UNESCO-IOC CHAIR OF MARINE TECHNOLOGY AT THE INSTITUTE OF MARINE SCIENCES, UNIVERSITY OF DAR ES SALAAM

TECHNICAL REPORT NO. IMS/2011/01

ENHANCEMENT OF ADAPTATION STRATEGIES OF COASTAL COMMUNITIES DEPENDENT ON COASTAL PANAEID SHRIMPS FISHERIES TO IMPACTS OF CLIMATE CHANGE AND VARIABILITY IN COAST REGION, TANZANIA

Alfred, N.N. Muzuka\textsuperscript{1,2}, Kahitira M. Bwire\textsuperscript{2} Mwanahija Shalli\textsuperscript{2} Margareth Kyewalyanga\textsuperscript{2} Gay M. Jacob\textsuperscript{3}, Lilian Ibengwe\textsuperscript{4}

\textsuperscript{1}Institute of Marine Sciences and UNESCO Chair of Marine Technology of the Institute of Marine Sciences, University of Dar es Salaam.
\textsuperscript{2}Institute of Marine Sciences, University of Dar es Salaam.P.O. Box 668, Zanzibar, Tanzania.
\textsuperscript{3}School of Ocean Sciences, Bangor University, UK
\textsuperscript{4}Department of Fisheries, Ministry of Fisheries and Livestock Development, Dar es Salaam.
EXECUTIVE SUMMARY

The present work, which was conducted in the Bagamoyo and Rufiji Districts, Coast Region aimed at contributing towards mitigation and adaptation to impacts of climate change and variability on coastal communities dependent on coastal panaeid shrimp fisheries. Specifically, the study intended to (a) identify existing fishing systems and factors influencing panaeid shrimp abundances and yields through collection of meteorological data discharges of the Rufiji, Ruvu and Wami rivers, (b) establish indigenous knowledge base on adaptation to climate change and variability, and (c) develop capacity in remote sensing and image processing for assessing coastal productivity. The work involved review of relevant documents with information on previous studies on challenges and coping strategies to extreme weather events and climate change in general, collection of meteorological and river discharges data from the Tanzania Meteorological Agency (TMA) and the Rufiji Basin Development Authority (RUBADA) in Dar es Salaam, Morogoro and Rufiji offices. Structured and unstructured interviews were also conducted through questionnaires to obtain information on indigenous knowledge on climate change adaptation strategies in Saadani Village and Kajanjo fishing camp (Bagamoyo District) and Dima and Kibanju fishing camps in Rufiji District. Collected meteorological data included monthly rainfall for Bagamoyo, Dar es Salaam, Pangani, Kibaha, Morogoro, Kilwa Masoko, Kibiti, Muhoro and Utete stations. In order to calculate mean rainfall, seasonal means as well as annual anomalies for coastal areas from Tanga to Mtwara, additional data from Tanga, Zanzibar and Mtwara were added. Discharge data collected covered stations located within the Rufiji and Wami-Ruvu basins. However, the collected data had many gaps and were not collected continuously on daily or monthly basis. Generally, temperature record indicated warming while annual rainfall declined in coastal Tanzania. Rising temperature and decline in rainfall have brought decline in the prawns’ resources and if this continues the coastal communities and coastal ecosystems will experience major impact probably leading to the collapse of fisheries industry.

Fishermen generally catch three species namely white prawns (*Penaeus indicus*), giant prawns (*Penaeus monodon*) and tiger prawns (*Penaeus semisulcatus*) in waters that are less than 10 m, but catch per unit effort has declined. In response to this decline, fishermen have resorted to increasing length of fishing nets, fishing other fish species or look for other alternative activities on land. Fishermen perceived rainfall variation, temperature and salinity as major factors responsible for decline in the abundance of shrimps although few acknowledged problems of over-fishing and habitat destruction. Major constraints limiting the use of indigenous knowledge in coping and adaptation processes appeared to be (i) poverty, (ii) inadequate and fragmented information/knowledge about climate change and adaptation options, (iii) lack/insufficient of capital to invest in non-fishing activities, and (iv) unpredictable rainfall. Although shrimp fishers have developed important indigenous strategies to adapt climatic changes; the magnitude of future impacts may limit their adaptive ability. External help from central and local governments, donors and private sector is therefore necessary to enhance their indigenous strategies. Also, efforts to raise awareness, adaptation planning and dissemination of information on alternative socio economic options that will help to build climate-resilience are required.
ACKNOWLEDGEMENT

This work could not be possible without financial assistance from IOC - UNESCO and Sida SAREC Marine programme. Authors acknowledge efforts made by UNESCO team and the management of the Institute of Marine Sciences for their valuable financial contribution toward this work.

