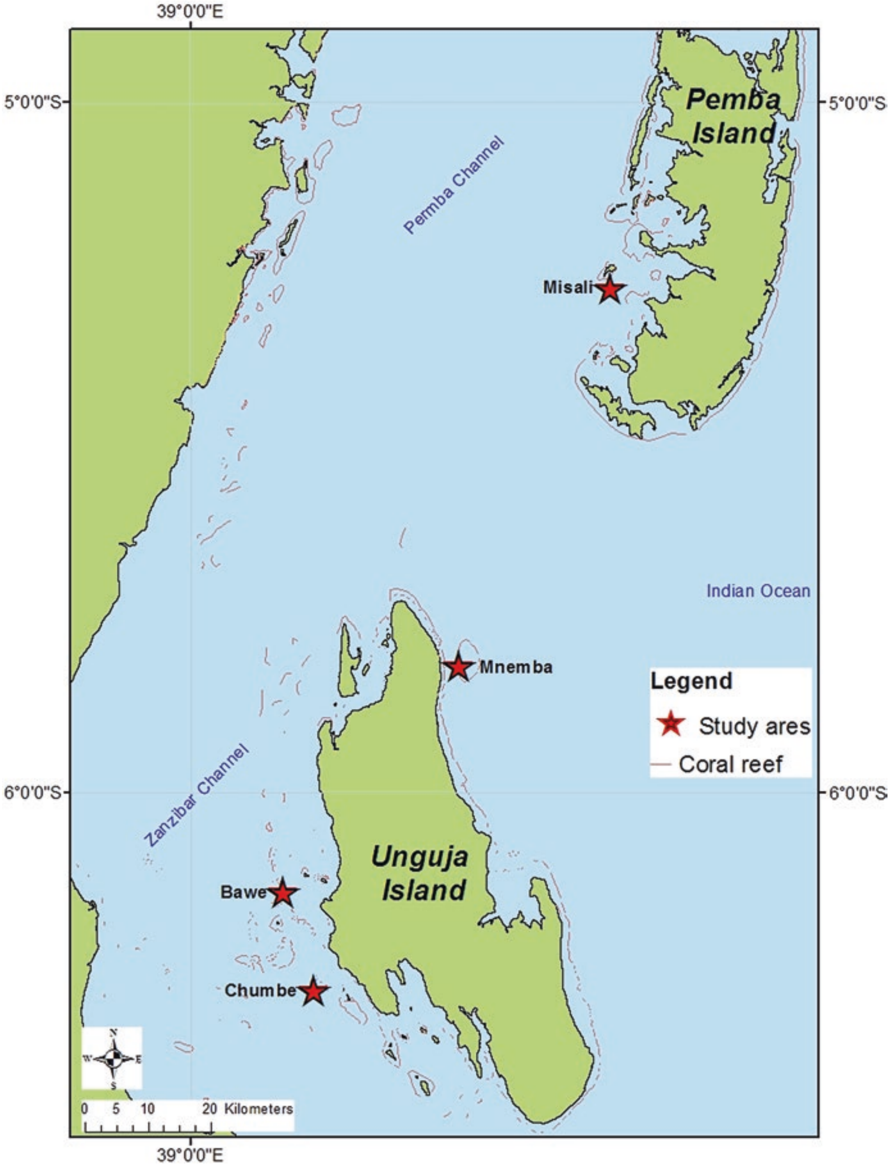

Fig. 2 Map of Zanzibar showing the locations of the study sites

Coral Bleaching Condition and Size Class Distribution Assessment

Coral bleaching levels and coral size class distribution were assessed by using methods described by Obura and Grimsdith (2009). A belt transect of 25 m × 1 m was used to sample for coral colonies larger than 10 cm in diameter, whereas sampling for corals smaller than 10 cm, which were considered as recruits, was done using six 1 m^2 quadrats located along the transect, at fixed intervals of 0, 5, 10, 15, 20, and 25 m. Four transects per plot were sampled. Within each transect, coral colonies whose center lay within the transect were identified to genus level, counted, and measured, and their health condition in relation to bleaching was assigned by using bleaching and mortality levels explained by Oliver et al. (2004). The size class scales considered for larger colonies were 10–20 cm, 21–40 cm, 41–80 cm, 81–160 cm, 161–320 cm, and greater than 320 cm. For smaller colonies, the size class scales considered were 0–2.5 cm, 3–5 cm, and 6–10 cm. The bleaching and mortality levels used were B0 for no bleaching coral (normal), B1 for partially bleached coral, B2 for completely bleached coral (white), B3 for bleached and partly dead coral, and D for recently dead coral (Plate 1). The mortality and bleached levels were presented as incidence of bleaching (IoB) and prevalence of bleaching (PoB). The former is the sum of bleached colonies in the site, whereas the latter is the ratio of bleached colonies in the site. The levels were as well presented in absolute and relative terms. Absolute term is the actual level of variable from the measurement made in field, whereas the relative term is the level of variable in relation to levels of other categories of the same type measured in the population.

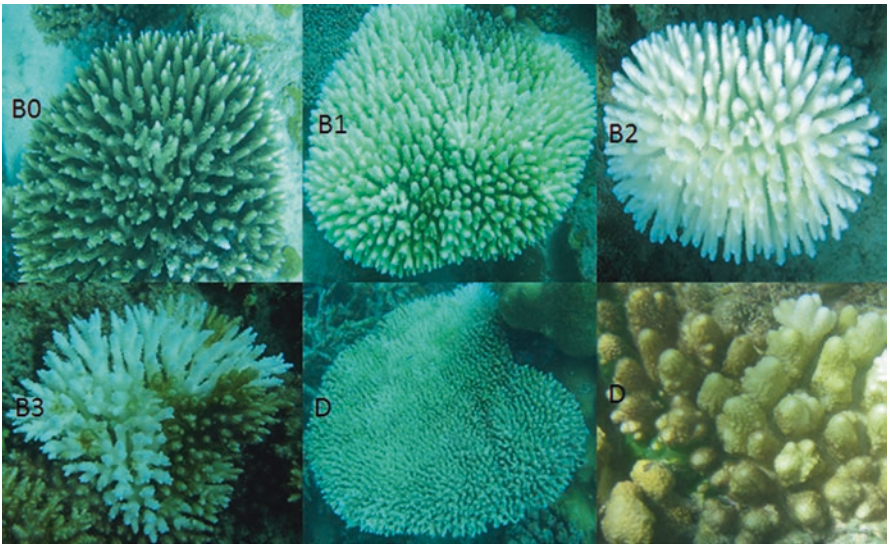

Plate 1 Categories of bleaching conditions considered during field assessment

Data Analysis

The statistical package STATISTICA 7 was used to analyze the data. Generalized linear model analysis of variance (GLM-ANOVA) was the primary method used to analyze the data. ANOVA and Kruskal-Wallis test were used to find the inter-plot and interreef variability in benthic categories, coral bleaching levels, and recruitment densities. Likewise, ANOVA was used to compare coral bleaching levels within and among sites. Coral genera diversity was estimated using Shannon diversity index (H″) based on coral cover, total number of coral colonies sampled, and recruit counts. Coral bleaching levels were processed into incidence and prevalence of bleaching, representing number and ratios of infected coral colonies, respectively.

Results

Benthic Cover

Live hard coral was the most dominant benthic category in Misali reef with an average cover of 32% followed by dead coral with algae (15%), whereas dead coral with algae was the dominant category in reefs of Bawe (41%) and Chumbe (46%) followed by hard coral cover, 27% for Bawe and 38% for Chumbe, respectively (Fig. 3). In contrast, Mnemba reef was mostly dominated by consolidated bare substrate (rock) (31%), followed by dead coral with algae (23%) and live hard coral (19%). Within site comparison showed no difference in cover between plots for both live hard coral and dead corals with algae in all sites. Interreef comparison (pooled data) in live hard coral cover showed that there was more live hard coral

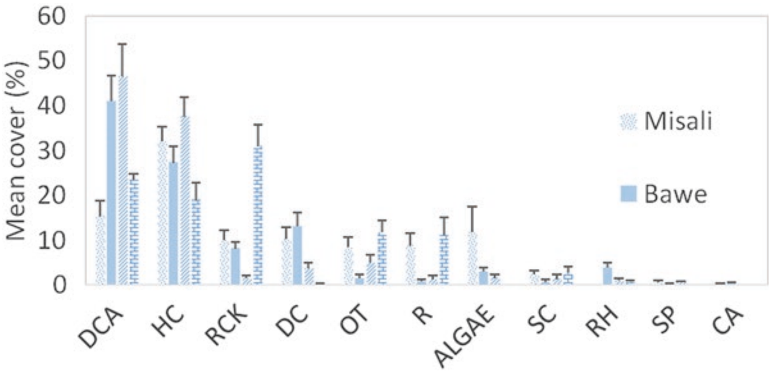

Fig. 3 Benthic cover distributions in reefs of Misali, Bawe, Chumbe, and Mnemba reefs during May–June 2016

cover in Chumbe relative to other sites (ANOVA, $p = 0.0123$,). Likewise, together with Bawe, Chumbe had more cover of dead coral with algae relative to Misali and Mnemba (Kruskal-Wallis test, $p = 0.021$,).

Coral Community Structure

The genera *Echinopora* (10%) and *Acropora* (6%) were the most dominant in terms of absolute cover in Misali as it was for *Galaxea* (13%) and *Porites rus* (7%) for Bawe, *Acropora* (16%) and *Echinopora* (6%) for Chumbe, and *Porites* (6%) and *Acropora* (5%) in Mnemba (Fig. 4). Based on frequency of occurrence in hard coral cover, the most frequently encountered coral genus in Misali was *Echinopora*, followed by *Acropora*, *Montipora*, and *Porites rus*, as it was for *Porites rus*, *Galaxea*, *Acropora*, and massive *Porites* in Bawe and *Acropora*, *Echinopora*, *Porites* massive, and *Porites rus* in Chumbe. The genus *Acropora* was the most frequently encountered in Mnemba, followed by massive *Porites*, *Echinopora*, and *Pocillopora* (Table 1). The highest coral genera richness was in Misali (37), followed by Chumbe (36), Mnemba (26), and Bawe (19). Shannon diversity index was highest in Misali (H′ = 2.8) relative to Chumbe (H′ = 2.5), Mnemba (H′ = 2.3), and Bawe (H′ = 2.2). The trend of highest frequency of occurrence based on total number of hard coral colonies counted was genera *Acropora*, *Echinopora*, *Montipora*, *Favia*, and *Goniastrea* for Misali reef; genera *Porites rus*, *Galaxea*, *Acropora*, and *Porites* branching for Bawe reef; genera *Acropora*, *Echinopora*, *Fungia*, and *Porites rus* for Chumbe reef; and genera *Acropora*, *Pocillopora*, *Porites* massive, *Stylophora*, and *Echinopora* for Mnemba reef (Table 2).

Fig. 4 (**a**): Distribution of absolute live cover of hard coral genera in Misali reef. (**b**): Distribution of absolute live cover of hard coral genera in Bawe reef. (**c**): Distribution of absolute live cover of hard coral genera in Chumbe reef. (**d**): Distribution of absolute live cover of hard coral genera in Mnemba reef

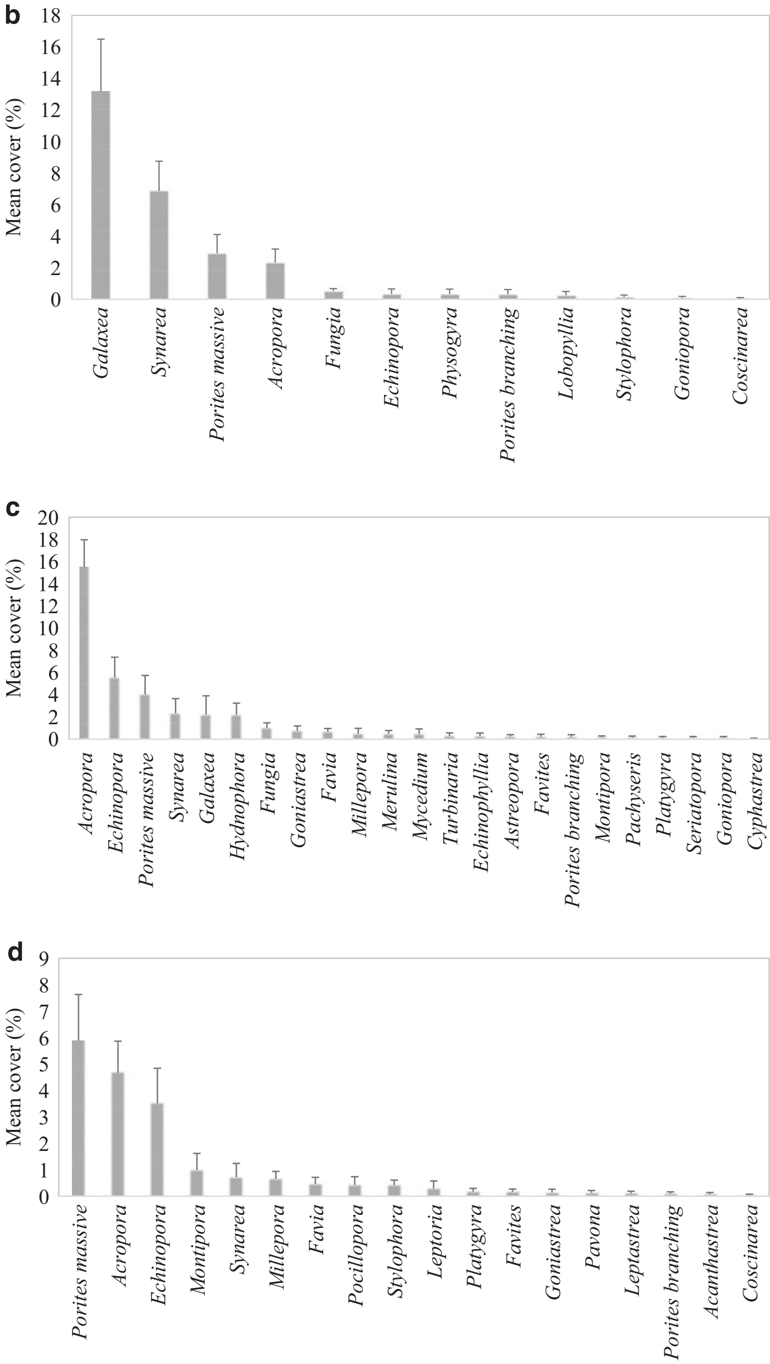

Fig. 4 (continued)

Table 1 Frequency of occurrences of hard coral genera observed in benthic cover of Misali, Bawe, Chumbe, and Mnemba reefs

	Misali		Bawe		Chumbe		Mnemba	
Sn	Genus	No.	Genus	No.	Genus	No.	Genus	No.
1	*Echinopora*	60	*Porites rus*	40	*Acropora*	65	*Acropora*	34
2	*Acropora*	41	*Galaxea*	38	*Echinopora*	24	*Porites mas.*	25
3	*Montipora*	24	*Acropora*	15	*Porites mas.*	11	*Echinopora*	14
4	*Porites rus*	19	*Porites mas.*	11	*Porites rus*	9	*Pocillopora*	8
5	*Favia*	8	*Fungia*	7	*Galaxea*	8	*Stylophora*	7
6	*Goniastrea*	8	*Porites bra.*	4	*Fungia*	8	*Montipora*	6
7	*Porites mas.*	7	*Echinopora*	2	*Hydnophora*	7	*Porites rus*	5
8	*Astreopora*	7	*Physogyra*	2	*Favia*	6	*Favia*	5
9	*Fungia*	6	*Stylophora*	1	*Goniastrea*	5	*Millepora*	4
10	*Porites bra.*	5	*Lobophyllia*	1	*Astreopora*	3	*Pavona*	3
11	*Lobophyllia*	5	*Coscinarea*	1	*Mycedium*	3	*Porites bra.*	2
12	*Platygyra*	4	*Goniopora*	1	*Montipora*	2	*Platygyra*	2
13	*Seriatopora*	4			*Porites bra.*	2	*Favites*	2
14	*Pocillopora*	3			*Merulina*	2	*Leptastrea*	2
15	*Favites*	3			*Platygyra*	1	*Leptoria*	2
16	*Physogyra*	3			*Favites*	1	*Goniastrea*	1
17	*Cyphastrea*	3			*Millepora*	1	*Coscinarea*	1
18	*Hydnophora*	2			*Seriatopora*	1	*Acanthastrea*	1
19	*Pavona*	2			*Cyphastrea*	1		
20	*Leptastrea*	2			*Goniopora*	1		
21	*Oxypora*	2			*Pachyseris*	1		
22	*Millepora*	1			*Echinophyllia*	1		
23	*Coscinarea*	1			*Turbinaria*	1		
24	*Merulina*	1						
25	*Acanthastrea*	1						
26	*Pachyseris*	1						
27	*Montastrea*	1						
28	*Plerogyra*	1						
29	*Plesiastrea*	1						

Key: *Porites mas.* Porites massive, *Porites bra.* Porites branching

Coral Bleaching Responses

A total of 3093 adult hard coral colonies were sampled in 800m^2 total surveyed area, with Misali contributing the highest number of colonies (39%) followed by Chumbe (23%), Mnemba (20%), and Bawe (18%) that contributed the least (Table 2). Incidence of bleaching (IoB) was relatively higher in Misali reef and was lowest in Mnemba. There was higher prevalence of bleaching (PoB) in Bawe (88%) relative to other surveyed sites (p = 0.0007; ANOVA). Similarly, high dead coral ratio (D)

Table 2 Coral health conditions, incidence, and prevalence of bleaching for coral colonies in Misali, Bawe, Chumbe, and Mnemba reefs

Incidence of bleaching							
Site/condition	B0	B1	B2	B3	D	Total	IoB
Misali	317	403	251	122	117	1210	893
Chumbe	175	205	96	103	136	715	540
Bawe	66	103	95	85	210	559	493
Mnemba	131	149	13	106	210	609	478
Total						**3093**	
Prevalence of bleaching							
Site/condition	B0	B1	B2	B3	D	Total %	PoB
Bawe	11.8	18.4	17.0	15.2	37.6	100	88.2
Mnemba	21.5	24.5	2.1	17.4	34.5	100	78.5
Chumbe	24.5	28.7	13.4	14.4	19.0	100	75.5
Misali	26.2	33.3	20.7	10.1	9.7	100	73.8

Key: *B0* normal condition, *B1* partially bleached condition, *B2* bleached condition, *B3* bleached and partially dead, *D* completely dead, *IoB* incidence of bleaching, and *PoB* prevalence of bleaching

was found in Bawe (38%) relative to other surveyed sites ($p < 0.0001$; ANOVA). Completely dead coral colonies in Bawe ($p < 0.0001$; ANOVA) and Mnemba reefs ($p < 0.0001$, ANOVA) had the highest contribution in total prevalence, which accounted for 38% and 35% for the former and the latter, respectively (Table 2). In contrast, partially bleached coral colonies in Misali ($p < 0.0001$; ANOVA) and Chumbe reefs ($p = 0.004$; ANOVA) contributed most to total prevalence, which accounted for 33% and 29%, respectively.

Absolute prevalence among hard coral genera ranged from 21% to 100% within sites (Table 3). Misali reef had the highest relative prevalence of bleaching observed in the genera *Acropora* (28%), *Echinopora* (13%), *Favia* (7%), and *Goniastrea* (7%), with the highest ratio of dead corals in *Acropora* (33%), which accounted for 85% in the total population. In Bawe reef, the highest relative prevalence of coral bleaching was observed in the genera *Porites rus* (23%), branching *Porites* (18%), *Galaxea* (16%), and *Acropora* (16%), with highest ratio of dead corals within genera found in branching *Porites* (94%), *Pocillopora* (84%), *Echinopora* (61%), and *Acropora* (46%). Branching *Porites* (39%), *Acropora* (19%), and *Porites rus* (16%) had the highest relative contribution of the dead corals in the population in Bawe reef (Table 3). Chumbe reef showed the highest relative prevalence of bleaching in genera *Acropora* (43%), *Echinopora* (9%), *Fungia* (5%), and *Porites rus* (5%) and highest absolute dead ratios within genera in branching *Porites* (100%), *Millepora* (90%), *Pocillopora* (75%), and *Acropora* (30%), with *Acropora* and branching *Porites* having the highest relative contribution to the dead corals in the population, by 63% for the former and 15% for the latter. In Mnemba reef, the highest relative prevalence of coral bleaching was observed in genus *Acropora* (30%) and *Pocillopora* (26%), with absolute ratios of dead corals of 53% and 60%, and relative contribution to dead corals in the population of 43% and 37%, respectively.

Table 3 Coral health conditions, incidence, and prevalence of bleaching, prevalence, relative prevalence, absolute dead ratios, and relative dead ratios for coral genera

(a) Misali

Genus	B0	B1	B2	B3	D	Total	IoB	PoB	Rel. PoB	Abs.% dead	Rel.% dead
Acropora	51	48	73	29	99	300	249	83.00	27.88	33.00	84.62
Echinopora	60	83	21	19	1	184	124	67.39	13.89	0.54	0.85
Montipora	48	28	20	2	2	100	52	52.00	5.82	2.00	1.71
Favia	15	30	24	10	1	80	65	81.25	7.28	1.25	0.85
Goniastrea	14	26	32	4	0	76	62	81.58	6.94	0	0
Stylophora	4	10	14	12	4	44	40	90.91	4.48	9.09	3.42
Porites rus	22	9	7	6	0	44	22	50.00	2.46	0	0
Seriatopora	2	19	6	12	4	43	41	95.35	4.59	9.30	3.42
Pocillopora	3	16	6	8	3	36	33	91.67	3.70	8.33	2.56
Favites	9	18	4	4	0	35	26	74.29	2.91	0	0
Porites mas.	11	15	2	4	2	34	23	67.65	2.58	5.88	1.71
Cyphastrea	7	12	3	1	0	23	16	69.57	1.79	0	0
Galaxea	4	11	5	3	0	23	19	82.61	2.13	0	0
Astreopora	17	5	0	0	0	22	5	22.73	0.56	0	0
Platygyra	7	8	4	0	0	19	12	63.16	1.34	0	0
Porites bra.	2	4	6	5	0	17	15	88.24	1.68	0	0
Lobophyllia	1	11	2	0	0	14	13	92.86	1.46	0	0
Hydnophora	6	3	2	1	0	12	6	50.00	0.67	0	0
Mycedium	4	5	3	0	0	12	8	66.67	0.90	0	0
Fungia	3	4	3	0	0	10	7	70.00	0.78	0	0
Leptastrea	5	5	0	0	0	10	5	50.00	0.56	0	0
Merulina	2	5	3	0	0	10	8	80.00	0.90	0	0
Gardinoseris	0	5	1	1	0	7	7	100.00	0.78	0	0
Physogyra	3	2	1	1	0	7	4	57.14	0.45	0	0
Coscinarea	1	5	0	0	0	6	5	83.33	0.56	0	0
Plesiastrea	4	1	0	0	1	6	2	33.33	0.22	16.67	0.85
Acanthastrea	3	2	0	0	0	5	2	40.00	0.22	0	0
Herpolitha	0	2	3	0	0	5	5	100.00	0.56	0	0
Pavona	3	1	1	0	0	5	2	40.00	0.22	0	0
Pachyseris	0	4	0	0	0	4	4	100.00	0.45	0	0
Symphyllia	1	2	1	0	0	4	3	75.00	0.34	0	0
Oxypora	2	1	0	0	0	3	1	33.33	0.11	0	0
Plerogyra	2	1	0	0	0	3	1	33.33	0.11	0	0
Diploastrea	1	0	1	0	0	2	1	50.00	0.11	0	0
Echinophyllia	0	2	0	0	0	2	2	100.00	0.22	0	0
Montastrea	0	0	2	0	0	2	2	100.00	0.22	0	0
Leptoria	0	0	1	0	0	1	1	100.00	0.11	0	0
Total	317	403	251	122	117	1210	893		100		100

Key: *B0* normal condition, *B1* partially bleached condition, *B2* bleached condition; *B3* bleached and partially dead, *D* completely dead, *IoB* incidence of bleaching, *PoB* prevalence of bleaching, *Abs.* absolute; *Rel.* relative, *Porites mas.* Porites massive, and *Porites bra.* Porites branching

(b) Bawe											
Genus	B0	B1	B2	B3	D	Total	IoB	PoB	Rel. Prev.	Abs.% dead	Rel.% dead
Porites rus	25	20	22	36	34	137	112	81.75	22.72	24.82	16.19
Galaxea	8	26	29	20	5	88	80	90.91	16.23	5.68	2.38
Acropora	10	16	16	5	40	87	77	88.51	15.62	45.98	19.05
Porites bra.	0	0	3	2	82	87	87	100.00	17.65	94.25	39.05
Fungia	4	23	8	2	7	44	40	90.91	8.11	15.91	3.33
Echinopora	0	1	7	6	22	36	36	100.00	7.30	61.11	10.48
Porites mas.	14	4	0	2	1	21	7	33.33	1.42	4.76	0.48
Pocillopora	0	0	1	0	16	17	17	100.00	3.45	94.12	7.62
Stylophora	0	4	1	10	2	17	17	100.00	3.45	11.76	0.95
Lobophyllia	0	2	5	0	1	8	8	100.00	1.62	12.50	0.48
Physogyra	3	1	1	0	0	5	2	40.00	0.41	0	0
Seriatopora	1	1	0	1	0	3	2	66.67	0.41	0	0
Coscinarea	0	1	1	0	0	2	2	100.00	0.41	0	0
Oxypora	0	1	0	1	0	2	2	100.00	0.41	0	0
Favia	0	0	1	0	0	1	1	100.00	0.20	0	0
Goniopora	0	1	0	0	0	1	1	100.00	0.20	0	0
Mycedium	1	0	0	0	0	1	0	0.00	0.00	0	0
Pavona	0	1	0	0	0	1	1	100.00	0.20	0	0
Symphyllia	0	1	0	0	0	1	1	100.00	0.20	0	0
Total	66	103	95	85	210	559	493		100		100

Key: *B0* normal condition, *B1* partially bleached condition, *B2* bleached condition, *B3* bleached and partially dead, *D* completely dead, *IoB* incidence of bleaching, *PoB* prevalence of bleaching, *Abs.* absolute, *Rel.* relative, *Porites mas.* Porites massive, and *Porites bra.* Porites branching

(c) Chumbe											
Genus	B0	B1	B2	B3	D	Total	IoB	PoB	Rel. Prev.	Abs.% dead	Rel.% dead
Acropora	56	75	26	44	86	287	231	80.49	42.78	29.97	63.24
Echinopora	12	22	11	11	2	58	46	79.31	8.52	3.45	1.47
Fungia	16	19	8	2	0	45	29	64.44	5.37	0	0
Porites rus	16	5	4	14	6	45	29	64.44	5.37	13.33	4.41
Galaxea	12	12	3	5	0	32	20	62.50	3.70	0	0
Porites mas.	22	2	1	1	2	28	6	21.43	1.11	7.14	1.47
Goniastrea	4	7	8	4	0	23	19	82.61	3.52	0	0
Porites bra.	0	0	0	0	21	21	21	100.00	3.89	100.00	15.44
Favia	0	9	7	4	0	20	20	100.00	3.70	0	0
Platygyra	8	6	4	1	0	19	11	57.89	2.04	0	0
Hydnophora	2	10	1	5	0	18	16	88.89	2.96	0	0
Seriatopora	1	4	1	7	0	13	12	92.31	2.22	0	0
Pocillopora	0	1	1	1	9	12	12	100.00	2.22	75.00	6.62

(continued)

Table 3 (continued)

(c) Chumbe

Genus	B0	B1	B2	B3	D	Total	IoB	PoB	Rel. Prev.	Abs.% dead	Rel.% dead
Astreopora	6	4	0	0	0	10	4	40.00	0.74	0	0
Millepora	0	0	1	0	9	10	10	100.00	1.85	90.00	6.62
Mycedium	0	7	1	1	0	9	9	100.00	1.67	0	0
Lobophyllia	2	2	4	0	0	8	6	75.00	1.11	0	0
Echinophyllia	6	1	0	0	0	7	1	14.29	0.19	0	0
Favites	2	0	5	0	0	7	5	71.43	0.93	0	0
Physogyra	1	3	2	0	0	6	5	83.33	0.93	0	0
Merulina	1	3	1	0	0	5	4	80.00	0.74	0	0
Montipora	0	2	2	1	0	5	5	100.00	0.93	0	0
Goniopora	3	1	0	0	0	4	1	25.00	0.19	0	0
Coscinarea	0	1	2	0	0	3	3	100.00	0.56	0	0
Pachyseris	0	3	0	0	0	3	3	100.00	0.56	0	0
Acanthastrea	2	0	0	0	0	2	0	0.00	0.00	0	0
Cyphastrea	0	1	0	1	0	2	2	100.00	0.37	0	0
Halomitra	0	1	1	0	0	2	2	100.00	0.37	0	0
Leptastrea	1	1	0	0	0	2	1	50.00	0.19	0	0
Oxypora	1	0	0	1	0	2	1	50.00	0.19	0	0
Podabacia	0	1	1	0	0	2	2	100.00	0.37	0	0
Herpolitha	0	0	1	0	0	1	1	100.00	0.19	0	0
Leptoria	1	0	0	0	0	1	0	0.00	0.00	0	0
Stylophora	0	0	0	0	1	1	1	100.00	0.19	100.00	0.74
Symphyllia	0	1	0	0	0	1	1	100.00	0.19	0	0
Turbinaria	0	1	0	0	0	1	1	100.00	0.19	0	0
Total	175	205	96	103	136	715	540		100		100

Key: *B0* normal condition, *B1* partially bleached condition, *B2* bleached condition, *B3* bleached and partially dead, *D* completely dead, *IoB* incidence of bleaching, *PoB* prevalence of bleaching, *Abs.* absolute, *Rel.* relative, *Porites mas.* Porites massive, and *Porites bra.* Porites branching

(d) Mnemba

Genus	B0	B1	B2	B3	D	Total	IoB	PoB	Rel. Prev.	Abs.% dead	Rel.% dead
Acropora	27	41	6	7	91	172	145	84.30	30.33	52.91	43.33
Pocillopora	4	23	0	24	77	128	124	96.88	25.94	60.16	36.67
Porites mas.	59	19	0	12	6	96	37	38.54	7.74	6.25	2.86
Stylophora	11	9	0	4	12	36	25	69.44	5.23	33.33	5.71
Echinopora	8	15	0	5	3	31	23	74.19	4.81	9.68	1.43
Favites	3	6	0	3	5	17	14	82.35	2.93	29.41	2.38
Porites rus	4	3	0	8	1	16	12	75.00	2.51	6.25	0.48
Goniastrea	0	4	1	8	2	15	15	100.00	3.14	13.33	0.95
Montipora	2	4	3	4	2	15	13	86.67	2.72	13.33	0.95
Porites bra.	1	1	0	9	3	14	13	92.86	2.72	21.43	1.43

(d) Mnemba

Genus	B0	B1	B2	B3	D	Total	IoB	PoB	Rel. Prev.	Abs.% dead	Rel.% dead
Favia	2	2	2	6	1	13	11	84.62	2.30	7.69	0.48
Platygyra	1	3	0	4	1	9	8	88.89	1.67	11.11	0.48
Astreopora	0	3	0	1	2	6	6	100.00	1.26	33.33	0.95
Gardinoseris	0	1	0	4	1	6	6	100.00	1.26	16.67	0.48
Cyphastrea	0	3	0	0	2	5	5	100.00	1.05	40.00	0.95
Pavona	1	3	0	1	0	5	4	80.00	0.84	0	0
Goniopora	2	0	0	2	0	4	2	50.00	0.42	0	0
Hydnophora	0	2	0	2	0	4	4	100.00	0.84	0	0
Leptastrea	1	2	0	1	0	4	3	75.00	0.63	0	0
Leptoria	0	1	1	1	0	3	3	100.00	0.63	0	0
Lobophyllia	1	2	0	0	0	3	2	66.67	0.42	0	0
Coscinarea	1	1	0	0	0	2	1	50.00	0.21	0	0
Galaxea	1	0	0	0	1	2	1	50.00	0.21	50.00	0.48
Acanthastrea	1	0	0	0	0	1	0	0.00	0.00	0	0
Diploastrea	1	0	0	0	0	1	0	0.00	0.00	0	0
Pectinia	0	1	0	0	0	1	1	100.00	0.21	0	0
Total	131	149	13	106	210	609	478		100		100

Key: *B0* normal condition, *B1* partially bleached condition, *B2* bleached condition, *B3* bleached and partially dead, *D* completely dead, *IoB* incidence of bleaching, *PoB* prevalence of bleaching, *Abs.* absolute, *Rel.* relative, *Porites mas.* Porites massive, and *Porites bra.* Porites branching

Adult Coral Size Structure and Bleaching Response

The size frequency distributions of adult hard coral populations showed dominance of coral colonies of between 11 cm and 40 cm diameter for Misali and Mnemba reefs, which accounted for 81% and 84% of the total population, respectively (Fig. 5). In contrast, the hard coral populations of Bawe and Chumbe reefs showed the dominance of coral colonies of between 21 cm and 80 cm diameter, which accounted for 64% and 68% of the total population, respectively. Similarly, high death rates were observed in corals colonies of between 11 cm and 40 cm diameter for Misali (8%) and Mnemba reefs (31%) and for coral colonies of between 21 cm and 80 cm diameter for Bawe (24%) and Chumbe (12%) (Fig. 5).

