THE INFLUENCE OF ENVIRONMENTAL FACTORS ON SPECIES DIVERSITY ON CRAB AND MANGROVE COMMUNITY IN PANNING AND NON- PANNING AREAS, WETE DISTRICT OF PEMBA, ZANZIBAR

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CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance by the Open University of Tanzania a thesis entitled: **The influence of environmental factors on species diversity on crab and mangrove community in salt panning and non-salt panning in Wete District; Pemba** in the fulfillment of the requirements for the degree of Master of Science (Environmental Studies).

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DECLARATION

I, ***Said H. Omar*** do hereby declare that this thesis is my own original work and that it has not been presented and will not be presented to any other University or other academic institution for a similar or any other degree award.

Signature: é é é é é é é é é é

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DEDICATION

This thesis is dedicated to my beloved wife Mrs. Shuwena Omar, my children; Hayqat, Hartha, Khawla, Khalila, Atif and Adil, my parents and my whole family for their love, care and support during the various stages of the production of this thesis.

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ABSTRACT

The influence of environmental factors on species diversity on crab and mangrove community in salt panning and non -salt panning in Wete District; Pemba by collecting data through field observation and experimental procedure. In Start 3 Trial version and Graph Pad Prism 6 version were used to analyze data. In this study 14 mangrove crab species were identified in Kangagani and 13 observed in Shengejuu. The species diversity index (H') in the non-salt pan zone was 2.42 and 2.40 for Kangagani and Shengejuu respectively, whereas Hô in the salt pan zone was 1.17 for both Kangagani and Shengejuu. Statistically, there was a significant difference of mangrove crab diversity in Kangagani between non-salt and salt pan zones where P = 0.0001, t=16.78 df=10. Results in Shengejuu also showed significant differences where P = 0.0350, t=2.318 df=15. Seven (7) species of mangrove plants were identified in Kangagani and 4 species were identified in Shengejuu in the non-salt Zones. Also five physico-chemical variables examined (salinity, temperature, pH, Relative humidity and rainfall). There was correlation of crabs abundance and soil pH where (p ’ 0.0026, r = 0.7374). The results showed there was correlation between temperature and crabs abundance where (p’ 0.0010, r = -0.6170). Mangrove crabs are the organisms that play a significant role in the dynamics of the mangrove ecosystems in the world. With regards to mangrove Crab Species diversity, different crabs were identified in both Salt Pan and Non- salt Pan Zones - located at Kangagani and Shengejuu study sites. Mangroves forest should be replanted the same species after destruction by salt producers and others environmental degradation

Key words: crab and mangrove diversity, salt panning and non-salt panning areas

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LIST OF ABREVIATIONS AND ACRONYMS

ANOVA:	Analysis of variance
AZASPO:	Association for Zanzibar Salt Processing Organizations
DMS:	Degrees Minutes Seconds
EA:	East Africa
FAO:	Food and Agriculture Organization
GPS:	Global Positioning System
IUCN:	International Union for the Conservation of Nature
JCBNP:	Jozani Chwaka Bay National Park
Kg:	Kilograms
NBS:	National Bureau of Statistics
NEM:	North East Monsoon
NGOs:	Non-Governmental Organizations
NOAA:	National Oceanic and Atmospheric Administration
RGoZ:	Revolutionary Government of Zanzibar
SEA:	South East Asia
SEM:	South East Monsoon
SMOLE:	Sustainable Management of Lands and Environment
TCMP:	Tanzania Coastal Management Partnership
TMA:	Tanzania Meteorological Agency
UDSM:	University of Dar es Salaam
UNEP:	United Nations Environment Programme
UTM:	Universal Transverse Mercator
WIO:	West Indian Ocean

WRI: World Resources Institute

CHAPTER ONE

INTRODUCTION

1.1 General Introduction

Mangroves are large and extensive types of trees up to medium height and shrubs that grow in saline coastal sediment habitats in the tropics and subtropics mainly between latitudes 25° N and 25° S (Hogarth and Peter, 1999). The remaining mangrove forest areas of the world in 2000 was 53,190 square miles (137,760 km^2) spanning 118 countries and territories. Mangroves are salt tolerant trees (halophytes) adapted to live in harsh coastal conditions. They contain a complex salt filtration system and complex root system to cope with salt water immersion and wave action. They are adapted to the low oxygen (anoxic) conditions of waterlogged mud (Mazda *et al.,* 2005).

About 73 species are considered "mangroves", in the sense of being a tree or shrub that grows in such a saline swamp, though only a few are from the mangrove plant genus, *Rhizophora*. However, a given mangrove swamp typically features only a small number of tree species (Augustin, 2014). It is not uncommon for a mangrove forest in the Caribbean to feature only three or four tree species. For comparison, the tropical rainforest biome contains thousands of tree species, but this is not to say mangrove forests lack diversity. Though the trees themselves are few in species, the ecosystem these trees create provides a home for a great variety of other organisms (FAO, 2007). Mangrove plants require a number of physiological adaptations to overcome the problems of anoxia, high salinity and frequent tidal inundation. Each species has its own solutions to these problems; this may be the primary reason why, on some shorelines, mangrove tree species show distinct zonation (Giri *et al.,* 2011). Small environmental variations within mangroves may lead to greatly differing methods for coping with the environment. Therefore, the mix of species is partly determined by the tolerances of individual species to physical conditions, such as tidal inundation and salinity, but may also be influenced by other factors, such as predation of plant seedlings by crabs (Lewis, 2004).

The worldwide mangroves distribution is divided into two hemispheres: the Atlantic East Pacific and the Indo West Pacific. The Atlantic East Pacific has smaller numbers of species than the Indo West Pacific (NOAA, 2014). Species composition is also very different between the two hemispheres. Out of a total taken as a sample approximately 73 mangrove species, only one, the mangrove fern, is common to both hemispheres.

The number of mangroves in the world are categorized like North and Central America 22402km2 (14.7%), South America 23883 km2 (15.7%), Middle East 624 km2 (0.4%), West and Central Africa 51049 km2 (33.5%), South East Asia 215 km2 (0.1%), South Asia 20040 km2 (13.2%), Australia/New Zealand 10171 km2 (6.7%) /10344 km2 (6.8%), East and South Africa 7917 km2 (5.2%) and Pacific Ocean 5717 km2 (3.8%) (Basha, 2016). In the United States, mangroves are distributed mainly along the Atlantic and Gulf coasts of Florida. They also occur in Puerto Rico, the U.S. Virgin Islands, Hawaii, and the Pacific Trust Territories (Ellison, 2002). The estimated coverage is approximately 1,750 km^2 of mangroves along the Florida coast, with the highest development along the southwest coast. The Gulf of Mexico and Caribbean regions are characterized by low species richness, with only four dominant species: Rhizophora mangle (red mangrove), *Avicennia germinans* (black mangrove), *Laguncularia racemosa* (white mangrove), and *Conocarpus erectus* (button mangrove or buttonwood). Black mangroves, however, can be found as far north as Texas, Louisiana, and Mississippi, indicating this speciesô greater tolerance to low temperatures and its ability to recover from freeze damage (McKee and Faulkner. 2000).

Mangroves grow along the shores of New South Wales (NSW) estuaries and in some places form extensive forests. Of the five species of mangrove that occur in NSW, *Avicennia marina* (Grey Mangrove) and *Aegiceras corniculatum* (River Mangrove) are the two most common (Copeland and Pollard, 1996). Mangrove lined creeks are important habitats for fish, crabs, birds and other animals. Mangrove trees provide large amounts of organic matter, which is eaten by many small aquatic animals. In turn, these animals provide food for larger fish and other animals. Mangroves also help maintain water quality by filtering silt from runoff and recycling nutrients (Wilton, 2002). Mangroves also play a vital role in protecting foreshores from storm surges, cyclones, tsunamis and wind and wave conditions (Hamilton, 2013).

Eastern African mangroves comprehend mangrove areas found in Mozambique, Tanzania, Kenya, and Somalia (Barbosa *et al.,* 2001). The overriding climatic inspirations on the most of the region are the seasonal wind patterns, associated with the Northeast monsoon (NEM) and the Southeast monsoon (SEM), which blow towards the mainland from the northeast and southeast at different times of year, and which affect the movement of the major coastal currents (Francis and Bryceson, 2001). Mangroves Eco region consist of the two largest stands of mangrove on the

East African coast (Zambezi and Rufiji Delta systems). In East Africa region Mangroves ranges between 2,555 km2 to 7,211 km2 (Dahdouh *et al.,* 2000). The most extensive areas of mangroves are found in the Rufiji River Delta in Tanzania and the Zambezi River Delta in Mozambique. Protected areas containing mangroves include Mafia Island Marine Park, Jozani National Park and Sadaani Game Reserve in Tanzania; Watamu Marine National Park and Ras Tewa Marine National Park in Kenya; and Bazaruto Marine National Park, Ilhas da Inhaca e dos Portuguese Faunal Reserve, Marromeu Game Reserve, Pomene Game Reserve, and Maputo Game Reserve in Mozambique.

Also in East Africa *Sonneratia alba* is very common, normally occurring in muddy soils is near to sea water. *Rhizophora mucronata* dominates on muddy soil and is commonly found in large homogeneous stands on upper river banks. *Bruguiera gymnorrhiza* occurs between *Rhizophora mucronata* and *Ceriops tagal* zones, or interspersed throughout them. *Ceriops tagal* has a weaker root system and is less capable of withstanding strong waves and currents (Kairo *et al.,* 2001)

In some areas, there has been a large decline of mangroves due to clearing or reclamation and changes in water flow from waterfront developments (Lloyd, 1996 and Benson, 2018). In other areas, mangrove communities are expanding due to the buildup of sediments from catchment clearing, development and storm water run-off. Mangroves are protected in New South Wales and a permit is required from NSW to undertake works or activities that may harm them (Saintilan and Williams, 1999).

In Zanzibar, some species of mangroves are more salt tolerant than others and, because of this, there are distinct zones in a mangrove forest where the boundaries between species can easily be seen (Adam, 2000 and Benson, 2018). The less salt tolerant trees are actually on the seaward side as they will be frequently washed by seawater.

Salt marshes are coastal wetlands that are flooded and drained by salt water brought in by the tides (Warren *et al.,* 2002). It can tolerate high soil salinity and occasional inundation from salt water. They usually have areas with vegetation interspersed with bare areas (salt pans). Salt marshes occur at the upper levels of the intertidal zone, often behind mangroves, and, theyǿre not subject to daily tidal inundation (Thomas and Connolly, 2001).

Salt marshes are characterized by plant species, such as *Sarcocornia quinqueflora* (samphire), *Sporobolus virginicus* (saltwater couch) and *Juncus* species (rushes). Salt marsh is important to fish as it provides sources of food, habitat and shelter when inundated at high tide. Salt marshes play an important role as a juvenile habitat for species such as bream and mullet (West et al., 1985). Crabs are common in salt marsh communities, and are a significant food source for bream and other fish species. Salt marshes can be found in estuaries along the whole NSW coastline, with the larger areas occurring in the Manning bioregion (Morrissey, 1995).