We greatly appreciate the tireless work displayed by our driver during field work, the Tanzania Meteorological Agency, the Rufiji Basin Development Authority, the Wami-Ruvu Basin Authority and the Rufiji and Bagamoyo districts’ authorities for their important advice and information they provided during meteorological and river discharges data acquisition. Lastly, but not least, we highly appreciate fishers community in the Bagamoyo and Rufiji districts to devote their valuable time and willingness to be interviewed.
TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXECUTIVE SUMMARY</td>
<td>ii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENT</td>
<td>iii</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>iv</td>
</tr>
<tr>
<td>1.0 INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>2.0 METHODOLOGY</td>
<td>2</td>
</tr>
<tr>
<td>2.1 Study Area Description</td>
<td>2</td>
</tr>
<tr>
<td>2.1.1 Rufiji River Delta</td>
<td>3</td>
</tr>
<tr>
<td>2.1.2 Ruvu River Delta</td>
<td>4</td>
</tr>
<tr>
<td>2.1.3 Wami River Delta</td>
<td>4</td>
</tr>
<tr>
<td>2.2 Data Collection</td>
<td>8</td>
</tr>
<tr>
<td>2.2.1 Meteorological Data</td>
<td>8</td>
</tr>
<tr>
<td>2.2.2 River Discharge</td>
<td>9</td>
</tr>
<tr>
<td>2.2.3 Indigenous Knowledge and Adaptation Strategies</td>
<td>9</td>
</tr>
<tr>
<td>3.0 RESULTS AND DISCUSSION</td>
<td>9</td>
</tr>
<tr>
<td>3.1 Meteorological Parameters</td>
<td>9</td>
</tr>
<tr>
<td>3.1.1 Temperature</td>
<td>9</td>
</tr>
<tr>
<td>3.1.2 Rainfall</td>
<td>13</td>
</tr>
<tr>
<td>3.2 River Discharge</td>
<td>16</td>
</tr>
<tr>
<td>3.3 Indigenous Knowledge on Adaptation to Climate Change and Variability</td>
<td>20</td>
</tr>
<tr>
<td>3.3.1 Respondent’s General Characteristics.</td>
<td>20</td>
</tr>
<tr>
<td>3.3.2 Respondent’s Economic Activities</td>
<td>21</td>
</tr>
<tr>
<td>3.4.3 Shrimp Fishing Communities Perspective on Climate Change and Variability</td>
<td>21</td>
</tr>
<tr>
<td>3.4.4 Panaeid Shrimp Fishing Systems and Factors Influencing Abundances and Yields</td>
<td>22</td>
</tr>
<tr>
<td>3.4.5 Fishermen Perception on Effects of Climate Change</td>
<td>23</td>
</tr>
<tr>
<td>3.4.6</td>
<td>Application of Indigenous knowledge in Adaptation to Climate Change</td>
</tr>
<tr>
<td>-------</td>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>3.4.7</td>
<td>Challenges to Indigenous Knowledge and Enhancement of adaptation Options</td>
</tr>
<tr>
<td>4.</td>
<td>TRAINING</td>
</tr>
<tr>
<td>05.0</td>
<td>CONCLUSION AND RECOMMENDATION</td>
</tr>
<tr>
<td>6.0</td>
<td>REFERENCES</td>
</tr>
<tr>
<td>7.0.</td>
<td>APPENDIX</td>
</tr>
</tbody>
</table>

| Fig. 1: | Inter-relationship between adaptation and mitigation *(Source: Zevallos, 2009)* | 2 |
| Fig. 2. | Map of Tanzania showing location of major rivers and administrative regions. *[http://www.reliefweb.int/*](http://www.reliefweb.int/)  Source: modified SADC FSTAU, FAO/GIEWS | 4 |
| Fig. 3. | Satellite image of the Rufiji delta showing several distributary channels | 5 |
| Fig. 4. | A map of the Rufiji delta showing detailed features and study sites locations | 6 |
| Fig 5: | The Wami River Sub-Basin in central Tanzania, East Africa | 7 |
| Fig. 6. | Mean monthly rainfall (mm) for three coastal meteorological stations | 8 |
| Fig. 7 | Variation in mean annual maximum temperature (upper), mean minimum temperature (middle) and difference in temperature between maximum and minimum (lower) for the past 48 years (1961-2009). at the Mwalimu Nyerere International Airport. Note that minimum temperature has been increasing at a faster rate than the maximum temperature since 1980. | 11 |
| Fig. 8 | Mean annual temperature (upper panel), monthly minimum temperature (middle) and monthly maximum temperature (bottom) for five years at the Kilwa Masoko meteorological station. Most of the months display a systematic increase in air temperature with time particularly for the months of July through November | 12 |
| Fig. 9. | Annual rainfall anomaly for the coastal Tanzania. All stations registered decrease except the Zanzibar Station | 13 |
| Fig. 10. | Annual and seasonal mean rainfall as well as annual and seasonal anomalies for the Bagamoyo station | 14 |
| Fig. 11. | Rainfall record at the Utete meteorological station | 15 |
| Fig. 12. | Rainfall record at the Mwalimu Nyerere International Airport | 15 |
| Fig. 13. | Rainfall record at the Bagamoyo meteorological station | 16 |
| Fig. 14. | Record of seasonal discharge of the Ruvu River as recorded at the Ruvu Morogoro Road Bridge since 1958. The record is characterized by uncontinuity in recording | 17 |
| Fig. 15 | Record of seasonal discharge of the Wami River as recorded at the Mandera Village since 1954. The record is characterized by uncontinuity in recording | 18 |
| Fig. 16 | Record of the Rufiji River discharge as recorded at Mpanga station since 1971. | 19 |
| Fig. 17. | Mean annual discharge of the Rufiji River for the past 35 years | 20 |
| Fig. 18 | Marital status for respondents involved in fishing activities in the | 20 |
| Fig. 19. | Level of education of people interviewed in the Bagamoyo and Rufiji districts. | 21 |
| Fig. 20. | Percentage (left) and frequency (right) of fishermen fishing in various water depth intervals. Depth intervals are in meters. | 22 |
1.0 INTRODUCTION

Climate has varied over geological time (IPCC 2001), however, the rate of change has been highest in the 20th century (IPCC 2001). High rate of change has been attributed to human activities which have increased concentration of atmospheric greenhouse gases. There are several greenhouse gases, which include water vapor, carbon dioxide, methane, nitrous oxide, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6) and ozone (Reckacewicz, 2000). An increase in the concentration of all these gases in the atmosphere has been associated with increase in the rate of global warming (IPCC 2007). For example, atmospheric CO$_2$ has increased from a pre-industrial concentration of about 280 ppm to about 388 ppm at present (IPCC 2007) and has been associated with a global temperature rise of 0.76°C (IPCC 2007). A global rise in atmospheric temperatures is projected to be between 1.8 and 4.0 °C by 2100 (IPCC 2007). If this happens, it will affect water temperatures and mixing in oceans and lakes, alter the predictability, timing and duration of extreme weather events, change the magnitude and pattern of precipitation, and alter surface water elevations and shorelines (Hlohowskyj et al 1996).