Coral Recruitment Density, Diversity, Size Structure, and Bleaching Response

Recruitment densities of hard corals ranged from 2.5 to 8.3 m^{-2} in Misali, where it averaged at 4.2 m^{-2} in station 1 and 6.8 m^{-2} in station 2, whereas in Bawe reef, recruitment of hard corals ranged from 1 m^{-2} to 3.2 m^{-2} and averaged at 2.2 m^{-2} and

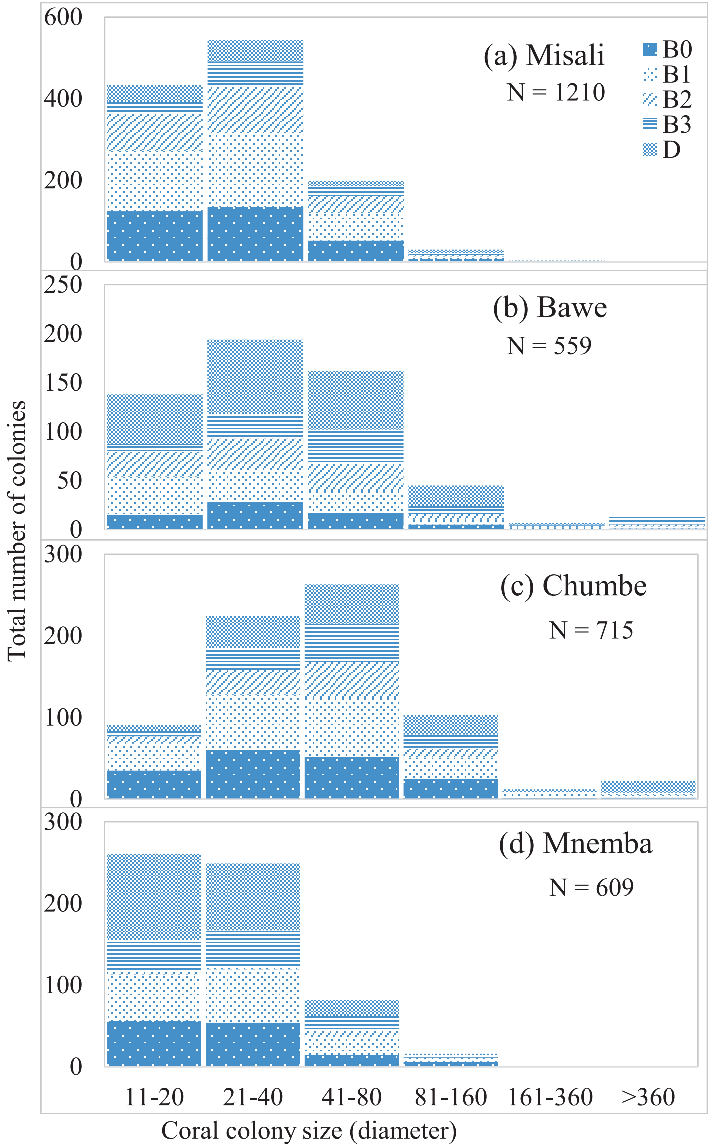

Fig. 5 Size frequency distribution and proportions of health conditions for coral colonies in Misali, Bawe, Chumbe, and Mnemba reefs

1.2 m^{-2} for stations 1 and 2, respectively. In Chumbe reef, the recruitment density of hard corals ranged from 0.6 m^{-2} to 2.2 m^{-2} and averaged at 1.6 m^{-2} in station 1 and 1.3 m^{-2} in station 2. Recruitment density of hard corals in Mnemba ranged from 2.2 m^{-2} to 7.5 m^{-2} with an average of 3.5 m^{-2} and 6.5 m^{-2} in station 1 and 2, respectively. There were no significant station variabilities in all sites. In average (pooled data), recruitment densities were higher in Misali and Mnemba reefs relative

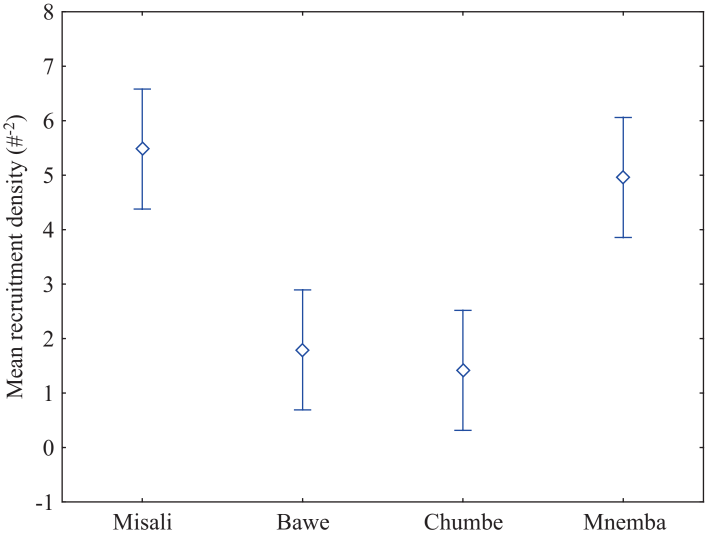

Fig. 6 Mean recruitment density of hard corals in Misali, Bawe, Chumbe, and Mnemba reefs

to Bawe and Chumbe reefs ($p < 0.0001$; ANOVA, Fig. 6). Coral genera richness in coral recruits was highest in Misali (26), followed by Mnemba (20) and Chumbe (13), and was lowest in Bawe (12). Shannon diversity index was highest in Misali (H′ = 2.6), followed by Mnemba (H′ = 2.2), Bawe (H′ = 2.1), and Chumbe (H′ = 2).

Size structure of hard coral recruits of Misali and Mnemba reefs showed more or less equal dominance for recruits of 3–5 cm and 6–10 cm, which accounted for between 38% and 40% (Table 4). In contrast, Bawe reef showed dominance of 3–5 cm recruits (52%), whereas the recruits of 6–10 cm were dominant at Chumbe reef (59%). Prevalence of bleaching for recruits was higher in Mnemba (75%) and Misali (61%) reefs relative to Bawe (58%) and Chumbe (56%) reefs (Table 4). High proportions of recruits were only partially bleached within sites, which accounted for between 36% and 38% in relation to other threats conditions. There was high death rate for recruits in Mnemba (28%), followed by Bawe (14%), and was lowest in Misali (7%) and Chumbe (7%). High death rate was mostly found in 6–10 cm recruits among size classes.

Discussion

Overview

By considering the magnitude of bleaching responses in relation to ratios of observed coral colonies in respective reef sites in this study, Bawe reef was found to have the highest bleaching susceptibility followed by Mnemba and Chumbe, with the lowest

Table 4 Size class distribution, incidence of bleaching, and prevalence of bleaching for coral recruits in Misali, Bawe, Chumbe, and Mnemba reefs

Site	Incidence of bleaching					Prevalence of bleaching			
Misali	Class	1–2.5	3–5	6–10	Sum	1–2.5	3–5	6–10	Sum
	B0	34	36	33	103	12.93	13.69	12.55	39.16
	B1	17	42	37	96	6.46	15.97	14.07	36.50
	B2	7	20	15	42	2.66	7.60	5.70	15.97
	B3	0	1	3	4	0.00	0.38	1.14	1.52
	D	1	5	12	18	0.38	1.90	4.56	6.84
	Sum	59	104	100	263	22.43	39.54	38.02	100.00
Bawe	B0	4	25	7	36	4.65	29.07	8.14	41.86
	B1	5	14	12	31	5.81	16.28	13.95	36.05
	B2	1	1	3	5	1.16	1.16	3.49	5.81
	B3	0	1	1	2	0.00	1.16	1.16	2.33
	D	0	4	8	12	0.00	4.65	9.30	13.95
	Sum	10	45	31	86	11.63	52.33	36.05	100.00
Chumbe	B0	2	10	18	30	2.94	14.71	26.47	44.12
	B1	5	7	14	26	7.35	10.29	20.59	38.24
	B2	0	1	3	4	0.00	1.47	4.41	5.88
	B3	0	2	1	3	0.00	2.94	1.47	4.41
	D	0	1	4	5	0.00	1.47	5.88	7.35
	Sum	7	21	40	68	10.29	30.88	58.82	100.00
Mnemba	B0	21	24	14	59	8.82	10.08	5.88	24.79
	B1	28	37	24	89	11.76	15.55	10.08	37.39
	B2	1	3	4	8	0.42	1.26	1.68	3.36
	B3	1	4	10	15	0.42	1.68	4.20	6.30
	D	2	23	42	67	0.84	9.66	17.65	28.15
	Sum	53	91	94	238	22.27	38.24	39.50	100.00

susceptibility in Misali (Table 2). Nevertheless, when these magnitudes were related to the pattern of change in coral cover of reef communities as an impact of bleaching, the results show that Bawe and Chumbe reefs lost more coral cover relative to Mnemba and Misali reefs (Table 5). As far as the assessment of ecological impact of stress to the reef community is concerned, the results suggest that it is more accurate to describe the trend of overall effect of stress by considering the total change of cover rather than ratios of observed number of coral colonies to total number of coral colonies alone. This is because different reefs have different coral size classes, which in turn determine the total number of colonies per unit area. Reefs with small coral colonies are expected to have more coral colonies per unit area than reefs with large coral colonies, and thus when bleaching occurs at a particular spot in the reef consisting of such small coral colonies, it will impact more colonies relative to a spot of the same area in the reef with large colonies. In this regard, it can be concluded that the effect of temperature stresses to reefs communities in Zanzibar for 2016 was higher in Bawe and Chumbe relative to Mnemba and Misali reefs.

Table 5 Comparison of reef live coral cover (%) in Misali, Bawe, Chumbe, and Mnemba reefs between 2016 and previously reported bleaching incidences

Site	Before 1998	After 1998	Loss 1998	2009	2012	2015	After 2016 bleaching	Loss 2016
Bawe	53	45	8	–	–	64	27	37
Chumbe	52	42	10	–	57		38	19
Mnemba	–	–	–	–	19	29	19	10
Misali	54	10	44	37	–	–	32	5

Bawe and Chumbe reefs had the highest coral cover prior to the 2016 bleaching among the four observed reefs (Table 5), and the cover was mostly dominated by the fast-growing species of branching and encrusting corals. Bawe reef was dominated by *Porites rus* (62%) followed by *Acropora* (14%) and branching *Porites* (7%), whereas Chumbe reef was dominated by *Acropora* (42%). It has been reported that fast-growing branching and encrusting coral species are the most susceptible to stresses in reef communities due to having thin tissues (Loya et al. 2001, McClanahan et al. 2007b). In this study, fast-growing branching species, which were dominant prior to bleaching, were the most affected. For instance, genus *Acropora* accounted for the most of dead corals observed on Misali (85%), Mnemba (43%), and Chumbe (63%). Likewise, branching *Porites* was the most affected genera in Bawe (39%) followed by *Acropora* (19%). The results therefore suggest that the impact of bleaching in four studied reefs was related to coral cover at local scale and concurred with other findings that fast-growing branching corals were the most affected.

Considering the latitude of the reef locations, the surveyed reefs were located within a range of about S 1° 2.9841, with Misali (S 5° 13.9935) and Chumbe (S 6° 16.9776) reefs being at the northern and southern tips, respectively. The regional (East African region) analysis of sea surface temperatures variability, during both non-ENSO and ENSO years, revealed significant latitudinal variations, with a pattern of increase toward the south (McClanahan et al. 2007a). The observed patterns of bleaching susceptibility in this study, that reefs located in relatively low latitudes (Bawe and Chumbe) were more susceptible relative to those reefs that were at relatively higher latitudes (Mnemba and Misali), are related to the pattern of sea surface temperatures variability in the region. The results of this study are further supported by larger areas based on sea surface temperature data from NOAA for regional prediction of coral bleaching, which indicated larger area of “Alert level 1” more in low-latitude zones than higher-latitude zones in the region (Fig. 1).

Coral cover analysis showed that Misali reef had the highest coral genera richness and highest Shannon diversity and was the least affected reef. Alternatively, Bawe reef was found to have the lowest coral genera richness and Shannon diversity index and indeed was the most affected reef. Prior to bleaching, Bawe reef was dominated mainly by stands of branching *Porites* as was *Acropora* for Chumbe (Muzuka et al. 2010) as the second most affected reef. The diversity of genera in the ecological community is important in maintaining the stability of the system (Schläpfer and Schmid 1999; Pausas and Austin 2001). It is thus possible that dominance of the monospecific stands of coral genera in these reefs made them less resistance to thermal stress as they provide uneven distribution of genera within community. The results suggest the existence of relationship between the coral diversity and resistance to bleaching within reef communities such that the more diverse reefs have greater chance to withstand temperature stresses than the least diverse reefs.

Misali and Mnemba reefs are located close to deep channels of the open ocean, whereas Bawe and Chumbe are not. The ocean water currents are important oceanographic components in mixing of heat in the oceanic water column (Thorpe 1995; Garrett 1996; Moum and Smyth 2001). With the observed pattern of impact on thermal stresses among the observed reefs, where Misali and Mnemba lost relatively low coral cover than Bawe and Chumbe, it could thus be argued that Misali and Mnemba reefs were advantaged to cooling effect of the currents coming from the deepwater channels in their proximities. The relatively higher coral recruits density and diversity observed in Misali and Mnemba reefs further suggest the optimistic rapid recovery to these reefs and thus with high potential in supplying the seedlings to other surrounding reefs.

Sea surface temperatures during 2016 El Nino in Zanzibar peaked at about 30.6 °C, which was relatively low by 0.1 °C to that of 1998 (Fig. 1a). Even though the temperature produced significant thermal stress to reefs in both occasions with longer-lasting period for 1998 thermal stress, the effect on coral cover on the observed reefs was more prominent in 2016 than 1998 (Table 5). The possible explanation for this finding could be the difference in intensity of stresses that reefs experienced between 1998 and 2016. It could be proposed that in 1998, the scale of other stresses (besides thermal stress) that were imposed on reefs was relatively low. This led to a condition that despite the high intensity of thermal stress, the deterioration rate due to long lasting higher temperatures was relatively low. But the 2016 thermal stress acted on reefs that are still in recovery process from the 1998 bleaching and are experiencing increased pressures from numerous human-related threats. The threats are due to population expansion which, along the coast, means an increase in harvesting of marine resources, thus exacerbating the situation further.

Implication for Reef Management

Coral reef recovery after stress is dependent on factors such as larval availability, larval settlement rate, recruitment, and growth. Understanding on the severity of the effect of thermal stress as a threat factor to coral reefs health is important for managers to take appropriate management measures to assist the recovery process. This study reports the magnitude of coral bleaching in Zanzibar reefs as an impact of thermal stress following the prolonged sea surface temperatures in the region in March–May 2016. Severity of thermal stress in coral reefs is dependent on factors such as reef topography, diversity, and community composition. Thermal stress on coral reefs in Zanzibar is associated with proliferation of algal communities (peaking in April–May (Muhando 2003)). Algal communities in reef ecosystems are threatening when they overgrow the corals as they weaken the reef resilience, a situation which occurs when herbivore densities in reef communities are below optimum level.

It is thus important for managers at this time of the year to first control any further reef disturbing activities to these damaged reefs such as destructive fishing and overfishing and second to strongly put efforts in controlling activities that will lower herbivore densities in coral reefs such as fishing of herbivore fish species. The effort should be highly invested on conserved reefs and on reefs with potential value for being marine protected areas so as to restore reef resilience by maintaining the diversity.

Marine conserved reefs have also a potential value of restocking other degraded reefs by providing seedlings through larval supply. The observed coral bleaching severity and its impacts to coral cover loss suggest that Bawe and Chumbe reef were the most affected relative to Misali and Mnemba reefs. Bawe reef has been also reported to be vulnerable to other stresses such as sedimentation (Muzuka et al. 2010). Chumbe reef is considered to be a vital larval source to many northern reefs including Bawe. It is thus suggested that there is an urgent need for management interventions to help rapid recovery for Bawe and Chumbe reefs.

The impact of temperature stresses in coral reef community is not only detriment to coral reef ecosystems, but it is also disadvantageous to other sectors of which their flourishment is directly linked to the health of coral reef ecosystems such as fisheries and tourism (Lange and Jiddawi 2009). For instance, it has been revealed that reef fish assemblages are impacted by the shift in benthic phase due to utilization of dominant benthic habitat either as food or shelter (Sale 2013). This means that any change in dominant live coral cover in the reef might bring substantial damage to not only survival of the overall reef community but also in turn might harm the economy of the nation. It should thus be anticipated that the 2016 observed damage on coral reef in Zanzibar due to thermal stress might threatens the fisheries and tourism sectors as well. This calls for the collaborative strategy among environmental, tourism, and fisheries managers in minimizing the anthropogenic threats so as in the short run to facilitate quick recovery to the damaged reefs and in the long run to make the reef ecosystems continue in providing their services.

Conclusion

The prevalence of bleaching among surveyed reefs varied between 74% (Misali) and 88% (Bawe). However, the effect of bleaching to coral cover loss was more pronounced in Bawe (37%) and Chumbe reef (19%). Genus *Acropora* was the most affected coral with higher relative proportions of dead colonies for Misali (85%), Chumbe (63%), and Mnemba (43%) and *Porites* for Bawe (39%). Genera *Porites* at Bawe and *Acropora* at Misali and Mnemba have temporarily lost their dominance to *Echinopora*, *Galaxea*, and *Porites*, respectively. Coral diversity was highest in Misali for both adult and recruit populations and was lowest in Bawe reef. Geographical location, coral community composition, diversity, and reef topography are suggested to be among the determinant factors for variability in coral bleaching prevalence and impact to coral cover loss.

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An Assessment of the Vulnerability and Response of Coastal Communities to Climate Change Impact in Lindi Region, Southern Tanzania

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Abstract The main objective of this research was to provide an understanding of how the coastal communities are changing in their vulnerability to climate change and how the livelihood systems are adapting to the change and the implications on coastal resource use, governance and management. Specifically, the study sought to assess the current trends in climate change and variability and their impacts on the livelihoods of the coastal communities; examine the vulnerability of the coastal communities to climate change and other stressors; investigate how local communities are coping with multiple stresses caused by climate change and variability; and examine the implications of the community responses to coastal resource use, governance and management. The study was conducted in eight villages in Lindi Rural and Kilwa Districts, Lindi Region. The "household" was used as a sampling unit. A total of 223 households (7.7% of the total households 2892) were randomly selected as the study sample. Household surveys, key informant interviews and FGDs were conducted to get information on the perception of the local community on climate change and its impacts on individual and community livelihood systems. Findings show that climate change and variability is a reality in the two districts. The data point to increasing temperatures and decreasing rainfall trends. Climate variations that have been taking place have inflicted heavy losses in agriculture, which is the main livelihood source for the majority of the population in the study villages. The high poverty levels in the two districts have worsened the situation, with individual households and communities becoming more vulnerable to climate change impacts. A majority of the poor and intermediate households have been experiencing food shortages for almost half of the year, and sometimes deaths have been reported, as was the case during the severe drought of 1997.

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Introduction

Although there is uncertainty of data on climate change, there is growing scientific evidence and predictions that point to the increasingly warming trend globally. According to IPCC (2014a), the average land and ocean surface temperatures have shown a warming trend of 0.850 °C over the period 1880 to 2012, the last three decades having been successively warmer at the earth's surface than the preceding decades since 1850. The period from 1983 to 2012 was likely the warmest 30-year period of the last 1400 years in the northern zone (IPCC 2014a). Earlier records by IPCC (2001) showed an increase of the global average surface temperature of about 0.60 °C since the end of the nineteenth century with the 1990s being the warmest decade in the instrumental record since 1861. Increase in maximum temperatures, numbers of hot days and the heat index had been observed over nearly all lands during the second half of the twentieth century (ibid). IPCC (2007a) also reported that the world had warmed by an average of 0.760 °C since pre-industrial times and that the global average temperatures were expected to increase by 1.80 °C to 40 °C if no mitigation measures were taken (IPCC 2007a).

Africa has not been an exception to this increased warming trend especially over the last 50 to 100 years (IPCC 2007a, 2014b). Projections show that the mean annual temperatures are likely to exceed 20 °C by the last two decades of the twenty-first century compared to the late twentieth century (IPCC 2014b). Further evidence shows that Africa was warming faster than the global average, with mean average temperatures expected to exceed an average of 30 °C to 60 °C by the end of this century (IPCC 2007a, 2014b). Most of Southern Africa is believed to have experienced upward trends in annual mean, maximum and minimum temperatures during the last half of the twentieth century (IPCC 2014b).

Available records on Tanzania show a dramatic change of climate, especially in the past (Benjaminsen et al. 2008; Kiage and Liu 2006; URT 2003). Kiage and Liu (2006), for example, revealed major changes in climate and vegetation with alternating warmer and cooler and wetter and drier periods for the past 50,000 years than the present. Temperature and rainfall variations have also been observed throughout the country. As reported by URT (2003), temperature variations were expected to increase by 3.50 °C particularly during the cool months, while rainfall showed a decreasing trend in some parts of the country (URT 2007). Along the coast of Tanzania, available records show a downward trend of temperature (Benjaminsen et al. 2008).

Much of the observed increase in global average surface temperature has been attributed to anthropogenic greenhouse gases. IPCC (2014a), for example, notes that more than half of the observed increase in global average surface temperature from 1951 to 2010 was caused by anthropogenic increase in greenhouse gas (GHG) concentrations together with other anthropogenic forcings. This human-induced climate change was taking place in various social and natural systems of the world with increasing magnitude of floods, droughts, rainfall variability and extreme events (IPCC 2001; Hannah et al. 2002). Climate model simulations for the twenty-first century have consistently projected increased precipitation in high latitudes and parts of the tropics and decreased precipitation in some subtropical and lower midlatitude regions (Bates et al. 2008).

Recent trends show that the magnitude of floods, droughts, rainfall variability and extreme events is increasing (Bates et al. 2008; IPCC 2007a, 2014a; Lawton 2010; Mwebaza 2010) as a result of climate change. Precisely, these factors have impacted the human health, agriculture, water, biodiversity and the environment in general. Evidences show that the changes in climate are already altering both the natural and human systems on all continents and across oceans (IPCC 2001, 2007a, b, 2014a). Recent climate-related extremes, especially droughts and floods, have also revealed significant vulnerability and exposure of many human systems to current climate variability (IPCC 2014a). The intensity, nature and consequences of environmental change, however, differ from region to region.

Climate change remains a major challenge in Africa. Climate is becoming more variable and less predictable in many areas and trends towards future changes are emerging. West Africa, for example, has seen a drop of 20–40% in annual rainfall between 1930 and 1990 (Salami 2010). Accordingly, many parts of Nigeria have experienced the effects of climate change with modifications of intensity and seasonality of the rains, elevation of average annual temperatures and increased frequency of widespread, high impact weather phenomena including drought and flooding. In Sudan, there are reports of rains falling late and the rainy season being shorter and warmer. Meanwhile the dry season was getting longer and hotter (Sulienam and Ahmed 2013).

In East Africa, current trends indicate successive poor rains, an increase in drought-related shocks and more unpredictable and sometimes heavy rainfall events (Oxfam International 2008). Projections also show an increase in temperature of up to 2–40C by 2080s, with more intense rain predicted to fall in the short rains *Vuli* (October–December) over much of Kenya, Uganda and Northern Tanzania as soon as 2020s and becoming more pronounced in the following decade (Oxfam International 2008). Such trends are expected to continue in the next 10–15 years. Moreover, there is evidence for a high degree of spatial and temporal variability of rainfall, with a decrease in rainfall observed over much of Eastern Africa during *Masika* between March and May/June over the last three decades (IPCC 2014b). This is clear evidence that Africa is at the highest risk of climate change, given the magnitude of existing stresses in the continent. These changes are likely to add to the vulnerability of the human systems, which is resulting from a complex interplay of natural processes and changing socio-economic and political circumstances.

Africa is expected to be more severely affected than other regions due to its greater vulnerability of its economies such as crop production, livestock keeping and tourism, to climatic variation, geographic exposure and low income (Collier et al. 2008; Yanda and Mubaya 2011). Accordingly, decreased crop productivity, especially cereals, and coastal flooding in low latitudes are expected to occur and so are animal and plant species extinctions. In the East African countries of Kenya, Uganda and Tanzania, climate-related vulnerabilities over the recent decades have already been successive poor rains, frequent droughts and unpredictable and sometimes heavy rainfall events, which make it difficult to plant and harvest crops (Oxfam International 2008).

The coastal zones of Tanzania, with a large and growing population and a low adaptive capacity due to low national wealth, are reported to be highly vulnerable to climate change and sea level rise (Kebede et al. 2010). Accordingly, most rural communities of the coast are very poor, earning less than USD 100 per capita. These communities also depend on multiple livelihood strategies that are closely linked to services provided by coastal ecosystems, including fishing, subsistence farming, seaweed farming, tree planting, coconut farming, firewood and building pole collection (Devisscher 2010). Climate change along with the high vulnerability of the low-lying coastal areas to sea level rise threatens the population, infrastructure and socio-economic development in the coastal zone (Kebede et al. 2010). It could also pose significant risks in the coastal zone due to the high concentrations of population, significant economic activities and important ecosystem services within low-lying areas.

The low national economy and other development indicators as well as high dependence on natural coastal resources add to the challenge. Already, agriculture in Lindi District has been observed to be vulnerable to climate change, and there is a significant risk that communities could face even warmer temperatures and less predictable rainfall (TFCG 2012). The potential impacts are likely to affect the most vulnerable due to multiple stresses and their low ability to prepare, adapt and respond. Research is therefore needed to explore how socioecological systems in the coastal areas are changing in their vulnerability to climate change and to understand how the coastal inhabitants are coping and adapting or are likely to adapt to future climate change impacts.

The main objective of this research was to provide an understanding of how the coastal communities are changing in their vulnerability to climate change and how the livelihood systems are adapting to the change and the implications on coastal resource use, governance and management. The motivation for this work came from the fact that there is considerable uncertainty about how climatic change futures will affect coastal areas and how the socio-economic systems are likely to adapt to these changes. Specifically, the study sought to assess the current trends in climate change and variability and their impacts on the livelihoods of the coastal communities; examine the vulnerability of the coastal communities to climate change and other stressors; investigate how local communities are coping with multiple stresses caused by climate change and variability; and examine the implications of the community responses to coastal resource use, governance and management.