Salt pans are uncommon in the Wet Tropics but can be found in extremely saline situations (Alongi and McKinnon 2005). Salt meadows of salt tolerant grasses and fleshy herbs occur in small patches among mangroves on higher and drier areas inundated only by king tides. Small depressions form salt scalds after the sea water evaporates. Salt pans, salt meadows and salt scalds are more extensive in the drier northern and southern extremities of the Wet Tropics (Australian Institute of Marine Science, 2006).

The crabs are types of animals that have several pairs of legs and a body made up of sections that are covered in hard outer shells (crustaceans) similar to prawns, shrimps and lobsters. There are more than 6,700 known species of crabs found in waters worldwide and these many crab species are split into around 93 different crab groups (FAO, 2006). Most crab species are found in the shallower ocean waters where the crabs tend to inhabit rocky pools and coral reefs. There are however, a number of species of freshwater crab that inhabit the waters in rivers and lakes and some species of tropical crab have been known to spend a great deal of time on land (FAO, 2009).

True crabs make up 20% of all crustaceans caught and farmed worldwide, with about 1.4 million tonnes being consumed annually. The horse crab, P*ortunus trituberculatus* accounts for one quarter of that total. Other important species include flower crabs (*Portunus pelagicus*), snow crabs (*Chionoecetes*), blue crabs (*Callinectes sapidus*), edible or brown crabs (*Cancer pagurus*), Dungeness crab (*Metacarcinus magister*) and mud crabs (*Scylla serrata*), each of which provides more than 20,000 tones annually (FAO, 2006). Generally, crabs don't get bigger than 40 cm in size, with the exception of the Japanese spider crab (*Macrocheira kaempferi*) that has been known to have a long span of over 4 meters. The smallest crab is the pea crab (*Pinnotheres pisum*) which grows to a few millimeters (Neal and

Wilson, 2005). Crabs have thick armored shell which protects them from immediate danger. Crab also has two front armored claws which it uses to catch its prey. Crabs hunt by sitting in a dark hole and catching potential prey that swims past. This allows the crab to feed effectively as well as staying hidden from those that would want to eat the crab (Andrea, 2006).

1.2 Statement of Research Problem

The approach to salt production in Pemba seems unsustainable. Construction of 20% of salt panning areas is started without official permission (Wolchock, 2006 and Matera, 2018). It is hoped that no permit- pan construction will cease to be an issue since the government has stated its commitment toward maintaining, but not expanding, the areas currently used for salt panning. The Environmental Management for Sustainable Development Act of 1996 specifies that projects involving reclamation of land require environmental impact assessments, the Departments of Forestry and the Environment are supposed to jointly carry out a preliminary site survey (Environmental Management Act, 1996). The salt production industry has the potential to generate substantial revenue for Pemba and to provide long-term employment to coastal peoples. However, salt panning is also an activity with clear and direct impacts on mangroves, an important but threatened coastal ecosystem. For salt production to be a sustainable industry for Pemba, economic and social benefits must be able to balance and minimize environmental costs over the long-term.

There is lack of information on the effects of salt panning on crab species diversity and abundance in mangroves ecosystem on the eastern coast of Pemba especially in the Kangagani and Shengejuu shehia. The sustainable management and conservation of crabs and mangroves around these areas require basic information on the occurrence of crabs, mangrove species diversity and identification of threats facing these resources.

The limitations of the salt panning industry are the lack of awareness of environmental degradation and unsustainable management of mangrove resources for the production of salt. This study carried out in two different locations and over two seasons aimed to determine the effect of salt panning on crab and mangrove species diversity and abundance by comparing sites in salt pan and non-salt pan areas. Similarly, environmental parameters: rainfall, temperature, relative humidity, salinity, and soil pH, the influences of which could lead to depletion of mangroves and crabs were also examined.

1.3 The Objectives of the Study

1.3.1 General objective

The main objective of this study is to determine the influence of environmental factors on crab and mangrove species diversity in Wete District; Pemba Zanzibar.

1.3.2 Specific objectives

i. To determine the crab species diversity in the non-salt pan and salt pan areas.
ii. To determine the mangrove species diversity non-salt pan and salt pan areas.
iii. To determine the environmental parameters that affect the diversity of the crab species in the study areas

iv. To determine the environmental parameters that affects the diversity of mangrove species in the study area.

1.4 Hypotheses

The specific hypotheses tested in this study were as follows:

Hypothesis 1

There is a significant difference in crab species diversity between salt and non-salt pan area

Hypothesis 2

There is a significant difference in mangrove species diversity between salt and non-salt pan area.

Hypothesis 3

There is possible correlation of environmental parameters (Salinity, pH, humidity and Temperature) on crab species diversity between salt and non-salt pan study area.

Hypothesis 4

There is possible correlation of environmental parameters (Salinity, pH, humidity and Temperature) on mangroves species diversity between salt and non-salt pan area.

1.5 Significance of the study

This study is a pre requisite for my Master Degree and will serve as backup to review environmental law and policy for our nation. This study was expected to assess the influence of environmental factors on species diversity on crab and mangrove community. The knowledge generated from this study anticipated to be used by policy makers to regulate and improve their policies and come up with new strategies when providing new techniques in combating the problem of environmental factors.

The study used as educational material to local and international educational institutions (Universities, Colleges and Schools) especially in understanding mangroves and crab species diversity in different areas of salt and non-salt panning. Also the study will help the responsible Ministries to understand the environmental factors influencing mangroves and crabs species can be used as an empirical review to reduce problems. The influence of environmental factors to mangroves and crabs is a serious for management not only in Zanzibar but other part of the world. If that is a case, this study may raise interest to other researchers to conduct same research within or outside of their location to reflect the influence of environmental factors on mangroves and crabs species diversity.

1.6 Organization of the work

The dissertation contains six chapters. Chapter one covers the background to the study, statement of the problem, objectives of the study, Hypothesis, and significance of the study. Literature review is addressed in chapter two together with definition of basic concepts and research gap. Chapter three presents the methodology used in this study and it also covers various issues including the research approach, Study area, sampling design and procedures, variable and measurement procedures and data processing and analysis. Results are addressed in chapter four. Chapter five presents the discussions And chapter six presents conclusion and recommendations together with directions for future study.

CHAPTER TWO

LITERATURE REVIEW

2.1 Chapter Overview

The chapter presents the some conceptual and research gap.

2.1.1 Mangroves Ecosystem

Mangroves are large trees , shrubs, ferns and palms, which are normally grow in or adjacent to intertidal zone and develop special adaptation in order to survive in this environment of more than 150,000 kilometers (FAO, 2007; Spalding. *et al.,* 2010). Mangroves grow in saline coastal habitats in the tropics and subtropics (Bojang and Ndeso Atanga, 2009). The term is also used as a tidal habitat with salt-tolerant trees and shrubs.

Comparable to rainforests, mangroves have a mixture of plant types. Sometimes the habitat is called a tidal forest or a mangrove forest to distinguish it from the trees that are also called mangroves (Duke, 2011). Mangrove trees are generally exceeding 0.5 m in height; that normally grows above mean sea level in the intertidal zone of marine coastal environments and estuarine margins (Duke, 2011). They are most often located along sheltered shores and can penetrate deep into the estuaries of rivers (Macnae, 1968). They also have a very plastic form; the same species can grow as a short stunted bush in unfavorable conditions or as a full sized tree reaching heights of 40 meters, forming dense forests several kilometers thick under favorable conditions (Macnae, 1968). The animals living in mangroves are diverse and include crabs, bivalves, birds, snails, insects, and reptiles (Haynes, 2011and **Gust, 2017**).

2.2 Economic Importance of Mangroves

Mangroves help to stabilize coastlines, reduce erosion from storm surges, currents, waves, and tides. The intricate root systems of mangroves make these forests attractive to fishes and other organisms seeking food, shelter from predators and spawning grounds as habitat for their larvae, as exemplified by the yellow-eyed mullet (*Aldrichetta forsteri*) and (*Mugil cephalus*). Many invertebrates (*Crustacean and Molluscan*) and vertebrates species (birds and monkeys) use the Mangrove ecosystems as breeding and living areas during part or all of their life cycles (Nascimento *et al.,* 2012; Hamilton *et al.,* 2011) and humans have depended and continue to depend on these as resources.

Mangroves have played and continue to play diverse important economic roles in the countries that possess them. For example: 64.3% of Thai mangrove forests area has been used for aqua culture, 26.3% are implicated in land development, 6.2% in salt production, and 3.2% in tin mining (Furukawa and Baba, 1993). 19,670 hectares of area covered by mangroves in Bangladesh along the Coxös Bazar coast has been used for salt production (Hossain and Lin, 2001). In West Africa, mangroves play a great role in agriculture, aqua culture, and the wood is used for domestic purposes such as fish smoking, salt cooking, shell burning and construction (Dacosta and Sow, 2009). On Uzi Island (Zanzibar) people use mangrove forest plant species as timber, making of charcoal, boats, and sail masts (Benfeld, 2013 and Benson, 2018).

However, an alarming 20 percent, equivalent to 3.6 million hectares of mangroves, have been lost worldwide since 1980. More recently, the numbers of net loss appears to have slowed down, although it is still disturbingly high. About 185, 000 hectares were lost every year in the 1980s; this figure dropped to some 118, 500 hectares per year in the 1990s and to 102,000 hectares per year currently (Bojang and Ndeso-Atanga, 2009).

Mangroves are used for construction, firewood, charcoal production, tannins, fruit, fencing, fish traps and medicine in Mozambique. *Rhizophora mucronata* bark is used to dye fishing nets. Dugout canoes and beehives are made from *Avicennia marina wood*. Molluscs and crustaceans, such as mangrove crabs, *Scylla serrata*, *mud creepers*, *Terebralia palustris*, and shore crabs, *Matuta lunaris*, collected from mangroves represent an important source of protein for human populations in Mozambique, especially on Inhaca Island (Taylor, Ravilious, and Green, 2003).

Mangrove wood is often used as fuel. *Rhizophora* species are especially utilized as they are rich in tannin and burn almost smokeless, imparting a pleasant taste to cooked food. Green *Avicennia marina* logs, however, are very smoky and slow burning so are often used by honey collectors and fishermen to keep away biting bees at night. Many villagers produce salt by boiling brackish water in clay bowls over fire. Mangroves are heavily exploited as a fuel source using this technique. With seven tons of wood needed to produce one ton of salt some coastal forests are now bare. On a larger scale salt is harvested from evaporation ponds, shallow brine-filled pits, usually built in cleared mangrove areas (Taylor, Ravilious, and Green, 2003).

2.3 Geological Significance of Mangroves

Mangroves generally follow the mud flat accretion, but mangroves also enhance the sedimentation numbers (Young and Harvey, 1996). In an Australian mangrove, Furukawa *et al.*1997, calculated that about 80% of suspended sediments brought into the mangrove were trapped there. Mangroves also facilitate the formation of flocks by their breakdown within the forest by physical and mechanical means (Wolanski, 1995and Gust, 2017). In addition to sedimentation, this also reduces turbidity in near shore waters protecting coral reef systems.