Climate change affects the survival, growth, reproduction, and distribution of individuals within a species, but impacts can also be shown at the level of populations, communities, or entire ecosystems. According to Root et al (2000) climate change has influenced distribution and dispersal of species communities in both aquatic and terrestrial environments. Furthermore, global climate change has impacted the marine and estuarine fish and fisheries and will continue to do so in the future (Roessig et al. 2004). Model projections have indicated that climate change will affect precipitation pattern, which is key to estuarine productivity, and thus affect estuarine fish and fisheries. This is reinforced by the fact that correlations have been found between river discharge and the productivity of several estuarine fisheries around the world (Growns and James 2005; Childs et al. 2008; Nicholson et al. 2008; Ives et al 2009). Such correlations appear to be particularly important for panaeids, which inhabit tropical to subtropical regions (Vance et al. 1998; Robins et al. 2005; Díaz-Ochoa and Quiñones 2008). However, information on responses of various ecosystems including shrimp species to these climatic changes is scanty in the East African region (Mkindi and Meena 2005). Hence, there is a need to document effects of climate variations on coastal shrimp fisheries and human societies depending on these natural resources in Tanzania.

Climate change has a major impact on resources and human wellbeing. One of the coastal resources that are vulnerable to impacts of climate change and variability is the coastal panaeid shrimp species. This is because coastal panaeid shrimp abundances and catches are influenced by habitat and climatic conditions such as temperature, rainfall and salinity. Thus, variations in such climatic parameters are likely to have impact on coastal panaeid shrimp abundances and human communities in Tanzanian who depend on these valuable resources, especially fishermen in rural villages of Bagamoyo and Rufiji Districts. However, not much has been done towards enhancement of coastal communities in rural areas to cope and adapt to impacts of climate change and variability in Tanzania.

Coastal panaeid shrimp fishery is economically important in Bagamoyo and Rufiji Districts, as it provides significant employment opportunities and it is a source of income and protein to villagers. The maximum annual sustainable yield of panaeid shrimps in Tanzania has been estimated to be between 1050 and 1400 metric tonnes, with Bagamoyo and Rufiji Districts fishing grounds contributing more than 80% of the total catch. Thus, impacts of climate
change on panaeid shrimps will have social and economic implications in these two districts and the nation at large.

For an ecosystem to survive impacts of climate change and variability it has to devise various adaptation and coping mechanisms. Adaptation to climate change is largely site specific. As site specific issues require site – specific knowledge, enhancement adaptation strategies for communities dependent on coastal panaeid shrimps fishery must involve integration of indigenous knowledge for changes in processes and cultural practices, to moderate potential damages or to benefit from opportunities associated with climate variations.

Impacts of climate change and variability are clearly seen all over the globe with major manifestation in developing countries, and thus calling for putting adaptation as a top agenda (Zevallos, 2009). While reducing greenhouse gas emissions focus should also be on how to adapt to the impacts which have already affected not only the community but also the economic development. Therefore, there is inter-relationship between adaptation and mitigation (Fig. 1).

Fig. 1: Inter-relationship between adaptation and mitigation (Source: Zevallos, 2009)

Adaptation has been seen as a viable option for responding effectively and equitably to anticipated negative impacts of climate change and variability (IPCC, 2007). In recent years, use of indigenous knowledge in climate change context has been gaining much recognition as a strategy that need to be considered when addressing climate impacts at local level (Macch, 2008; Nyong et al., 2007; UNFCCC, 2007; IPCC, 2007). Over centuries local communities in many least developed countries, including Tanzania, have built up knowledge about changes in their environment and developed novel ways of adapting to these changes (Liwenga et al, 2006; Paavola, 2004). Collectively indigenous knowledge has provided local communities with the ability to survive and produce under risk conditions due to climate
change, environmental stress, changing policies and incomplete market structures (Macch, 2008; Nyong et al., 2007)

In assessing impact of climate change and variability on coastal panaeid shrimps remote sensing and image processing is needed. Remote sensing technique is required particularly in estimating levels of ocean productivity. However, such expertise is poorly developed if not lacking in Tanzania. Thus there is a need of developing such an expertise through collaborative efforts particularly through that of School of Ocean Sciences, Bangor University, UK. One PhD student involved in this project was earmarked for this training. Thus, the objectives of the work were to contribute towards mitigation and adaptation to impacts of climate change and variability on coastal communities dependent on coastal panaeid shrimp fisheries of Bagamoyo and Rufiji Districts, Coast Region and build capacity in remote sensing. Specifically the study intended to (a) Identify existing panaeid shrimp fishing systems and factors influencing panaeid shrimp abundances and yields in Bagamoyo and Rufiji Districts through collection of data on meteorological and discharge for the Rufiji, Ruvu and Wami rivers, (b) establish indigenous knowledge base on adaptation to climate change and variability, (c) develop capacity in remote sensing and image processing for assessing coastal productivity

2.0. METHODOLOGY
2.1. Study Area Description
The study was conducted in coastal Tanzania in the Bagamoyo and Rufiji Districts, Pwani (Coast) region (Fig. 2). and the study covered communities living in close proximity to the Rufiji, Wami and Ruvu deltas (Fig. 2.). The three deltas are rich in biological diversity. Most notable are the mangrove forests, macro-invertebrates, and fish. An inventory carried out in 1989 showed that the mangroves of mainland Tanzania cover about 115,500 ha (Semesi, 1991). The Rufiji Delta alone is about 53,255 ha (40 percent of total). Eight species of mangroves are found in these deltas: *Avicennia marina*, *Bruguiera gymnorrhiza*, *Heritiera littoralis*, *Ceriops tagal*, *Lumnitzera racemosa*, *Rhizophora mucronata*, *Sonneratia alba*, and *Xylocarpus granatum*. Mangroves protect the coastline against destructive waves, help in microclimate stabilization, and enhance water quality in coastal streams and estuaries. Also, mangroves retain sediments and nutrients, provide habitat for fish, and supply forest and wildlife resources (Lugendo et al. 2005)
2.1.1. Rufiji River Delta