Conceptual Framework

The conceptual framework shown in Fig. 1 will guide this research. The framework recognizes inherent susceptibilities of human environment systems exposed to climate change and variability. It is based on the widely accepted definition of IPCC (2007b) that vulnerability is a function of the character, magnitude and rate of

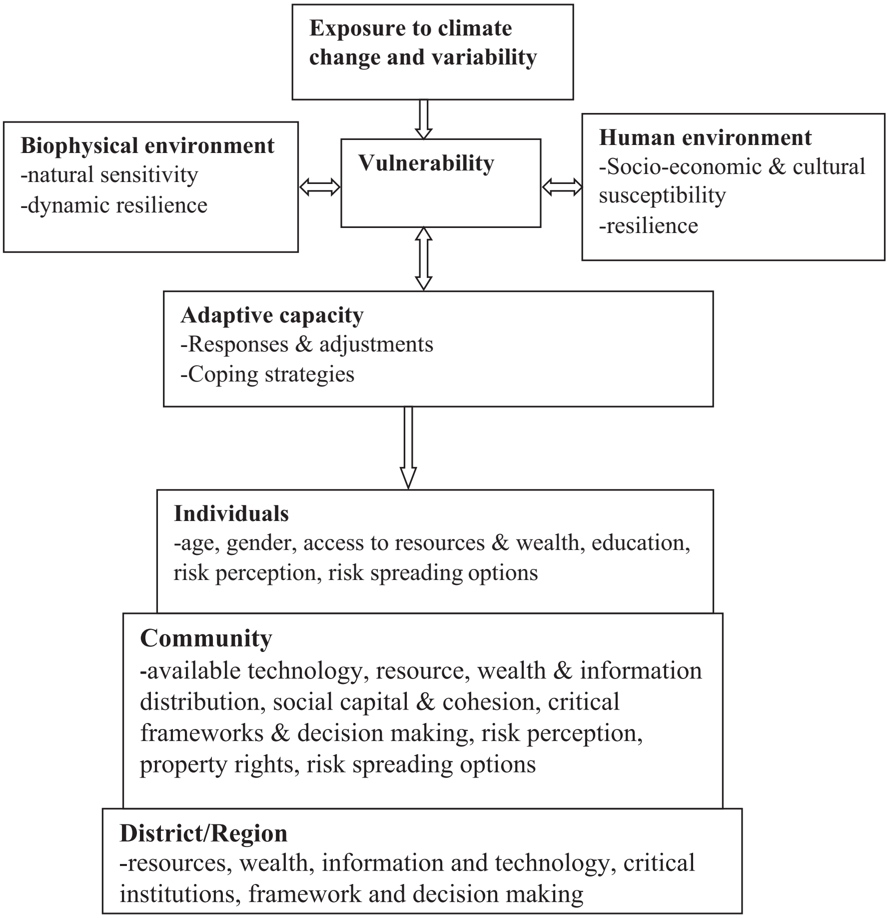

Fig. 1 Integrated Vulnerability Assessment Framework. (Source: Adopted From Dolan and Walker 2004)

climate change and variation to which a system is exposed, its sensitivity and its adaptive capacity. As climate change impacts are unevenly distributed among and within nations, regions, communities and individuals due to differential exposures and vulnerabilities, the framework highlights determinants of adaptive capacity at the local scale.

The framework is relevant to this research as it can be used to examine the relationships between climate-related vulnerabilities and adaptation practices which is the focus of this research. The framework which originally was developed and used for the coastal communities in Brazil has also been found relevant for this study because it can be used to assess vulnerability of coastal communities in similar ways.

From Fig. 1 exposure to climate change and variability can be characterized by susceptibility, resilience and resistance from the natural and human environment.

Both the human- and natural-induced susceptibility lead to vulnerability and reduced resilience. The two are dynamically interacting and coevolving systems that share vulnerability. In the context of coastal areas, however, apart from rising seas, short-term exposure to variability and extreme events is also an important source of vulnerability superimposed on long-term climate change.

According to Smit and Pilifosova (2003), adaptive capacity is an inherent property of the systems (both human and natural) that defines its capability to deal with exposures individually or at community level. Adaptive capacity and resilience, however, are affected by a number of factors such as poverty, gender, education, access to resources and technology, involvement in decision-making, age, power and perceptions, among other variables. In this line, individuals and communities that are structurally organized to minimize the effects of hazards while being able to recover quickly by restoring socio-economic vitality and social networks are resistant and resilient. This is also possible with adequate support from the district, region or national spheres.

Methods and Materials

Description of the Study Area

This study was conducted in eight villages located in Lindi Rural and Kilwa Districts, in Lindi Region (Fig. 2). The villages were Kilolambwani, Mvuleni B, Mnang'ole and Kijiweni in Lindi District as well as Mitole, Migeregere, Kikole and Ngea in Kilwa District. Lindi District lies between latitudes 9° 30' S and 10° 45' S and between longitudes 38° 45′ and 40° 00′ East of Greenwich. Kilwa District, on the other hand, is located north of Lindi District between latitudes 8° 20′ and 9° 56′ and between longitudes 38° 36′ and 39° 50′ East of Greenwich.

The biophysical conditions of Lindi Rural and Kilwa Districts are described in detail in URT 2011, TFCG (2012) and DED (2013). The climate in Lindi District is influenced by the south-east and the north-east trade winds, which also influence the onset and amount of precipitation. The annual rainfall ranges between 800 mm and 1200 mm, the rain seasons comprising the short *Vuli* rains (November to January) and the long *Masika* rains falling from March to May (URT 2011). According to TCFG (2012), 85% of the rain falls between December and April, although there is a dry spell that is experienced in February. Rainfall, however, is not uniformly distributed. Wide variations of precipitation are experienced throughout the district. The average temperature ranges from 24 °C to 27 °C, with September to December being the hottest months.

Kilwa District has a coastal climate, with rainfall being influenced by the monsoon winds. The district has two rainy seasons, the *Vuli* short rains experienced from late October to December and the *Masika* long rains received from mid-March to May. Rainfall ranges from 800 mm to 1400 mm per year, although the distribution varies according to locality (DED 2013). For example, the area north of Kilwa

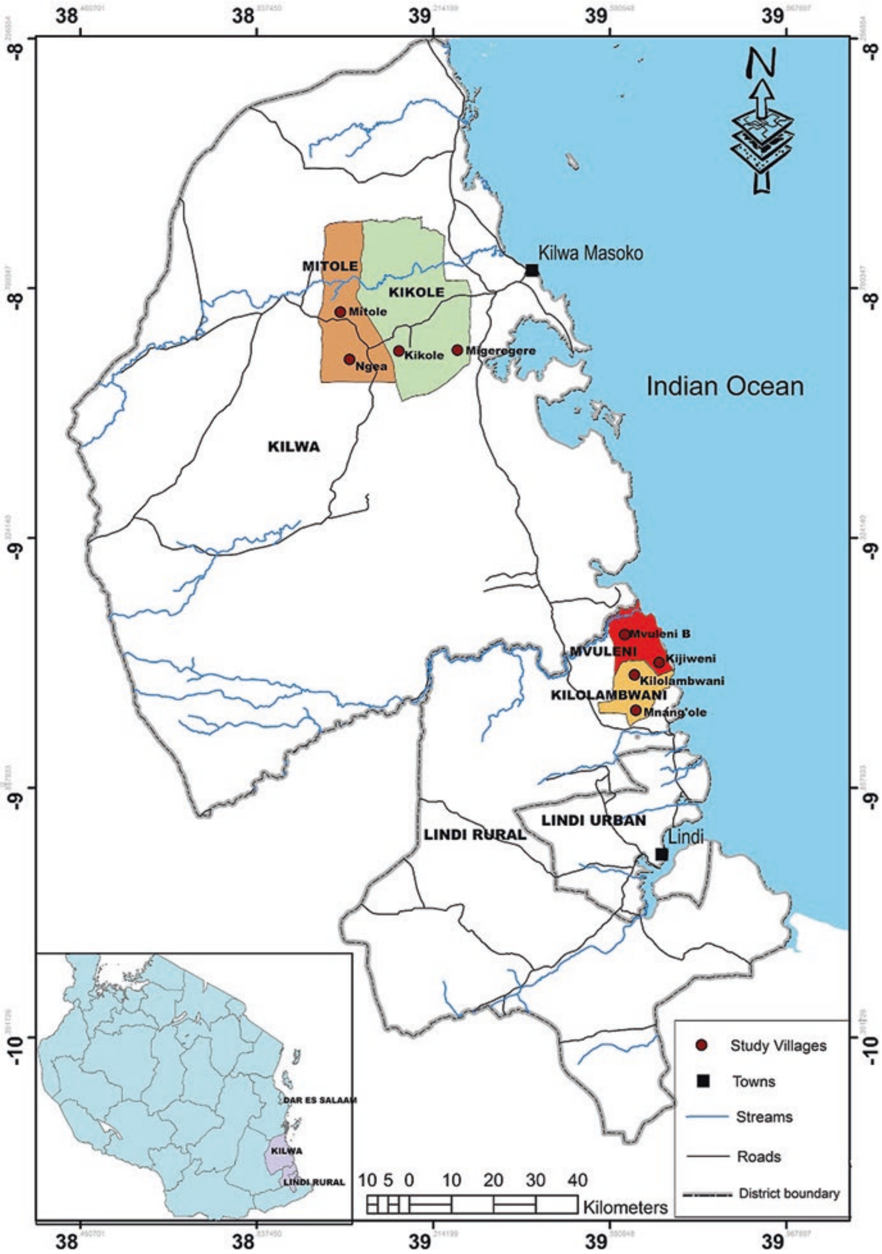

Fig. 2 Location of the study villages in Lindi and Kilwa Districts

Masoko receives very high rainfall of between 1000 mm and 1400 mm, while the south receives 800 mm to 1400 mm. The district is hot and humid, with temperatures ranging between 22 °C and 30 °C. Because the district lies along the coast, it has very high humidity, nearly 98% to 100% during the long rains.

The vegetation cover is predominantly dry miombo woodlands, although variations in vegetation cover exist in different areas. For example, the low-lying coastal strip in Kilwa District is covered by the East African coastal forests and thickets, while the upland areas have heterogeneous vegetation cover, with the miombo belt dominating much of the landscape (DED 2013). Human activities, however, have greatly reduced the extent of the coastal forests.

The main economic activities in the two districts are farming and fishing. The main crops grown are maize, cassava, sorghum, cashew nuts, groundnuts and recently simsim (sesame). Agriculture is mostly rain-fed and thus it is highly susceptible to drought. Although Lindi District has 10,000 ha, which have potential for irrigation, only 1416 hectares (14.16%) is presently under irrigation (Mwakalinga 2014). In Kilwa, the area being irrigated is only 1.85%. Kilwa District is, however, rich in marine resources, including a variety of fish (about 350 species). Despite this richness, only 20% of the people depend directly on the use of these marine resources for their livelihoods (DED 2013). This is mainly through artisan fishing, fish and seaweed farming, lime obtained from burning corals and harvesting of mangrove for business and domestic purpose.

Livestock keeping is also practiced in the two districts. The 2011 estimates indicate that Lindi district had 10,650 cattle, 19,410 goats and 4627 sheep, while Kilwa had 1436 cattle, 4879 goats and 5000 sheep (URT 2011). More recent statistics, however, show a significant increase in livestock numbers particularly in Kilwa District due to immigration of livestock keepers into the district from the adjacent Rufiji District. Thus, currently, Lindi and Kilwa Districts have a total of 13,009 and 18,156 local cattle, respectively (Regional Executive Secretary, 2015 personal communication). In addition, Kilwa has 92 improved cattle breeds and 9834 goats, while in Lindi Rural District, there are 1106 improved cattle breeds and 25,897 goats.

Selection of the Study Area

Lindi and Kilwa Districts were selected for this study because they are located along the coast and are among the most vulnerable districts in the region. According to Mwakalinga (2014), all districts in Lindi Region have pockets of vulnerable areas. Some districts, however, are more vulnerable than others. Such districts, arranged by descending order of vulnerability, are Kilwa, Lindi Urban, Lindi Rural, Liwale, Nachingwea and Ruangwa (Mwakalinga 2014). Because this study was interested in examining rural livelihood systems, Lindi Urban District was excluded. Based on the above arrangement of decreasing vulnerability and hinterland location, Liwale, Nachingwea and Ruangwa were also excluded.

With the assistance of the district authorities in Kilwa and Lindi, two most vulnerable wards in each district were selected for the study. These were Kilolambwani and Mvuleni in Lindi District and Kikole and Mitole wards in Kilwa District. Furthermore, two most vulnerable villages in each of these wards were selected. Only those villages with agriculture/livestock/fishing as their main livelihood sources and those that were easily accessible by road were selected for the study. In total eight villages were selected for the study.

Sampling Frames, Procedures and Sample Size

The target population for this study comprised all households engaged in agriculture and/or fishing and livestock keeping as their main livelihood sources. In selecting the sample population, the study used the "household" as a sampling unit. Lists of heads of household and the total number of households in each village obtained from the respective Village Executive Officers (VEOs) were used as sample frames from which representative sample sizes were determined.

According to Kothari (2004), for a sample to be representative, it should range between 5% and 10% of the population, in this case households. It was the intention of this study to obtain 10% of the households in each village to constitute the sample size. However, this was not the case in some villages due to time limitations and logistical problems. Thus a total number of 223 households, constituting 7.7% of the total households (2892) in all the study villages, were randomly selected as the sample (Table 1).

The age of the surveyed head of households ranged from 22 to 75 years, with a mean of 46.6. More than 87.5% of the surveyed respondents belonged to the active age group (22 to 60 years), and only 12.5% was elderly people of 70 years and above. Of these respondents 57% were males and 43% were females. The married respondents were 83%, 6.7% were widows while 4.5% never married. The other 5.8% were separated or divorced. The education levels of the respondents ranged from no education to attainment of certificates and a diploma. On average 36.3% were illiterate, 57.8% had progressed to primary school education only and 5.8%

Table 1 Sample size of the selected villages in Lindi Rural and Kilwa Districts

District	Ward	Village	Total HH*	Sample HH	% of Total
Lindi Rural	Kilolambwani	Kilolambwani	221**	30	13.6
		Mnang'ole	265	20	7.5
	Mvuleni	Mvuleni B	363	30	8.3
		Kijiweni	477	30	6.3
Kilwa	Kikole	Kikole	370	30	8.1
		Migeregere	329**	30	9.1
	Mitole	Ngea	180	23	12.8
		Mitole	687	30	4.4
		Total	2892	223	7.7

Key: *Based on 2015 internal village census
**Based on 2012 Population Census

had gone to secondary and technical education. Average household size of the respondents consisted of a minimum of one and a maximum of 14 members in the family with a mean of 2.57 and a standard deviation of 1.78. This meant that family sizes were on average moderate for a developing rural community in Africa and was far below the average household size for Lindi District, which was 3.8 (URT 2011).

The target population also included key informants at the village level who were largely made up of village chairmen and VEOs in each village, agricultural extension officers, longtime residents and project leaders or members associated with the sample villages. These were purposively selected for in-depth interviews. The focus group discussion (FGD) members were also purposively selected based on their occupation and were believed to have relevant knowledge on climate change and the response of the communities to climate change impacts. There were three such FGD groups in each village, each consisting of six to seven members who separately represented farmers, livestock keepers and those engaged in fishing activities. There were two additional groups in Kilolambwani, one representing members of the Cassava Farming Association and another group representing members of the Village Natural Resources and Environment Committee.

Data Collection Methods

Different methods were used to collect both qualitative and quantitative data, which included primary and secondary data. These are presented below in relation to each of the specific objective:

Specific Objective 1 Assess the current trends in climate change and variability and their impacts on the livelihoods of the coastal communities.

In this task, recent meteorological station data (mean maximum and minimum temperature as well as total monthly rainfall) for a period of 10 and 30 years for Kilwa and Mtwara Meteorological Stations, respectively, were collected from the Tanzania Meteorological Agency (TMA). The Kilwa Station started its operations only in 2005, and thus only 10-year records (2005–2015) were available. Because there is no weather station in Lindi District, we had to use the Mtwara station data covering the period 1985–2015. These data were subjected to descriptive statistics with a view to investigating the trends in climate change and variability. Household interviews, key informant interviews and FGDs were conducted to get information on the perception of the local community on climate change and its impacts on individual and community livelihood systems. Some of the information that were collected included peoples' understanding of climate change, local indicators of climate change, trend of precipitation in the last 30 years and length of the growing season. Other variables were climate change impacts experienced in agriculture, livestock and fisheries in the locality, crops affected, prevalence of pests and diseases as well as status of fish catches.

Specific Objective 2 Examine the vulnerability of the coastal communities to climate change and their adaptive capacity.

The methodology used for assessment of vulnerability as adopted from Tetra Tech ARD (2013) is illustrated in Fig. 3. Vulnerability assessment focused on the exposure of individuals and communities to climate change impacts, their sensitivity to climate change and adaptive capacities and vulnerability of livelihood systems, including agriculture and fishing. Livestock keeping was not a dominant activity in the study villages; therefore, it was not given priority.

Primary data on assets (type and status of houses, land ownership, credit and others), agricultural production, fishing activities, income, of-farm activities, coastal resource use and governance were also collected. Secondary data included participation in decision-making, gender roles as well as legal frameworks for management of coastal resources. Household survey using structured questionnaires, key informant interviews and FDGs were carried out in each study village. The data collected from questionnaires formed the basis of the quantitative analysis of household-level vulnerability through resource dependency and poverty and quantitative analysis of adaptive capacities.

Specific Objective 3 Investigate on how local communities are coping and adapting to multiple stresses caused by climate change and variability.

In this task, relevant information on various coping and adapting strategies employed at all levels to cope with the impacts of climate change was obtained

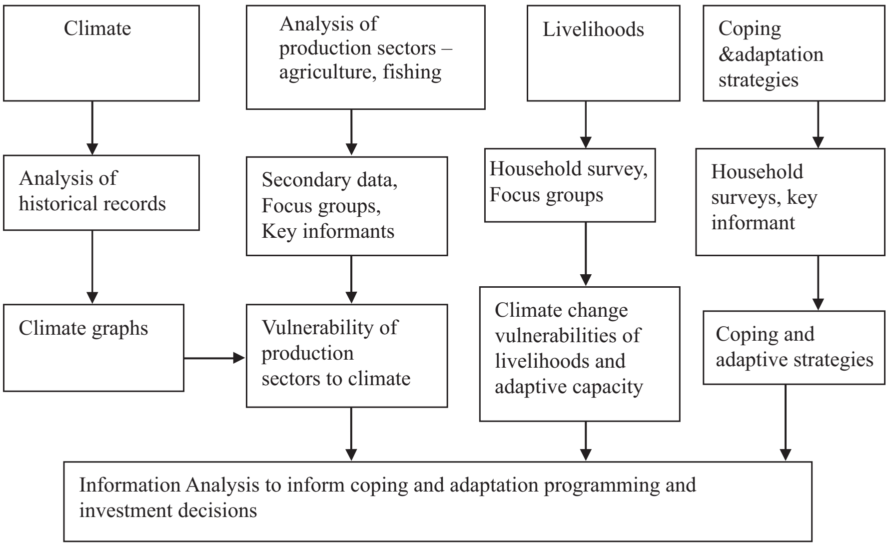

Fig. 3 Methodology for assessing of vulnerability and adaptive capacity of livelihood systems. (Source: Adopted from Tetra Tech ARD 2013)

from the questionnaire interviews. The data gathered were subjected to computer processing and analysis using the IBM Statistical Package for Social Science (Version 20) programme to produce descriptive statistics such as frequencies, means and percentages. Cross-tabulations on variables such as age, gender, education, remittances and physical assets were made against different coping strategies by districts. The results are presented in this chapter in various forms, including text, tables and graphs.

Data on community adaptation and institutional inertia in the treatment of present climate extremes were also collected through qualitative data from community-level officials and from households within these communities, as well as discussions with key informants at the local level. This involved semi-structured interviews with community officials and with households within those communities during the survey period. This strategy aimed at producing qualitative data on community-level institutional practices; on household-level adaptation; and on underlying views on the hazardous nature of the physical environment. The collection of both quantitative and qualitative data was expected to promote the adoption of a comprehensive and multidimensional approach used in climate change adaptation and mitigation studies.

Specific Objective 4 Examine the implications of the community responses to coastal resource use, governance and management.

In this task, the data collected through the methods described in Objective 2 and Objective 3 were analysed and interpreted to show the implications of community responses to coastal resource use, governance and management. Specific attention was paid to participation in decision-making, gender roles as well as legal frameworks for management of coastal resources as well as other variables.

Results and Discussion

Climate Change and Variability

This section provides evidence for climate change and variability. It presents the local community's understanding of climate change and variability and analyses the trends of temperature and rainfall over a 30-year period to provide evidence for climate change and variability in the study districts. According to IPCC (2001) climate change is defined as a statistically significant variation in the mean state of the climate or its variability, persisting for an extended period that ranges from decades or longer. Climate variability on the other hand refers to the short-term (daily, seasonal, annual, interannual, several years) fluctuations or variations in climate (Grains Research and Development Corporation 2011). These include fluctuations associated with El Niño (dry) and La Niña (wet) events.

Local Understanding of Climate and Perceptions on Indicators of Climate Change and Variability

An inquiry was made to respondents on their understanding of the concept of climate. The respondents generally defined climate by referring to various weather parameters such as rainfall, temperature, wind, drought, floods and diseases occurrence as indicated in Table 2**.** This is obvious as almost all the respondents interviewed in surveyed villages were smallholder farmers (97.7%) who depended on climate. In this case rainfall, temperature and drought are the main obstacles for crop production as observed elsewhere by IPCC (2007b); URT (2007); Majule et al. (2009); Shemsanga et al. (2010); and Lyimo and Kangalawe (2010). This made it easier for the respondents to relate these weather parameters as the main elements of climate.

A considerable number of respondents also perceived climate as wind, possibly due to poor knowledge on the linkage between wind and climate.

The study also revealed that there was a growing awareness among the respondents that climate change was occurring in their locality. Most of the respondents (98.7%) agreed that there was a change in climate conditions, while only 1.3% was unaware of the changing climate. These findings compare well with those of Lyimo and Kangalawe (2010) and Majule et al. (2009). Similarly, Juana et al. (2013) studying on climate perceptions and adaptations elsewhere in Africa concluded that there was increasing awareness of climate change among local communities in Sub-Sahara Africa.

During key informants' interviews and from the questionnaire survey, it was noted that respondents obtained knowledge about climate change through different pathways. These included own experience, the media (radios and televisions), village meetings, from extension officers, NGOS, CBOs and FBOs, researches and meteorological bulletins. Of these different ways, own experience was a popular method indicated by 74.5% of the respondents, followed by media (17.6%) and village meetings (4.5%). The remaining pathways were lowly ranked by respondents indicating that their efforts in raising awareness and climate change education to farmers in these surveyed villages were minimal.

Table 2 Respondents' understanding of climate

Parameters	Responses	
	Frequency	Percentage
Climate as rainfall	200	26.9
Climate as temperature	187	25.2
Climate as drought	164	22.1
Climate as wind	107	14.4
Climate as floods	78	10.5
Climate as diseases occurrence	7	0.9
Total	**743***	**100.0**

**Key*: Based on multiple response analysis

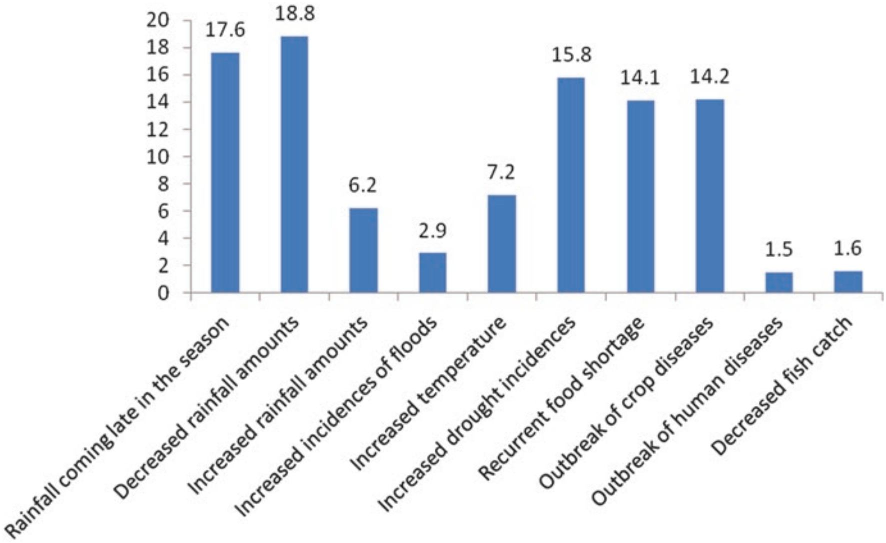

Fig. 4 Local indicators of climate change. *Based on multiple responses

Despite the fact that agricultural support services, including extension services, are essential for enhancing farmers' productivity (Sokoni 2014), only 2.7% of the respondents indicated to have frequently received extension services, while 35% had occasionally received the services, and 62.3% had never received any extension services at all. The lack of extension and support services tended to enhance vulnerability of the farmers to the impact of climate change as it reduced their adaptive capacity. Farmers require better knowledge and technology among others since for human systems, success of adaptation depends critically on availability of necessary resources, not only financial and natural resources but also knowledge, technical capability and institutional resources (Brown et al. 2012; Jacobs et al. 2015).

Figure 4 shows the parameters that were mentioned by the respondents as local indicators of climate change. Decreased amounts of rainfall, rainfall coming late and increased drought incidences were the highly ranked indicators of climate change. The higher ranking of these indicators means that they had a significant impact on communities' livelihoods. Other significant identified indicators of climate change included outbreak of crop diseases (14.2%), recurrent food shortages (14.1%), increased temperature (7.2%) and increased rainfall amounts (6.2%) crop.

Trends in Climate Change and Variability

Trend analysis of rainfall and temperature data was performed to give an indication of the changing climate and variability. The results indicate that climate variability was evident in Lindi and Kilwa Districts as illustrated in Figs. 5 and 6**,** respectively.

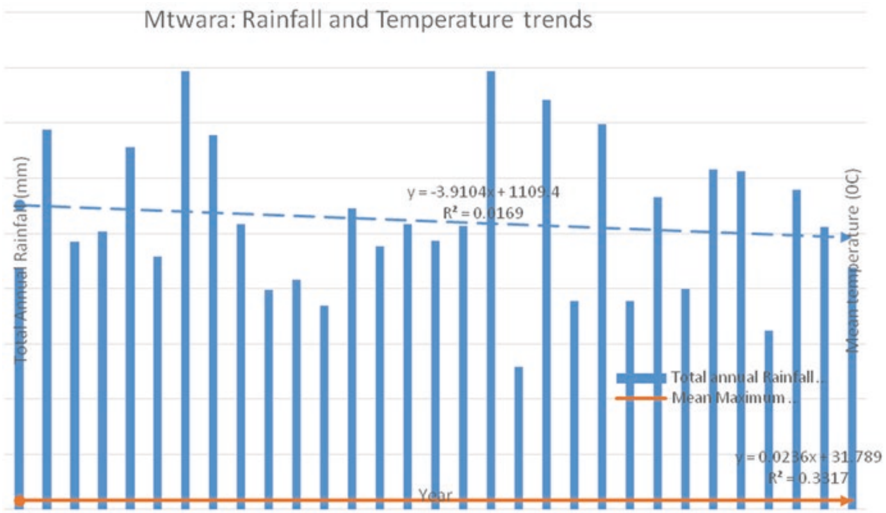

Fig. 5 Rainfall and Temperature Trends at Mtwara Meteorological Station, 1985–2015

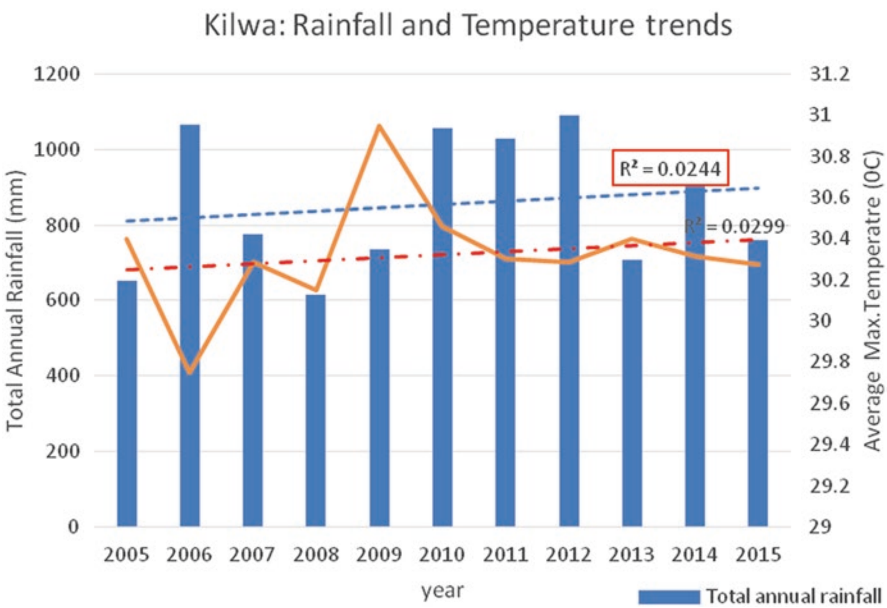

Fig. 6 Rainfall and Temperature Trends at Kilwa Meteorological Station, 2005–2015

An increasing trend of temperature and decreasing trend of rainfall were observed in Lindi District over a 30-year period (1985–2015), while in Kilwa District, the 10-year data (2005–2015) indicate an increasing trend of rainfall and temperature. The results for Kilwa, however, must be interpreted with caution because a 10-year period may be too short for one to arrive at any conclusive statements. Nevertheless, the data give an indication of the possible trends in the changing climate and variability.