Although mangroves have been shown to increase sedimentation, it has been postulated that it does not represent land building, but land retaining during sea level rise (Snedaker, 1995; Ellison, 1996). If their sediment budget is not high enough, mangroves will retreat landward with rising sea level and increased wave action (Ellison, 1996). However, as long as there is adequate freshwater input to maintain an optimum low salinity, along with low sulfate, proper nutrient balance and productivity, it has been hypothesized there would be a net accumulation of peat proportional to the rising sea level and mangroves would not retreat. With low freshwater input, high salinities would lower production and high sulphate concentrations would increase anaerobic peat decomposition (Snedaker, 1995). This hypothesis fits well the findings of Tack and Polk (1999), which demonstrated a positive correlation between groundwater flow and mangrove forest presence (Gillikin, 2000).

2.4 Adaptations to Salinity of Mangroves

Mangroves can establish and grow under a relatively wide range of flooding and salinity conditions but is generally restricted to the intertidal zone where there is less competition with freshwater plants. Mangroves have developed a series of physiological and morphological adaptations that have allowed them to successfully colonize these environments (National Oceanic and Atmospheric Administration- Earth System, 2014).

Mangroves do not require salt water to survive, but because of poor competition with freshwater vegetation and unique adaptations to the intertidal zone, they are generally found under the influence of salt water. Salinity is mainly determined by local hydrology, where input of salt water comes from the periodic tides and fresh water comes from rivers, rainfall, groundwater, and runoff. High evapotranspiration (water loss through the soil and plant leaves) in the tropics and subtropics can increase salinity considerably, especially under environments with restricted water flow. Thus, salinity can fluctuate widely within mangrove forests, both over time and space (National Oceanic and Atmospheric Administration- Earth System, 2014).

2.5 Mangrove Physiological Adaptation

Mangrove species share important traits that allow them to live successfully under environmental conditions that often exclude other species; they have *hydrophytic* and *xerophytic* characters, possess exposed breathing roots, have extensive supporting roots, salt excreting leaves and are viviparous (http://www.sms.si.edu/irlspec/Mangroves.htm ; Hamilton *et al.,* 2011; Metras, 2011).

Mangroves prevent salts from entering their tissues, or are able to excrete excess salts that are taken in. For example, Red mangroves (*Rhizophora mangle*), excludes salts at their root surfaces via a reverse osmosis process (Odum and McIvor, 1990).

Moreover, Mangroves growing in the intertidal zone are subjected to large fluctuations in salinity; they are inundated by seawater (high salinity) during high tides, whilst at low tide, or during heavy rains or floods, they can be exposed to fresh water (low salinity) (Lovelock, 1993; Wolchock, 2006). Also, Ho. *et.al* (2008) reported that Mangroves at low tides may be washed by rain water. This creates stress on species only adapted to saline marine environment. Viles and Spencer (1995) reported that, the unique adaptations of some species are leaves that secrete salts to keep the internal salinity manageable.

2.6 Factors Influencing Mangrove and Salt marsh Communities.

Mangroves and salt marsh species have specialized physiological adaptations (including the ability to exclude or secrete salt from their plant tissue), which allow them to survive and reproduce in these otherwise uninhabitable saline environments. Different mangrove and salt marsh species are able to tolerate these harsh environments to varying degrees, depending on the adaptations of each species. Low rainfall and limited freshwater runoff give rise to hyper saline soils. Consequently, mangrove forests in this region comprise more salt tolerant species with extensive salt marsh areas Salt marsh plants are generally more tolerant of dry, saline conditions than mangroves (Goudkamp and Chin, 2006).

2.7 Mangrove Species and Distribution

Mangroves are found in the tropics and subtropics ï between latitudes 25° N and 25°S (Bojang and Ndeso-Atanga, 2009). Currently, mangroves cover an area of about 15.2 million hectares which is equivalent to 152,361 km^2 with the largest areas found in Asia and Africa, followed by North and Central America (Spalding *et al.,* 2010 FAO, 2007).

In East Africa and the WIO regions, mangroves are estimated to cover 1.2 million hectares with the largest areas covered found in Mozambique and Madagascar (Semesi, 1990). The WIO and the East African regions must be considered low in floristic diversity compared to the Southeast Asian mangrove forests, which has more than 40 species (Kathiresan and Bingham, 2001).

There are approximately 73 species of mangroves recognized worldwide (Lovelock, 1993; Spalding *et al.,* 2010). Tree diversity in mangrove areas is low compared to tree diversity in other land forested areas because few tree species can withstand high salinity, anaerobic sediments, acidic soils, and unstable substrates (Wang. *et al.,* 2003).

2.8 Mangrove in South East Asia (SEA)

South East Asia (SEA) has 71% of the total global species and the mangrove cover is estimated to be 51.049 Km^2 (Spalding *et al.,* 2010). Species found in the Western Indian Ocean (WIO) and Eastern Africa (EA) regions are also present in SEA. However, some species found in SEA do not occur in the WIO and EA regions; examples are: *Nyapa fruticanus, Agilitis rotundifolia, Arostecium danaeifolium a*nd also *Acanthus ebracteatus* (Spalding *et al.,* 2010).

2.9 Mangrove in West Indian Ocean and East Africa Regions

The West Indian Ocean (WIO) Region comprises of three coastal states (Kenya, Tanzania and Mozambique) and four island states (Madagascar, Mauritius, Seychelles and Comoros). The East Africa Region is comprised of two coastal states (Kenya and Tanzania) and three land locked states (Uganda, Burundi and Rwanda).The WIO region has 10 species of mangrove; with the various countries making up this region harboring different numbers of species: Madagascar, 8 species; Mauritius, 4 species; Seychelles, 6 species; Comoros, 8 species; Somalia, 9 species; Kenya, 8 species; Mozambique,10 species; and Tanzania, 10 species.

The following are examples of the mangrove species found in the WIO region: Rhizophora mucronata, Brugeira gymnorhiza, Sonneratia alba, Ceriops tagal, Avicennia marina, Pemphis acidula, Lumnizera racemosa, Heritierra littoris, Xylocarpus granatum and Xylocarpus muluccensis (Richmond, 2002 and Spalding *et al.,* 2010) and). Acrostichum aureum (mangrove fern), *Pemphis acidula*; is reported in WIO and EA regions (Mozambique and Tanzania) and also other parts of the world including South East Asia (Spalding *et al.,* 2010).

2.10 Mangrove in Tanzania

In Tanzania, mangroves occur along the coast on gently sloping shores, around river estuaries and creeks, and cover 1,286.75 km^2 (Spalding *et al*., 2010). The Rufiji River delta has about 50,000 hectares of mangroves and is the largest single mangrove forest stand (Semesi and Adelaida 2000).

The mangrove forest in Zanzibar covers approximately 18,000 hectares, 67% of which is found on Pemba Island and the rest on Unguja (Shunulla and Alan 1996; Hamilton *et al.,* 2011). In Zanzibar, the mangrove community consists of 10 species of mangroves (Hilal *et al.,* 2003; Hamilton *et al.,* 2011 and Othman, 2013), the same species found in the East Africa and WIO regions. However, all 10 species do not occur in all the areas; the species distribution differs from one area to another. For example, eight (8) species of Mangroves were reported on Uzi Island and nine (9) species in Kisakasaka ï Unguja; *Heritierra littoris* being the species that was found in Kisakasaka and Misali Island (Benfield, 2013; Gabriel, 2018).

2.11 Aspects of crabs

Crabs are the crustacean of the order Decapoda and suborder Brachyura, characterized by the small size of the abdomen, which resembles a short tail curved under the thorax, all important viscera being included in the thorax (Ramzi, 2010). The term extends also to some of the suborder Anomura (purse-crabs, hermit-crabs, etc.), characterized by a condition of abdomen intermediate between that of the Brachyura and that of the *Macrura*, or long-tailed decapod crustaceans, such as the lobster, crayfish, etc. All the crabs, besides many other *crustaceans*, were in the *Linneian Cancer* (genus); but the number of species is very great, considerably more than 1000, and the Brachyura alone are now arranged in many genera and families (Ng, *et al.,* 2008).

Crabs, like all arthropods change their shell, not at fixed intervals or seasons, but according to the exigencies of their growth, the change being made with great frequency when they are very young but rarely in advanced age. Indeed, from the molluscs and other animals sometimes found adhering to the carapace, it is inferred that the same covering is sometimes worn for a number of years (Neal and Wilson 2005).

These various crabs differ very much in the form of the carapace, which in some is orbicular or nearly so; much broader than it is long; in others, also in its smoothness, or roughness with hairs, tubercles, or spines; in the length of the legs (Lowe and Marie 2006). The eyes are compound, with hexagonal facets, and are elevated on stalks, which are generally short, but sometimes considerably lengthened, and which have the power of motion, so as to turn the eye in different directions (EDAW, 2005).

Crabs are inhabitants of almost all seas. Some crabs inhabit fresh water, particularly in the warmer parts of the world; and others, known as land-crabs, live among moist herbage, or burrow in sand or earth.

Crabs are generally flesh or carrion eaters, though some forms seem to prefer vegetarian diet. They are always active and are noted for running sideways, rather than straight ahead (Varadharajan and Soundarapandian, 2012).

Crabs become interesting in the aquarium, from their readiness in seizing food, their activity in tearing and eating it, and their pugnacity. The number of specimens is apt, however, to be soon diminished by the stronger killing and eating of the weaker (Samuel, et al., 2004).

Crabs vary greatly in size and color, as might be expected from the great number of species and their wide distribution. The giant crab of Japan (*Macrocheira kaempferi*), although only a foot across the disk, which is 18 inches long, has such long legs as occasionally to be 15 to 18 feet from tip to tip of the first pair (Samuel, et al 2004). The great stone-crab of Tasmania, which has short and very thick legs, has been known to reach a weight of over 30 pounds. On the other hand, many species of crab are only a fraction of an inch across.

Crabs in mangrove habitats show distinct distributional patterns related to characteristics, salinity, degree of tidal inundation, and wave exposure (Kathiresan and Bingham, 2001). Mangrove crabs have developed osmoregulatory mechanism to enable them adapt and live in the intertidal, mangrove habitats (Holliday, 1985; Schneider, 2005). Mangrove crab diversity is very high with an estimated 275 species from seven families of brachyurans: Ocypodidae, Sesarmidae, Grapsidae, Xanthidae, Portunidae, Geocarcinidae and Varunidae (Cannicci et al., 2009).

2.12 Crab Distribution

Mangroves worldwide harbour a diversity of crab species. For example Malaysia is known to have 100 brachyuran mangrove crabs, while Singapore harbours 76 species; with thelatter representing 22 percent of the total brachyuran fauna for the island state including Cleistocoeloma, Macrophthalmus, Metaplax, Ilyoplax, Sesarma*, Scylla serrata,*and *Uca* (Gillikin and Schubart, 2004; Tan and Ng, 1994). *Portunus sanguinolentus , Thalamita crenata, T. Foresti, T. prymna , Scylla serrata , Cardisoma carnifex,Pachygrapsus, Pseudograpsus, Thalassograpsus, Neosarmatium meinerti, Neosarmatium smithii,* are found in Mayote, Kenya, Tanzania, Mozambique, Madagascar, Comoros, Seychelles, Réunion, Mauritius, Indonesia, Taiwan, China, Japan, Philippines, Australia, New Zealand, New-Caledonia, Fiji, Samoa, French Polynesia and Hawaii (Ckleva, et al., 2011).