The Rufiji Delta is located about 200 km south of Dar es Salaam (Fig. 2), and within the Rufiji District of the Coast Region. The delta is a relatively healthy and productive natural system, whose functioning is tied to the freshwater inputs and annual flood cycles of the Rufiji River and thus climate change and variability. The Rufiji River is formed by several major tributaries such as the Great Ruaha, Kilombero and Luwegu Rivers which together drain the largest river basin in Tanzania, with an area of some 177 000 km$^2$ (Fig. 2) The Rufiji River basin covers roughly 20 percent of Tanzania’s area (Semesi, 1991; Rufiji Basin Development Authority, 1981). The entire delta area is generally flat with some 43 islands. The Rufiji delta is formed by 8 main distributary channels interwoven with smaller channels and creeks (Sørensen 1998; Fig. 3). The delta supports the largest mangrove, and prawns are by far the most important fishery in the delta from an economic point of view. Prawn species mainly fished are *Metapenaeus monoceros* (King) *Penaeus monodon* (Tiger)
and *P. indicus* (White). Prawns make up 75-80% of cash income of fishermen. After prawns, dagaa and mbarata are the most important types of fish in the delta.

Fig. 3. Satellite image of the Rufiji delta showing several distributary channels.
Fig. 4. A map of the Rufiji delta showing detailed features and study sites locations.

2.1.2. Ruvu River Delta
The Ruvu Delta is located about 67 km northeast of Dar es Salaam, and the main catchment area is the Uluguru Mountains in Morogoro Region (Fig. 2).

2.1.3. Wami River Delta
The Wami delta is about 90 km from Dar es Salaam and has its sources in the Kaguru Mountains and flows to the southeast across the Mkata Plains to the Indian Ocean (Figs. 2 and 5). The Wami River Sub-Basin is one of the most important river systems in Tanzania, draining a centrally-located area of >40,000 km² (Fig. 5). It has its headwaters in the Eastern Arc Mountains and its estuary within the newly created Saadani National Park (Fig. 5).

Freshwater to marine linkages drive the ecology of the Wami River estuary, which lies at the river’s mouth near Saadani Village and bridges the land to sea continuum along the Indian Ocean coastline. Riparian village residents report that saline water intrudes in the Wami River channel to distances of approximately 5 km upstream from the coast during dry periods (Anderson et al. 2007). The presence of saltwater in the river channel helps sustain mangrove
forest ecosystems along the estuary. During the transition and wet seasons, the Wami River forms a giant freshwater plume that has been documented to extend ~2 km into the Indian Ocean (Anderson et al. 2007). Saadani Village has long been the site for artesanal and commercial productive prawn fisheries. Species of pwans commonly fished are *Penaeus monodon*, *Penaeus japonicus*, *Penaeus indicus* and *Penaeus semisulcatus*, and its productivity and abundance has been observed to be a function of freshwater inputs.

Rainfall in Tanzania mostly occurs during March–May (long rains) and October–December (short rains) seasons (Fig. 6) as the intertropical convergence zone (ITCZ) migrates through the equator from south to north, and vice versa (Nicholson 2000; Nicholson and Yin 2001; Zorita and Tilya, 2002) Like other tropical regions, interannual variability of rainfall in East Africa results from complex interactions of forced and free atmospheric variations. These include interactions between sea surface temperature (SST) forcing, large-scale atmospheric patterns, and synopticscale weather disturbances including monsoon and trade winds, persistent mesoscale circulations, tropical cyclones, subtropical anticyclones, easterly/westerly wave perturbations, and extratropical weather systems. Relative to the long rains, the short rains tend to have stronger interannual variability, stronger spatial coherence of rainfall anomalies across a large part of the region, and a substantial association with El Nin˜o–Southern Oscillation (ENSO).
2.2 Data Collection
Before embarking on full assessments and implementation in the field a review of secondary information was conducted. Collectively, secondary data was collected through review of relevant documents with information on previous studies on challenges of and coping strategies to extreme weather events and climate change in general.

2.2.1. Meteorological Data
Meteorological data were obtained from the Tanzania Meteorological Agency (TMA) at the Dar es Salaam office. Collected data include monthly rainfall for Bagamoyo, Dar es Salaam, Pangani, Kibaha, Morogoro, Kilwa Masoko, Kibiti, Muhoro and Utete Stations. In order to calculate mean rainfall as well as seasonal means for coastal areas from Tanga to Mtwara, additional data from Tanga, Zanzibar and Mtwara were added. A year was divided into four seasons namely: dry season (January-March), long wet season (April-June), dry season (July-September) and short wet season (October-December). These average values were used to calculate annual as well as seasonal anomalies. Anomalies were calculated by deducting the obtained mean values for the coastal area from the mean value of each year. The data from the Bagamoyo meteorological station, which are total monthly rainfall values, were collected.
since 1961 and extended up to 2009, while those from the Mwalimu Nyerere International Airport (MNIA), ranged from 1971 to 2009. The Utete record dates back to 1922, and is the longest and generally continuous record of monthly rainfall in the coastal area. Temperature data was made available for the MNIA, while wind data was given in form of monthly frequencies for period 1990-1999, as recorded at the MNIA and Morogoro. The frequencies recorded at 6 and 12 hours were for the following speed (KNOTS) intervals, 1 to 3, 4 to 6, 7 to 10, 11 to 16, 17 to 21, and Over 22.

2.2.2. River Discharge
River discharge data for the Rufiji River was collected from the Rufiji Basin Development Authority (RUBADA) offices in Dar es Salaam and Rufiji while those of Wami-Ruvu basin were collected from the Morogoro offices. Data provided covers stations located within the Wami-Ruvu Basin. The collected data had many gaps and were not collected continuously on daily or monthly basis.

2.2.3. Indigenous Knowledge and Adaptation Strategies
Various methodological approaches were used in this study to collect the qualitative information. The study used focus group discussions, seasonal calendars and key informants interviews. Structured and unstructured interviews were conducted through questionnaires. In each of the study villages and camps fishermen were randomly selected, and a total of 80 households were selected from both districts of Bagamoyo and Rufiji. The aim was to capture aspects such as history of climate related events, panaeid shrimp catches, fishing communities’ perceptions of climate variability/change, and identification of mechanisms for coping and adapting to climate risks related to coastal panaeid shrimp fishing activities.