A more detailed analysis of rainfall data from Mtwara Meteorological Station provides evidence for extreme rainfall events, with below average rainfall having been experienced in 1993–1997, 2003, 2005, 2007, 2009 and 2012. This is supported by the household survey data, of which 96% of the respondents confirmed that rainfall was decreasing (Table 3).

Similarly, information from the key informants and focus groups in all of the surveyed villages confirmed that the study villages experienced severe droughts in 1996/1997, 2007 to 2009 and 2012/2013 that led to severe food shortages. In Kilwa District, the periods from 2007 to 2009 as well as 2013 (Fig. 6) show reduced amounts of annual rainfall. The year 1997 was also reported by key informants in Kilwa District to be a bad year associated with severe drought.

From Figs. 5 and 6, it can be observed that periods of severe droughts were followed by years of above-average rainfall. Periods of extreme heavy rainfall events that were reported by the key informants and focus groups in Lindi District were in 1998, 2008, 2013 and 2015. These years were associated with floods that devastated crops in some villages. The same was also reported by key informants in Kilwa District, where severe floods were experienced in 1998.

During the FDGs, villagers complained as well about diminished, erratic and unreliable rainfall. They also complained that rainfall seasons were becoming very unpredictable. They said that currently there was only one rainy season, while previously there were two such seasons. They also complained of the late onset of the rains. Sometimes rains would start normally but end early. Extreme events of rainfall with sometimes heavy rains that caused floods were also reported. The same findings were reported by the key informants. The situation was said to have worsened since the late 1990s when increased incidences of drought had been experienced in Lindi District. There was thus a general feeling that rainfall had decreased in Lindi District since the 1ate 1990s. This is supported by rainfall data shown in Fig. 5.

Vulnerability, Livelihoods and Climate Change

This section analyses the extent to which coastal communities are vulnerable to multiple stressors, including climate change. It describes the socio-economic activities being undertaken by the communities, their poverty levels and vulnerability based on a wealth ranking exercise as well as the impact of climate change on the livelihood systems, focusing on the vulnerability of these systems.

Table 3 Perception on the trend of rainfall by villages

	Village name								
	Ngea	Mnang'ole	Migeregere	Kikole	Kijiweni	Mitole	Mvuleni B	Kilolambwani	Total
Increasing	0	4	0	0	2	0	0	0	6
Decreasing	23	16	28	30	28	30	29	30	214
No change	0	0	0	0	0	0	1	0	1
No idea	0	0	2	0	0	0	0	0	2
Total	**23**	**20**	**30**	**30**	**30**	**30**	**30**	**30**	**223**

Main Socio-economic Activities in Lindi and Kilwa Districts

The results of this study show that the respondents engaged in various socio-economic activities ranging from nature and non-nature-based activities (Table 4). The extent of a household engagement into various activities depended on the socio-economic conditions of the household.

Specifically, majority of the respondents (97.8%) engaged in rain-fed agriculture as their main source of livelihood. This statistic was over and above the national one that indicates that almost 80% of the population residing in rural areas in the country engaged in small-scale agriculture as the main source of livelihoods (URT 2013). The main crops grown by the respondents included maize, simsim, cashew, paddy, cassava and millet. Of these crops simsim and cashew nuts were for commercial purposes, while the remaining was for subsistence. The higher engagement of the respondents into rain-fed agriculture suggests that many livelihoods are susceptible to the impacts of climate change.

Crop cultivation was also dominated by smallholders who used crude hand hoes. Data from the survey and interviews revealed that crop production in Lindi District was declining causing food shortages in many households of the district. For example, in the surveyed villages, 57.4% of the respondents experienced frequent food shortages in their households, 38.1% had occasionally experienced food shortages while only 4.5% of the respondents had not experienced food shortages over the last 20 years.

Unlike in other parts of the country, livestock keeping was not a popular activity in Lindi and Kilwa Districts. Only 42% of the respondents kept livestock, mainly local chicken and goats. Only three respondents (1.3%) had cattle. These findings are supported by the 2013/2014 regional livestock statistics, which show that there were more chicken and goats than cattle in Lindi Region (Table 5). Most of the cattle that are kept are of the local breed. During FGDs and interviews, it was revealed that most of those who kept cattle were immigrants thrown out from Rufiji District.

Table 5 Number of livestock in Lindi Region 2013/2014

S/N	Type	Livestock numbers		Total
		Improved breed	Local breed	
1	Cattle	1106	12,909	14,015
2	Goats	302	25,897	26,199
3	Sheep	–	5965	5965
4	Duck	–	4110	4110
5	Chicken	2400	372,003	374,403
6	Pigs	306	–	306
7	Rabbit	–	2120	2120
8	Donkey	–	17	17
9	Dogs	–	1928	1928

Table 4 Main occupation of respondents

Occupations	Frequency	Percentage
Farming	218	97.8
Livestock keeping	1	0.4
Carpentry	1	0.4
Fishing	2	0.9
Civil servant	1	0.4
Total	**223**	**100.0**

Off-farm activities were also practiced by 30.9% of the respondents. These activities included fishing (7.2%), petty trading (12.1%), charcoal making (2.7%), tailoring (4.0%), driving (1.3%), carpentry (3.1%) and civil service (0.4%). These activities not only supplemented household livelihoods, especially when agriculture was affected by climatic factors, but also strengthened their adaptive capacity to climate change impacts.

Poverty Levels and Vulnerability of Coastal Communities

Based on the wealth ranking exercise that was conducted in each village, three wealth/poverty categories were identified. These were the well-off category, the moderately better-off and the poor category (Table 6). The results show that the well-off category at community level constituted between 2% and 15% of the population in the study villages; the moderately better-off constituted about 20% to 30%, while the poor formed the majority (75–98%) of the respondent households.

Based on the wealth ranking exercise, households in the different study villages were clustered into the respective wealth groups as shown in Table 7. The findings reveal that a majority of the households in the two districts fell into the poor category. Only a small percentage of households in three out of eight villages surveyed were in the better-off category. These findings are supported by data from the questionnaire interviews, which showed that a majority of the respondents (65%) belonged to the poor category, 28.3% belonged to the intermediate (moderately better-off) while only 6.6% belonged to the well-off category (see also Mung'ong'o and Moshy in this monograph).

During the wealth ranking exercise, it was revealed that there was no well-off category in Migeregere, Ngea, Kikole, Mnang'ole and Kijiweni villages. Three of these villages are in Kilwa District, which clearly shows that households in Lindi District were slightly better off than those in Kilwa District. This also shows the extent of vulnerability of households in Kilwa District and confirms the results of Mwakalinga (2014) which showed that Kilwa District was the most vulnerable among all districts in Lindi Region.

The fact that a majority of the respondents and villagers in general were in the poor category is an indication of the highest level of livelihood vulnerability of the community. This situation, however, is associated with the high level of poverty (Kebede et al. 2010; URT 2011), and in such a situation, vulnerability increases more when the impact of climate change is in interaction with other non-climatic factors.

Table 6 Wealth/poverty categories in the study villages

Wealth Group	% of households	Characteristics	Assets owned
Well-off	2–15	Engaged in agriculture, business; employ casual labour in farms, able to send children to schools, three meals a day	Shops and kiosks, brick houses or plastered houses with floor and corrugated iron sheets, bicycles, 4–6 acres of land, 4–7 acres of cashew farms, livestock, motorcycles, solar panels, television sets and dishes, mobile phones, income above 100,000 per year (some earn up to Tshs 3 million a year)
Intermediate (moderately better-off)	20–30	Petty traders, salaried employees, engaged in agriculture and fishing, can afford two meals a day, sell labour in big farms for cash income, able to buy children's clothes and medicine, most youths and middle-aged persons	Shops, kiosks, mud houses plastered and with corrugated iron sheets and floor, some grass-thatched houses, a few brick or stone houses, small farms (2–4 acres), 3–4 goats, 2 acres of cashew farms, regular hand hoes, income of 60,000–100,000 per year
Poor	75–98	Old people, some do not own houses, engaged in agriculture and/or fishing (15%), cannot send children to school, cannot afford medical services for children, sells labour as main activity, one meal a day, experience food shortage for 6–7 months a year, rely on good Samaritans for food	Grass-thatched mud houses, very small farms (< 1 to 2 acres), a few cashew trees (6–8) Small hand hoes

Table 7 Household clusters based on wealth groups in the study villages

	Percentage of households in the wealth categories		
Village	Poor	Intermediate	Better-off
Kilolambwani	75	20	5
Mnang'ole	98	2	0
Mvuleni B	55	30	15
Kijiweni	75	25	0
Kikole	80	20	0
Migeregere	90	10	0
Ngea	70	30	0
Mitole	60	30	10

Due to poverty that is compounded by crop failure (which is a source of income), most respondents used grass as roofing materials (Table 8) instead of iron sheets which were used by only a few. Regionally data shows that about 77.8% of total households use grass as roofing materials, 20.1% use iron sheet and 1.8% use grass

Table 8 Type of houses by villages

Types of houses	Village name								Total
	Ngea	Mnang'ole	Migeregere	Kikole	Kijiweni	Mitole	Mvuleni B	Kilolambwani	
Mud and grass roofed	22	11	25	10	22	22	23	10	145
Mud and iron roofed	0	7	5	17	5	5	6	18	63
Layer brick and grass roofed	1	0	0	0	0	0	0	0	1
Layer brick and iron roofed	0	2	0	3	1	1	1	1	9
Block and iron roofed	0	0	0	0	2	2	0	1	5
Total	**23**	**20**	**30**	**30**	**30**	**30**	**30**	**30**	**223**

and mud. With the noted physical hazards such as extreme droughts, storms and floods, majority of the respondents are vulnerable due to the nature of the houses they are living in. The houses are not stable to withstand intense storms. Loss of agricultural production translated into hardships and worsened rural communities' livelihoods. Of the surveyed respondents, for example, 81.6% indicated that their life status was becoming worse, while only 16.6% of the respondents reported to have a better life over the last 30 years. Respondents further indicated that the worse condition was contributed by low production (55.2%), decrease in income (15.7%), food insecurity (4.9%), ageing and low prices of agricultural products (93.1%), respectively.

Majority of the respondents own relatively small-sized land used for agriculture (Table 9), a situation which increases the rate of vulnerability to the impacts of climate change.

Agricultural development in the surveyed villages is not only constrained by climate change and variability but also the size of land under agriculture. During FGDs it was revealed that due to the nature of the land where one had to clear forests and woodlands to prepare land for cultivation compounded with lack of tractors, only a few individuals could have more than 15 acres. The nature of land acquisition also created vulnerability to climate change as most forests have been cleared for agriculture. This is evident from the survey data where a majority of the respondents acquired the land they were using for agriculture through clearing forests (Table 10).

The education level of the respondents is also a source of vulnerability to the impact of climate change. The results of this study show that education levels were very low in the two districts. The data show that 24% had no formal education at all, 12% did not complete primary school and 58% completed primary school education. Only 6% had some tertiary education and were employed as teachers, health officers and auxiliaries in the villages. Compared to the national statistics, however, Kilwa and Lindi Districts have the lowest literacy rate of 47% and 49%, respectively, compared to other districts in the country (URT 2011). However, some of these relatively illiterate farmers had progressed to the well-off and intermediate wealth groups.

Gender, age and marital status are other sources of vulnerability. Key informants revealed that majority of the people who constitute the poor category were the elderly people (60+), single women and the widows. Their vulnerability was based on the nature of the shifting cultivation practiced in the area that one required good health to be able to clear forest land for crop production almost each year. The youth were able to do this and that is why they had at least 5–10 acres of land unlike the elderly and widows. The women were not only vulnerable because of their gender, but it was also due to the lower literacy level they had compared to men. A cross tabulation between gender and education level revealed a significant difference between male and female respondents. In the *no education* category, females were twice as males. For those who completed primary education, males were 36%, while females were 22%. This data compares well with the regional data which shows that literacy rate is high for males compared to females.

Table 9 Size of land owned by villages (acres)

Size of land	Village name								Total
	Ngea	Mnang'ole	Migeregere	Kikole	Kijiweni	Mitole	Mvuleni B	Kilolambwani	
<5	13	9	17	17	17	18	10	17	118
5–9	9	4	12	10	11	9	10	9	74
10–14	1	5	0	2	2	2	5	1	18
15–19	0	2	1	1	0	0	2	3	9
20–24	0	0	0	0	0	0	1	0	1
25–29	0	0	0	0	0	1	2	0	3
Total	**23**	**20**	**30**	**30**	**30**	**30**	**30**	**30**	**223**

Table 10 Means of land acquisition in the study villages

Means of land acquisition	Number of respondents by villages								
	Ngea	Mnang'ole	Migeregere	Kikole	Kijiweni	Mitole	Mvuleni B	Kilolambwani	Total
Bought	0	1	0	0	3	0	1	9	14
Inherited	0	0	0	2	7	2	2	13	26
Given by relative	1	0	1	0	2	0	0	0	4
Cleared forest	22	19	29	28	18	28	27	8	179
Total	**23**	**20**	**30**	**30**	**30**	**30**	**30**	**30**	**223**

Generally the communities in the studied villages were very vulnerable to the impact of climate change as they were exposed to both the physical hazardous events (such as extreme drought and floods) as well the social conditions (high level of poverty) that exist among the coastal communities. Village wise the social vulnerability was, however, not homogeneous. It varied from one village to the other as shown in Tables 8, 9 and 10.

Impact of Climate Change on Livelihood Systems

The fact that local communities in the surveyed villages largely depend on rain-fed agriculture (Table 11) makes their livelihoods and food security highly vulnerable to climate change and variability. As shown in Fig. 4, not only had rainfall decreased but it had also been coming late in the season (see Fig. 4). This was also emphasized during the FGDs, where it was noted that agriculture had been heavily affected by climate variability. Farmers could no longer determine when to start planting crops as the seasons had shifted. Apart from seasonal shifts, extreme climatic shock/events such as extreme drought (74.4%), floods (21.8%), high temperature (1.7%) and storms (2.0%) had intensified in recent years.

These climatic events cumulatively or singly had resulted into reduced crop harvests, increased incidences of food shortages, declines in fish stocks and loss of income as indicated in Table 12**.**

Increased incidences of crop failure were among the most noted impact of climate change among the communities. Such crop failures had been responsible for recurrent food shortages in some villages and had resulted into physical deterioration and migration of some community members. During FGDs in Kilolambwani, Mvuleni B, Migeregere and Mitole villages, it was revealed that there had even been death incidences in some villages as a result of hunger.[1]

The results show that food insecurity is high in the study villages. Of the 223 surveyed respondents, only 4.5% were food secure, while the majority (95.5%) reported food shortage incidences especially over the last 3 consecutive years. The major reasons for food shortages were crop failures due to inadequate rainfall and drought. However, it should also be noted that the problem of food shortages is also compounded by the high priority given to cash crop production.[2] Table 13**,** for example, shows that more acreage of the arable land was being devoted to simsim and cashew than food crops such as maize, millet, cassava and paddy.

Additionally, food shortage was compounded by the problem of destructive animals such as monkeys, warthogs and elephants. The problem is very severe as most of the villages are surrounded by the miombo woodlands and reserved forests.

[1] Three deaths were reported to have occurred in Mvuleni B in 1997 due to severe drought.

[2] In cases of stable and fair markets, increased production of simsim has, however, been associated with improved life.

Table 11 Production sector most affected by climate change in villages

Sector	Village name								Total
	Ngea	Mnang'ole	Migeregere	Kikole	Kijiweni	Mitole	Mvuleni B	Kilola Mbwani	
Agriculture	23	20	30	30	24	30	29	28	214
Livestock	0	0	0	0	0	0	1	0	1
Fisheries	0	0	0	0	6	0	0	2	8
Total	**23**	**20**	**30**	**30**	**30**	**30**	**30**	**30**	**223**

Table 12 Impact of climate change as experienced in the study villages

Impacts	Responses	
	Number	Percent
Increased incidences of crop failure	219	46.2
Decline in fish stock	22	4.6
Decline in diversity of fish	6	1.3
Inadequate local fish supply	44	9.3
Loss of livestock	6	1.3
Loss of income	177	37.3
Total	**474***	**100.0**

**Key:* Based on multiple responses

Table 13 Acreages allocated to various crops

Statistics	Acreage allocated to different crops					
	Paddy	Maize	Simsim	Cashew	Cassava	Millet
Mean	0.641	2.367	2.874	1.648	0.717	1.350
Median	0.000	2.000	2.000	0.000	0.000	1.000
Mode	0.0	2.0	2.0	0.0	0.0	0.0
Std. deviation	1.2895	2.1267	2.2705	3.1467	1.5878	2.0159
Range	10.0	10.0	12.0	21.0	10.0	12.0
Minimum	0.0	0.0	0.0	0.0	0.0	0.0
Maximum	10.0	10.0	12.0	21.0	10.0	12.0

Although crop pests and diseases were lowly ranked during the FGDs, respondents complained about the loss of produce due to new diseases. It was also revealed that although some of the diseases had been there for quite some time, their magnitude and effect had doubled and were affecting all crops. Some of the diseases and pests mentioned included mealy bug, grasshoppers (which affect cassava), powdery mildew (**ubwiliunga**), blight, dieback, fusarium (affecting cashews) and aphids (**vibaruti, maungu, kiasali** – affecting simsim). The increased prevalence of crop diseases was reported by 94.6% of the respondents. An inquiry was also made to understand whether the current prevalence of the mentioned crop diseases was related to climate change or not. The results indicated that 86.5% confirmed that the diseases were related to climate change.

Coping Strategies and Challenges to Address Climate Change Impacts

UNFCCC (2008) defines adaptation to climate change as the process that entails taking the right measures to reduce the negative effects of climate change (or exploit the positive ones) by making the appropriate adjustments and changes. Respondents in the surveyed villages were asked on their understanding of the concept of adaptation to climate change. Several definitions were provided as presented in Table 14**.**

Table 14 Understanding adaptation to climate change by villages

Responses	Number of respondents by villages								Total
	Ngea	Mnang'ole	Migeregere	Kikole	Kijiweni	Mitole	Mvuleni B	Kilolambwani	
Environmental conservation	2	0	5	6	2	1	3	3	22
Reduce climate change impact	1	4	6	6	5	2	4	6	34
Reduce drought effects	4	1	0	0	0	5	0	2	12
Respond to climate change impact	1	6	1	1	10	0	0	3	22
Improve income	0	1	0	0	0	2	2	0	5
I don't know	15	8	18	16	13	20	20	12	122
Changing farming practices	0	0	0	1	0	0	1	4	6
Total	**23**	**20**	**30**	**30**	**30**	**30**	**30**	**30**	**223**

Table 15 Household adaptation strategies to climate change impact

Strategy	Responses	
	Frequency	Percentage
Crop diversification	170	35.2
Planting drought tolerant varieties	159	32.9
Planting early maturing varieties	80	16.6
Planting high yielding varieties	52	10.8
Investing in children education	8	1.7
Seeking alternative source of income	13	2.7
Migration	1	0.2
Total	**483***	**100.0**

**Key:* Based on multiple responses

The various meanings of adaptation given by respondents were an indication that they were aware of the impacts they were facing.

The assessment of available adaptation strategies indicated that households had several coping and adaptation strategies (Table 15), which is an indication that households are not homogeneous. At household level strategies ranged from crop diversification, planting drought resistant crops, planting early maturing crop varieties as well as outmigration. Crop diversification was the most opted strategy with priority on simsim production for cash income and cassava for food. Cultivation of drought-resistant crops such as cassava and millet was also a significant strategy. Planting of cassava is actually a regional policy which requires every household to have at least 2 acres of cassava as a preparedness measure against impacts of drought.

Respondents also indicated that apart from their own effort, there were institutions that were helping them to adapt to the impacts of climate change. Of the total respondents, 49.3% indicated having received different support from institutions, while 50.7% had never been supported by any institution. The supporting institutions as mentioned by the respondents included the government (37.7%), government and NGOs (7.6%) and NGOs (mainly faith based) (3.6%). These institutions basically provided food relief (37.2), training (3.1%) and seeds (0.4%).

Interviews with key informants and FGDs revealed that charcoal making and timber trade had become widespread as alternative livelihood strategies. It was revealed that quite a number of the villagers were engaging in these activities because agriculture had become problematic. Unlike in the past years, persistent unreliable rains had discouraged some of the farmers from entirely depending on agriculture.

Discussions with the district officials revealed that irrigation farming in valley bottoms was also being emphasized as a strategy to cope with drought. It was thus that currently Lindi District had six irrigation schemes, of which two were operational. The schemes were expected to help farmers produce rice, maize and vegetables throughout the year. The aim is to increase food production and sustain food security of the whole region.

Table 16 Challenges in adapting to impacts of climate change

Challenges	Responses	
	Frequencies	Percentage
Destructive animals	131	29.9
Inadequate fund to buy inputs	145	33.1
Crop pests and diseases	37	8.4
Lack of farming inputs	82	18.7
Lack of extension services	39	8.9
Low price of cash crop	4	0.9
Total	**438***	**100.0**

**Key:* Based on multiple responses

In the surveyed villages, it was noted that most of the adaptation strategies were either from individual effort or from directives from the regional or district authorities. At the village level, there were no village activities done collectively to adapt to climate change. It was only in Kilolambwani village where farmers had a collectively owned cassava farm. Arrangements for this farm were that on harvesting, farmers could sell the produce or distribute it among the members for household use. This reduced the negative impacts of drought, especially when there was crop failure at individual farm level.

Several challenges in adapting to climate change impacts were identified by respondents as presented in Table 16**.** Of the mentioned challenges, lack of inputs (33.1%), destructive animals (29.9%) and lack of extension agricultural services (8.9%) emerged as the most important challenges to the farmers in the surveyed villages.

These challenges reduced the ability of the community to effectively adapt to impacts of climate change. During the FGDs, it was revealed that people had been demoralized to cultivate crops such as maize and cassava because of destructive animals. The low price of agricultural produces which was associated with the free market economy where the government did not control the price was another disturbing factor. Farmers complained of private buyers who offered them low prices without any options for negotiation since the government did not buy the products, especially simsim.

Implications of the Community Responses to Coastal Resource Use, Governance and Management

In recent years forest clearance in reserved and unreserved forests has increased due to shifting agriculture mostly for cultivation of simsim – a lucrative cash crop of which the price ranges from Tsh 1600 to Tsh 2500. The promising increase in price has attracted a lot of villagers, especially the youth, to engage in simsim production. With regard to cultivation of simsim, key informants in Migeregere village revealed that the farms could be put into use for 2 years only after which the farmer had to clear a new forested land for production of the crop. Lack of fertilizers and pesticides, compounded by climate change that had increased simsim crop diseases and pests, necessitated the opening up of new farms after a very short period of use of the original land. In fact Miya et al. (2012) confirms that shifting cultivation has been a common practice for all annual crops in Lindi and Kilwa Districts and that only immigrants to the districts practiced permanent farming.

Secondly, forests were being cleared for charcoal making (Plate 1) and fuel wood requirement as well as logging and timber trade. Charcoal and timber production were on increase as there was a great demand and reliable market in areas such as Dar es Salaam, Zanzibar and Mafia Island. Timber and charcoal production were conducted by both the licensed and illegal traders. A discussion with Ngea's VEO, for example, indicated that timber production was legally permitted in his village reserved forests. Those with legal permits (license) paid 50% of the total harvest to the village, 5% to the municipality, 40% to natural resources sector and 5% to the Mpingo Conservation Development Initiative. The VEO also revealed that illegal logging was on the highest rate compared to legal logging and timber production.

Third, forests were being lost through burning of forests. In the surveyed villages, there was minimal tillage due to the use of crude tools; hence, they depended on the use of fire for farm preparation as well as the tendency of people to light fires for hunting of small animals in the miombo woodlands. During the surveys, for example, burnt forests were a common feature in many places (Plate 2).

Generally, shifting cultivation, logging and timber trade, charcoal production and fuel wood requirements and fires are the major drivers of forest loss in Kilwa and Lindi Districts. This is confirmed by a study by Milledge et al. (2007) and Malimbwi et al. (2005) who have indicated that the forests in Lindi Region are highly degraded. The surveyed communities were, however, aware that the forests were changing and forest loss was associated with the decrease of rainfall and the increased drought they were now facing (Gwambene 2007).

Conclusions and Recommendations

This study embarked to provide an understanding of how the coastal communities were changing in their vulnerability to climate change and how the livelihood systems were adapting to the change and the implications on coastal resource use, governance and management. The motivation for this work came from the fact that there is considerable uncertainty about how climatic change futures will affect coastal areas and how the socio-economic systems are likely to adapt to these changes. Specifically, the study sought to assess the current trends in climate change and variability and their impacts on the livelihoods of the coastal communities; examine the vulnerability of the coastal communities to climate change and other stressors; and investigate how local communities were coping with multiple stresses caused by climate change and variability. And finally, the study aimed at examining

Plate 1 Pieces of wood prepared for charcoal production in Ngea village. (Source: Photos by the Authors, 2015)

Plate 2 Part of the degraded forests due to fire in Ngea village. (Source: Photos by the Authors, 2015)

the implications of the community responses to coastal resource use, governance and management.

From the preceding results and discussion, it is evident that climate change and variability is a reality in Lindi and Kilwa Districts. Both the temperature and rainfall data, especially for Lindi District, and the data from the questionnaires and information from key informants and FGDs all point to increasing temperatures and decreasing rainfall trends, which could be an indication of climate change. Further analysis and scientific evidence, however, is needed to prove categorically that climate change is already happening. What this study has done is to show that the climate variations that have been taking place have inflicted heavy losses in agriculture, which is the main livelihood source for the majority of the population in the study villages. The high poverty levels in the two districts have worsened the situation, with individual households and communities becoming more vulnerable to climate change impacts. As it has been observed, a majority of the poor and intermediate households have been experiencing food shortages for almost half of the year, and sometimes deaths have been reported, as was the case during the severe drought of 1997.

Although there have been attempts to diversify economic activities and the crops grown, with the addition of the cash crop simsim,[3] opportunities are limited due to limited assets owned by the poor households. This is a clear indication that these coastal communities are vulnerable in multiple ways, not only to climate change. Hence even their ability to adapt to climate change is curtailed.

Although the government has always come in to rescue the situation with food relief in times of hardship, such measures can only provide temporal relief to individual households. What is actually needed is to strengthen the capacity of the farmers to adapt to the impacts of climate change. This can be done by providing technical support to farmers to reduce risks as well as providing opportunities to invest in agriculture and allow for innovation and adaptation to take place. Provision of small loans and credit facilities could help in providing such opportunities. There is also need to strengthen assets, such as financial, human and social capital, that would help the communities to invest in less climate dependent livelihoods.

At the ecological level, future climate projections such as those by Arnell et al. (2014) suggest that African people would be living in water-stressed watersheds by the year 2050. The studies also speculate that suitability of cropland for crop cultivation will decline across much of sub-Saharan Africa, primarily due to reductions in available moisture. River and coastal flood risk will increase in particular for many East African coastal communities. Therefore, adaptation to climate change impacts coupled with actions to lower greenhouse gas emissions should be given top most priority in order to meet the sustainable development goals (SDGs), particularly those that target poverty reduction and combating climate change and its impacts (ICSU and ISSC 2015). Identification of adaptation benefits from any specific development activity require an idea about how climate change is projected to affect that location and the system, as well as about the effectiveness of strategies for reducing vulnerability and increasing adaptation to such changes.

[3] The crop is emerging as a major cash crop almost replacing cashew nuts in the two districts.

Understanding how climate change will affect the composition, structure and functioning of the ecosystems and how these changes might affect the livelihoods of the millions of people depending on their goods and services has been declared a top priority by the scientific community (IPCC 2007b).

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Coastal Communities' Perceptions on Climate Change Impacts and Implications for Adaptation Strategies in Mtwara, Southern Tanzania

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Abstract This chapter discusses vulnerability and adaptation of the coastal communities to climate change impacts with the aim of contributing to an understanding on how vulnerability and livelihoods are constructed among coastal communities, with particular focus on Mtwara communities along the southern coast of Mtwara Region, Tanzania. This study aimed at identifying pathways to reduce vulnerability and enhance resilience of livelihoods of the concerned coastal communities. The study was conducted in four villages purposively selected based on the existing diversity reflecting issues related to fishing as well as farming livelihoods. The selection of the villages was also made to cover both the coastal strip and the nearby zone, to capture issues related to coastal fishing and farming. A total of 200 households were included in the survey, 122 of whom were males. The research methods used in the two phases included key informant interviews, FGDs, transect walks and on-sight observations. The study also employed an integrated assessment of socio-ecological systems' vulnerability to climate change and variability as well as adaptive capacity and the implications of these in resilience. Climatic data from the TMA were also obtained in order to complement the observations from the field. Data from this study show that challenges and impacts associated with climate change are evident in this coastal environment of Tanzania. Common impacts included destruction of coral reefs, coastal erosion, destruction of coastal infrastructures and human settlements. They also included intrusion of seawater into freshwater wells and crop fields in the areas. Sea level rise was probably the most challenging climate change issue in the region since it threatened not only the livelihoods of the already stressed coastal communities but also the economy and integrity of the coastal ecosystems and resources.

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Introduction

Climate change is a global challenge, which manifests itself at local levels and in various socio-economic and natural systems. The adverse impacts of climate change are already being experienced in many parts of the world. Based on IPCC climatic projections, it is stipulated that these impacts will continue to be felt in many sectors. Almost all socio-economic systems and many facets of people's lives across geographical locations will be impacted (IPCC 2001, 2007, 2014). This chapter discusses vulnerability and adaptation of the coastal communities to climate change impacts with the aim of contributing to an understanding on how vulnerability and livelihoods are constructed among coastal communities, with particular focus on Mtwara communities along the southern coast of Tanzania. This study aimed at identifying pathways to reduce vulnerability and enhance resilience of livelihoods of the concerned coastal communities.