Some of the crabs, like true crabs, account for more than 17% of crustacean and because of far above the ground nutritional value (proteins and minerals), the extraction of chitin and chitosan for pharmaceutical and chemical applications and using their skins as food for livestock and poultry are valuable in the world (Gillikin, 2004). Recently, due to human activities such as illegal harvesting, over-water supplying and aquatic ecosystems such as coastal pollution, crab populations have encountered serious damages. Therefore, identification, biological and ecological studies of these animals, are important ways to help to protect and restore their populations, do research activities, development of economic species and make more food resources and entrepreneurship in the coastal areas (Stieglitz, 2000).

Among various shores, rocky shores, because of bed stability and a variety of habitats such as algal cover, presence of cracks and fissures in rocks, spaces available under stone fragments, and tidal pools filled with water in the tidal range at ebb-tide time, have more diversity and distribution of macro benthos (especially crabs) than muddy and sandy beaches. Therefore, in these areas crabs have high diversity (Micheli, 1991).

2.13 Crabs Distribution in West India Ocean Region (WIO)

This region exhibits a high level of species richness, including 3,000 species of molluscs, 300 species of crabs, 10 species of mangroves, and more than 400 echinoderms (UNEP/Nairobi Convention Secretariat, 2009). The Island States of the WIO region are inhabited by brachyuran crabs due to the presence of mangroves. The waters of Madagascarôs mangroves, for example, are rich in fish and crabs (<http://ramsar.wetlands.org/Portals/15/MADAGASCAR.pdf>).

In Madagascar the upper zones of mangroves serve as the habitat of various crabs including marsh crabs, Sesarma spp., while fiddler crabs, *Uca spp*., *giant mud crabs*, *Scylla serrata*, hermit crabs, *Epixanthus dentatus* identified dominate the Mangroves closer to shores (Ckleva, et al., 2011).

2.14 Crabs Distribution in East African Region (EA)

Fondo (2006) mentions 35 crab species, including Callapa callapa, Grapsus spp, Cardisoma carnifex, Scylla serrata, Uca spp, Uca annualipes, Uca urvillei, Uca chorophthalmus, Uca tetragonon, Ocypode ryderi, Ocypode ceratophthalmus, Neosarmatium smithii, Chiromantes eulimene, Sarmatium crassum, Sesarma vielosum, Epixanthus deatatusas occurring in the East Africa Region, (http://www.madeinnys.com/mangrove/mangroves.htm).

It is reported that, EA in general, has a limited number of brachyuran crabs associated with mangroves (about 35 species) compared to Southeast Asia with 100 brachyuran mangrove crabs known to occur in Malaysia, and 76 species in Singapore (Gillikin and Schubart, 2004: Tan and Ng, 1994) .Most crabs of this region are either fiddler crabs (Family Ocypodidae, Genus Uca), or sesarmid crabs (Family Grapsidae, Subfamily Sesarminae), though various other members of the

Gecarcinidae, Grapsidae, Ocypodidae, Portunidae and Xanthidae also occur (Hartnoll et al., 2003; Crane, J.; 2015).

2.15 Crabs Distribution in Tanzania

In Tanzania about Six (6) species of *Uca (*Ocypodidae*) - Uca annulipes, U. gaimardi, U. inversa inversa, U. vocanshesperiae, U. tetragonon andU.urvillei* have been recorded (Skovand Hartnoll, 2001). Other *Uca spp*. has also been reported as occurring in Bagamoyo (Muruke et al, 1999; Lilleston (2005). *Cypraea annulus, Uca spp., Macrophthalmus spp., Thalamita spp., Clibanarius longitarsus, and Coenobita rugosus* have also been reported to be present in Kunduchi, Tanzania (Mlay et al., 2004 and Gust, 2017).

2.16 Crabs Distribution in Zanzibar

In the part of Zanzibar, 16 species of mangrove crabs belonging to four families have been identified at the Nyeke mangrove forest, Uzi Island, Zanzibar. These include *Metograpsus messor, Eurycarcinus natalensis, Perisesarma guttatum ,Perisesarma ortmanni, Uca annulipes, Uca inversa inversa, Neosarmatium meinerti , Neosarmatium smithii , Scylla serrata and Platypodia granulose* (Mchenga and Ali, 2013). Benfield (2013) reported of the presence of *Uca inversa, U. urversa, U. chlorophthalmus, U. vocans, U. annulipes, an unidentified Uca species, three species of Sesarma - S. guttatum, S. smithii, S, meinererti* - an unidentified Sesarma species *and a Cadisoma carnifex in Uzi and Kisakasaka.*

The Mangroves of the Jozani Chwaka Bay National Park (JCBNP) Pete area are home to two burrowing decapod crab families - Ocypodidae and Grapsidae (sub family Sesarminae) (Olafsson et al., 2002; Bisang, N. 2009). In the review of Omar (2009), 1,252 crabs were identified on Misali Island in Pemba and these belong to 37 species of intertidal crabs representing the following families: Ocypodidae example, Ocypode ceratophthalmus, Ocypode ryderi and *Uca* urvillei; Grapsinae, example, *Grapsus tenuicrustatus; G.albolineatus and Sarmatium crassum; Portunidae, example, Scylla serrata; Calappidae, example, Matuta lunaris; Menippidae, example, Erphia smithi*.

The following nine (9) species of crabs - *Clappa spp, Calcinus laevimanus, Clibanarius streolatus, C.vioscens, Unidentified Hermit crabs, Clibanarius violancens, Uca chrophthalmus, and Uca lacteal annulipes have been recorded on Misali* (Gorgean, 2007).

Five species -*Neosarmatium meinerti, Cardisoma carnifax, Coenobita rugosus, C. violancens and Ocypode ryderi* have been recorded in the Western Mangroves while the South East mangroves have 8 species for example *Uca* tetragonon ; *Uca* urvillei; U. *chlophthamus; Sessama guttatum; Coenobita violascens; Coenobita rugosus* (Gorgean, 2007). On the eastern coast of Pemba the population of crabs declined due to salt pans (Wolchock, 2006).

2.17 Socio-economic importance of Crabs

Crabs supply food for food-fishes, are of great service as scavengers, and are used as human food in various parts of the world (Babu, 2005). In the United States the principal crab so used is the blue crab (*Callincctcs hautains*), hundreds of thousands of which are sent to market every year from the waters of Chesapeake Bay alone. The little pea-crabs (Pinnotheres *bicristatus*) often found in oysters are regarded as a great luxury. The species which are most frequently used are those of the genus Cancer, especially the great *cancer pagurus* (Bueno, 2005), and there is no reason why the two eastern crabs which have just shed their shell, and are covered only by a soft skin, are regarded as best, and are called *'shedders or 'soft-shelled*.

Many people who live near seashore have most likely consumed crabs. They are famous as a delicacy all around the world. Both the profit-making and sport crab fishery contribute to the local economy (FAO, 2011). In British Colombia for several first nations, the crab harvesting is an important sports and cultural activity also crabs are one of the major decomposers in the naval environment. In other terms, Crabs help in cleaning up the bottom of the sea by collecting decaying plant and animal substances. Many fish, birds and sea mammals rely on crabs for a food source.

2.18 Adaptations to Salinity of Mangrove Crabs

Mangrove trees and crabs are some of the estuarine species that have adapted to unique environmental conditions. In almost all estuaries the salinity of the water changes constantly over the tidal cycle. To survive in these conditions, plants and animals living in estuaries must be able to respond quickly to drastic changes in salinity (NOAA, 2008). Plants and animals that can tolerate only slight changes in salinity are called stenohaline. These organisms usually live in either freshwater or saltwater environments. Most stenohaline organisms cannot tolerate the rapid changes in salinity that occurs during each tidal cycle (Salgado Kent and Mc.Guinness 2006).

Plants and animals that can tolerate a wide range of salinities are called euryhaline. These are the plants and animals most often found in the brackish waters of estuaries (Emmerson, 2000). There are far fewer euryhaline than stenohaline organisms because it requires a lot of energy to adapt to constantly changing salinities. Organisms that can do this are rare and special. Some organisms have evolved special physical structures to cope with changing salinity (Johnson, 2003.). The smooth cord grass (*Spartina alterniflora*) found in salt marshes, for example, has special filters on its roots to remove salts from the water it absorbs. This plant also expels excess salt through its leaves (Cannicci , 2002). Unlike plants, which typically live their whole lives rooted to one spot, many animals that live in estuaries must change their behavior according to the surrounding waters' salinity in order to survive. Oysters and blue crabs are good examples of animals that do this (Jordao and Oliveira, 2003).

Adult male crabs live in the low-salinity waters upstream, while adult female crabs live in the higher-salinity waters near the mouth of the estuary (Vanessa et al., 2012). During the crabs' mating, the high-salinity preference of the female overlaps with the lower the salinity preference of the male (Kristensen, 2008). After mating, female crabs migrate offshore, sometimes up to200 m, to high-salinity waters to incubate their eggs. The females release their larvae, called *zoeae*, during spring high tides. The *zoeae*, resembling tiny shrimp, develop in the coastal waters (Fluech, 2012).

Zoeae require water with a salinity over 30 ppt (parts per thousand) for optimal development, which is only found in the ocean (Fluech, 2012).

2.19 Crabs as Keystone Species Influencing Function and Structure in Mangrove Forests.

Studies in tropical Australia (and confirmed in other tropical mangroves worldwide) found that grasped crabs, especially sesarmids, consume a significant fraction of leaf litter lying on the forest floor (Robertson et al., 1992), thus reducing the detritus subsidy to the adjacent coastal zone.

Grapsidae and Ocypodidae crabs are the most important organisms influencing the structure and function of many tropical mangrove forests, after bacteria and the trees (Lee, 1998, 1999; Kristensen, 2008). Through their life activities, they exert extraordinary influence on a wide variety of mangrove processes. Through their consumption of mangrove leaf litter, they significantly reduce the amount of detritus available for export, thus enhancing retention and recycling of nutrients and organic matter internally; their wastes can support coprophagous organisms further ensuring conservation of materials within the forest, and their selective consumption of mangrove propagules affects forest structure by reducing the recruitment and relative abundance of tree species whose propagules are preferentially consumed (Alongi, 2009).

Bioturbation by crabs also results in changes in soil texture and chemistry, surface topography, degree of anoxia, and abundance of meiofauna while stimulating microbial production. The presence of crab burrows enhances the flow of tidal water through the forest floor, speeding up the flow of water and associated dissolved and particulate material between forest and adjacent waterway (Ridd, 1996). Crabs, however, are not keystone species in all mangrove ecosystems.

In temperate Australian mangrove-salt marsh systems and in some Caribbean mangroves, crabs play only a minor role in litter decomposition and in structuring forests and, in fact, often avoid eating mangrove leaves and seeds (Smith et al., 1989; Saintilan et al., 2000; Guest et al., 2004, 2006). In mesocosm experiments, Kristensen and Alongi (2006) found that the presence of the fiddler crab, *Uca vocans*, stimulated the growth and development of *Avicenia marina* saplings but depressed the abundance and productivity of microalgae mats at the soil surface. The association between the saplings and the crabs also greatly influenced the pathways of microbial decomposition with sulfate reduction being more important than iron reduction in the presence of crabs and saplings. Fiddler crabs and tree roots thus appear to have complementary effects on sediment microbial processes (Alongi, 2009).