Indigenous knowledge on climate change adaptation strategies was collected from the Saadani Village and Kajanjo fishing camp in Bagamoyo District. Fishing camps along the Ruvu River were disserted owing to closure of prawns fishing activities at the time of visit. Young and elderly people at the Saadani village and Kajanjo fishing camp were interviewed. The Kajanjo camp is located in the southern part of the Saadani village near the Wami river mouth. The fishing camp which is located in mangrove forest is bordered to the western part by extensive salt pans and to the east by the Indian Ocean. In the Rufiji Delta, interview was held at Dima and Kibanju, and like in the Bagamoyo district, interview involved both Young and elderly people. The major activity here was smoking ‘mbarata’ fish for selling in southern Tanzania particularly Mtwara region.

3.0 RESULTS AND DISCUSSION
3.1. Meteorological Parameters
3.1.1. Temperature
Maximum and minimum temperature record at the MNIA station showed a general increase with time (Fig. 7) Mean annual maximum temperature at the MNIA has been generally increasing since 1961, while mean minimum temperature declined in early 70s to 80s but since then it has been increasing at a fast rate reducing the difference between maximum and minimum temperatures (Fig. 7). An increase in air temperature with time has been also recorded at the Kilwa Masoko Meteorological station (Fig. 8). Although the Kilwa Masoko record is shorter, this might be a sign of warming that has been reported worldwide. This implies that Dar es Salaam has been becoming hotter and hotter. Rising temperature might have big impact on ecosystems and fisheries. Temperature change has both direct and indirect impacts on fish stocks that are exploited commercially. Direct effects act on physiology and
behavior and alter growth, development, reproductive capacity, mortality, and distribution. Indirect effects alter the productivity, structure, and composition of the ecosystems on which fish depend for food and shelter. For example an increase in water temperature in Lake Tanganyika during the 20th Century has been cited as a cause of decrease in aquatic ecosystem productivity of the lake (O’Relly et al., 2003).

Strong links between temperature and fish catch have not been reported for tropical Tanzania so far with the exception of Lake Tanganyika. Studies in African estuaries showed that effects may occur on the level of fish assemblages (Whitfield and Harrison, 2003; Whitfield, 2005; Meynecke et al 2006). Underlying mechanisms (e.g., initiation of breeding cycles in mud crabs) may be controlled by trigger values, which are unlikely to be detected in broad spatial and temporal analyses in tropical and subtropical marine environments where taxa are less affected by increasing temperature (Smith, 1990).
Fig. 7 Variation in mean annual maximum temperature (upper), mean minimum temperature (middle) and difference in temperature between maximum and minimum (lower) for the past 48 years (1961-2009) at the Mwalimu Nyerere International Airport. Note that minimum temperature has been increasing at a faster rate than the maximum temperature since 1980.
Fig. 8 Mean annual temperature (upper panel), monthly minimum temperature (middle) and monthly maximum temperature (bottom) for five years at the Kilwa Masoko meteorological station. Most of the months display a systematic increase in air temperature with time particularly for the months of July through November.
3.1.2. Rainfall
Average rainfall for the Tanzanian coastal area is 89.5 mm, while seasonal averages are 100.3 for the January-March season, 138.6 for the April-June season, 25.8 for the July-September season, and 92.6 for the October-December season. Both seasonal and annual anomalies indicated a decline in rainfall in most coastal areas except Zanzibar Island (Figs. 9 and 10). The Zanzibar Island has recorded an increase in rainfall with time (Fig. 9).

Fig. 9. Annual rainfall anomaly for the coastal Tanzania. All stations registered decrease except the Zanzibar Station.
Fig. 10. Annual and seasonal mean rainfall as well as annual and seasonal anomalies for the Bagamoyo station.

An 87 years record of total annual rainfall at Utete showed major decline in precipitation since 1980 (Fig. 11). However, linear regression showed a decline in precipitation in southern Tanzania (Fig. 9). A similar decline in precipitation has been recorded at the Bagamoyo and
MNIA meteorological stations for the past 48 years (Figs 12 and 13). The decline was also depicted for the months of November, December, January February March and April at the

Fig. 11. Rainfall record at the Utete meteorological station.

Fig. 12. Rainfall record at the Mwalimu Nyerere International Airport.
Fig. 13. Rainfall record at the Bagamoyo meteorological station.

Bagamoyo stations (Fig. 10). The observed decline in precipitation in recent times may have an impact to estuarine fisheries and coastal communities. Many commercially important fish species especially coastal panaeid shrimps use estuarine habitats such as mangroves, tidal flats and seagrass beds as nurseries or breeding grounds. Lifecycles of fish species (e.g. panaeid shrimps) dwelling in estuarine environment have been observed to correlate with rainfall and temperature patterns (Staunton-Smith et al., 2004 Growns and James, 2005) an indication that fisheries may be sensitive to effects of climate change. According to Staunton-Smith et al. (2004) and Growns and James (2005) there is a strong relation between freshwater runoff and some important commercial fisheries species (e.g., mullet (Mugil spp.), flathead (Platycephalus spp.), whiting (Sillago spp.), prawns (Family Penaeidae), and mud crabs (S. serrata). Available evidence indicate that river flow is a critical factor in maintaining nutrient and detrital input to estuaries, as well as preventing the development of hypersaline conditions within these systems (Blaber and Blaber, 1980; Robertson and Duke, 1990; Forbes and Cyrus, 1993; Whitfield, 1994). Thus the observed decline in rainfall implies decline in supply of nutrients and detrital materials to the estuarine and thus reduction in productivity, leading to decline in revenue and protein for coastal communities depending on estuarine fisheries.