Coastal resources and ecosystems have immense contribution to livelihoods of coastal communities and national economies through inter alia, fishing, tourism and agriculture. Nevertheless, even without climate change, these coastal areas face many challenges associated with human and environmental change. Climate change, however, threatens the integrity of these ecosystems and their continued ability to provide ecosystem goods and services to the local communities (Bosire et al. 2010). Climate change is expected to amplify many of these and other stresses by increasing vulnerability on already highly vulnerable systems by developing new impacts and/or intensifying the already occurring impacts with synergic and cascading effects (EEA 2008). It is expected to affect coastal resources and ecosystems through sea-level rise, increase in sea surface temperatures, flooding, sedimentation and even prolonged droughts (Bosire et al. 2010; URT 2012).

Changing weather patterns affect the distribution and range of species and disrupt the natural balance of many ecosystems with implications for availability of fish and other coastal resources, including mangrove forests. Furthermore, coastal ecosystems are particularly sensitive to the increase in sea surface temperature, ocean acidification, rising water tables and altered runoff patterns (ETC-ACC 2010a). Climate change is increasing the frequency of natural disasters with overarching impacts on the health and adaptive capacity of coastal ecosystems (IPCC 2007). This is occurring at a time when there is an ever-increasing human dependence on coastal resources and growing populations in the coastal zone (Table 1). In some regions already stressed with overpopulation, poverty, internal conflicts, resource overuse and the spread of diseases, the additional impacts from climate change can be devastating.

Other common impacts are destruction of coral reefs, coastal erosion and submergence of small islands, destruction of coastal infrastructures and human settlement, intrusion of seawater into freshwater wells and crop fields and degradation of mangroves. Incidences of coral bleaching, due to extensive exposure of corals to warmer than normal water temperatures, have also been noted to increase (URT 2012). The National Climate Change Strategy (2012) emphasizes, however, that sea level rise is probably among the most challenging climate change problem since it threatens not only livelihoods of the already stressed coastal communities but also the economy and integrity of the coastal ecosystems and resources.

Table 1 Household sample proportions from the wards and villages and gender composition of the respondents (%)

Wards	Villages	Frequency	Gender		%
			Male	Female	
Nalingu	Mnazi	50	28	22	25.0
Msanga Mkuu	Sinde	50	32	18	25.0
Mayanga	Nangumi	50	36	14	25.0
Ndumbwe	Mnyundo	50	26	24	25.0
Total	Villages	200	122	78	100.0

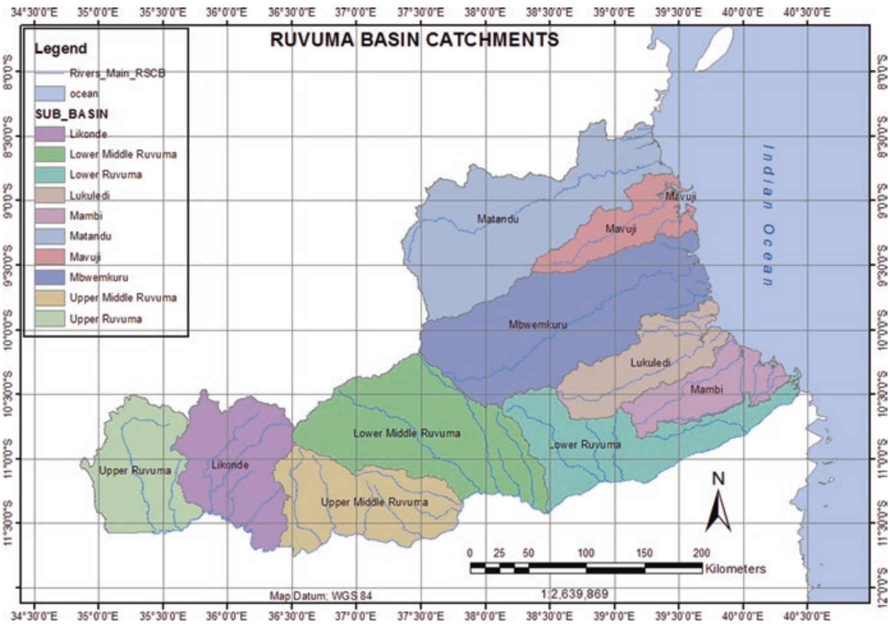


Fig. 1 Map locating the Ruvuma Basin Catchment

Methods and Materials

The Study Area

The study was conducted in Mtwara Region which is located in southern Tanzania. The Region is situated within the Ruvuma River Basin Catchment (Fig. 1). Four villages were selected for the study based on the existing diversity, as such reflecting issues related to fishing as well as farming livelihoods. Accordingly, the selection of the villages was made in such a way that it covered both the coastal strip, comprising of fishing communities, and the nearby zone, to capture issues related to coastal farming activities. The selected villages were Sinde, a fishing village in Msanga Mkuu Ward; Nalingu, in Mnazi Bay, in which communities engage in both fishing and farming; Hiyari village where communities engage in rain fed farming; and Mnyundo, in which both rain-fed and irrigation farming are practised. The selection provided room for comparative assessments of coastal systems' vulnerabilities to climatic and non-climatic factors due to their heterogeneity in bio-geophysical and socio-economic characteristics.

Data Collection Methods

The study used a multidisciplinary approach that drew on both qualitative and quantitative techniques. The study was conducted in phases. The first phase entailed a qualitative assessment of perceptions of climate variability and change, vulnerability assessment and understanding of existing adaptation measures. The research methods used in this phase included key informant interviews (KKI), focus group discussions (FGDs), transect walks and on-sight observations. This was achieved through stakeholders' consultation and discussions with key informants and groups of local communities.

In the second phase, quantitative methods were employed, and these included household surveys, analysis of vulnerability indicators based on the key livelihood systems. Conventional methods of coastal vulnerability assessments to climate change have mainly focused on natural resources and less on the dynamics of human and ecological process and even less on non-climatic environmental and socio-economic changes (Nicholls et al. 2007). Hence, this study employed an integrated assessment of socioecological system vulnerability to climate change and variability as well as adaptive capacity and the implications of these in resilience. Climatic data from the TMA were also obtained in order to complement the observations from the field.

In order to obtain a representative sample of the household survey, the four villages were sampled from four different wards: two wards, namely, Msanga Mkuu and Nalingu, represented the coastal areas, and Mayanga and Ndumbwe wards represented the farming communities in the hinterland. A total of 200 households were included in the survey. Of the 200 households, 122 respondents interviewed were males, while the rest were female. From each of the villages at least 25% of the total number of households in the village was sampled. Table 1 below shows household proportions from the wards and villages and gender composition of respondents.

Apart from household surveys, stakeholders' consultations were conducted with Mtwara regional, district and village level authorities. Further consultations were made with key stakeholders such as the Ruvuma River Basin Catchment staff as well as the Mnazi Bay-Ruvuma Estuary Marine Park (MBREMP) authorities. Focus group discussions (FGDs) at village level comprised 15–20 participants. The FGDs ensured that both men and women were represented, so as to capture well the different gender perceptions.

The household surveys were conducted using a structured questionnaire. All these consultations and interviews helped in establishing perceptions and experience with regard to climate variability and change at household and community levels, to examine generic changes in vulnerabilities of coastal livelihood systems through characterization of climatic non-climate factors that could be contributing to changes in these vulnerabilities in the respective communities and to explore communities' responses and adaptation strategies from household and community levels. To triangulate information that was obtained, the findings were synthesized in an integrated manner before being presented to feedback sessions with the key stakeholders across levels.

Results and Discussion

Analysis of Coastal Livelihood Patterns

It is understood that coastal ecosystems provide a myriad of ecological goods and services, food security and livelihoods of communities. Main livelihood activities that were reported by the respondents and observed in the study are presented in Table 2. Analysis of household survey data shows that mixed farming and fishing were the main livelihood activities along the coastal strip. While 50% of respondents in Mnazi Bay reported crop farming as their major livelihood strategy, 38% reported fishing. However, crop farming was widely practised in the hinterland villages. For example, in Mnyundo village, 100% of respondents practised crop farming, while 96% in Nangumi village practised farming.

Fishing was reported by only about 20% of all the respondents in the study area. It was reported that although fishing had been the traditional livelihood strategy in the coastal area for a very long period, it has been overtaken by farming due to poor productivity of the sector as a result of number of factors, including changes in the marine resources management regimes and climatic change. It was noted by one key informant that many middle-aged people had increasingly adopted fishing-farming mixed strategy while youth were mostly still engaged in fishing alone. The reason for this was that the youth had the energy to go far into the sea where fish catches were still good compared to the shallow waters.

Table 2 below shows the respondents' main livelihood strategies. Business-related activities in the study area were also related to fishing and agricultural production

Table 2 Respondents' main livelihood strategies

Village names	Livelihood strategy (%)			Total
	Farming	Fishing	Business	
Mnazi	50.0	38.0	12.0	100
Sinde	52.0	40.0	8.0	100
Nangumi	96.0	0.0	4.0	100
Mnyundo	100.0	0.0	0.0	100
Total	73.5	19.5	6.0	100

activities, as reported by more than 5% of all respondents. It was observed that while most men dealt with relatively bigger business activities such as maintaining retail shops, women were engaged in selling fish products and vendoring of crops.

Local Communities' Perceptions of Climatic Data

Climate change and variability in Mtwara Region is manifesting itself through an array of changes. The findings from FGDs and household surveys across all study villages indicate that villagers perceived climate change as a change of many things associated with changes in temperature, rainfall as well as wind patterns coupled with scarcity in the climate sensitive resources such as water and food.

Temperature Patterns

Analysis of respondents' perception on the behaviour of temperature over the past 30 years indicates that more 87% of them perceived an increasing temperature trend for the last 30 years. This trend is corroborated by the TMA data for 1971–2015 for Mtwara Region which revealed increasing temperatures during the period (Figs. 2 and 3).

As it can be seen from the two graphs above, both maximum and minimum temperatures show an increasing trend. Furthermore, respondents during the FGDs in the

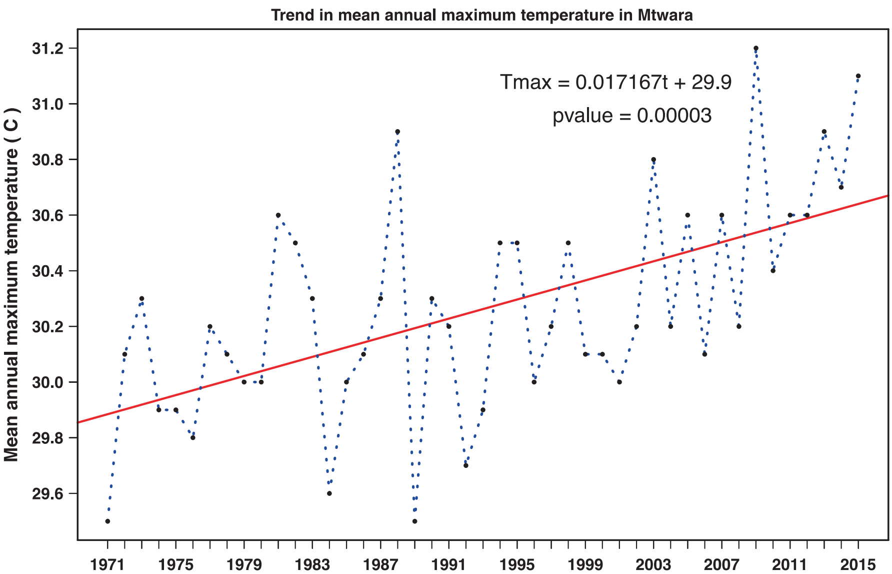


Fig. 2 Trend in annual maximum temperature in Mtwara. (Source: TMA data, 1971–2015)

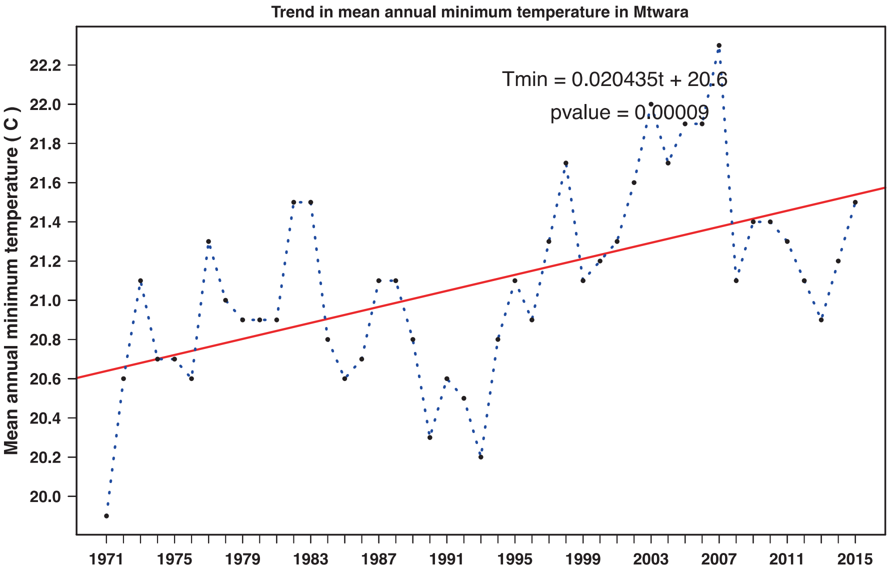


Fig. 3 Trend in annual minimum temperature in Mtwara. (Source: TMA data, 1971–2015)

study villages explained that they had been experiencing extremely higher temperatures that had not only affected livelihoods activities, but also they had had several health complications, including feeling body dehydration due to too much sweating. They further indicated that they had experienced a sharp increase in temperature over the 2 years. Accordingly, they explained that most of the people abandoned their bedrooms and slept outside in the open because it was too hot inside. Children and elders were mentioned to be the most affected during such hot conditions.

Associated with increase in temperature is sea level rise. According to the IPCC Assessment Report (2007), sea level is projected to rise by between 18 and 59 centimetres by the end of the twenty-first century (Nicholls et al. 2007). In addition, with high confidence, IPCC (2014) asserts that between 1901 and 2010, the global mean sea level rose by 0.19 m and that the rate of sea-level rise since the mid-nineteenth century has been larger than that of the previous two millennia. This makes coastal human systems particularly vulnerable to sea level rise. As a consequence of these realities, and considering projections by the IPCC that over the twenty-first century temperature will continue to rise, the ocean will continue to warm and acidify, and global mean sea level to also rise (IPCC 2014). It is thus that climate change is considered by many to be one of the most serious challenges of the twenty-first century and a priority for immediate action for coastal areas (Rahmstorf 2010).

With regard to the impacts of climate change on coastal natural resources, it has been established that incidences of coral bleaching, due to extensive exposure of corals to warmer than normal water temperatures, have been noted to increase (URT 2012). This has implications in the sustainability of the integrity of the coastal socioecological systems.

Trends in Rainfall Data

Analysis of annual rainfall data over a period of over 30 years indicates that the amount of rainfall per year has been declining (Fig. 4). It should be noted, however, that this is not a linear decline in rainfall rather a trend indicating fluctuating rainfall patterns across years.

Findings obtained during FGDs with local communities as well as from HH interviews indicate that villagers have been experiencing fluctuations in rainfall conditions, with some areas experiencing more droughts while others experiencing flooding incidences. The observed changes in rainfall patterns were reflected in the following attributes (also reflected in Fig. 5 below):

- General reduction in the average amounts of rains
- Changes in temporal and spatial distribution of rains
- Increased incidences of erratic rains

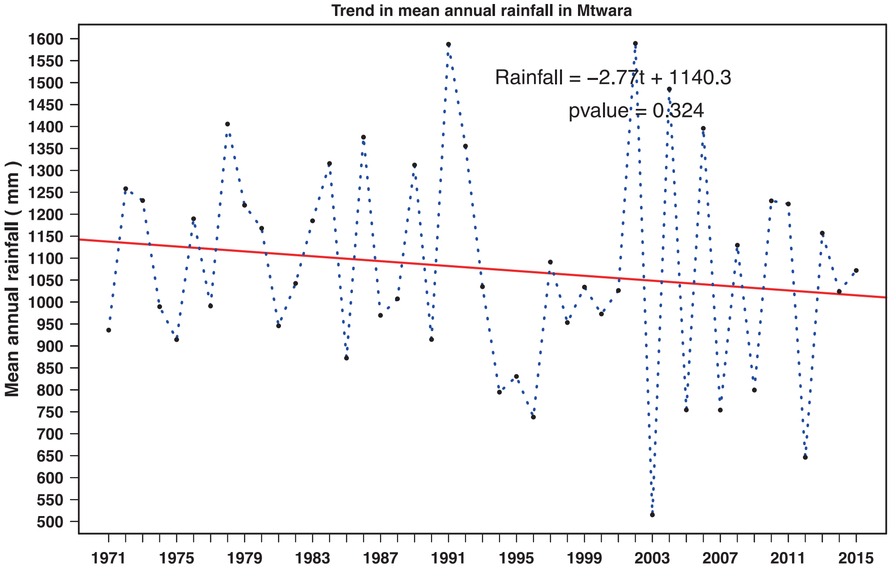
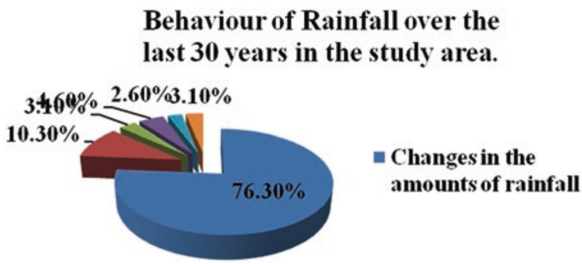


Fig. 4 Trend in mean annual rainfall in Mtwara. (Source: TMA data, 1971–2015)

Fig. 5 Perceptions on rainfall behaviour over the last 30 years



According to the key informants, climatic changes have resulted into increased drought incidences or long dry spells, especially in the hinterland areas. Furthermore, climate change has also been associated with increased flood events, especially along the Ruvuma River and the lowland areas, and sea level rise along the coast, especially at Msanga Mkuu, Mnazi Bay, Namela village, Sinde and Ndoko villages.

While a majority of respondents (76%) reported a decreasing trend in rainfall amount over the past 30 years, others reported the following:

- Changes in the rainfall patterns/seasonality (10%)
- Changes on onset and cessation of rainfall (7%)
- Changes in the rainfall distribution within season (3%)
- Changes in the intensity and duration of raining (3%)

Local Communities' Perceptions in Wind Patterns

Changes on wind patterns were also probed to especially estimate its impact on fishing activities along the coast. It was learned during the FGDs in Mnazi that much of the fishing activities depended on the timing of south-easterly and north-westerly monsoon wind patterns, popularly known as *Kusi* and *Kaskazi,* respectively. Respondents were asked if they had experienced any changes with the north-westerly as well as the south-easterly monsoon winds. Their responses are as indicated in Fig. 6, whereby the findings show that respondents had experienced increased strength in both types of winds. Analysis shows that the south-easterly winds were perceived to be very strong by 45% of all respondents, whereas the

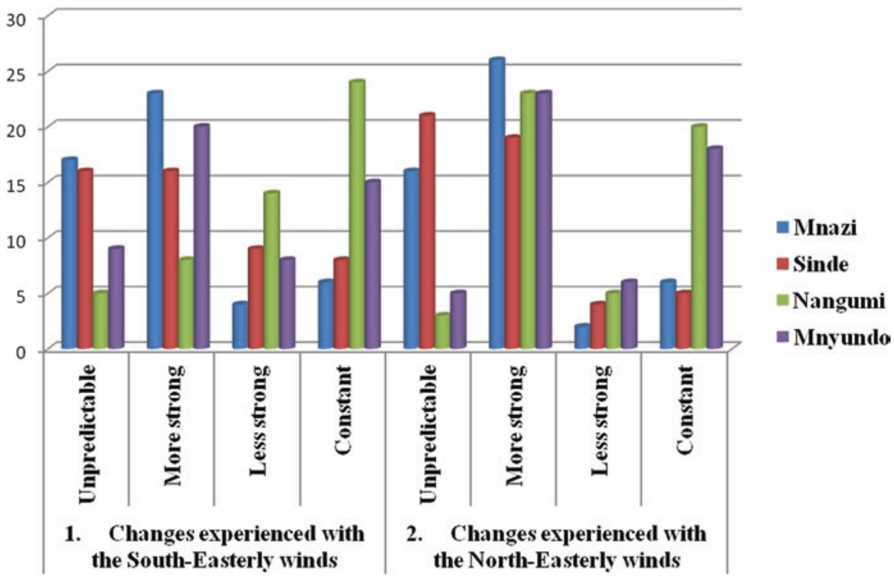


Fig. 6 Experiences with north-westerly and south-easterly monsoon winds

north-westerly winds were perceived to be very strong by 33.2% of all respondents in the study sites.

Discussions with local communities through FGDs revealed that both *Kusi* and the *Kaskazi* winds were apparently becoming stronger and unpredictable. Villagers explained that when the winds were too strong to the extent of bringing about negative impacts on fishing activities, the impacts could be as follows:

(i) Increased accidents in the fishery: There are a number of cases whereby fishermen had drowned in the deep waters due to strong waves caused by strong winds.
(ii) Destruction of fishing boats due to strong waves (breaking of wood-made boats).
(iii) Sailing speed had dwindled and took much time to reach the fishing sites.
(iv) Fish tended to hide very deep in the sea and in rock cleavages due to strong waves making it hard for fishermen to trap them. It was hard to set fishnet traps in strong winds.

Impacts and Vulnerability of Coastal Livelihoods

Fishing

Based on findings obtained, particularly during FGDs as well as the interviews with key informants, it was noted that among the climatic-related impacts, sea-level rise had effects on fishing activities in the sense that fishers could not reach far into the sea where fish catches were abundant. This was partly due to:

- Poor/traditional fishing vessels that could not afford deep sea water especially due to increased wind intensity and speed.
- Changes in the pattern, timing and increased intensity of winds changed fishing seasons and ability of fishers (especially smallholder fishermen) to sail in the deep sea, respectively.
- Declining of fish catches in the shallow waters due to temperature increase especially some species that are unable to gloom well in areas with higher temperatures.
- Strong waves due to strong winds disturbed shallow fish breeding grounds like in most shallow coral reefs.
- Loss of marine biota in the sea that supported fish life, e.g. algae and sea grasses.

Apparently, decline in fish catches was not always due to climatic factors discussed above. Respondents also mentioned that decline in fish catches was also associated with unsustainable fishing methods, specifically blast fishing. Blast fishing was reportedly conducted along the Mgao and Sudi Bays. Local communities further explained that Tanzania was the only country in Eastern and Southern Africa that still practised blast fishing as a form of fishing. A monitoring exercise that was conducted in 2015 at Sudi Bay coastline found out that there were at least ten fishing blasts per day, meaning so much destruction of coral reefs and fish breeding sites. Hence, climate change impacts seem to have added more problems to an already heavily challenged fishing sector.

Agricultural Production

In the agricultural sector, it was reported during FGDs and KII that extreme weather events such as drought and floods had resulted into reduced productivity of crop farming. The consequences had been drying of crops, particularly paddy, maize, cashew nuts and cassava. Other impacts associated with climatic factors that were reported included increased incidences of crop pests as a result of increased temperature and change in rainfall amounts and pattern. Participants indicated that such diseases had become severe and common in drying of coconuts, rotting of cassava, rotting of groundnuts due to too much rain (*ukoma*) and drying of cashew nuts.

Changes in farming seasons had caused persistent late onset of rainfall for the past few years. Furthermore, during FGDs, local communities explained, for instance, that in the past (over a period of 15 years), the planting dates had normally followed the onset of the rains in November, but nowadays, the planting dates had shifted to January. According to some informants, the situation started being experienced during early 2010.

It was further reported that the increase in intensity of winds, sea level rise and ocean waves had also contributed to the destruction of some agricultural crops along the coastline. Villagers mentioned that coconut trees, for instance, along the coast had been eroded due to strong ocean waves caused by sea level rise and increased offshore winds. This was reported to be the case particularly in Mnazi Bay and Msanga Mkuu villages. Climatic changes had consequently negatively impacted agricultural production resulting into severe food shortages and rising food prices.

Adaptation Strategies and Implications on Communities' Resilience

Respondents reportedly adapted to the impacts of climate change through a number of mechanisms. Figure 7 lists the coping and adaptation measures that local communities considered applicable to their local environments. The findings show that many households sought for assistance from relatives/friends and had also been reducing household food consumption during adverse climatic extremes.

In the hinterland villages, searching for wild roots and fruits such as *Ming'oko* had been the most common coping mechanism to droughts for many years. Respondents informed the researchers that *Ming'oko* wild roots were widely used when available in order to save other foods for future use. Some respondents added that *Ming'oko* were also used for generating small income through selling. The money earned was used to buy needed household food items.

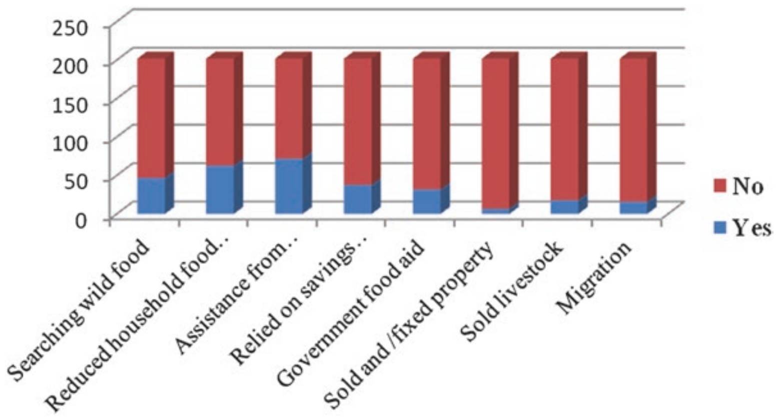


Fig. 7 Household coping mechanisms during hardship from climate extremes

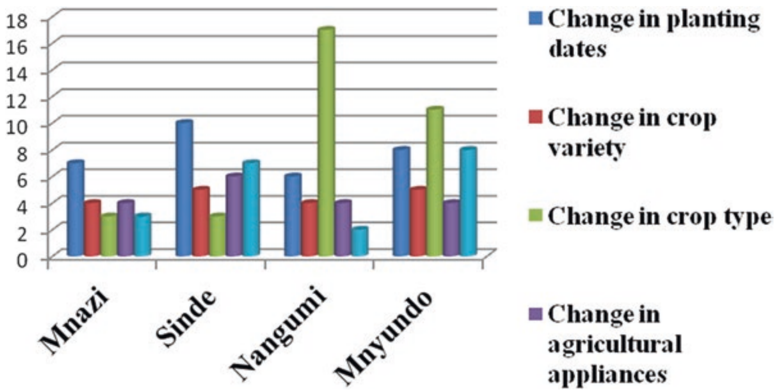


Fig. 8 Adaptation strategies to climate change impacts in agriculture

With regard to agricultural production, villagers reportedly adapted to the impacts of climate change through a number of strategies as indicated in Fig. 8. Changing the types of crops grown was widely practised in hinterland villages of Nangumi and Mnyundo. It is in the hinterland areas where vegetables and fruit production was possible with a variety of crops involved, including maize which is not widely grown in the coastal villages. While the highland arable lands were increasingly being occupied with cashew nuts and coconuts, the hinterland areas proportion of land suitable for various crops was increasing, especially with well-established irrigation systems.

With regard to fishing activities, respondents reported that they adapted to climate change impacts by migrating to fish-abundant areas and changing fishing techniques and gears (Fig. 9). Respondents mentioned many areas where they usually migrated to in search for better fish catches. These places included Mozambique, which is just across the border, Kilwa, Rufiji, Nungwi, etc. Furthermore, it was

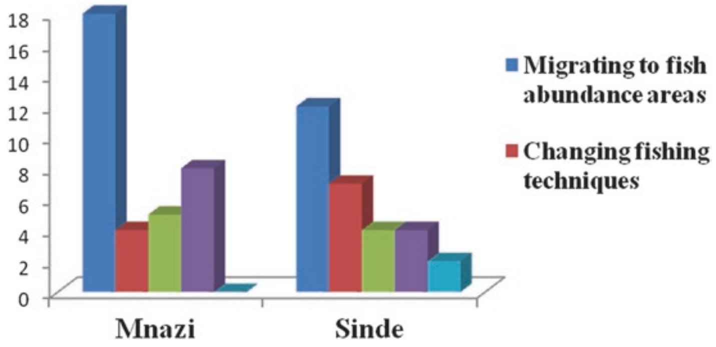


Fig. 9 Households' coping mechanisms to climate change impacts in fishing activities

explained that when fish catches diminished in some areas, fishers tended to use different fishing techniques and gears, such as turning to hand lining and/or using long lines with multiple hooks tied onto boats. Others reported that they tended to flip altogether into other livelihood strategies away from fishing.

Further findings from this study have established that there have been shifts in the livelihood patterns as a result of climate change impacts on livelihoods of the people. In coastal areas such as Mnazi village respondents had adopted a mixed farming and fishing strategies to minimize risks of climate impacts. While farming was the only major livelihood strategy in hinterland villages of Nangumi and Mnyundo, the only dominant shift in livelihoods was through seeking off-farm activities, such as engaging into petty business activities.

Conclusion and Recommendations

Generally, data from this study have shown that challenges and impacts associated with climate change are also evident in the Tanzanian coastal environment. Common impacts such as destruction of coral reefs, coastal erosion, destruction of coastal infrastructures and human settlement, intrusion of seawater into freshwater wells and crop fields and degradation of mangroves had become common phenomena in the areas. Sea level rise was probably the most challenging climate change issue in the region since it threatened not only the livelihoods of the already stressed coastal communities but also the economy and integrity of the coastal ecosystems and resources. Apparently the extreme events associated with climate change and variability have had great impacts on both fishing and agricultural livelihood systems.

Climate change adaptation strategies in the coastal areas will thus need to emphasize on addressing multiple climate change impacts in the context of integrating the key livelihood strategies as a way of livelihood diversification, in areas where both activities can be undertaken. Further diversification of the livelihood systems can be achieved through promotion of alternative sources of livelihoods other than agriculture and fishing, such as business, beekeeping, livestock keeping and tree planting associated with entrepreneurship skills as well as natural resources management.