2.20 Osmoregulation in Crabs

Osmoregulation is the process of regulating water potential in order to keep fluid and electrolyte balance within a cell or organism relative to the surrounding (http://www.biology-online.org/dictionary/Osmoregulation).This process enables the organisms to keep a constant, optimal osmotic pressure within the body or cell. It is the way by which an organism maintains suitable concentration of solutes (salts) and amount of water in the body fluids. An example employed by organisms is excretion (getting rid of metabolic wastes and other substances toxic to the body when they are in large amounts) (http://www.biology-online.org/dictionary/Osmoregulation).

Marine invertebratesô species have developed osmoregulatory mechanisms and conforming types are found in organisms that live in intertidal zones where the concentration of salts is fluctuating on a daily basis (Schneider, 2005).

Holliday (1985) reported that if the salinity of the medium changes, salts move in or out of the crab by diffusion and water also moves in or out by osmosis and the body fluids quickly approach ionic and osmotic equilibrium with the external medium. (Holliday,1985) again reported that when crabs encounter low-salinity waters most of them cannot control the salt concentration and osmotic pressure of their body fluids; because the osmotic pressure of their body fluids is very close to that of the external medium.

Crabs have developed various organs to keep the osmotic pressure of the hymolymph within a stable range, and many brachyuran crabs living in intertidal regions and estuaries are hyper- hypo-osmoregulators (Chung and Lin, 2006). Also crabs simply hide in mud caves which are less affected by solar heat and evaporation, resulting in a relative constant temperature and humidity (Ho et al., 2008).

2.21 Mangrove Crab Burrows

Mangrove crabs are crabs that live among mangroves, and may belong to many different species and even families (Warren and Underwood, 1986). They have been shown to be ecologically significant in many ways. They keep much of the energy within the forest by burying and consuming leaf litter. Crabs normally burrow in the ground; however some of these crustaceans can climb trees to protect themselves (Peter, 1996). The hermit crab and the mangrove crab are among the crustaceans that can climb trees as a defense mechanism. Furthermore, their feces may form the basis of a coprophagous food chain contributing to mangrove secondary production (Belg, 2012).

Priyadarshani, et al..(2001) reported that the reduction of *Fiddler* crab density for a single growing season decreased above ground production by 47% and burrowing, the crabs increased soil drainage, soil oxidation-reduction potential and there was in situ decomposition of below ground plant debris.

Mangrove crab larvae are the major source of food for juvenile fish inhabiting the adjacent waterways, indicating that crabs also help near shore fisheries. The adult crabs are food for threatened species such as the crab plover (Hemmi and Zeil, 2003).

Crab burrows alter the topography and sediment grain size of the mangrove, and help aerate the sediment. Removing crabs from an area causes significant increases in sulfides and ammonium concentrations, which in turn affects the productivity and reproductive output of the vegetation, supporting the hypothesis that mangrove crabs are a keystone species (Kristensen, 2008). Burrows are important to fiddler crabs for a number of functions, allowing them to adopt a semi terrestrial existence and avoid environmental stresses by behavioral means. Fiddler crabs excavate burrows in the sediment, to avoid excessive wave action and obtain relief from hot and cold ambient temperatures and desiccation (Smith et al., 2009).

Burrowing and foraging activities of crabs promote the creation of estuarine intertidal flats. They remove large amount of sediment and change the substrate characteristics, increasing water and organic matter contents as well as their penetration in the sediment layers. The micro fauna community structure is affected by the sediment distinctiveness and presence of the burrowing crabs in the intertidal habitat (Gribsholt et al., 2003). Crabs excavate and maintain semi-permanent open burrows and remove large amounts of sediment during feeding and burrow maintenance forming a surface mound around burrows. In spite of the abundance and widely distribution information on this behavior, not enough information is available about the effect of this crab behavior on the structure of the micro fauna community.

Burrows provide a refuge from both aerial and terrestrial predators during exposed periods and from aquatic predators during flooding, water for physiological needs, and also sites for molting and reproduction (Andreetta et al., 2014). The architecture of the burrows plays an important ecological role in the life history of fiddler crabs as they are semi-terrestrial and active at low tide, returning to their burrows at high tide.

Since the burrow is a place of refuge from predators, its structure must be advantageous to the crab when it is necessary to make a hasty retreat when pursued or threatened (Kristensen, 2000). Especially in anoxic sediments burrows have greater ecological significance as they help to improve the aeration of the sediments?

Burrow morphology has been described by using plaster of Paris, rubber, or epoxy resin casts. General burrow morphology varies in diameter, depth, volume, and angle of the burrow with respect to the shoreline (Michaels and Zieman, 2013). General burrow design has been studied in several species of the fiddler crab including *Uca pugilator, Uca rapaxUca pugnax Uca panacea, Uca longisignalis, Uca spinicarpa,Uca vocator, Uca subcylindrica, Uca tangeri, Uca annulipes and Uca vocans* (Naureen and Noor, 2012).

2.22 Salt Pan

Salt panning has been practiced for many years in the world; however, it began in the San Francisco Bay, California in 1770 and then at the Great Salt Lake in Utah in 1847 andexpanded in the last decade in South east Asia . Globally, salt industries produce between 279,000 and 280,000 thousand metric tons per year (Richmond 2002; Thys, 2003). For example in 2010 Bangladesh produced 360 Metric tons, Colombia 375 thousand metric tons, India 17,000 thousand metric tons, Mozambique 110 thousand metric tons and Tanzania 28 thousand metric tons . Salt pans in Tanzania have been estimated to cover 3093 ha in 1998 (Semesi 1998). In addition to deforestation, salt pans are responsible for elevating local soil salinity and for producing a hyper saline runoff that may impair mangrove growth and regeneration (Faki 2003; Shunula ; Alan, 1996 and Matera 2018). Effects on animal populations, such as fish, birds, crabs, and shellfish inhabiting the mangroves, are not well understood (Wolchok, 2006).

Salt panning has also been and is being practiced on the East African (EA) coast and the West Indian Ocean (WIO) regions as seen in Kenya, Tanzania, Mozambique, Madagascar and Mauritius (Semesi, 1998; Ortega et al., 2001: Richmond, 2002; and Liu et al., 2002). Pemba Island produces 4,566 of salt kilograms per annum (Wolchock; 2006) equivalent to 4.57 tons (http://www.metric-conversions.org/weight/tonnes-to-kilograms-table.htm).

However, construction of evaporation salt pans causes threats to crabs in mangrove ecosystem. Salt panning is said to be one among the threats to mangrove resources in the world as in Tanzania (Faki, 2003). The major economic activities in Tanzania impacting on mangrove areas are agriculture and salt production by solar, where 75% of salt is currently made via solar production (Tamatamah, 2007).

2.23 Sustainability of Salt Panning

Numerous studies have been conducted on Mangrove species and habitats, however, minimal information exists vis-à-vis the sustainability of salt panning as Mangrove areas are used for this purpose. Kairo and Skov, (2011) found that the different tree species is a home to different residents. For instance, the mangrove snail, *Littorea articulata*,might prefer *Avicennia marina*, but the Atlas moth (*Attacus atlas*) prefers *Sonneratia alba*. Therefore, having more tree species means attracting more ǿresidentô species.

On the other hand, Kairo and Skov (2011) found that a totally undisturbed system might also be unproductive, as it becomes dominated by few species, or because it becomes too infrequently renewed (e.g. a still pool of water might suffer from oxygen depletion or lack of nutrient mixing). Often, a moderately disturbed system is the most productive, because it keeps renewing itself, and is dominated by many species. Barkati and Rahman (2005) found that ñthe mangrove trunks, forest floor, seaweeds and water pools.

Within the mangroves provide a favorable habitat to support a wide variety of animal life at various life cycle stagesò. Preliminary study conducted in Maputo found out the presence of small mangrove forest could act as an input source of organic matter and other food materials could influence the presence of crab abundance, for example *Dortilla fenestrate* - *Ocypodidae* (Pereira and Goncalves, 2000).

Studies have shown that salt pans increase pressure on surrounding mangroves by encouraging the use of the mangroves. A study conducted in Pemba noted that 78% of salt producers reported using mangroves near their salt pans. This is significantly higher than the reported use of other mangrove stands, indicating that the salt pan areas are more heavily used (Wolchok, 2006).

The sustainability of salt panning by using mangrove habitats therefore needs to be investigated as for example by studying the abundance and species diversity of crabs and mangroves distribution, the effects of environmental parameters as well as impact on coastal people that depend on salt production as a source of income.

2.3 Knowledge Gap

Numerous studies have been conducted about crabs and mangrove ecosystems in different parts of the world. Like Skov et. al. (2002) Quantifying the density of mangrove crabs: *Ocypodidae* and *Grapsidae, Nomann and Pennings* (1997) Fiddler Crab Vegetation interactions in hypersaline habitats in Georgia; Frusher, S.D, Giddins, R.L, and Smith III, T.J (1994) Distribution and Abundance of Grapsid Crabs *(Grapsidae*) in a Mangrove Estuary: Effects of Sediment Characteristics, Salinity Tolerances, and Osmoregulatory Ability.

There is, however, no literature or researcher expressing about the crab and mangrove Species Diversity and Abundance in Salt Panning and Non- Salt Panning Areas on the Eastern Coast of Pemba. These studies leave a knowledge gap in the government authority such as Ministry of Fisheries and Livestock in Zanzibar as a result this situation instigates researchers to fill this gap by Comparative study on crab and mangrove Species Diversity and Abundance in Salt Panning and Non- Salt Panning areas on the Eastern Coast of Pemba- Zanzibar.

CHAPTER THREE

METHODOLOGY

3.1 Overview

This chapter focuses at the research philosophy, Study area, sampling design and procedures, variable and measurement procedures, methods of data collection and data processing and analysis.

3.2 Research Approach and Philosophy

The research philosophy used in the study is pragmatic philosophical stance as it employed the use of quantitative methodology. The purpose of using this method is to be able to examine further into the dataset to understand its meaning and to use one method to verify findings from other method (Creswell & Plano, Clark, 2007).

3.3 Research Design

Research design is defined as the plan, outline or arrangement that is used to produce answers to research problems (Orodho, 2003), According to Kothari (2004), a research design is the displaying of conditions for data collection and analysis in a mode that aims at combining relevance to the research purpose and economy in procedures. It is a conceptual structure within which research is conducted. The design constitutes the blueprint for the collection, measurement, and analysis of data.

The research design used in this study was experimental research design and observation due to the nature of the study. The researcher conducted experiment during the field work survey to test salinity availability and pH values concentration. Hence these designs were used so as to increase level of reliability of gathering data

(Cassell and Symon, 1994). Some of the coalesce methods of research design ensured high degree of reliability of data, understanding the related aspects of the research, elasticity and openness of data collection and more holistic interpretation of the research problem. Experimental research design was used to gather the information about the distribution of crabs, mangrove diversity, crab diversity and mangrove regeneration as well as physico-chemical parameters that affect the existence of mangrove crabs in study area.