3.2. River Discharge

Records of river discharge for the Ruvu and Wami are poor and characterized by uncontinuous recording (Figs.14 and 15). In contrast, mean annual discharge for the Rufiji River at Mpanga has been relatively continuous and showed a general decline in discharge with time (Fig. 16). Mean annual discharge over a period of 35 years ranged from 8.4 m³/s to 31.7 m³/s and discharge has been declining with time (Fig. 17). However, decrease in river discharge is only for the months of April, May and June. Discharge during the short rainy season of October–December has either remained constant or slightly increased. Since discharge play a significant role in estuarine productivity, a decline in discharge during the long rainy season probably had a major impact on prawns productivity.
Fig. 14. Record of seasonal discharge of the Ruvu River as recorded at the Ruvu Morogoro Road Bridge since 1958. The record is characterized by uncontinuity in recording.
Fig. 15 Record of seasonal discharge of the Wami River as recorded at the Mandera Village since 1954. The record is characterized by uncontinuity in recording.
Fig. 16 Record of the Rufiji River discharge as recorded at Mpanga station since 1971.
3.3 Indigenous Knowledge on Adaptation to Climate Change and Variability

3.3.1. Respondent’s General Characteristics.

Of the 80 respondents involved in the survey in the one village and three camps 86% were males and 14% were females. The gender imbalance can be attributed to the fact that fishing activities including coastal panaeid shrimps in coastal communities is considered to be a male activity. Among the respondent married people were dominant (84%) while separate couples were the least (2%; Fig. 18). Marital status has implication on social organization (Low, 2005; Hegga, 2006) which also has implication in terms of adaptation strategies in a household.

Most of the people involved in fishing activities had a primary school education (75%), while a small number (4%) had secondary education (Fig. 19). The number of those with informal education i.e. who had no chance of going to school was relatively high (21%) given the national effort of reaching the millennium development goals by 2015. Fishermen with secondary education were those who did not obtain nation form four examination certificate. A large number of people in the surveyed sites were immigrants (82%) from other parts of the nation especially from near by villages and districts such as Kisarawe (Coast Region) and Handeni (Tanga Region). The immigrants mainly came in search for coastal resources,
especially coastal panaeid shrimps. Many of them had lived in the area for more than 25 years and with extensive experience of environmental and climatic conditions of the surveyed areas.

![Graph showing percentage and frequency distribution for formal education levels.](image)

Fig. 19. Level of education of people interviewed in the Bagamoyo and Rufiji districts.

### 3.3.2 Respondent’s Economic Activities

Fishing, particularly for shrimps was a major occupational activity (87%) of respondents of the communalities in the surveyed camps and villages for both Bagamoyo and Rufiji districts. Other activities that preoccupied coastal communities in the surveyed areas included small scale agriculture and petty business. Low levels of education might be the major reason of decreases the portfolios of diversification other than climate sensitive livelihoods such as shrimp fishing activities. This has implication to the adaptation options of the household in times of climatic and environmental stress. Penaied shrimps fishing activity in Saadani is generally carried out during rainy seasons, while during other periods of the year fishermen resort to fishing other type of fish species. Fishermen in the Rufiji delta undertake fishing activity for coastal panaeid shrimps throughout the year. However, fishermen in the delta also resort to fishing other fish species especially *Hilsa kelee* locally known as ‘Mbarata’ Thus, coastal communities within the Rufiji delta may be hit hard once there is a major decline in prawns abundances as a result of climate change.

### 3.4.3 Shrimp Fishing Communities Perspective on Climate Change and Variability

Most of respondents in the surveyed area were knowledgeable about climate variability and noted a decreasing trend on shrimps catch that was associated with an increase in fishing efforts. Elements of climate such as rainfall, temperature and wind were identified by respondents as major drivers of weather in their area. However, humidity was not widely considered as part of the climate. In describing climate, 95% of respondents related climate to rainfall, 92% temperature and 14% to wind. Awareness and knowledge of causes of climate change and variability by the coastal communities in the study areas were interesting. A sizeable percentage of respondents (42.7%) attributed the changes to anthropogenic influences such as deforestation and bad practices of agricultural activities taking place in the area. Even those respondents who did not understand the causes of climate change, they noted to have experienced changes in temperature, rainfall, wind strength and directions, as well a decrease in catches of coastal panaeid shrimps. Long term rise in temperature was observed by 91% of respondents; fluctuation of rainfall was noticed by 72%, where as 87% noticed decrease in the amount of rainfall. These perceptions by people on trends of climate descriptors in the study area are highly supported by meteorological and river discharge data as discussed in section 3.1.
3.4.4 Panaeid Shrimp Fishing Systems and Factors Influencing Abundances and Yields

Large quantities of panaeid shrimps are widely caught during rainy seasons and in less than 10 meters of water depth in estuarine environment (Fig. 20). Fishing gears used by most of shrimp fishermen are primitive and include walking in waters less than 2 meters (30% of respondents), canoes locally known as ‘mitimbwi’ (52.5% of respondents) and the rest (16%) small boats using outboard engines. All respondents (100%) indicated the use of fixed or towed seine nets with mesh size ranging from 1.5 – 2.5 inches. According to Bwathondi et al, (2002), the exploitation of coastal panaeid shrimps by artisanal fishery system is an ancient activity in Tanzania, particularly in Bagamoyo and Rufiji districts. However, decrease of catches of shrimps, have made most people either use longer seine nets (ranging from 150-450 feet) or shift to other activities including offshore fishing system (catch other fish species), agriculture and small business activities, as adaptation mechanisms.

Almost all respondents (100%) interviewed from both districts, mentioned that there are three types of coastal panaeid shrimps which are commonly found in both Bagamoyo and Rufiji districts. These species includes white prawns (*Penaeus indicus*), giant prawns (*Penaeus monodon*), tiger prawns (*Penaeus semisulcatus*). Few of the respondent indicated to fish other types of shrimps brown prawns (*Metapenaus monoecros*) and flower prawns (*Paneus japonicus*). The survey revealed that white prawns is the commonest and most abundant species relative to other species, followed by the giant prawns Fishermen noted that abundance of prawns is high in years with high precipitation and cooler weather conditions. Furthermore, it was noted that rough weather conditions may hinder or reduce number of fishermen going for fishing activities. These findings are in agreement with the work of Bwathondi et al (2002), who have reported existence of five common penaeids species in Tanzania. The total catch is generally composed of 66% *Penaeus indicus*, 18% *Penaeus monodon*, 15% by both *Penaeus semisulcatus*, and *Metapenaus monoecros*, and 1% *Penaeus japonicus*, (Bwathondi et al., 2002) Furthermore, the respondents pointed out that, panaeids shrimps are short lived species with their life cycle usually ranging from one year to two years. Therefore, in view of key informants, experiences from local fishermen and experts, coastal panaeid shrimps fishing activities are highly influenced with environmental factors and extreme weather events.