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The Human Rights Dimensions of Conservation and Climate Change Initiatives in Coastal Tanzania: Examples of Villagers' Successful Struggles for Their Rights

Betsy A. Beymer-Farris, Ian Bryceson, and Chris Maina Peter

Abstract Abuse of human rights in conservation initiatives, such as REDD+, wildlife conservation, etc., has raised concern in many project reviews. Few studies have, however, examined the human rights dimensions of conservation and climate change. In this chapter the authors address this gap by showing how outsiders, with the assistance of the state, attempted to control areas historically governed by local residents in the name of conservation and climate change policy initiatives in the Mafia Island and Rufiji Delta, Southern Tanzania. The interventions were implemented with the old-fashioned premise that the villagers were destructive and extravagant resource users. The authors also try to illustrate how the international linkages to worldwide conservation narratives and to development aid by rich countries promoting climate measures in poor countries to try to absolve their carbon emissions revealed the ways in which such vested interests attempted "to misuse their money, power, and influence."

Introduction

> It was 6 o'clock in the morning when they broke down my door and found me inside my house. They began to whip me five times and took me outside, whipped me 15 times, and kicked me with boots. They told me they would shoot me. As a soldier was hitting me, he said he was sent so villagers would not use [fishing] nets, even of any kind. They tore up my

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> house and took my phone. They had us all stand in a line and made us jump up and down like frogs while beating and interrogating us. When it was my turn, I didn't manage to explain myself because I was so sad, I began to cry. Then I went unconscious. As I write this letter, my body is still hurting. – Ally Mohamed Hatibu[1]

This quote depicts reality for some people living in one of the world's most biodiverse marine protected areas, the Mafia Island Marine Park in coastal Tanzania. Sadly, human rights abuses as an externality of conservation polices are not new. Our interest in the human rights related to conservation and climate change initiatives in coastal Tanzania began during exploratory fieldwork in 2005. We simply asked villagers what we needed to examine and address in our research. Their unequivocal response? Our rights – both civil and political rights as well as economic, social, and cultural rights.

Few studies examine the human rights dimensions of conservation and climate change. Specifically, how people draw upon human rights as a way to struggle for their rights in instances where conservation or climate change initiatives result in human rights abuses. This gap in the existing literature is surprising given its emergence in the policy arena. The world's most powerful international conservation organizations including BirdLife International, Conservation International, Fauna & Flora International, International Union for the Conservation of Nature (IUCN), The Nature Conservancy, Wetlands International, Wildlife Conservation Society, and World Wide Fund for Nature (WWF) recently established the "Conservation Initiative on Human Rights" (CIHR 2018). The CIHR focuses on "promoting the positive links between conservation and rights of people to secure their livelihoods, enjoy healthy and productive environments and live with dignity" (CIHR 2018).

Rights-based rhetoric is also present in the policy arena for climate change where the Preamble of the Paris Agreement to the United Nations Framework Convention on Climate Change makes it clear that all States "should, when taking action to address climate change, respect, promote, and consider their respective obligations on human rights" (UN Climate Change 2018). If governments, multinational organizations, and nongovernmental organizations are genuine about implementing human rights into conservation and climate change practice, they must study past human rights abuses, include local people in the development of future policies, and ensure accountability in implementation.

In our perspective of human rights, as means of struggle, one joins the oppressed/exploited/dominated or ruled against the oppressors/exploiters/dominant and the ruling to expose and resist the situation which generates human rights violations (Shivji 1989). Not only do we examine how human rights as provided in the Bills of Rights in constitutions can be used to advance the struggles of villagers living in some of the most resource-rich areas in coastal Tanzania; we attempt to locate where, how, and why the formation of rights struggles is waged by villagers themselves. As this chapter documents, we actively supported villagers' in their demands for respect of their human rights and to oppose and fight injustices related to the conceptualizations of and implementations for conservation and climate change initiatives in coastal Tanzania.

[1] A primary school teacher at Jibondo Island in the Mafia Island Marine Park

Conservation, Human Rights, and Villagers' Struggles for Their Rights in the Mafia Island Marine Park (MIMP)

Establishment of MIMP: Local Impetus and Participatory Rhetoric

An important marine and coastal biodiversity "hotspot," the MIMP was established in 1995. The Marine Parks and Reserves Act, 1994 (Act No. 29 of 1994) was passed in November 1994 and the Park was officially gazetted in April 1995.

MIMP is located approximately 120 km southeast of Dar es Salaam in the Indian Ocean and is part of the Mafia archipelago that covers a total area of 972 km^2 and is comprised of five inhabitable islands and a number of smaller islets and reefs. The total area of the park, land and sea, is 822 km^2 and encompasses the smaller islands of Chole, Juani, and Jibondo. Approximately 18,000 people living in 11 villages reside within MIMP's boundaries. MIMP is the largest marine protected area in Africa and holds the highest marine biodiversity in the Western Indian Ocean (McClanahan et al. 2007; Obura 2012).

Efforts to establish MIMP began in the late 1980s and early 1990s when village leaders realized that they were unable to solely use traditional management practices to stop destructive fishing practices by outsiders through the use of dynamite explosives. They requested the government to take concrete actions to protect their coastal and marine resources (Francis and Machumu 2014). The rhetoric surrounding the creation of MIMP included "village governments within marine parks should participate fully in all aspects of the development of, or any amendment to, the regulations, zoning, general management plan for the park" and village liaison committees were created to "represent the views of resident fishing communities" (Francis and Machumu 2014: 163 and MPRU 2006).

Conservation management strategies for MIMP focused on enforcing a ban on dynamite fishing through regular patrols by villagers living in MIMP together with MIMP officials and WWF representatives (WWF played a role as technical advisors for MIMP, funded by DFID and NORAD). This proved to be MIMP's greatest success as dynamite fishing was completely stopped inside and even outside the park boundaries after 2 years.

MIMP in Practice: Exclusion of Local Knowledge

MIMP's management strategy also focuses on the closure of rich fishing grounds and fishing method restrictions in other areas (Fig. 1). Core zones were created where no resource extraction is allowed. Specified-use zones only allow certain types of fishing gear (handlines, basket traps, and set nets) and for octopus and shellfish collection. General-use zones share the same restrictions as specified-use zones but allow for the use of shark nets (greater than 7-inch mesh size). In order to fish in specified- and general-use zones, resident fishers are required to obtain a

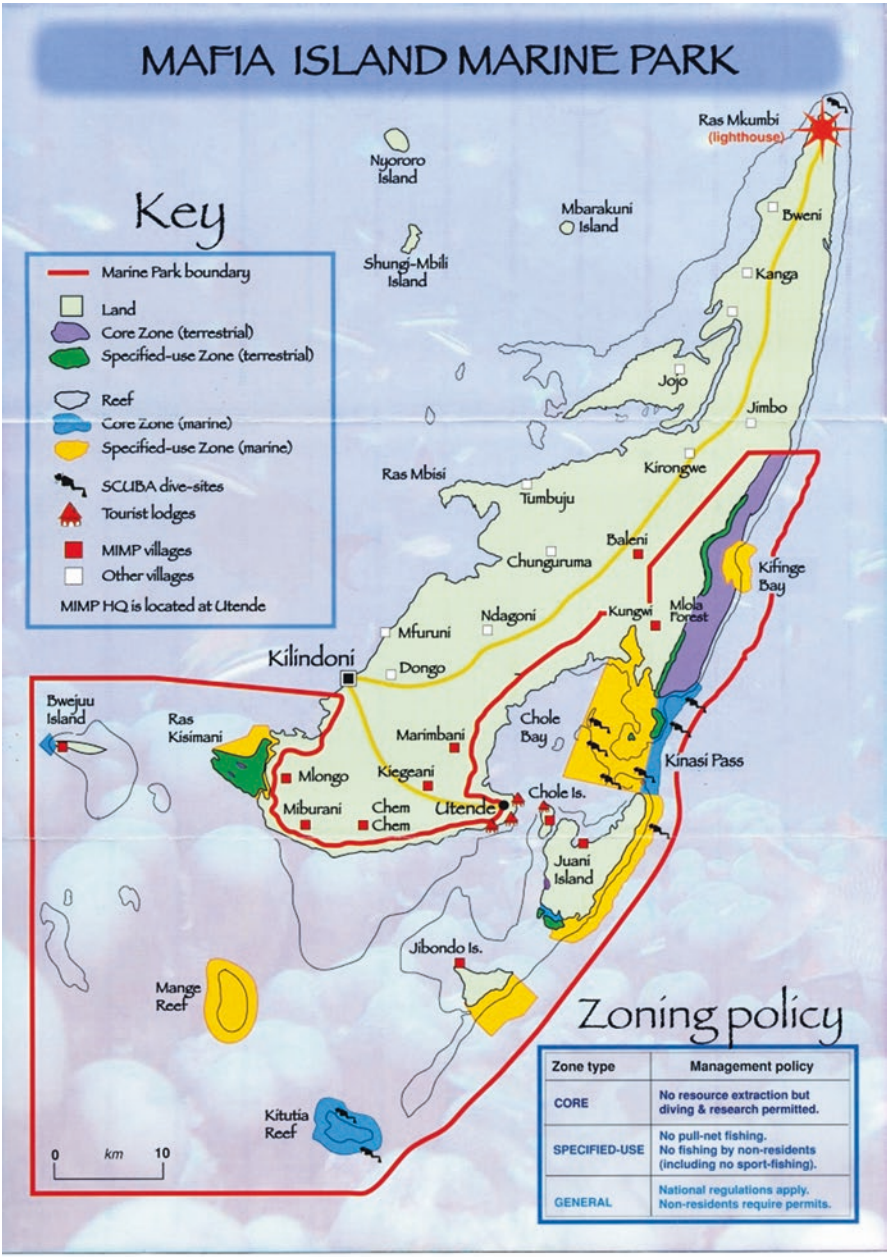

Fig. 1 Research study area of Mafia Island and the Mafia Island Marine Park (MIMP)

Local Resident User Certificate (LRUC) issued by MIMP officials. According to the Ministry of Livestock and Fisheries National Fisheries Policy of 2015, fishers are also required to obtain a license to fish and licenses for their fishing vessels from the Ministry of Livestock and Fisheries (United Republic of Tanzania 2015).

Conflicts between small-scale fishers and MIMP officials are traceable to the management strategy for MIMP and the ways in which it was created. In 1988, the Institute of Marine Sciences of the University of Dar es Salaam (UDSM) which is based in Zanzibar, supported by the British NGO, Frontier-Tanzania, initiated a study to examine the patterns of resource use within MIMP's boundaries (Horrill et al. 1996). Scientists conducted fisheries assessments where they "accompanied local users to the sites of resource use at regular intervals throughout the year" and "in direct interaction and consultation with users enabled the collation of knowledge of traditional management with specific identification of areas the fishermen already considered to be of key importance for stock management" (Horrill et al. 1996: 52).

In the study's conclusions, Kitutia reef is described as an "important site for Jibondo fisherman," Mange reef "a favored fishing ground for Jibondo and Mafia fisherman", and Chole, Juani, and Miburani villages are "highly dependent on resources in Chole Bay" (Horrill et al. 1996: 55). Despite these areas serving as important fishing grounds for those living in MIMP's boundaries, Kitutia reef became a core zone where no resource extraction is allowed. Mange reef and areas of Chole Bay became specified-use zones where fishing is restricted entirely or limited.

While fishers initiated and supported the creation of the park to halt dynamite fishing by outsiders, fishers living within MIMP argue that there was not a strong consensus over designations for core, specified-use, and general-use zones in MIMP. This is particularly the case for Jibondo Island where villagers are almost entirely dependent on fishing for their livelihoods (fishing comprises 80–90% of their means of production) because the island has an unusual limestone substrate topography not suitable for farming and it also has exceptional fresh water scarcity. Fishers from Jibondo, in particular, feel they were "duped" because they showed the scientists and conservationists their best fishing areas – including Chole Bay sites and Kitutia Reef – from which their access would later be restricted because it was designated a Core zone (personal communication, June 2010). Thus, despite the rhetoric of local inclusion and participation in Tanzania's Marine Park and Reserve Act of 1994 that guided the creation of MIMP, many fishers actually feel their views were not respected or incorporated in the management strategy.

Fishers also oppose the logic of static zoning strategies for MIMP's management, being the permanent designation of zones, because they do not align with traditional management practices. Restricted access to vital fishing grounds and strict regulations disrupt traditional fishing methods where fishing would take place on specific reefs according to the monsoon seasons. Fishers describe how fish stocks in the southern and eastern parts of Mafia recover seasonally because of the monsoon winds. For example, monsoon winds render fishing of the outer reefs possible only during the northeast monsoon, *kaskazi*, while the fish reproduce during the 5 months of the southeast monsoon, *kusi*. Mafia's eastern and southern reefs (where the Marine Park is situated) are also inaccessible during the two masika months due to heavy rains of each year allowing for regeneration. For these reasons, fishers protested that the marine park authorities unilaterally enacted rigid regulations that conflict with traditional management practices of shifting fisheries because they are not based upon knowledge of the particularities of the southeastern coast of Mafia.

As contestation over MIMP's management strategy grew, MIMP subsequently began de-emphasizing consultation with and participation by villagers, and MIMP policies and management have become one-sided and more protectionist. These same small-scale fishers that sought to protect the biodiversity within MIMP against destructive fishing practices 10 years earlier are now considered the main threat to its resources as a result of "overfishing." Claims of overfishing by small-scale fishers are legitimized by conservation narratives and in the scientific community. WWF cites a lack of marine protected areas with no-take zone restrictions for fishing as a cause for overfishing (WWF Overfishing 2018). WWF argues that a problem related to overfishing is the fact that "only 6% of the world's oceans have been declared as marine protected areas (MPAs) and 90% of existing MPAs are open to fishing" (WWF Overfishing 2018).

The marine and coastal resources focused on for marine protected areas are usually the most productive fishing areas upon which thousands of livelihoods of small-scale, subsistence-based fishers around the world depend. Despite this, WWF argues that MPAs with strict no-fishing restrictions (like MIMP) can still "translate to improved food security for people who rely on the ocean for their daily sustenance and livelihoods" (WWF Overfishing 2018). Many scientific studies also support no-fishing zones for marine and coastal conservation. For example, in Tanzania, Wells et al. (2007) call for an increase in marine and coastal conservation areas to 10% and no-fishing zones to 20–30%.

These narratives do not withstand scrutiny. Enormous catch rates by large industrial fishing fleets as well as the huge quantities of wild-caught fish used as feed for a growing aquaculture industry are heavily impacting the world's fisheries resources. If increased levels of exploitation of marine fisheries by industrial fishing fleets and expansion of carnivorous-fish based aquaculture continue, the world's fisheries will be increasingly unsustainable (Pauly and Zeller 2017). In contrast, small-scale fisheries, i.e., artisanal, subsistence, and recreational fisheries, may represent the future of sustainable fisheries (Pauly 2018). This raises the important question of who is overfishing and why is conservation focused mainly on marine protected areas in places where small-scale fishers depend? Along with fishers, we argue that the depiction of small-scale fisheries in Mafia Island as being responsible for overfishing lacks empirical evidence and misrepresents the problem. Research findings in Mafia do not show evidence of overfishing or widespread destruction of habitats (Bryceson et al. 2006).

Nonetheless, MIMP unilaterally introduced new regulations to restrict traditional fishing practices by small-scale fishers. These regulations were based upon the Marine Parks and Reserves Regulations of 1999 (Government Notice No. 85 of 1999) and include restrictions for some types of nets for fishing and increased permissible sizes for mesh for fishing nets. Conservation organizations working in MIMP strongly supported restrictions on fish mesh net sizes. As stated by one of WWF Tanzania's representatives in 2004, the "biggest issue at the moment [for Mafia Island] is the use of small-mesh seine nets" because "these nets can have a mesh-size of just a quarter of an inch and catch a lot of juvenile fish and because they are weighted and dragged along the seabed, which damages fish habitats like corals and seagrasses thereby undermining the productivity of the fishing grounds" (Rubens 2004). Ambiguity and confusion regarding what is considered "legal fishing gear," in particular fishing mesh net sizes in MIMP, is another source of conflict between fishers and park officials.

This conflict is again a result of applying general foreign management practices that disregard local conditions and knowledge. Fishing mesh net size regulations emanate from European fishing theories that were developed for the management of temperate fish stocks with low biodiversity. The idea of mesh net size restrictions specifically began in British colonial legislation that envisaged fishing as a recreational sport (Kolding and van Zwieten 2011). In these instances, mesh size regulations make sense since you have few species that meet specific size requirements. However, in places like Mafia Island where there is a huge range of fish species and sizes of fish, certain nets are used based on the species of fish that is targeted. For example, local fishers argue that only allowing the use of large-meshed nets disregards the fact that many of the smaller species of fish, which reproduce and grow rapidly, can never reach a large enough size to be caught in such nets.

These species are small throughout their life cycle. For example, some species of *Siganids* and *Scarids* have a high fecundity so they reproduce quickly, but they are quite small even when fully grown, so they would never be able to be caught in large mesh net sizes. These small-sized fast-reproducing fishes are an important source of protein for the poorest of fishers because their nets (known as **msembwe** in Kiswahili) are cheap enough for them to purchase and can be used from the shore without a boat. Similarly, small-scale fishers often target pelagic sardines, necessarily with small-mesh nets because they would also pass through large mesh sizes. This illustrates how outside management practices are imposed upon villagers with the effect of denying important food sources to those who are the most vulnerable.

Creating restrictions for larger mesh net size can be even more problematic for the overall biodiversity of fish species because, ironically, large species are targeted that are actually in more in need of regulated harvesting pressures because of their low fecundity rates. While fishers have known this for quite some time, mesh net size regulations are now being questioned in Europe and internationally by newer thinking concerning fisheries management for more balanced ecosystem sustainability (Garcia et al. 2012). Another problem arises from dual regulatory authority of legal fish mesh net sizes by both MIMP and Tanzanian Fisheries regulations and frequent changes over time of permissible net sizes by one or the other. Fishing authorities argue for rigid mesh-size regulations, with marine park officials introducing even stricter regulations on the mesh-size allowed.

MIMP's management strategy also emphasizes including villagers in private sector activities in the local economies where marine protected areas are based (Francis and Machumu 2014). MIMP is considered one of the world's best diving sites for its high biodiversity and the possibility of seeing whale sharks. In response, tourism is booming. Mafia Island is now home to one of the world's most expensive hotels, Thanda Island Hotel that is $10,000 per night. The tourist hotels within MIMP with beachfront locations and access are all foreign owned and operated aside from one (Big Blue Hotel is partly owned by a Mafia resident). Land for these hotels was appropriated from villagers, fences erected, and access to beaches and landing sites have progressively been restricted for villagers. Snorkeling and SCUBA-diving tourism facilities were also established in parallel and operated by hotel-linked and foreign-owned enterprises to the exclusion of attempts by local residents to operate such tourism services. A small number of residents in MIMP gained employment opportunities in these hotels, but the overwhelming majority of villagers do not benefit from the lucrative tourism industry in MIMP.

MIMP Management and Human Rights

According to MIMP (2006), over 137 random patrols were conducted in 2005 by park staff and village enforcement units. This resulted in impounding eight drag nets, one gill net, and four boats. Thirty fishers were also taken to court. The majority of the cases resulted in acquittals. MIMP was dismayed that "few were given minimal punishment which couldn't commensurate with the gravity of offenses committed" (Francis and Machumu 2014).

Thereafter, MIMP officials enlisted the Tanzanian army to deal with the issue of overfishing by small-scale fishers (CHRAGG 2012: 3). On December 11 and 13, 2008, the army and MIMP officials went to the island of Jibondo to confiscate fishing nets.[2] While confiscating the nets, armed soldiers broke into homes, destroyed property, and beat and whipped the citizens and their elected village leaders, including women (some of whom were pregnant) and children (Appendix A). The suffering endured is captured by the opening quote of this chapter by the primary school teacher for Jibondo who was so badly beaten that he fell unconscious. This was directly violating the Constitution of the United Republic of Tanzania, 1977 which in its Bill of Rights (Part III of Chapter One) provides for both privacy and protection of private property (Articles 16 and 24, respectively). Villagers' wrote a formal statement of the human rights violations that took place during this incident (Fig. 2). The statement was subsequently submitted to the Commission for Human Rights and Good Governance as an exhibit during its Public Inquiry on this matter.

Immediately following this human rights violation, our research team informed the most senior government official on Mafia Island, the then District Commissioner (DC), Hon. Manzie Omary Mangochie. District Commissioners in Tanzania are

Fig. 2 (continued) on Human Rights and Good Governance but argue it was accidental because the soldiers had not been prepared for a task of this nature and thus their failure to implement the terms of reference of their task. This is captured in Paragraph 4.3 of the Commission's Report which says: "*Maafisa wa Jeshi walikiri kuwa vitendo vya kuteswa kwa wanakijiji wa Jibondo vilitokea lakini kwa bahati mbaya. Walieleza kuwa hiyo ilitokana na wanajeshi kutoandaliwa vizuri hali iliyopelekea hadidu rejea kutotekelezwa kama ilivyotakiwa.*" See the Commission's report at page 21.)

[2] The army also conducted violent actions against other villagers, and CHRAGG also conducted inquiries in Kilindoni and Kiegeani (Kilindoni is the small town in Mafia Island outside of MIMP, and Kiegeani village is within MIMP).

TAARIFA YA WATU WA JIBONDO WALIOPIGWA NA WANAJESHI NA KUIBIWA MALI ZAO TAREHE 11 NA 13/12/2008

1. ALLY KHATIBU MOHAMED

Ilikuwa saa 12 walinikuta ndani, walivunja mlango na kunikuta na kuanza kunipiga fimbo tano (5) walipo nitoa nje wakanipiga fimbo 15 na buti moja tukaenda kwa Khatibu Mwijuma, walipoingia ndani walimkuta Hamisi Hamza.

Tulipotoka nje mimi nilipokuwa najitetea Mwanajeshi mmoja alisema nitakushuti nilipojibu afadhali unipige ndipo Mwanajeshi akaamua kunipiga kichwa na kusema sisi tumetumwa na hatutaki ivuliwe nyavu hapa Jibondo hata kipande kimoja na tumewatoa majeshi ya anzuani Komoro Je. Nyinyi mtaweza kutuzuia. Baada ya hapo tukapita nyumba kadhaa , tulipokuwa tunaelekea ofisini Mwanajeshi alitamka mnamfuata Bwana wenu yeye anastarehe na mkewe, nyinyi sasa mnaona mnavyoadhibiwa.

Tulipofika Hospitali tulimkuta mwanajeshi kwa umbo ni mnene akiwa na baadhi ya watu waliokamatwa nasi tukawekwa mbele yao. Baada ya muda yule mwanajeshi akaanza kuhoji, ilipofika zamu yangu nilishindwa kujieleza kwa vile nilikua najisikia uchungu mkubwa huku nikitokwa na machozi.

[UNOFFICIAL TRANSLATION]

THE REPORT OF RESIDENTS OF JIBONDO WHO WERE BEATEN BY THE SOLDIERS AND ROBBED OF THEIR PROPERTIES ON 11^{TH} AND 13/12/2008

1. ALLY KHATIB MOHAMED

It was at 18 hours in the evening and they found me at home. They broke the door and they began beating me five strokes (5). They removed me outside and continued to beat me 15 more strokes and hit with boots. We went to Khatibu Mwijuma's house where we found Hamisi Hamza inside.

When we got out, I was still trying to defend myself when one soldier told me that he is going to shoot me. Whe I challenged him to shoot me, he hit me with his head. We have been sent at Jibondo to ensure that no one fishes with the net here. We have removed the soldiers of Anzuani in the Comoro Islands, can you effectively block us from doing our duty? We passed through several houses on our way to the office. One soldier said that we are looking for your Boss. He is enjoying life with his wife and you here – see how you are being punished.

When we reached the hospital we found a huge soldier with some of the people who had been arrested and we joined them and told to stand infront of them. Then the huge soldier began the interrogation. When it came to my turn I failed to talk because I was bitter and pained and tears were flowing from eyes.

Fig. 2 Report of the people of Jibondo who were beaten by the Soldiers and Robbed of their Property on December 11 and 13, 2008. Research Study Area of Mafia Island and the Mafia Island Marine Park (MIMP) (This story is conceded by the army in their discussion with the Commission appointees of the President. Their job is to represent the highest form of governance in Tanzania, the State House, at the district level. At this meeting, our research team presented the DC with the proper policies and legal regulations for fishing gear in Tanzania and outlined the proper procedures for dealing with small-scale fishers who are not abiding by park rules of management. The DC assured our research team that it was an isolated incident that would not be repeated.

Villagers asked for our support in learning more about their human rights and how to enforce them. In response, we organized a workshop on human rights, titled "Asserting Rights, Defining Responsibilities: Perspectives of Small-Scale Fishing Communities on Coastal and Fisheries Management in Eastern and Southern Africa" in June 2008. This workshop drew upon the expertise of the International Collective in Support of Fishworkers (ICSF 2008). ICSF is an international nongovernmental organization that works toward the establishment of equitable, gender-just, self-reliant, and sustainable fisheries, particularly in the small-scale, artisanal sector. ICSF is committed to disseminating information about human rights, particularly among fisherfolk. ICSF prepares guidelines for policymakers that stress the development of fisheries and management that is just, participatory, and sustainable in nature, and helps create the space and momentum for the development of alternatives in the small-scale fisheries sector (ICSF 2008). At the ICSF Workshop, the elected village leader from Jibondo Island located in MIMP, Mr. Fakhi Ali Hassan, made the following statement:

> In order to oppress people effectively, you have to do three things: deprive them of knowledge, deprive them of their means of production, and divide and rule them. In response, we should: share knowledge, because knowledge is strength; struggle and protect our access to resources and the means of production; and stand together, irrespective of political parties.

Despite the DC's promises that human rights violations would never again happen in MIMP, 2 years later on February 15 and 16, 2010, MIMP officials and the army returned to Jibondo Island to confiscate all fishing nets of all mesh sizes.[3] A total of 110 nets were confiscated, including 9 seine nets of newly declared illegal mesh size and 101 other nets of legal mesh sizes. The issue of fishing nets became so contentious that a European dive master with impunity slashed a local fisher's net while out on a dive with tourists in MIMP. The loss of fishing nets and the inability to pay back loans for the nets resulted in hunger, malnutrition, and increased poverty for villagers living on Jibondo Island. A study by Moshy et al. (2013) found that children were almost four times higher in underweight percentages than national standards in Tanzania. Other villagers living in MIMP's boundaries were facing similar hardships as a result of fishing restrictions. This is aptly described in a study by Moshy and Bryceson (2016: 7) where an elderly fisher on Chole Island in MIMP explained their inability to fish in this way:

> They [the MIMP] have restricted all the [endowed] areas. In the beginning there was slavery; now slavery is back. Blessed be the former slavery for in the evening you would eat at your master's place; in the current slavery you neither eat at your master's, nor are you going to find food for yourself where it is found.

[3] See the Report of the Commission on Human Rights and Good Governance, 2012, at page 3.

The violent nature of conservation enforcement in Jibondo was unfortunately not an isolated incident in Tanzania. Kamat (2014) describes displacement, dispossession, social dislocation, and intensified hardships due to increasing poverty, marginalization, and food-related insecurity as a result of the establishment of a marine park in Mtwara (southeastern Tanzania). And 6 months after the net confiscation in Jibondo Island, armed people wearing military attire and suspected to be soldiers shot two fishers, killing one, while trying to confiscate villagers' nets in the northern Tanzanian coastal village of Tongoni (George 2010).

Villagers on Jibondo Island appealed to District authorities on Mafia Island about these human rights abuses on several occasions, but did not receive any response. Given that the confiscation of nets was a direct order from the Prime Minister's Office, it was appropriate to appeal to him directly. Bryceson and others who were conducting research in the area sent a letter of concern and appeal to the Prime Minister at the time, Hon. Mizengo Pinda, on March 18, 2010, with copies to all the relevant government authorities in Tanzania and with the Norwegian Embassy.[4] The letter described the human rights violations that took place on Jibondo Island and resulting hunger and malnutrition experienced by villagers living on the island. The letter argued that fishers had the right to modify their confiscated nets to the regulated size; that fishers must be provided with information about fisheries policies, laws, and regulations (and particularly amendments to them); that fisher's participation in MIMP management is consultative; and that MIMP policies do not harm villagers. It also asked for MIMP to refrain from using the army for enforcement of violations. The letter called for the establishment of a commission for an entirely new and independent study on fish mesh net sizes in Tanzania. Lastly, the letter identified an imbalance related to the focus on small-scale fishers as the source of overfishing rather than large-scale industrial fishing fleets in Tanzania.

After the letter was disseminated, the DC called Bryceson, the researcher, to a meeting on July 17, 2010. When Bryceson arrived to the meeting, top officials from all divisions and security sectors were seated in full uniform.[5] At the meeting the DC argued that the letter to the Prime Minister was frustrating because it "superseded his authority" and stated that "specific people with bad intentions misled the research team of their understanding of the situation on Jibondo Island" (personal communication, July 27, 2010). The DC and the Warden for MIMP spoke for 40 min.

Bryceson then responded that he was grateful and flattered that so many important people were invited to the meeting. Bryceson reminded the DC and Warden that he and the research team consistently informed them fully of their presence and

[4] Chief Secretary in the President's Office, the Private Secretary to the President, the Chairperson of Jibondo Village, the Village Executive Officer of Jibondo Village, the Minister of Livestock and Fisheries Development, the Director of Fisheries, the DC of Mafia Island, and the Warden in Charge of MIMP, and the Norwegian Embassy in Tanzania

[5] Mr. Kalango (the District Executive Secretary), Mr. Kahundi (Acting District Executive Director), Mr. Upunda (Head of the Prisons for Mafia District), Mr. Chambe (Head of Police for Mafia District), Mr. Hemedi (Acting Bureau Chief and District Chief of the Army, Militia and Security), Mr. Kugopya (District Fisheries Officer), and all senior officials from MIMP (Mr. Msumi, Mr. Melele, Mr. Mahala, and Ms. Msumange)

research activities and followed all correct procedures for research. He explained that it is the ethical duty of researchers to report human rights violations whenever they occur. The need to inform the Prime Minister was also connected to the order having come from his office concerning nets. Immediately after the meeting, several of the senior security personnel approached Bryceson and thanked him for his clear explanation.