3.4 Study Areas

This study was conducted on Pemba Island, which with its sister island, Unguja, together with several smaller islands make up the Zanzibar Archipelago, a part of the United Republic of Tanzania. Pemba Island lies approximately 40 km off the east coast of mainland Tanzania in the Western Indian Ocean and covers an area of 868 km^2. It is located between 4º 45ô S and 5º 30ô S Latitude and between 39º 3ô E and 40º E Longitude (Walchock, 2006). Pemba Island has a population of 362,000 people out of a total of 1,303,569 for the whole of Zanzibar (National Bureau of Statistics, 2013).

This study was conducted at two different mangroves forest sites near the villages of Shengejuu and Kangagani, both located in the Wete district on the Eastern coast of Pemba (Figure 1).The main economic activities in the Kangagani and Shengejuu villages revolve round subsistence farming, lime block cutting, fishing, stone mining and engaging in evaporative Salt production (Mbarouk, 2010).

Shengejuu is located at an elevation of one meter above sea level and its coordinates are $5^0$4ô0ò N and $39^0$48ô0ò E in Degrees Minutes Seconds (DMS).Its Universal

Transverse Mercator (UTM) position is EQ83 and its Joint Operation Graphics references is SB37-07. It has an area of 4.0 km^2 and a population of 1,753 peoples according to 2012 population and housing census (National Bureau of Statistics, 2012).Kangagani also has an elevation of one meter above sea level. Its coordinates are 5°10'0" N and 39°49'60" E in DMS.Its UTM position is EQ92 and its Joint Operation Graphics reference is SB37-07.It has an area of 4 km^2 and a population of 3,135 peoples according to 2012 population and housing census (.National Bureau of Statistics, 2012).

However, on the part of the climate, the climate of Pemba can be mostly separated into two monsoon periods, the Northeast monsoon trade winds blowing from the northeast between December and April, and the Southeast monsoon trade winds blowing from the southeast between May and November. The Northeast monsoon is normally characterized by lower wind speeds, calmer seas and higher sea surface temperatures, and the late Northeast monsoon is the usual bleaching period in this region. The Southeast monsoon is normally characterized by higher wind speeds, rougher seas and lower water temperatures (Grimsditch et al., 2010).

There is some variation in mean annual rainfall for the study areas. The mean annual rain fall of Kangagani is 1760 mm and the average temperature ranges between 26 °C and 32 °C. Meanwhile, the mean annual rain fall of Shengejuu is 1860 mm, the long rains average 363mm per month and the short rains average 175 mm per month (Beentje, 1990; Abdullah et al., 1996).

The annual relative humidity range for Pemba Island is 79% - 82 % (January ï December); January ï March relative humidity range is 79% - 78 % and April ï June, relative humidity range is 82% - 84 %. These represent the dry and rainy seasons respectively (Abdullah et al., 1996).

Field data were collected using different instruments of the specific environment parameters to compare the known data of this study. The main reasons that led to the selection of these Study areas (Shengejuu and Kangagani mangroves forests zones) was that, these were the villages where most mangroves forests are largely concentrated and highly utilized by the local people for different uses or consumption such as salt production.

Figure 3. 1: Map of Pemba Island showing the location of Study areas Kangagani and Shengejuu in the East of Pemba Island

(Source SMOLE). Modified by the Researcher, 2014

3.4 Population of the study

Based on the 2012 United Republic of Tanzania Census, the population density of Kangagani is estimated to be 783.8 people per square kilometer and that of Shengejuu is estimated to be 438.3 people per square kilometer. Their annual growth numbers is 5% which is greater than the National average of 3.1% (RGOZ, 2009). Pemba Island is dominated by bimodal rain fall pattern; the main long rainy season Masika occurs between March and June in a year and the short rainy season Vuli, occurs in October and December (Jumah et al., 2010).

3.5 Sample Design and Sample Size.

A sample is a finite part of a statistical population whose properties are studied to gain information about the whole population (Webster, 1985). Sampling is the procedure a researcher uses to gather people, places or things to study. It is a process of selecting a number of individuals or objects from a population such that the selected group contains elements representative of the characteristics found in the entire group (Orodho and Kombo, 2002).

Systematic together with random sampling techniques were employed in biodiversity assessment and measurement physicochemical parameters of sampling plots and quadrants. This technique was selected based on the nature of the forests and it was more convenient and quick method of obtaining samples.

Twenty (10) plots were selected for each study site whereby each plot was 20 m x20 m where 80 quadrants of (5 m x 5, 10x10 m, and 15x15) were established with in plots. And this quadrant were settled for the interval of 5m from one quadrant to another along both study area in Shegejuu and and Kangagani (within salt pans and non-salt pans. The length of transect were 100m in both study areas, where five (5) plots of 20m x 20m each were settled in each transect. Transect salt pans at Shengejuu were measured South East of reservoir, while mangrove were measured NE from the reservoir pans to the mangroves. Transect salt pans at kangagani were measured South East of reservoir pans while mangrove were measured NE from the reservoir pans to the mangroves. These sampling plots were placed and GPS coordinates were recorded (Plate 1). However, systematic and stratified samplings together were employed in selecting observation of crabs community and mangrove community, measured environmental parameters and also anthropogenic activities. Stratified sampling was selected because it is the sampling technique that can identify the items that are in strata like mangroves and crabs in a same quadrant, also can minimize sampling error and reduce population variability (Folz, 1996).

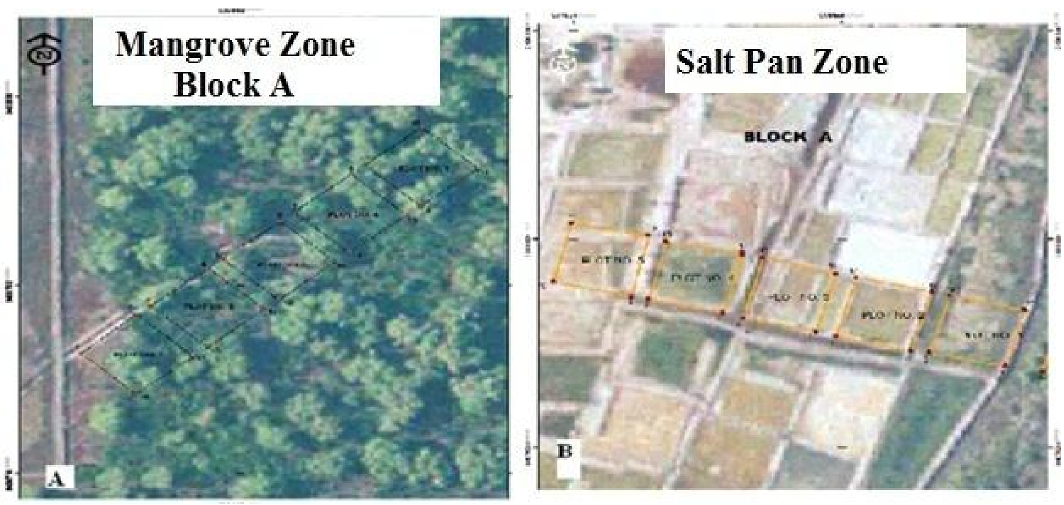


Plate 3. 1: Non Salt (A) and Salt Pan (B) Study Areas

3.5.1 Setting up Transects

A transect is a path along which one counts and records occurrences of the species of study. It requires an observer to move along a fixed path and to count occurrences along the path and, at the same time (in some procedures), obtain the distance of the object from the path **(Buckland**, 1993). These results in an estimate of the area covered and an estimate of the way in which detection ability increases from probability (far from the path) towards (near the path). Using the raw count the estimation of the abundance of populations (such as terrestrial mammal species) can achieved using a number of different types with in transect, such as line transects.

3.5.2 Line Transects

A line transect is carried out by unrolling the transect line along the gradient identified. The species touching the line may be recorded along the whole length of the line (continuous sampling). Alternatively, the presence or absence of species at each marked point is recorded (systematic sampling). If the slope along the transect line is measured as well, the results can then be inserted onto this profile. In this study Systematic line in this study Systematic line transects were placed using GPS from the beginning of the reservoir pan to the harvesting pan Transect salt pans at shengejuu were measured South East of reservoir pans while mangrove were measured NE from the reservoir pans to the mangroves. Transect salt pans at kangagani were measured South East of reservoir pans whereas mangrove were measured NE from the reservoir pans. The lengths of these transects were 100 m on the panning and non-panning. In this transect in the salt pan zone few crabs species were observed. Transects were laid using Global Positioning System (GPS) in both the non-salt panning (mangrove) and salt-panning areas.

3.5.3 Salt-panning area line transects

3.5.3.1 Non-salt-panning (mangrove) area line transects

These transects were laid perpendicular to the shoreline. The length of transect were 100 m for every study area. (Plate 2)

A B

Plate 3. 2: Salt Pan (A) and Non Salt Pan (B) Zones of Study areas

3.6 Data Collection Methods

Data collection method refers to gathering information aimed at providing some facts (Kombo and Tromp, 2006). Every research involves data collection. This study used varieties of techniques to obtain data and improvement of the data obtained from other instruments. These methods were used in order to ensure validity of information collected. This is due to the fact that the quantitative research design allows the researcher to use these methods of data collection through measurement and observation.

3.6.1 Primary Data

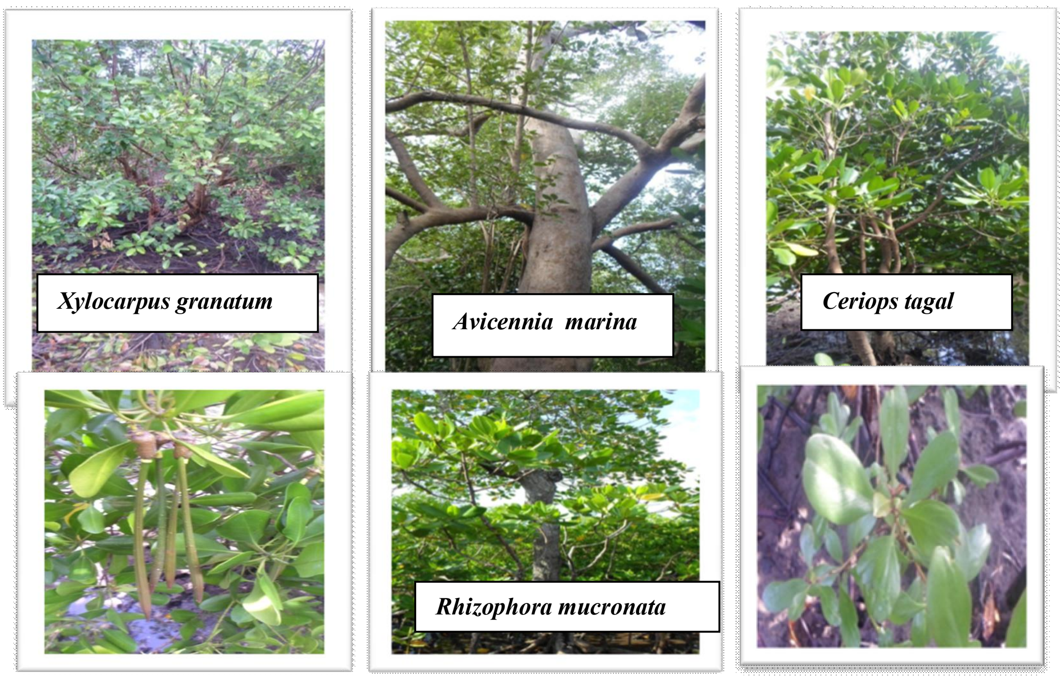
According Kothari (2004), the primary data are the brand new data collected for the first time from the field and are original or firsthand information. Primary data are data which are collected specifically for the investigation (Williamson et al. 2000). Usually primary data are collected through various data collection techniques such as measurement, questionnaires, focused group discussion; physical site visits (observation) and interviews so as to meet the purpose of the study (Bricki and Green, 2002). Due to the nature of this study, mainly Primary data was collected and used data collect through measurement and observation techniques.