![Fig. 20. Percentage (left) and frequency (right) of fishermen fishing in various water depth intervals. Depth intervals are in meters.](image)

Respondents’ perception on factors influencing abundances and yields of panaeid shrimps in their coastal waters, showed interesting results, in that a total 88% of the respondents perceived rainfall variation, temperature and salinity as major factors. Discussion with key informants revealed that rainfall availability is related to coastal panaeid shrimp yield.
According to their experience and perception rainfall amount is correlated with amount of shrimp catches. Respondents (98%) noted that higher catches are realized during rain seasons, while low yields are realized during dry seasons. High catches during rainy seasons were attributed lowers salinity, and sea surface temperature of estuarine waters and increase in food availability for shrimps.

Respondents’ arguments are supported by various scholars (RUBADA, 1983; Gammelsrød, 1992). According to the work of the Rufiji Basin Development Authority (RUBADA, 1983) there is close association between changes in the salinity and abundance of the shrimps in the Rufiji Delta. Generally, heavy rains, which normally occurs from March to May, causes decrease in the salinity level in the estuary creating a conducive environment for growth and survival of juvenile prawns. Similarly, the work of Gammelsrød (1992) on the relationship between runoff of the Zambezi River and shrimp abundance revealed a positive correlation between rainfall and shrimp abundance. Thus, one of the influencing factors on the increase/decrease in catch rates in the Bagamoyo and Rufiji districts is variability in rainfall.

The combined effect of rainfall, river discharge, temperature and salinity can be extremely important on survival, distribution, abundance and subsequent catch of the coastal panaeid shrimps (Knudby et al, 2009). Because of this, vulnerability of coastal panaeid shrimp species to impacts of climate change and variations may range from changing in foraging patterns to community structures (Knudby et al., 2009) leading to a decline in shrimp abundance. Although climatic factors are responsible for decrease in the abundance of shrimps, interviews revealed that the observed decline in coastal panaeid shrimp catches could be a result of accelerated non climatic factors such as over fishing, destructive fishing practices, increased demand and habitat destruction. Most probably all of these factors have affected coastal panaeid shrimp species distribution, abundance and catches in the study areas.

3.4.5 Fishermen Perception on Effects of Climate Change

It is generally perceived by the majority (95%) of the people in the two districts surveyed that, climate change and variability has direct effect on artisanal shrimp fishery activities. Results from interviews and key informants discussion revealed that, increase in temperature and changes of amount and timing of rainfall in the studied areas, had affected coastal panaied catches and physical conditions of estuarine water. With changing climate local panaeid shrimp fishery (87% of respondents) reported general decreasing catch trends and incomes. According to respondents, this has caused a lot of social insecurity to most of people who previously depended on the fishery, forcing communities to shift to other social economic activities and fishing other fish species. With primitive fishing gears being used it is difficult to access rich fishing grounds offshore. Hence, enhancement of initiatives on adaptation options and mechanisms to local communities dependent to these resources is of urgency.

3.4.6 Application of Indigenous knowledge in Adaptation to Climate Change

Majority of the people (89% of respondents) in the villages and camps surveyed in the two districts acknowledged the existence of traditional methods or indigenous knowledge of forecasting climate and adapting climate associated impacts in their communities. Early local warming systems for predicting events are based on keen observation and experiences of behaviour of winds, onset of rains and temperatures. In Saadani and Kajanjo villages for example, almost all respondents pointed out the shifts in the direction of prevailing winds from southeast “kusi” to northeast “kaskazi” direction to be an indication of onset of hot and
humid conditions with rainy season approaching. Similarly a change of wind direction from northeast to southeast is an indication that the cold season is about to start and it is associated with light rains, hence shrimp fishing times might be starting. To a great extent, indigenous knowledge or systems have aided fishers and farmers in combating climate uncertainties in coastal panaeid shrimp exploitation in Bagamoyo and Rufiji districts as well as managing their vulnerability. Generally, fishers and farmers are highly dependent on these systems to manage their livelihood activities.

Artisanal shrimp fishers in Bagamoyo and Rufiji district appeared to have wide knowledge about coastal penaeid shrimp resources, including information on location of shrimp resources, migration patterns, movement and seasonal abundance. The shrimp fishers interviewed were also knowledgeable on details of coastal panaeid shrimps’ feeding and reproductive behaviours. This knowledge has been utilized to the advantage in reducing fishing time while increasing fishing efficiency and sustainability.

Most respondents reported that shrimp fishers shift or exploit other fish species further offshore at times of low abundance. Penaeid shrimps species and fishing grounds are reserved for exploitation when conditions are relatively favourable, usually during rainy seasons. However, low income, poverty and low technology have been pointed out to be a major hindrance to exploitation open ocean fisheries resources in a move to cope and adapt to climate change effects.

Seasonal fishing is another strategy that coastal panaeid shrimp fishers use in Saadani to adjust with prevailing situations. In the past coastal panaeid shrimp fishing activities were carried out throughout the year with high yields. Owing to climatic effects such as low rainfall and high temperature, coupled with high exploitation rate and extreme weather events such as strong winds, shrimp fishing activity in recent years is carried out seasonally. Voluntary open-closure system allows shrimp population to recover from fishing pressure, leading to sustainable fishery.

Diversification from coastal panaeid shrimp fishing to non-fishing activities is being practiced in order to reduce their vulnerability to climate change. Shrimp fishers are increasingly embracing small scale business, causal labour, charcoal burning and small scale farming activities. In the Saadan village, owing to potential threat of crop destruction from the Saadan nation park, agricultural activity is not pursued as an adaptation option.