Additional Actions to Support Villagers' Struggle for Their Rights

Frustrated by a lack of response at the District level to the human rights violations that took place, the research team decided to seek the expertise of Chris Maina Peter, who is a Professor in the School of Law at the University of Dar es Salaam.[6] Maina Peter provided Kiswahili copies of the Tanzanian Constitution and other human rights materials to disseminate throughout the villages in MIMP in order for villagers to know their rights.

The research team also provided an opportunity for elected village leaders from the villages in the MIMP to gather and learn about their human rights and how to respond to human rights violations by inviting them to a workshop on "Science Outreach" in Zanzibar in December 2010. The workshop was organized by the International Science Foundation of Sweden, ISF, and the Western Indian Ocean Marine Science Association (WIOMSA).

With copies of the Tanzanian Constitution, human rights materials, and discussions with Maina Peter, villagers learned more about their constitutional rights and the formal mechanisms in place to protect Tanzanians from human rights violations. Maina Peter recommended villagers on Jibondo Island contact the Commission for Human Rights and Good Governance (herein referred to as "the Commission"). The Commission is created under Article 129(1) of the Constitution of the United Republic of Tanzania of 1977 as amended by Act No. 3 of 2000.[7] The Commission was officially inaugurated on March 15, 2002. The Commission serves to promote and protect human rights and principles of good governance. As stated in the Tanzanian Constitution, "the Commission shall be an autonomous department, and without prejudice to other provisions of this Article, in exercising its powers in accordance with this Constitution, the Commission shall not be bound to comply with directive or orders of any person or any department of government, or any opinion of any political party or of any public or private sector institution" (Article 130(2)). The Commission receives, investigates, and addresses allegations and com-

[6] Chris Maina Peter is also a member of the UN International Law Commission (ILC), a legal body elected by the UN General Assembly. Maina Peter previously served as a member of the United Nations Committee on the Elimination of the Racial Discrimination (CERD), one of the treaty bodies under the Office of the United Nations High Commissioner for Human Rights.

[7] The Constitution has to be read together with Human Rights and Good Governance Act, 2001 (Act No. 7 of 2001) which details the working of the Commission.

plaints on violations of human rights and abuses of power throughout the country. It also conducts research to disseminate to the Tanzanian people about their human rights and duties in accordance with the Tanzanian Constitution and laws of Tanzania.

Determination by the Tanzanian Commission for Human Rights and Good Governance

Subsequently, on November 18, 2011, villagers of Jibondo Island sent a letter of formal complaint to the Commission outlining the human rights violations that took place in 2008 and again in 2010. After the complaints were received, the Commission conducted an investigation into the actions of MIMP officials who were suspected of abusing or misusing the authority and functions of office and for violating human rights and the principles of good governance. The investigation took several months. Representatives from the Commission traveled to all the villages within the MIMP to obtain villagers' accounts of the incidents and to meet with government and MIMP officials on Mafia Island.

After a preliminary investigation, the Commission concluded that violations of human rights did indeed take place in Mafia Island. Shortly thereafter, the Commission held a Public Inquiry on February 14, 16, and 17, 2012, in villages inside and outside MIMP on the Island. A Public Inquiry as a tool is used by the Commission to enable people to talk about issues affecting them and to express their views in public and before the Commission. In this case it also provided the opportunity for all involved (i.e., villagers; government officials including those from the army and local, district, and regional public offices; the Ministry of Livestock and Fisheries; and MIMP officials) to express their views in a controlled environment. Hon. Commissioner Ali Hassan Rajabu, who was a Commissioner of the Commission at the time, presided over the meetings. Many villagers including women, youth, and elders wrote statements and read them aloud at the inquiry. The meetings also gave an opportunity for the Commissioner to provide preliminary information related to the Commission, its functions, its limits, and the rights and responsibilities of citizens in Tanzania. Villagers made public statements including[8]:

- The definitions of illegal mesh net sizes were not clearly explained and that there were contradictions with national mesh net size requirements.
- There is due process that includes MIMP's responsibility to properly inform villagers of any changes in fisheries regulations at the national level and for MIMP.

[8] These complaints were made during the public hearing in the villages of Kilindoni, Jibondo, and Kiegeni between February 14 and 16, 2012. See the Report of the Commission on Human Rights and Good Governance, 2012 at pages 4 to 14.

- There is not a journalist in Mafia Island to report violations of "the various events of violations of human rights occurring which need to be heard by the public of Tanzania" (CHRAGG 2012: 7).
- "The confiscation of fishermen's equipment by officers of the park results in the inability to repay the loans taken from the bank" (CHRAGG 2012: 7).
- "District leadership has abused, harassed, and arrested villagers due to their position of rejecting MIMP" (CHRAGG 2012: 7).
- Women fishers stated "they were insulted by MIMP officials" (CHRAGG 2012: 8). When women fish for octopus, they wear special clothes (where they are only partially dressed), during one instance of octopus fishing, MIMP officials followed women to their fishing sites and took pictures of them only partially clothed" (CHRAGG 2012: 8).
- They are not "overfishing" and questioned the need for mesh net size restrictions.
- They argued they were "mistreated, abused, and ruined rather than having legal action taken against them" (CHRAGG 2012: 10).
- When describing the destruction of property, the beatings, and the confiscation of nets, villagers proclaimed, "Is it possible, our government can do such things to us?" (CHRAGG 2012: 10).

Commissioner Rajabu asked MIMP officials, the District Commissioner, the Deputy Permanent Secretary, Ministry of Livestock and Fisheries – Dr. Yohana Budeba, and representation from the army who is also the people's militia advisor, Captain Marando) to explain themselves. The proceedings of that Inquiry have been fully described in a formal report titled "Report of the Public Inquiry done in Mafia District in the Villages of Kilindoni, Jibondo and Kiegeani from 14th – 17th February, 2012" (CHRAGG 2012).

The Report by the Commission provides documentation of the violations of human rights that took place and concludes that they were both illegal and unconstitutional. The Report states that the army used excessive force which is prohibited by the law (CHRAGG 2012: 5) a fact which was also conceded by the army itself (CHRAGG 2012: 21). The Report also unequivocally states that "one is allowed to fish in MIMP after obtaining a permit and license, and they are also allowed to use nets from two inches and a half (2½)" (CHRAGG 2012: 6). The correct legal procedures in cases when fishers used nets that were the wrong size or those that were illegal include officials at the District level from the Ministry of Livestock and Fisheries and MIMP first informing fishers about legal fishing equipment and any changes to these rules. Then, they must first issue warnings if there were any infringements. If fishers continued to use illegal or incorrect equipment, fishers must be taken to court.

The Commission's Report also emphasizes the importance of involving village governments in all aspects of conservation including the creation, distribution, and implementation of MIMP's General Management Plan and that MIMP officials and Mafia District leadership must "work closely with the village leaders and their communities including having regular meetings to discuss problems they face" and at these meetings "citizens should be given sufficient freedom to express their views" (CHRAGG 2012: 22). The Report also calls on the on the Ministry of Livestock and

Fisheries to work with MIMP to protect and respect human rights and engage in good governance (CHRAGG 2012: 23). This includes avoiding governance decisions that are against small-scale fishers and to cooperate with and learn from them (CHRAGG 2012: 23).

The Commission's Report had wide reaching ramifications. The Report has been used as evidence in court cases by villagers enforcing their rights. It was also sent to all ministries and tabled before the National Assembly. It has also been used by public institutions and the private sector to advise on human rights and good governance.

Despite this success, the struggle continues. On the May 25, 2015, for example, MIMP officials returned to Jibondo Island and confiscated four legally registered boats. During this incident, one MIMP official, one Besta Msumange, stated "it would be better if you play with my body than touch the marine environment" (personal communication, May 25, 2015). However, unlike previous disputes with MIMP and past violations of human rights that left villagers despondent, villagers are now empowered. They know how to respond to any human rights violations because in the words of the village leader from Jibondo Island in MIMP, one Fakhi Ali Hassan:

> They have knowledge, because knowledge is strength; they have the strength and power to struggle and protect access to resources and their means of production, and they are able to stand together, irrespective of political parties.

Indeed, villagers had knowledge of the correct laws and rules governing MIMP and with whom to contact in the event of any human rights infringements. In doing so, Hassan sent a letter of complaint to the Regional Commissioner of Coast Region (who is above the District Commissioner in Tanzania), Hon. Ms. Mwantumu Mahiza, arguing that legally registered boats were illegally confiscated. Second, they were prepared to struggle and protect access to resources and the means of production. In doing so, villagers traveled to MIMP headquarters and took the boats back into their lawful possession. They stated to MIMP officials, "if you think having these boats are a problem, then let's go to court" (personal communication, May 25, 2015). The Regional Commissioner responded to Hassan's letter of complaint and visited Mafia Island. She rebuked MIMP officials for confiscating the boats, for misusing the law, and for failing to follow the law themselves. Lastly, the villagers were able to stand together, irrespective of political affiliation (Fig. 3).

Climate Change, Human Rights, and Villagers' Successful Struggles for Their Rights in the Rufiji Delta Mangrove Forests

Our second case study involves the implementation of carbon forestry policies in Tanzania's Rufiji Delta mangrove forests. One of the leading strategies to address the impacts of climate change is carbon forestry. In carbon forestry programs, "carbon credits" are purchased to offset carbon dioxide emissions. Credits can be purchased by individuals, corporations, or funds donated by nation states. The funds provided by these carbon credits are used to maintain and enhance forest cover to sequester

Fig. 3 Village leaders from Mafia Island. From left to right, Makame Mohamed of Banja village (CCM, the ruling party), Mohamedi Haji Tuki of Jimbo village (Civic United Front, CUF), Maburuki Sadiki of Chole village (CCM), Fakhi Ali Hassan of Jibondo village (CUF), Ahmadi Suleiman Kidagaa of Juani village (CCM), and Saidi Seifu of Kiegeani village (CUF)

carbon dioxide emissions created elsewhere. The funds paid for credits are often targeted to developing countries with a narrative that financial benefits go toward poor communities who protect and develop forest cover.

A prominent carbon forestry policy is Reducing Emissions from Deforestation and Degradation (REDD+). REDD+ is a framework through which developing countries are rewarded financially for any emissions reductions achieved for a decrease in the conversion of forests to alternate land uses (Parker et al. 2009). In theory, official REDD+ principles seek to protect people's rights to forest resources. However, in the quest to commodify forests for carbon credits, people needing to cut down some trees at small-scales to support their livelihoods complicates this process. This case study chronicles the implementation of REDD+ in the Rufiji Delta, Tanzania, and ensuing human rights violations.

Carbon Forestry and the Rufiji Delta Mangrove Forests Are Identified as a REDD+ Site

Tanzania is home to the Rufiji Delta mangrove forest, the largest contiguous mangrove forest in sub-Saharan Africa covering over 53,000 hectares. Mangrove forests have been identified as a species with exceptional ability to sequester carbon dioxide and deposit in sediment. The ecosystem also provides services that mitigate the effects of global climate change. For example, mangrove forests act as a buffer for sea-level rise; protect against damage caused by tsunami waves, erosion, storms; and serve as a nursery for fish and other species that support the livelihoods for people living along the coast. As mangrove forests become more valuable for the carbon they sequester and the ecosystem services they provide, new "deals" are being made to conserve them.

Norway, a country that is estimated to have generated over $1 trillion dollars in wealth from its oil and gas industries, is a leader in donor funding for addressing the impacts of global climate change and the main donor providing funds for REDD+ programs. The Royal Norwegian Embassy launched REDD+ in Tanzania in 2008 with a promise to fund 500 million kroner (approximately $60 million dollars) over a 5 year period. Given the Rufiji Delta's unique attributes, it was a key component of the Tanzania REDD+ program.

The Ministry of Natural Resources and Tourism (MNRT) in Tanzania is responsible for the conservation of natural and cultural resources and the development of tourism in the country. Although the Royal Norwegian Embassy initially intended to provide all REDD+ funding in Tanzania to the MNRT to implement and oversee the Tanzanian programs, there was reported corruption within the MNRT for mismanaging previous Norwegian Official Development Assistance (ODA) contributions (Keenlyside et al. 2016 citing Jansen 2009). As a result, the Royal Norwegian Embassy decided to disburse funding to implementing partners that included a mixture of NGOs and research and academic institutions (Keenlyside et al. 2016).

In 2010, WWF and the Norwegian government signed a contract "Enhancing Tanzanian Capacity to Deliver Short and Long Term Data on Forest Carbon Stocks Across the Country" with the Rufiji Delta mangroves listed as a proposed project site (WWF and MFA 2010). Official REDD documents showed that WWF would oversee a pilot REDD+ project in the Rufiji Delta (Fig. 4 and refer to discussion and appendices in Beymer-Farris and Bassett, 2013).

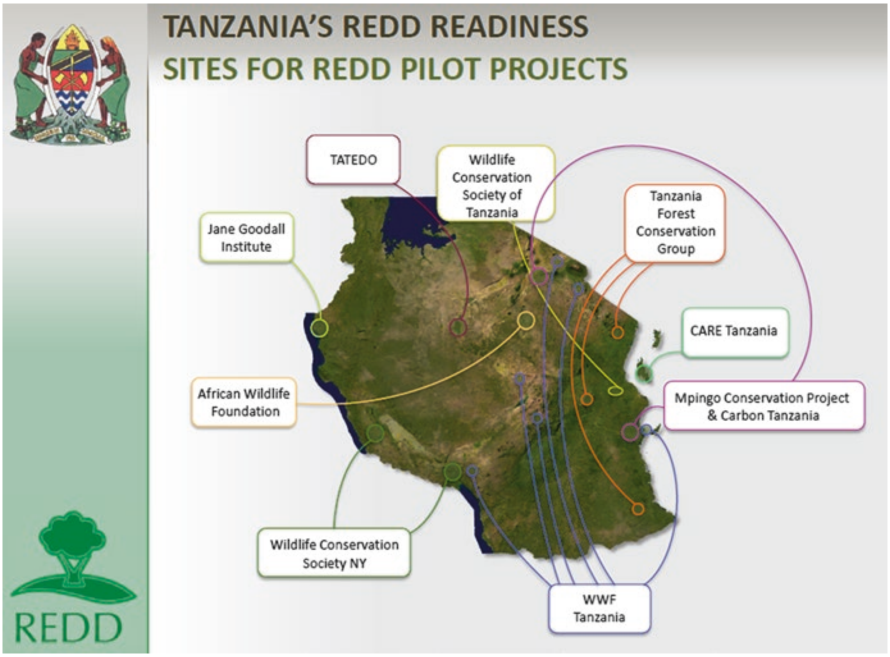

Fig. 4 Map of Pilot REDD+ Project Sites overseen by various NGOs in Tanzania with WWF slated to oversee an pilot REDD+ project site in the Rufiji Delta. (Source: Beymer-Farris and Bassett 2012, 2013)

"REDD+" Flags Are Raised but Ignored

Plans for pilot REDD+ projects in Tanzania, with the Rufiji Delta listed as one project site overseen by WWF, were in place while Beymer-Farris[9] was in the Rufiji Delta conducting her doctoral research. During this period, WWF officials working in the Rufiji Delta were also employed in parallel by the Tanzanian Forestry and Beekeeping Division (FBD) of the Ministry of Natural Resources and Tourism (now the Tanzania Forest Service Agency) (Beymer-Farris and Bassett 2013). Through her doctoral research, Beymer-Farris learned from persons employed by both WWF and the FBD that there were plans to evict 18,000 residents from their land. The justification used for these evictions were environmental narratives created by the Tanzanian state and WWF that depicts Rufiji Delta villagers as invaders and destroyers of the mangrove forest (Beymer-Farris and Bassett 2012). These negative and ahistorical depictions were then used to justify and give urgency to planned evictions of villagers who have lived in and sustainably used the mangrove forests for centuries.

As soon as these evictions were proposed, the authors of this chapter raised a "REDD+" flag about the possibility for environmental injustices to take place in order to get Tanzanian forests ready for REDD+. Beymer-Farris and Bryceson appealed directly to the Norwegian Embassy in Tanzania to inform them that evictions were planned in the Rufiji Delta and their concerns over the role of REDD+ funding incentivizing forest evictions given that this was an area slated for REDD+ projects. The researchers also reached out to Tanzanian officials in the hopes to stop the planned evictions.

They made public appeals with presentations at the Association of American Geographers (AAG) meetings in Washington, DC, in April 2010 and Seattle, Washington, in April 2011. These are high-profile meetings of over 6000 attendees including experts from prominent policy and conservation organizations. At the AAG meeting in Washington, DC, Beymer-Farris's PhD supervisor, Professor Thomas Bassett, presented her research to a panel together with experts from these powerful conservation and environmental policy institutions.[10] At this panel Bassett raised a "REDD+" flag about the potential for carbon forestry programs to incentivize forest evictions prior to their implementation as a mechanism for those in power to capture carbon credit funds. Bassett also described the power conservation organizations like WWF have in legitimating environmental injustices through ill-conceived environment narratives of forest destruction by local people as was the case in the Rufiji Delta. At the AAG meeting in Seattle, Washington,

[9] Beymer-Farris received her PhD from the University of Illinois at Urbana-Champaign in the Department of Geography.

[10] The panel was titled "Biodiversity, Livelihoods, and Conservation: Emerging Trends, Challenges, and Responses" with influential panelists from the policy and academic arena including top officials from the World Wildlife Fund (WWF), Tom Dillon, a key representative from USAID, a representative from the Department of State, Alan Thornhill, as well as representatives from the National Science Foundation (NSF).

Beymer-Farris presented her research with WWF representatives (including Michael Mascia who is the Director for Social Science) present.

Despite their knowledge, neither WWF nor the Norwegian Embassy made public statements denouncing the planned evictions in the Rufiji Delta. To date, neither has provided any evidence that they sought to prevent the planned evictions of which they were aware, and of which we believe impacted the implementation of the REDD+ project in the Rufiji Delta. Beymer-Farris and Bryceson's public and private attempts to stop the planned evictions were not successful. In the early hours of October 25, 2011, both Beymer-Farris and Bryceson received numerous phone calls in desperation from Rufiji Delta villagers that armed police officers together with staff of the FBD were engaging in forced evictions. They set fire to the villagers' rice fields and houses, cut down permanent crop trees (which represent and legitimate customary land tenure), and said they could no longer farm rice and would have to leave the delta. More than 3800 huts were burned down. The officials told the villagers they would shoot them if they tried to resist.

It was not the WWF, the Norwegian Embassy, or the Tanzanian state that stopped the attempted evictions in the Rufiji Delta, it was the villagers themselves. On the night before the fourth day of the attempted evictions, unarmed villagers swam through the mangrove forest rivers and surrounded the armed police and forestry officials in order to make a citizens' arrest. In recounting the event, villagers said to the armed police and the FBD,

> You might be able to shoot me, and kill a couple of us, but we are many and you are relatively few. But we, the Warufiji, drown our enemies. We suggest you put down your guns and we will take you back peacefully to where you came from and out of Salale Ward [the specific geographic term for this area of the Rufiji Delta]. (Personal communication, October 30, 2011)

Villagers said that swimming silently through the mangrove streams is a tradition in the Rufiji Delta because "no one can beat them in the water" (personal communication, October 30, 2011). After the armed police and FBD surrendered, the villagers escorted them out of the delta and called the Regional Police Commander to inform him that they had captured some "criminals" who were unlawfully destroying their properties, crops, and resources.

Participants Deny, Delete, and Discredit

Media scrutiny of the attempted evictions was intense. When the attempted evictions took place, a series of news stories were published in Tanzania, Norway, the UK, and in other internationally recognized websites. On January 4, 2012, an article based on Beymer-Farris's research was published titled "The REDD Menace: Resurgent Protectionism in Tanzania's Mangrove Forests" in one of the leading environmental journals, Global Environmental Change (Beymer-Farris and Bassett 2012). Debates ensued about the planned evictions in the Rufiji Delta, the politics of carbon forestry in Tanzania, the power of environmental narratives created by

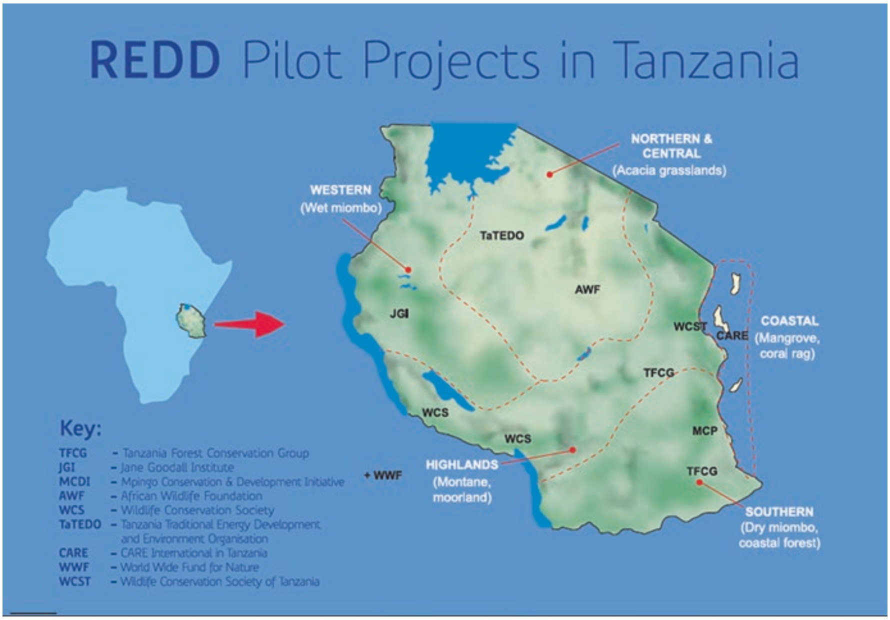

Fig. 5 Screen capture of the map sent by WWF to Beymer-Farris that lists WWF as one of many NGOs implementing REDD pilot projects in Tanzania, but places its activities in an undefined location outside of Tanzania. (Source: Beymer-Farris and Bassett 2013)

conservation organizations like WWF that are used to legitimate environmental injustices, as well as the role of Norwegian REDD+ funding in the Rufiji Delta. Rather than acknowledge any role or invite stakeholders to the table, the major participants denied responsibility, deleted publicly accessible records, and attempted to discredit Beymer-Farris's research.

For example, after the "REDD Menace" article was published online, Jason Rubens (previously the Programme Coordinator for WWF Tanzania) emailed Beymer-Farris and stated that all of the websites cited in the article "no longer appeared online" (personal communication, February 1, 2012, and Beymer-Farris and Bassett 2013). They were replaced by a new map in which WWF is listed as one of the many NGOs implementing REDD Pilot projects in Tanzania, but places its activities in an undefined location outside of Tanzania (Fig. 5).

WWF representatives also engaged in efforts to discredit Beymer-Farris. This included numerous emails sent to top officials at Norwegian and Tanzanian academic and policy institutions as well as a series of news stories and online websites contesting Beymer-Farris's research findings and arguments that Beymer-Farris was "naïve" and her research was "a professional flop," "biased," and "rubbish" (WWF Webposting January 13, 2012; Hansson 2012). WWF also tried to prevent Beymer-Farris and Bassett's "REDD Menace" article from being published in the journal, *Global Environmental Change*, calling Beymer-Farris's research "pure fantasy" and that she made "gross generalizations and assumptions, rather than building a case based on credible research" (personal communication, February

3, 2012). While WWF's efforts did result in a review of the article by the journal's entire editorial board, the board agreed that it was scientifically sound, merited publication, and it was published (Beymer-Farris and Bassett 2012).

The Royal Norwegian Embassy in Tanzania also sent their own employee to the Rufiji Delta to conduct an independent investigation, "the embassy made its own investigation of the Rufiji case, including a local employee [Yassin Mkwizu, Programme Officer for the Royal Norwegian Embassy] who visited the area and spoke with the local population and local authorities" (Bistandsaktuelt no. 1 of 2012). Officials from the Embassy stated publicly on two occasions that human rights violations did not take place as a result of the attempted evictions in the Rufiji Delta. Inger Naess, the former Environment Counsellor for the Norwegian Embassy in Tanzania, stated:

> There has been no violence or direct violation of human rights during these [attempted evictions of villagers in the Rufiji Delta] actions. This kind of conflict is related to population growth and a situation of a lack of land use planning and unresolved land rights. It is important that these challenges be taken seriously while safeguarding the rights of the population. It is up to local Tanzanian authorities to manage protected areas in line with national law and international conventions. (Bistandsaktuelt, no. 1 of 2012)

In addition, Svein Bæra, the Communications Adviser in the Ministry of Foreign Affairs in Norway, also stated publicly (Salvesen and Gedde-Dahl 2012) that:

> *The Norwegian Embassy visited the Rufiji area and had meetings with authorities and human rights groups. These meetings have not revealed any links between Norwegian-funded activities and forced relocations of population from this area.* No evidence has been found indicating that human rights violations have occurred in the forced relocation of Rufiji Delta villagers.

During the Embassy's own employee's visit to the Rufiji Delta, Beymer-Farris and Bryceson received phone calls from the villagers stating "two people are here [in the Rufiji Delta] telling us they came on your [Beymer-Farris and Bryceson's] behalf and that we should talk with them to help the situation" (personal communication, November 24, 2011). Beymer-Farris and Bryceson asked the villagers to take pictures of the Norwegian Embassy representatives to document this incident and told the villagers that we did not know these people and that they were not sent on our behalf. These two persons claimed to be Saidi Ali and Fatuma, but these turned out to be false names.

While the evictions stopped, the struggle did not end for the villagers. In lieu of evicting the villagers from the Rufiji Delta, forestry officials, without consultation or collaboration, imposed a new mechanism of control by concocting new licenses to farm rice. The license permits or denies rice farming on an annual basis, effective for 5 years. The farmer pays a fee for the license to farm on their own land. As part of the license, farmers cannot plant permanent tree crops in the rice fields and are required to plant mangroves in half the farm. Villagers are also mandated to weed the mangroves from an invasive vine in the area and are not allowed to establish any shelter in the rice fields. Interestingly, the Forestry and Beekeeping Division decided to have only three of the four villages in the Rufiji Delta sign the contracts. Perhaps this was a mechanism to attempt to divide and rule the villagers and decrease their collective power.

Fig. 6 The leaders and representatives of the four Rufiji Delta (Salale Ward) villages joined their counterparts from Mafia Island at one of the meetings held at Nyamisati Village

Knowledge Is Power: Discussions About Human Rights with Villagers

With the attempted evictions and the proposal for unjust rice farming licenses, Beymer-Farris and Bryceson again sought out advice and support from Maina Peter to organize a series of meetings with villagers so they could learn about their human rights.[11] At these meetings, the researchers brought copies of the Tanzanian Constitution, telephones, cameras, and other recording devices, as well as copies of all of the media stories and reports published about the villagers in the Rufiji Delta. For one meeting, the researchers decided to invite villagers from Mafia Island to the Rufiji Delta so they could share their experiences learning about and enacting their human rights as a result of unjust conservation management (Fig. 6).

At this meeting, villagers from Mafia Island discussed their positive experiences working with the Tanzania Commission on Human Rights and Good Governance (hereinafter referred to as the Commission or CHRAGG) in helping them struggle for their human rights. Mr Fakhi Ali Hassan, the Chairperson of Jibondo Village,

[11] One of these meetings was held at Nyamisati Village in the Rufiji Delta (also referred to as Salale Ward) on 23rd of June, 2013.

where severe human rights violations took place as a result of enforcement of conservation in the MIMP, told the Rufiji villagers:

> If you wish to oppress someone, then you should deny them knowledge; deny them their means of production; and divide and rule them.

Hassan then outlined the three examples of how this was happening in the Rufiji Delta: (1) the FBD and WWF not informing all villagers of plans and interventions, (2) preventing them from growing rice so they cannot sustain their lives and livelihoods, and (3) trying to divide and rule them through contracts, payments, and different forms of treatment between the four villages within the Rufiji Delta (personal communication, June 28, 2013).

Also at this meeting, a villager from Jibondo Island located in the MIMP held up their license to fish (Local Resident User Certificate) and declared: "the rice farming contract is your trap, this is mine" and pleaded with the villagers to not sign the contracts because their fate would be the same as those living in the MIMP (personal communication, June 28, 2013).

A villager in the Rufiji Delta stated at the meeting, "we feel tricked about these contracts and into signing them" and that the local Counsellor ("**Diwani**" in Kiswahili) came to his village and declared "we will come to the Rufiji Delta with army soldiers to use greater force than the last time unless the contracts for the licenses are signed" (personal communication, June 28, 2013).[12] The sentiments of villagers' strong opposition to the contracts were reflected in a news story in Norway "if we have to plant mangroves on half the soil, there will be no sustainability in rice cultivation, it is like digging our own grave" (Makoye and Zachrisen 2012).

These meetings empowered villagers to stand together across the four villages and also communicated important information about the Tanzanian Constitution, 1977, and the role the Commission has had in recognizing and responding to human rights violations. As a result, the village chairpersons representing all four villages in the Rufiji Delta (Mchinga, Mfisini, Kiomboni, and Nyamisati, also known as the Salale Ward) traveled to the Commission's headquarters in Dar es Salaam to make a formal complaint about the human rights violations in the Rufiji Delta (Fig. 7).