3.6.2 Frequency by which Data were observed

Frequency data of a particular observation is the number of times the observation occurs in the data. It can show either the actual number of observations falling in each range or the percentage of observations (Carlson and Winquist, 2014). In the latter instance the distribution is called a relative frequency distribution. In this study, the frequency was used to collect data for the different species using transects within each plot of observation in the study areas. Within each plot of the study area the frame of quadrant of the 5m x 5m were placed for every 5m intervals from one quadrant to another and the counts were made of crab species, crab burrow (holes), mangrove species, seedlings and saplings.

3.6.3 Mangrove Species Observation

Mangroves species are salt-tolerant evergreen forests plants that create land-ocean interface ecosystems. They are found in the intertidal zones of marine, coastal or estuarine ecosystems of tropical and sub-tropical countries and areas. Mangroves are a significant habitat for sustaining biodiversity and also provide direct and indirect benefits to human activities (Mudithaet al., 2014**).** In this study the mangroves species were observed and identified (Plate 3**)** using different documents like that of Lovelock, C. (1993); World Atlas of Mangroves (Spalding et al. (2010) and Metras (2011) as well as Taxonomy of Mangrove Plants. Different kinds of Mangroves species were identified using the guide. The guide which was used to identify mangroves was (The Botany of Mangrove by Tomlinson, (1986). Cambridge University Press, Cambridge, UK), the Mangrove Reference Database and Herbarium. Plant Ecology and Evolution Massó i Alemán *et al.*, (2010) ; Beentje, and Bandeira, Field Guide to the Mangrove Trees of Africa and Madagascar (2007) also **Mangroves**: Ecology, Biology and Taxonomy. James and Metras, (2011),



Rhizophora mucronata

Lumnitzera racemosa

Plate 3. 3: Observed Mangrove Species found in panning and Non- panning

3.6.4 Crab Species Collection

Crabs are decapods crustaceans of the infra order brachyuran, which typically has a very short projecting, and usually are entirely hidden under the thorax. They live in all the world's oceans, in fresh water, and on land, are generally covered with a thick exoskeleton and have a single pair of claws.

In this study, Crab specimens were collected from the different plots and were divided into a number of frames. Crab samples were collected by digging out one-ninth of a square meter (0.33 m^2) to a depth of 10-20 cm with a spade (Warren, 1990). The block of sediment were then dug out and examined carefully (Sasekumar, 1974 and Priyadarshani et al., 2008).

Fourteen species of mangrove crabs were collected - *Cardisoma carnifex, Cardisoma* spp. (unidentified found only at Kangagani Mangrove sites), *Epixanthus deatatus, Metopograpsusmessor, Metopograpsusthukular, Neosarmatium africanum, Neosarmatium smithii, Perisesarma guttatum ,Scylla serrata ,Uca annulipes,Uca chorophthalmus, Uca inversa inversa Uca tetragonon*and *Uca urvillei*. Non identified crabs (in the field) were preserved using a suitable fixative of 70% alcohol to be identified later.

3.6.5 Crab Observation

Several species of crab are found in marine waters and along its shores, though only a few are large enough to be of commercial and sport interest. Crabs are most commonly harvested with crab pots but are also caught using ring nets, dip nets, and by wading in shallow water during spring and early summer. In this study crab species (Plate 4) were observed by the researcher. The crabs specimens recorded, were identified up to species level using the following documents (Ng et al., 2008; Sweat, 2009; Fushimi and Watanabe, 1999). This identification was based on (Decapod Crustacean Phylogenetic taxonomy by Joel et al., 2009), By Manning and Holthuis.1981). West African brachyuran Crabs,(Crustecia: Decapods., also Marine Brachyuran Crabs of India By Jigneshkumar et al., (2018) and Crane, (2015). Fiddler Crabs of the World: Ocypodidae: Genus UCA.

Plate 3. 4: Observed Crab samples present at study sites

3.7 Measurements of Environmental Parameters

The following environmental parameters soil temperature, salinity, pH, rainfall and relative humidity ï were measured following Priyadarshani et al., (2008).

3.7.1 Soil temperature

Soil temperatures were measured and recorded by inserting two glass mercury thermometers mode lN. DPT - 02103 into the soil at randomly selected points of the Nested quadrants, done four (4) times per nested quadrants (5x5, 10x10,15x15 and 20x20) m^2 and then average means were calculated per quadrate and eventually average means per month. Measurements of soil temperature were done for a period of six months from March to May (Rainy season) and June to August (Dry season) for both salt pans and non-salt pans study sites.

3.7.2 Salinity

Water samples were collected from the four (4) sites using a measuring cylinder of 500 ml capacity. The total concentration of salts in water were measured by using Baumes (Be) heavy hydrometer (Brand Vee Gee) inserted within a measuring cylinder which contained seawater from each quadrate frame of (5, 10,15and 20) m2within all the five major quadrate numbers 1 up to 5 (20x20m^2).Finally, average means were calculated from study areas monthly and seasonally for both rainy and dry seasons.

3.7.3 Soil pH

Soil pH was measured by using pH test Strips dipped in the soil at randomly selected points in both salt pans and non-salt pans of Shengejuu and Kangagani study sites.

The readings were recorded, according to the color change from 1 up to 14. Seven (7) was neutral, 1up to 6 indicated acidic while 8 to 14 indicated alkaline conditions. The average measurements of pH of the soil water were calculated per small study plot as follows (5x5, 10x10, 15x15 and 20x20) m2 for a period of 6 months from March to May and June to August as rainy seasons and dry seasons respectively.

3.7.4 Relative humidity

The relative humidity at randomly selected points of the study sites was measured using KT-905 Temperature humidity meter (Digital) with a range 10% - 99%. The instrument was kept in the soil for a few minutes (1 ï 2 minutes) until the relative humidity readings were constant and then readings were recorded. Selected points were made along the salt pans and non-salt pans within study areas, also average means were calculated per nested quadrate, per month and eventually per season for both dry and rainy seasons. Relative humidity values were measured and recorded for duration of six months.

3.7.5 Rainfall data.

The rainfall data from study sites during two seasons (March to May (rainy season) and June to August (dry season) in 2014 were collected. weekly rainfall data were collected at four (4) randomly selected points at study areas during the field work in 2014. Rainfall data were collected using a rain gauge. The collected data were analyzed to obtain maximum, mean and minimum rainfall information for each study site.

3.8 Validity and Reliability

3.8.1 Validity

Validity refers to the degree to which a study accurately reflects or assesses the specific concept that the researcher is attempting to measure (Campbell, 1966). In respect to validity, the rule says that, the instrument is considered to be valid when it provides accurate measure thus validity refers to soundness of the interpretation of the test (Thomas and Nelson, 1990).

Validity is examined in order to find out whether the instruments measure what they are supposed to measure (Kothari, 2004; Tabachnick and Fidell, 2007). The validity of the test depends on its purpose; whereby the purpose of the validity is to increase the truthfulness and effectiveness of the finding by eradicating the confusion of the variables which allows for the better assurance of this study. In this study validity was attained in various ways - through the use of probability sampling so as to reduce biasness during the dissemination of transect for measurement and by the use of different methods of data collection such as measurement, observation as well as documentary review.

3.8.2 Reliability

Reliability is a matter of whether a particular technique applied repeatedly to some object would yield the same results each time (Babbie, 2008). To achieve reliability in this study, the researcher employed multiple techniques in which one instrument complemented the other.

The measuring instruments are reliable when they provide consistent results even if they are repeatedly used (Kothari, 2004). To ensure reliability of this study, different techniques - chi square test and two tailed test were used for data analysis. The data collection instruments were tested several times in the same location so as to find out to what extent they were reliable by providing the expected and required information. There was no problem identified for the data collection instruments as well as the data collected. Therefore the results of this study are reliable and represent the attributes of population under study.

3.9 Data analysis

Data analysis is a process of inspecting, cleaning, transforming, and modeling data with the goal of highlighting useful information, suggesting conclusions, and supporting decision making (Adler, 2008). Since this study, to a large extent, was quantitative in nature, most of the information gathered was analyzed numerically. The data collected through measurement were analyzed and presented in tables, charts and graphs and also condensed in order to draw conclusions. In Stat-Graph Pad Prism was used in analyzing the data. Chi- square test and two tailed T - test were used to compare species diversity, crabs burrows ; mangroves regeneration numbers between Salt and Non-Salt Pan areas of the study and also correlation analysis were for various environmental parameters versus mangroves and crabs by Pearsonôs correlation Coefficient. The observations were dependent variable and the sites being compared were independent variables. The quantitative data was compiled for making primary analysis. The data was presented in table and graph forms. Species diversity was calculated.

Diversity of mangrove crabs in a particular site was calculated using Shannon Weiner index of diversity using the formula below:

H=-× PilnPi

Where:

i=1

H = the Shannon diversity index

Pi = fraction of the entire population made up of species i

S = numbers of species encountered

Ɇ = sum from species 1 to species S

CHAPTER FOUR

RESULTS

4.1 Mangrove Crab Species Diversity in Zonation (Salt and Non-Salt Pan).

Fourteen (14) mangrove Crabs species were identified in Kangagani while thirteen (13) mangroves Crab species were identified in Shengejuu in the Non salt zone (Table 1). *Neosarmatium smithii* was the dominant species in Kangagani making up 15.0% of the total mangrove Crab Species identified. *Neosarmatium africanum* was the dominant species identified in Shengejuu and constituted 15.7% of the total mangrove Crab Species identified in this area. Only one crab species un identified *Cardisoma spp*. This was found in Kangagani but not found in Shengejuu study area

Table 4. 1: Crab Species Abundances in Salt and Non-Salt Pan area

Kangagani Study Site			**Shengejuu Study Site**		
Species	**Number**	**%**	**Species**	**Number**	**%**
Cardisoma. Carnifex	666	1.2	*Cardisoma carnifex*	416	1.13
Cardisoma. Spp	52	0.09	*Epixanthus*	846	2.30
Epixanthus deatatus	1906	3.28	*Metopograpsasmessor*	2542	6.92
Metopograpsus messor	4500	7.8	*Metopograpsua thukular*	3633	9.89
Metopograpsus thukular	4909	8.5	*Neosarmatium africunum*	5497	15.7
Neosarmatium africanum	7464	12.9	*Neosarmatium smithii*	4399	11.98

Neosarmatium smithii	8415	15.0	*Perisesarma guttatum*	5231	14.25
Perisesarma guttatum	1062	1.8	*Scylla serrata*	1744	4.75
Scylla. Serrata	3446	5.93	*Uca annulipes*	2486	6.77
Uca anulipes	5277	9.09	*Uca chorophthalmus*	3464	9.43
Uca. Chorophthalmus	6976	12.01	*Uca inersa inversa*	2945	8.02
Uca inversa inversa	5568	9.6	*Uca tetragonom*	1514	4.31
Uca tetragonom	3407	5.9	*Uca urvillei*	1914	5.21
Uca urvillei	4429	5.6			
Total	***58077***	***100***	***Total***	***36701***	***100***

Kangagani has large numbers of mangrove crabs compared to Shengejuu area in the Non salt pan areas **(Table 4.1),** though, the areas where data collection took place were of equivalent sizes. The large numbers of Crab species in Kangagani could therefore be attributed to the nature of the forest, the nature of the area itself and the role played by the various environmental parameters.