Other strategies reported by respondents and key informants were intensification of panaeid shrimp fishing activities. These days, fishers have reported to increase the duration of staying in water fishing, including increasing length of their nets. Despite these efforts, they report to have continuous decrease of shrimp catches. As a result, they have been tremendously increasing of the price per kilo of shrimps in the studied areas.

3.4.7 Challenges to Indigenous Knowledge and Enhancement of adaptation Options.

Major constraints limiting the use of indigenous knowledge in coping and adaptation processes appeared to be (i) poverty which prohibit fishermen to acquire modern fishing facilities such as boats and nets that can enable them to ply deep water areas, (ii) inadequate and fragmented information/knowledge about climate change and adaptation options among shrimp fishers, (iii) lack/insufficient of capital to invest in non-fishing activities, (iv) unpredictable precipitation rendering agriculture to be an reliable activity (v) unsustainable
harvesting of terrestrial and marine resources such as mangroves, illegal fishing methods and habitat degradation (vi) high vulnerability to impact of climate change and variability associated with lack of capacity on climate related impacts and extreme events. Efforts to raise awareness, adaptation planning of pilot project and detailed information on alternative socio economic options, assistance in developing climate-resilient development activities are required. Means to facilitate acquisition of modern fishing gears such as boats for high seas fishing and technology are extremely required. Although most respondents (76%), appeared to build interest in capacity building without such assistance, these communities will remain vulnerable to the impacts of climate change and variability

4.0 TRAINING
A 3 days intensive training course on remote sensing and image processing was conducted between 5-7 October 2010 by members from the School of Ocean Sciences, Bangor University. A total of 6 participants attended the training which included 1 PhD student and 5 MSc students. The following matters were covered
(i) Introduction to GIS
   The main objectives were to expose students with basic GIS knowledge and techniques
   - Definitions of GIS and applications
   - Components of GIS
   - Projection – Map, Earth, cylindrical, planer and conical
   - Presentation of the real world in GIS
   - Basic GIS rules – projections, resolution, datum and coordinate system
   - Feature models – vector and Raster
(ii) Image processing and use of satellite imagery
   - Main objectives were to i) introduce students to principles of image processing, and ii) make students be able to use image processing software through practical
   Therefore the following were covered:-
   - Important definitions and terminologies
   - Resolution and scales
   - Geostationary orbiting satellites
   - Polar orbiting satellites
   - Improved resolution of Landsat
   - Improved resolution of aerial photography
   - Image processing techniques
   - Image processing with ERDAS imagine
   - Data merging and generation of derivative datasets
   - Using/ordering satellite data

For detailed training materials with references see appendix 1.

5.0 CONCLUSION AND RECOMMENDATION
Meteorological parameters indicated a general trend of decline in precipitation that are associated with an increase in maximum air temperature as well as increase in minimum air temperature. Trend of rising temperature if it continues will have major impact on ecosystems and fisheries. Most likely it will affect physiology, behavior and alter growth, development, reproductive capacity, mortality, and distribution of shrimps. Also, reduction in precipitation in concomitant with increase in temperature will amplify impacts on livelihood activities of coastal communities hindering achievements of the national initiatives on poverty reduction goals.
Several indicators were identified for climate change and variability by shrimp fishing communities in Bagamoyo and Rufiji districts. The overall perception of climate change and variability in the area is that, there are pronounced changes in amount and timing of rains and frequency of drought, in turn these have also affected major river discharge trends in these districts. Shrimp fishers in the studied areas have developed important indigenous strategies to adapt climatic changes; however, the magnitude of future impacts may limit their adaptive ability. External help from central and local governments, donors and private sector is therefore necessary to enhance their indigenous strategies.

Efforts to raise awareness, adaptation planning of pilot project and detailed information on alternative socio economic options, assistance in developing climate-resilient development activities are required. Means to facilitate acquisition of modern fishing gears such as boats for high seas fishing and technology are extremely required. Although most respondents (76%), appeared to build interest in capacity building without such assistance, these communities will remain vulnerable to the impacts of climate change and variability.
6.0 REFERENCES


O’Reilly C. M., Alin S. R, Plisnier P-D., Cohen A S. and Brent A. McKee B.A. Climate change decreases aquatic ecosystem productivity of Lake Tanganyika, Africa *Nature* 424, 766-768

*Relationship*. University of Waterloo Press, Ottawa, Canada 142 pp.

tropical Australian mangrove system. Estuarine, Coastal and Shelf Science 31, 723-743.

Freshwater-flow requirements of estuarine fisheries in tropical Australia: a review of the state
of knowledge and application of a suggested approach. *Marine and Freshwater Research*
**56**, 343–360. doi:10.1071/MF04087

Change on Marine and Estuarine Fishes and Fisheries*. University of California Press, USA
109 pp.

RUBADA (Rufiji Basin Development Authority), 1981. Promotion and regulation of
development activities in the Rufiji basin. Unpublished report.

Multipurpose Project on Fisheries in the Rufiji Delta and Mafia channel- Mid Study report.
Atkins Land & Water Management 110pp

Vol. 3. Mangrove Management Plan of Bagamoyo District, Ministry of Natural Resources
and Tourism/NORAD. Catchment Forest Project 1991.

Smith, L.D., 1990. Patterns of limb loss in the blue crab, Callinectes sapidus-Rathbun, and

A field report presented to the Danish Council for Development Research

quantity and timing of fresh water flowing into a dry tropical estuary affect year-class
strength of barramundi (Lates calcarifer)? Marine and Freshwater Research 55, 787-797.

*UNEP/WMO Information on Climate Change*. Geneva, Switzerland 210 pp

Factors affecting year-to-year variation in the catch of banana prawns (*Penaeus merguiensis*)
and environmental variation in two estuaries in tropical northeastern Australia: a six-year

Whitfield, A.K., 1994. Abundance of larval and 05 juvenile marine fishes in the lower
reaches of three southern African estuaries with differing freshwater inputs. *Marine Ecology