The Commission's Public Inquiry in the Rufiji Delta

After meeting with the Commission, the village chairpersons in the Rufiji Delta arranged a series of meetings in their villages to discuss their experiences with the Commission and to share their goal of solidarity among each other to struggle for their human rights. The chairpersons expressed their great hopes that the Commission

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[12] A sample of these highly controversial and disputed contracts is reproduced in Commission for Human Rights and Good Governance, *Report on Public Inquiry on the Land Dispute in Salale Ward in Rufiji, Coast Region*, 2013, page 17.

Fig. 7 Village chairpersons from the Rufiji Delta (Salale Ward). From left to right, Jumanne Kikumbi (Chairperson of Nyamisati Village), Hamisi Yusuf Mtimba (former Chairperson of Kiomboni Village), Ahamada Mahmoud Ngokoro (Chairperson of Mchinga Village), and Yusufu Swale Mamboka (Chairperson of Mfisini Village)

would arbitrate in favor of respect for their human rights and ensure their rights are protected in perpetuity.

After the hearing the complaints from the chairpersons from the Rufiji Delta, the Commission concluded that human rights violations had occurred during the attempted evictions. In response, the Commission organized a Public Inquiry in Nyamisati, Kiomboni, Mchinga, and Mfisini villages.[13] The Public Inquiry took place on August 13, 2013. It was the first time the then Chairperson of the Commission, the Hon. Justice (Retired) Amiri Ramadhani Manento, attended a public inquiry. The Public Inquiry in the Rufiji Delta was spearheaded by the hard work of Ms. Mary Massay who is the Secretary of the Commission and Francis Nzuki who is the Director for Human Rights in the Commission. Elected leaders and more than 500 villagers (men, women and elders) from Nyamisati, Mchinga, Mfisini, and Kiomboni villages attended and spoke at the meeting. The Coast Region Administrative Secretary, the District Executive Director for Rufiji District, the Rufiji District Commissioner, the Member of Parliament, representatives from

[13] Public hearing is one of the mandates of the Commission under the Human Rights and Good Governance Act, 2001 (Act No. 7 of 2001) to establish if there has been human rights violations in a situation following complaints by the citizens.

the Office of the Regional Commissioner for the Coast Region, the Tanzanian Forest Service Agency (formerly the FBD), the Rufiji Planning Officer, the Ministry of Natural Resources and Tourism, the Prime Minister's Office, and the Police Department also attended the meeting and were provided the opportunity to speak.

Villagers' statements at the Public Inquiry focused on their customary land rights, outlining a history of land use and cultivation in the Rufiji Delta, the sustainability of rice cultivation, the violation of human rights as a result of the attempted evictions, and the proposed contracts for licenses to farm rice. Villagers wanted to know who ordered the evictions and what procedures were followed since they did not have the villagers' consent. They also wanted to know why they were not compensated for the destruction incurred by the attempted evictions. They asked why the district did not intervene on their behalf during the evictions and only came upon learning that police officers and the FBD were subdued through a peaceful citizen's arrest.

Villagers also raised an important issue about possible corruption by the FBD, as one Mr. Masham Mluma noted:

> The officers for the mangrove project come with a single pair of trousers, but in only two days, they have a second pair and those coming with bicycles go away driving their own cars. (CHRAGG 2017: 6)

Women also spoke out at the meeting. Ms. Zainab Ali Mkwere emphasized that women were primarily affected by the attempted evictions from their rice fields because women bear the majority of the responsibility to cultivate rice and this was impeded, leading to severe hunger and malnutrition for children and adults (Fig. 8).

Fig. 8 Ms. Zainab Ali Mkwera standing together with the Hon. Justice (Retired) Amiri Ramadhani Manento. Given that women in coastal Tanzania often sit on the floor at the back of public meetings and rarely speak, there is a saying in Tanzania, "when a woman speaks, it must be genuine"

She argued that rice was their only staple crop and without the ability to cultivate rice, they will starve (CHRAGG 2017: 7). Other powerful statements by the villagers included:

- "The act of evicting us from our native area is an insult unheard of since his existence in this world" Mr. Shabani (CHRAGG 2017: 4).
- "We deserve respect and recognition of our dignity and survival" and "it is our right to life to use the resources needed for our livelihood" Mr. Hamisi Yusuf (former Chairperson of Kiomboni Village) (CHRAGG 2017: 3).
- "We want to know who, between the people and the conservation projects, has a right to settle in this area, aren't we, the Salale people, and free citizens?" Mr. Ahamada Mahmoud Ngokoro (Chairperson of Mchinga Village) (CHRAGG 2017: 6).

In response to the villagers' claims, the Coast Region Administrative Secretary, was provided the opportunity to speak and focused his arguments on unsustainable rice cultivation by villagers that is destroying the mangrove forests as the rationale for their evictions. He argued, "Rice cultivation in the Rufiji Delta was degrading breeding sites for marine organisms due to application of harmful elements such as fertilizers and herbicides" (CHRAGG 2017: 14). He also argued that the area was threatened by sea-level rise. This would lead to the submergence of the isles in the years ahead so villagers must be evicted in advance of the impacts of sea-level rise. He stated that "since the process of obtaining areas for relocation would take a long time, people would be allowed to continue rice cultivation on a contractual basis provided they grow mangrove forests as well" and outlined the long-term plans for relocating villagers out of the Rufiji Delta (CHRAGG 2017: 14).

Villagers were given the opportunity to respond to the statements made by the Coast Region Administrative Secretary. Villagers emphatically stated their shifting rice cultivation at small-scales did not degrade breeding sites due to the use of harmful chemicals. They argued they lived in poverty and could not afford to purchase chemicals. The Commission then relied on previous studies conducted in the Rufiji Delta that found no traces of agricultural chemical inputs, thereby substantiating the villagers' claims (CHRAGG 2017: 19). Villagers also argued emphatically that they had not agreed, nor would they give their consent to the contracts for rice cultivation in the Rufiji Delta. Lastly, villagers argued that sea-level was falling steadily for several millennia in the Rufiji Delta. This was supported by academic literature that showed that sea-levels were falling as a result of plate tectonic activity. Due to plate tectonic activity, uplifting is taking place (Woodroffe and Horton 2005).

During the Public Inquiry, villagers heavily contested contracts for licenses to farm rice based on the following reasons. Firstly, this was their own land which they have been cultivating from time immemorial. Why should they be licensed to use the same?[14] Secondly, rice is the only staple food crop so growing rice is their fundamental human right to food and to livelihoods to guarantee their survival as

[14] Some produced original receipts of Poll Tax they had paid from around 1930 indicating longevity of having lived in this area and thus making the whole question of licensing them to use the same land ridiculous.

human beings (CHRAGG 2017: 20). Thirdly, mangroves are fast-growing tree species and would overtake their rice farms within 5 years if villagers were ordered to plant mangroves in half their fields. Fourthly, farmers were required to do the labor of forest officials in weeding the mangroves. Fifthly, famers were not allowed to farm permanent crops as a mechanism to remove customary land rights that are symbolized by permanent crop trees.

And sixthly, rice is a salt-intolerant crop so when the river salinities fluctuate, farmers must move to a new area to farm rice leading to a shifting rice cultivation practice. Thus, allocating strict boundaries for rice farms prohibits these needed shifts in rice farming and do not make ecological sense to the villagers. Moreover, shelters built in the rice fields protect farmers from dangerous wildlife such as hippos and crocodiles. Hence, prohibiting these structures endangered people's lives. And, additionally, the villagers believe the state used divide and rule tactics by permitting three of the four villages in the delta to have licenses to farm rice.

The Commission's Report and Recommendations for Respecting Human Rights in the Rufiji Delta

The Commission's findings are outlined in their report titled "Report on Public Inquiry on the Land Dispute in Salale Ward in Rufiji Coast Region" (CHRAGG 2017). The report acknowledges that human rights violations occurred during the attempted evictions. It begins with a comprehensive historical analysis of land use in the Rufiji Delta, which resulted in the villagers' land rights. This includes evidence of established settlements many centuries prior to Tanzania's Independence in 1961 as well as customary land tenure through the existence of permanent crop trees, registered villages through the Village Land Act of 1999 (Act No. 5 of 1999), documents of House and Poll (Kodi ya Kichwa) tax as early as 1935, ancestral burial grounds, and the number of rice varieties (over 11) which signifies a history of rice cultivation that potentially dates back to 1700 AD.

In sum, the Commission's Report provides a clear recognition of customary land tenure in forests reserves by stating that, "villagers in Salale Ward are vested with ancestral customary title to the whole land comprising the Salale Ward, and that such a title constitutes a deemed right of occupancy under the Land Ordinance, 1923 (Chapter 113 of the Laws of Tanzania) which preceded the Village Land Act, 1999" (CHRAGG 2017: 11). In addition, the Commission also recognizes the role of village governments in the management of the mangrove forests by stating that "because the Rufiji Delta mangrove forests fall under a Joint Forest Management agreement in Tanzania, village governments have primary protection and management responsibility of the forest" (CHRAGG 2017: 12).

The Report also provides the historical background of the Rufiji Delta and statistics on the total land area under cultivation. The entire Salale Ward of the Rufiji Delta contains 39,718 ha of mangrove forests. Within those forests only 1536 ha are under rice cultivation so the extent of rice farms is quite small in size, and the practice of shifting rice cultivation allows for regeneration of mangrove trees.

The Commission's Report also discusses the rapid growth rate of mangrove trees and how the practice of shifting rice cultivation can improve, rather than destroy, mangrove forests as small-scale disturbances created by small-scale rice farms can stimulate and encourage mangrove forest growth (CHRAGG 2017: 9).

These statistics and accounts from the villagers led to the Commission's conclusion that the practice of small-scale rice cultivation is a sustainable livelihood that enhances, rather than destroys, the mangrove forest. As such, the Commission determined that villagers "have been the vanguard in preserving mangrove forests as the main source for their livelihoods" (CHRAGG 2017: 21). That the villagers "have been living in the area for a long time and depend on and protect the mangrove forest due to the benefits they obtained from these important resources" (CHRAGG 2017: 23).

Important Conclusions from the Commission's Report

The Commission, therefore, called for the immediate suspension and removal of the contracts and licensing system because "they have the legal effect of turning villagers to squatters on their own land – land which have been occupied by their forefathers for centuries and there is evidence to this effect" (CHRAGG 2017: 25). The Commission argued that the requirement for villagers to pay fees for occupying their own lands "was sending families without money to pay into poverty, starvation and destitution without good cause" (CHRAGG 2017: 24). The Commission also determined that the contracts and licenses have no solid basis in the law and provide punitive and unacceptable conditions. The contracts and licenses endanger villagers' lives through refusal to construct structures to protect themselves against wild animals, including hippos and crocodiles. In sum, the Commission argued that "contracts and licenses deny the villagers their right to food, livelihood, their culture and organized life as a people" (CHRAGG 2017: 26).

A summary of the Commission's Report found that "it is obvious that the question of relocating the residents from Mfisini, Mchinga, Kiomboni, and Nyamisati does not arise" (CHRAGG 2017: 26). This is in stark contrast to the position of the Royal Norwegian Embassy that believes "this kind of conflict is related to population growth and a situation of a lack of land use planning and unresolved land rights" (Bistandsaktuelt no. 1 of 2012). The Commission also found sufficient evidence to prove how responsible villagers from these villages have been in dealing with the environment around them:

> They have not only cared for the mangrove forests, which sustain their livelihoods, but they have cared for all the resources sustainability in the Rufiji Delta while cultivating rice and fishing for their livelihoods and kept their culture intact without causing any damage to what is around them. (CHRAGG 2017: 27)

The Commission further noted that:

> The law of the land, and customary law is firmly on the side of villagers – given their long stay in this area as evidenced by oral statements and documents produced before the Commission at the Public Inquiry. (CHRAGG 2017: 27)

The Commission's Report then provides a series of formal recommendations. These include the following:

1. Continued engagement with all stakeholders in this dispute through frequent visits in order to facilitate an equitable and just natural resource management plan in the area that secures peoples' right to their land, resources, and livelihoods and to ensure that local people have significant decision making authority over the conservation of the important natural resources in this area.
2. A three-way consultation process in formulation and implementation of the various policies and strategies by government, its agencies, and departments. The process should involve the local authorities, the central government, and the people. These villages are Nyamisati, Mchinga, Mfisini, and Kiomboni. Picking and choosing among these villages which enjoy the same cultural, social, economic, and historical background complicates the situation which is not helpful.
3. The government at all levels and its agencies should work together with the people of the Rufiji Delta (Salale Ward) in seeking solution to the current problem once and for all so that people can be able to go about their daily life in peace and guaranteed their security under the law which is a prerequisite of a democratic state that believes in the rule of law.
4. A more humane and legal relationship between the Forestry Department and the people of the Rufiji Delta (Salale Ward), a relationship that will not only ensure conservation of the environment and the resources of this area but also ensure that the people are protected and valued as bona fide citizens of the United Republic of Tanzania.

Official Launch of the Commission's Findings

On February 5, 2017, the research team observed the Commission's formal launch of the Report in the Rufiji Delta. The official launch of the Commission's Report was spearheaded and led by the new Chairperson of the Commission at this time, Hon. Bahame Tom Mukirya Nyanduga (Fig. 9). During the launch, public speeches were made to announce the Commission's findings. Over 1000 published copies (in Kiswahili) of the Report were disseminated throughout Nyamisati, Kiomboni, Mfisini, and Mchinga villages in the Rufiji Delta. Villagers celebrated a successful moment in the long struggle for their rights.

The public launch of the Commission's Report was on the same day as the 50th anniversary of the Arusha Declaration of 1967. The Arusha Declaration is considered by many as the foremost symbol of struggle and resistance in Tanzania (Shivji 1989). In the words of Julius Nyerere in the Arusha Declaration:

> We have been oppressed, we have been exploited, and we have been disregarded. It is our weakness that has led to our being oppressed, exploited and disregarded. Now we want a revolution - a revolution to end our weakness, so that we are never again exploited, oppressed, or humiliated.

Fig. 9 Official launch of the Commission's Report in the Rufiji Delta with the Commission's Chairperson, Hon. Bahame Tom Mukirya Nyanduga, holding the published Reports

Fig. 10 Rufiji Delta villagers celebrating the launch of the Commission's Report and the long (and continued) struggle for their human rights

The sentiments and potency of the Arusha Declaration are seemingly all but forgotten by the state in Tanzania today (Shivji 1989). However, the launch of the Commission's Report in the Rufiji Delta provides a sign of hope. In the words of Maina Peter during the launch of the Report: "this is what the path to emancipation looks like" (Fig. 10).

Conclusions

In this chapter we have tried to show how recently outsiders, with the assistance of the state, have attempted to control areas historically governed by local residents in the name of conservation and climate change policy initiatives. These interventions depict and brand the villagers as "destroyers" and "intruders," despite scientific and historic evidence to the contrary. We further illustrate the international linkages to worldwide conservation narratives and to development aid by rich countries promoting climate measures in poor countries to try to absolve their carbon emissions revealed the ways in which such vested interests attempted to misuse their money, power, and influence.

We recount the struggles of villagers and their elected leaders in Mafia Island and Rufiji Delta in coastal Tanzania for recognition of and respect for their rights in the face of interventions by state institutions and international conservation organizations. The chapter shows how the villagers courageously asserted their rights in the face of threats to their livelihoods, while outside interests sponsored or ignored increasingly violent measures by the state. Despite this, we show how villagers have proven that they are the rightful custodians of the natural resources in Mafia Island and the Rufiji Delta, especially of fisheries and forestry resources, which they have governed traditionally for centuries.

These two cases are particularly interesting, because the villagers collaborated with one another and with researchers to appeal to the Tanzanian authorities at the national level, including the Commission for Human Rights and Good Governance. The Commission, in turn, conducted transparent public hearings and reached thorough and fair conclusions that the villagers' rights had indeed been violated. These decisions recognize and apply constitutional principles to the villagers' fundamental and human rights, including their role in the management and governance of the areas and resources where they live, which serve as the sources of their livelihoods. In the wise words of Tanzania's former Prime Minister, Hon. Judge Joseph Sinde Warioba (Warioba 2014):

> *People want all national values respected. You cannot have good governance without promoting transparency and accountability. People need also human rights enforced and they need development goals and directions especially for fisherman, livestock keepers, and agriculturalists.*

We hope that these lessons learned in Mafia and Rufiji will lead to deeper understanding and greater recognition of coastal peoples' rights and also lead to a fairer and wiser governance of Tanzania's coastal areas and resources.

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Part III
Conclusions and Synthesis

Climate Change and Socio-ecological Systems' Vulnerability in the Coastal Areas of Tanzania: A Synthesis

Claude Gasper Mung'ong'o and Haji Mwevura

Introduction

Reducing the vulnerability of coastal communities to marine climate change requires that communities have some intrinsic capacity to adapt. To assist adaptation planning and the implementation of adaptation strategies, identifying barriers and enablers to adaptation is critical. Adaptive capacity, resource dependence, local climate change exposure, and biological sensitivity were used to assess socioeconomic vulnerability to climate change in five Tanzania mainland coastal districts of Pangani, Rufiji, Kilwa, Lindi, and Mtwara. Such vulnerability assessment was also done in the three island communities of Zanzibar, Pemba, and Mafia. This last chapter of the monograph summarizes the findings of the case study assessments, draws the main conclusions from them, and identifies the best adaptation strategies that utilize available assets, improve adaptive capacity, and reduce socioeconomic vulnerability (Metcalf et al. 2015).

Climate Change and Its Impacts in the Coastal Areas of Tanzania

Findings from all the eight studies in Tanzania have demonstrated that climate change had happened and was still happening in the study areas. Has this change been a result of localized forcings or from most globally induced climate change? Carbon stock and emission estimates made by Godoy et al. (2011) showed that coastal Tanzania still had significant forest cover area, both in terms of carbon

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storage and especially in terms of biodiversity conservation. Although deforestation rates remained relatively high near Dar es Salaam and in some parts of Pwani Region, generally deforestation of the coast had decreased substantially after 2000. Similarly, emissions from deforestation had substantially been reducing from the 1990s to 2000–2007 for all the five coastal regions. For example, "…total emissions from reserves decreased from 0.03 Mt CO_2 yr^{-1} to 0.02 Mt CO_2 yr^{-1}" (Godoy et al. 2011). These estimates would place the cause of such climate changes into the forcings of global climate change, probably in the relationship between the AMO stationary Rossby wave and the onset of the Indian summer monsoon as suggested by Semazzi et al. (2015).

Whatever the explanation, the notable local impacts of climate change have included decrease of rainfall, change of rainfall seasons and patterns, emergence of crop diseases and pests, decrease of fish catch, intrusion of salinity in the rivers, and general decline of crop productivity. Temperature and rainfall data from the TMA and as supported by questionnaire data and information from key informants and focus group discussions all point to increasing temperatures and decreasing rainfall trends. The findings further reveal that the impacts of climate change have been increasing over time but have been severe in the last 10 years.

Climate change has had both negative and positive impacts on the availability and distribution of coastal resources. Although further analysis and scientific-based evidence are still needed to prove that climate change was already happening, these studies have shown that the climate variations have been inflicting losses in agriculture, which is the main livelihood source for the majority of the population. For example, changes in climate factors have had serious impacts on the seaweed productivity in Unguja. The study by Hassan and Othman in "Seaweed (*Mwani*) Farming as an Adaptation Strategy to Impacts of Climate Change and Variability in Zanzibar" shows that rainfall had affected seaweed more in the ability of seaweed to survive, in its quality, in its yield, and in washing away of newly planted seaweed. Meanwhile, temperature variability had increased vulnerability of seaweed to diseases and desiccation. In general the study found out that *Mwani* production had changed toward a declining trend over the last 5 years.

As a result, poverty had in fact been exacerbated as shown by Mung'ong'o and Moshy ("Poverty Levels and Vulnerability to Climate Change of Inshore Fisher-Mangrove-Dependent Communities of the Rufiji Delta, Tanzania") and Misana and Tilumanywa ("An Assessment of the Vulnerability and Response of Coastal Communities to Climate Change Impact in Lindi Region, Southern Tanzania"). On the other hand, while fresh water and fish resources had decreased, mangrove forests had increased in some of the study areas as argued by Mwiturubani ("The Impact of Climate Variability and Change on Communities' Access to and Utilization of Coastal Resources in Pangani District, Tanzania") and Mung'ong'o and Moshy ("Poverty Levels and Vulnerability to Climate Change of Inshore Fisher-Mangrove-Dependent Communities of the Rufiji Delta, Tanzania"). The increase of the coverage of mangrove forests is partly due to the strict rules imposed on their accessibility and utilization but also due to increased salinity in rivers like Pangani and the Rufiji which create favorable conditions for mangroves' growth. Thus climate change has also shaped the way coastal communities access and utilize these and other coastal resources.

The negative impacts of climate change on the livelihoods of coastal communities are likely to continue in the future. Although there have been attempts to diversify economic activities and the crops grown, with the addition of crops like simsim, which is emerging as a major cash crop almost replacing cashew nuts in Lindi and Mtwara, opportunities are limited due to limited assets owned by the poor households as indicated by Misana and Tilumanywa ("An Assessment of the Vulnerability and Response of Coastal Communities to Climate Change Impact in Lindi Region, Southern Tanzania") and other such studies as Shikuku et al. (2017). This is a clear indication that these coastal communities are vulnerable in multiple ways, not only to climate change. Hence even their ability to adapt to climate change is curtailed. As observed in the Rufiji, Kilwa and Lindi case studies, the high poverty levels in the districts are worsening the situation, with individual households and communities becoming highly vulnerable to food shortages for almost half of the year.

Much as many adaptation and mitigation options can help address issues of climate change in the coastal communities, realistically not one single option fits all. To realize these measures requires policies and cooperation among various institutions and local NGOs. Adaptation and mitigation responses are underpinned by common enabling factors. These include effective institutions and good governance at the local level.

As shown in a study in Madagascar (Westerman et al. 2012), generalized strategies developed at the national level address vulnerability, adding to a variety of international initiatives. Yet, such high-level planning inevitably remains vague and indeterminate for most of the island's coastal communities, with little meaningful implementation on the ground. Therefore, local measures to build resilience and adaptive capacity are critical to ensure that resource-dependent communities are able to cope with the immediate and long-term effects of climate change.

As argued by Adger et al. (2005), the causes of vulnerability are embedded in the political economy of resource use and the resilience of the ecosystems on which livelihoods depend. Hence, individuals and communities who undertake adaptive strategies that involve the mobilization of assets, networks, and social capital both to anticipate and to react to potential disasters need to be capacitated so that they can rise to exploit the resources and opportunities that are available to them at any particular moment.

Currently, all government ministries in Zanzibar have policies that have taken into account climate change issues. But there is need to have innovative techniques and investments in environmentally sound technologies and infrastructure which can adapt and mitigate climate change impacts so as to enhance sustainable livelihoods, whether they come from the government or private sector.

The submissions in this collection have further shown that in the process gender issues should not to be ignored. Tradition and culture have most of the time kept women in low profile in many decision-making activities, including participation in climate change initiatives. Women are poorly represented in training, research, and decision-making organs, despite the fact that nowadays it is an administrative requirement that there should be at least one female representative in each established committee in the villages. Women are most affected as they have to go into distant places to collect wood and water.

Moreover, many of the studies undertaken in this volume and elsewhere have been focusing on individual components of complex systems and have not been able to address issues or inform interventions such as those that aim at empowering communities from a gender perspective in the study areas in a holistic manner. As a result, actions or interventions to address climate variability and change have been facing challenges or have become only partially effective.

So if good adaptation mechanisms are applied, it will assist them to solve such problems. One example is the water installation in Nungwi by the Zanzibar government whereby participation of women and other vulnerable groups in the management of the scheme has reduced the gender gap in ensuring equitable sharing of valuable ecosystem services.

It has been recommended that the governments at all levels, NGOs, CBOs, and local communities join their efforts and resources to design and implement adaptive strategies and/or response measures that effectively address these effects. What is needed is community education on climate change impacts or what Lance Gunderson calls "the need for experimentation and learning to build adaptive capacities" (Gunderson 2010) and the presence of social networks to assist in creating awareness on climate change impacts and livelihood diversification to reduce direct dependence on the fisher-mangrove-agriculture ecosystems. Such livelihood diversification strategies include provision of capital for small businesses and establishment of environmentally friendly activities such as compound-based livestock keeping (zero-grazing) and modern beekeeping.

Such capacity building of communities and other relevant stakeholders to effectively respond to climate change impacts in agriculture, fisheries, and mangrove conservation sectors envisages three key outcomes:

(i) Improved output and income through supported sustainable agriculture and fisheries practices.
(ii) A critical mass of vulnerable communities and other relevant stakeholders are capacitated and equipped and practice low-cost and efficient wood-saving technologies that will reduce significantly the impacts of mangrove deforestation.
(iii) Strengthened institutional capacities to plan, govern, and respond to climate change impacts in agriculture, fisheries, and mangrove conservation in the study area.

Sea Temperatures, Coral Bleaching, and Productivity in Island Environments of Tanzania

As far as the island studies are concerned, most of the impacts of climate change have been manifesting themselves in the form of increase in sea surface temperatures, sea level rise and its accompanied coastal flooding, and saline water intrusions. Studies from Mafia Island and elsewhere discovered, for example, that sea surface temperatures had increased by 0.56 °C from 2001 to May 2016 (e.g., Sebastian 2016). Although the increase tended to vary annually, it was consonant with the observations made elsewhere from the Indian Ocean where the temperatures had risen by 0.696 °C from 1982 to 2011 (Maheshwari et al. 2013).

Increase in SST from the normal seasonal season maximum for corals to survive (27 °C) has severe impact on corals since zooxanthellae are vulnerable to such increase. This increase affects the light-dependent reaction of photosynthesis process of zooxanthellae algae by triggering production of oxygen peroxide species. These species damage cells of the algae leading to death of zooxanthellae and expulsion from the coral, hence bleaching. Therefore, increase in SST of 0.56 °C in Mafia Island from 2001 to 2015 has been influencing coral bleaching even though it is said to have been outcompeted by high rates of recovery due to effective management and monitoring of corals put forward by the Mafia Island Marine Park (Moshy 2016). The Mafia study by Sebastian (2016) clearly shows that coral reefs recover well when anthropogenic-induced impacts to corals, like illegal fishing and coral mining, are well contained. Coral cover offers a variety of ecosystem services to fish species such as breeding sites and nurseries, and this was because they have the ability to support more fish species per unit area than any other marine environments.

By considering the magnitude of bleaching responses in relation to ratios of observed coral colonies in respective reef sites in the Zanzibar, geographical location, coral community composition, diversity, and reef topography are suggested by Ussi and colleagues in ("Poverty Levels and Vulnerability to Climate Change of Inshore Fisher-Mangrove-Dependent Communities of the Rufiji Delta, Tanzania") to be among the determinants of variability in coral bleaching prevalence and impact to coral cover loss. The results from the coral reef behavior study in Zanzibar Island suggest the existence of the relationship between the coral diversity and resistance to bleaching within reef communities such that the more diverse reefs have the greater chance to withstand temperature stresses than the least diverse reefs.

The observed patterns of bleaching susceptibility in this study that reefs located in relatively low latitudes were more susceptible relative to those reefs that were at relatively higher latitudes are related to the pattern of sea surface temperature variability in the region. The results of this study are further supported by larger area-based sea surface temperature data from NOAA for regional prediction of coral bleaching, which indicated larger area of "Alert Level 1" more in low latitude zones than higher latitude zones in the region.

Coral reef recovery after stress was also dependent on factors such as larval availability, larval settlement rate, recruitment, and growth. Understanding the severity of the effect of thermal stress as a threat factor to coral reefs' health is important for managers to take appropriate management measures to assist the recovery process.

The impact of temperature stresses in coral reef community is not only detrimental to coral reef ecosystems, but it is also disadvantageous to other sectors of which their flourishment is directly linked to the health of coral reef ecosystems such as fisheries and tourism. However, while there are various carbon-financing instruments, including restoration of forests (REDD+) and emissions trading, few address the need to finance healthy ocean and aquatic ecosystems, although these are essential for continued uptake of CO^2 and greenhouse gases.

Human Rights Dimensions of Conservation and Climate Change Initiatives

Few studies examine the human rights dimensions of conservation and climate change, especially so on how people draw upon human rights as a way to struggle for their rights in instances where conservation or climate change initiatives result in human rights abuses. Betsy Beymer-Farris, Ian Bryceson, and Chris Maina Peter examine the human rights dimensions of conservation and climate change initiatives in Africa's first and largest marine-protected area, the Mafia Island Marine Park, and a proposed carbon forestry climate change initiative in the Rufiji Delta mangrove forest in coastal Tanzania. Despite "rights-based" rhetoric of climate change and conservation policies, severe human rights abuses took place in these resource-rich areas. Beymer-Farris, Bryceson, and Maina Peter demonstrate the power of villagers to draw upon their human rights as provided by the Bills of Rights in the Tanzanian Constitution to challenge *and* change ill-conceived conservation and climate change policies. As a result, they provide a deeper understanding and greater recognition of human rights that can result in fairer and wiser governance of Tanzania's coastal areas and resources.

The East African Climate Paradox: The Remaining Gray Area?

As already pointed out, the findings from all the seven studies in Mainland and those of the Islands in Tanzania have demonstrated that climate change has happened and is still happening in the study areas. However, it is not clear yet how much of these changes are due to local forcings and how much is due to globally induced climate change forcings. Readings from literature suggest, for example, that of recent the East African climate has been experiencing a series of devastating droughts, whereas the majority of climate models predict increasing rainfall for the coming decades (Rowell et al. 2015). This is what has been called the "East African climate paradox" that has implications for viable adaptation policies in the future.

Lyon and Vigaud (2017) believe the models that bring forth such a paradox exhibit major errors in simulating the observed East African climate and large-scale SST patterns. These errors are said to be amplified in projections resulting in reduced confidence in current projections of the region's climate. There is need, therefore, for research priorities now shifting gear to "focus on providing a process-based expert judgment of the reliability of East Africa projections, improving the modeling of aerosol impacts on rainfall, and better understanding the relevant natural variability" as proposed by Rowell et al. (2015) and Suverijns et al. (2016).

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