The species diversity index (H') in Mangroves (Non Salt Pan Zone) was 2.42for Kangagani and 2.40 for Shengejuu. The slight differences in species diversity between the two mangroves forests found during the study could be attributed to the presence of almost homogeneous physico-chemical parameters that determine the distribution of mangrove trees worldwide. Thus, the corresponding physical conditions (e.g. soil type) between the two forests may contribute to reducing the diversification of mangrove species in the study sites. It has been observed that, large areas of Kangagani mangrove forest have been covered with sandy soil and silt like that of Shengejuu hence the species that are able to survive in Shengejuu can also exist in Kangagani mangrove ecosystem.

In term of seasons (Rainy and Dry seasons), the results showed that, species diversity index (H') during the rainy season for Kangagani was 2.44 and was 1.98 during the dry season. In the study areas of Shengejuu the species diversity index (Hô) was 2.41 during the rainy season and 1.99 during the dry season. Statistical tests(two tailed test showed significant difference in mangrove Crab species diversity between the two seasons (Rainy and Dry seasons) of Kangagani and Shengejuu villages (P = 0.0001, t=37.4 DF=4 and P= 0.0092, t =4.7 DF=4) respectively. These results demonstrated that, most species were present during the rainy seasons than the dry season (Figure 2).

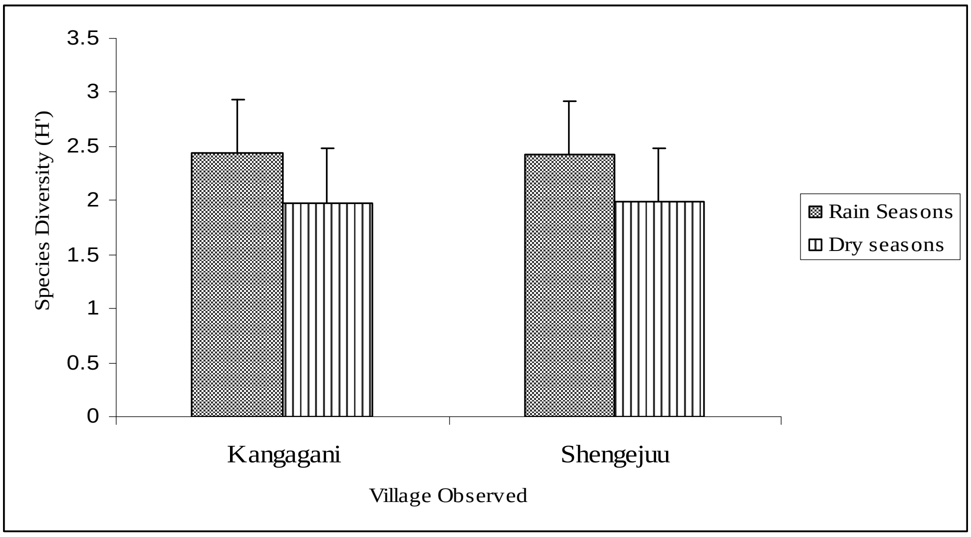


Figure 4. 1: Crab species diversity between seasons observed at the study sites

In the Salt Pan Zones, however, only four (4) Crab species were found in both Kangagani and Shengejuu (Table 4.2). The results indicate that, *Uca chorophthalmus Cardisoma carnifex, Uca annualipes* and *Scylla serrata* were present in the two areas of saltpans but also in the non-salt pans.

Table 4. 2: Crabs species abundance in Salt Pan Zones

	Kangagani		**Shengejuu**	
Species	**Number**	**%**	**Number**	**%**
Uca . chorophthalmus	1742	49.2	1811	50.0
Uca . annualipes	407	11.5	452	12.5
Cardisoma carnifex	1092	30.8	1071	29.5
Scylla serrata	302	8.5	291	8.03
Total	**3543**	**100**	**3625**	**100**

The study results indicate that *Uca chorophthlmus* was the dominant crab species at the study sites at Kangagani and Shengejuu, representing 49.2% and 50.0% respectively of all crabs species found. In the salt pan zones the study results showed that, Kangagani has large numbers of mangrove crabs than Shengejuu (Table 4.2). The species diversity index (Hô) in the Salt Pan areas was 1.17 for Kangagani and 1.17 for Shengejuu. Analysis done vis-à-vis the seasons, Rainy and Dry seasons, revealed statistically significant difference of species between the two seasons at the Kangagani and Shengejuu Salt Pan study sites (two tailed test P = 0.0016, t=7.333

df=4 and P = 0.0149, t=4.097 df=4) respectively. These results indicate that the species diversity and density were more pronounced in the rainy season than the dry season (Figure 4.2)

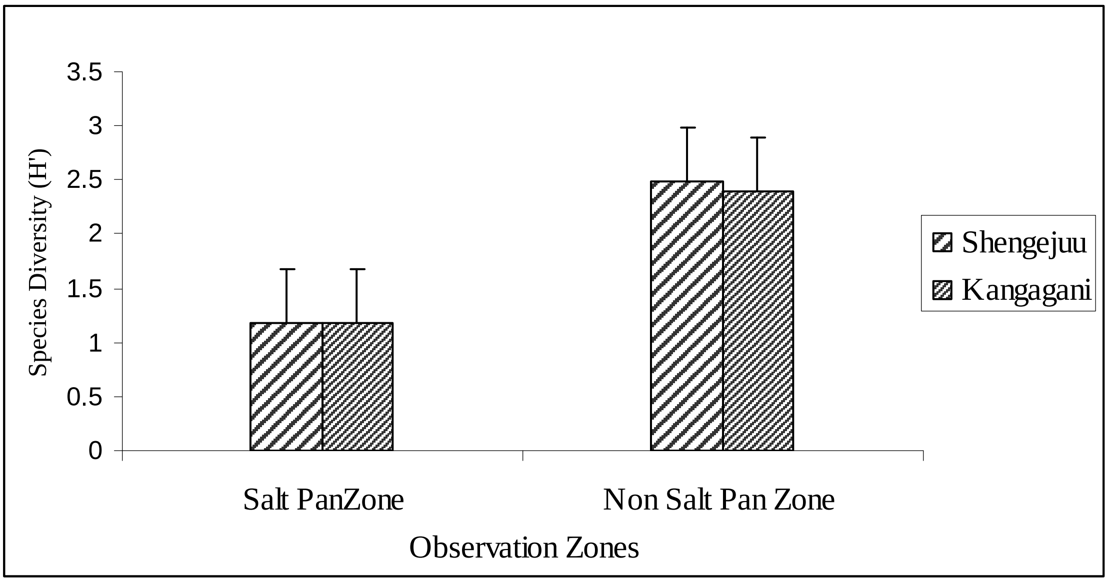


Figure 4. 2: Crab Species diversity between Salt and Non salt Pan Zones

The study results revealed that Kangagani has more crab diversity in the Non Salt Pan zone compared to the Salt pan areas. The species diversity index (Hô) was 2.48 and 1.17 for Non Salt and Salt Pan Zones respectively. At the Shengejuu study site the species diversity index (Hô) were 2.40 and 1.17 for the Non Salt and Salt Pan zones respectively (Figure 4.3). There was statistically significant difference between the crab diversity in Kangagani Non salt and Salt Pan Zones (P = 0.0001, t=16.78 df =10) as well as in the Shengejuu sites (P = 0.0350, t=2.318, df=15).

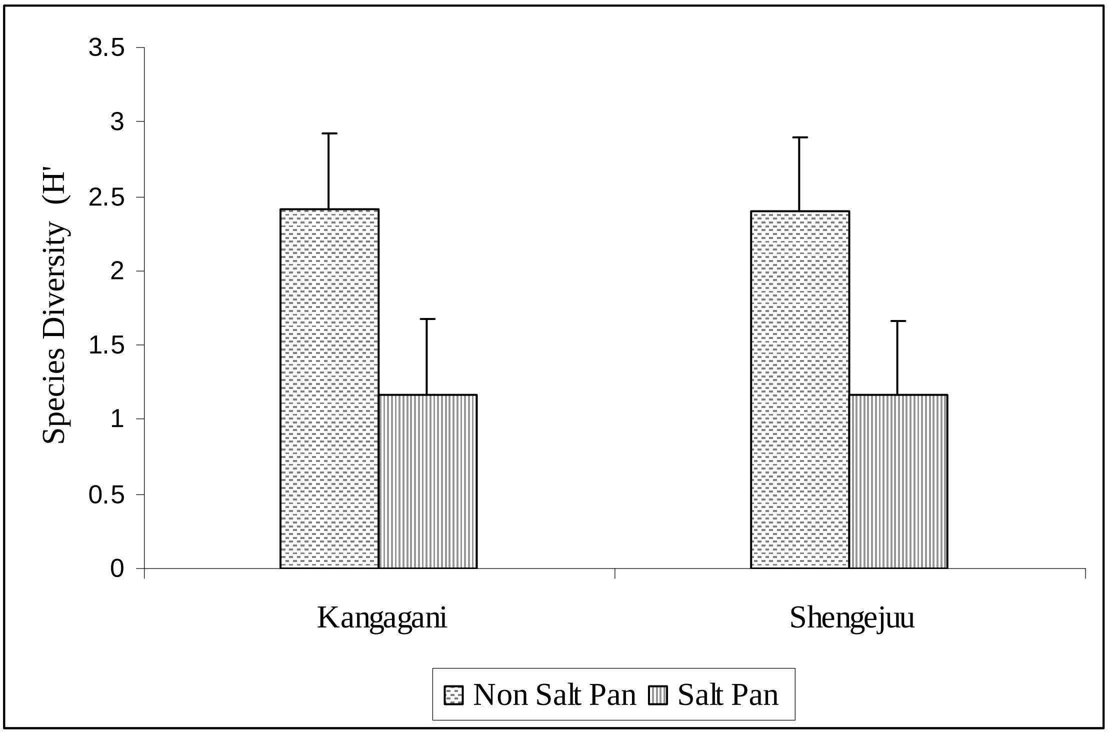


Figure 4. 3: Species diversity in zonation

4.2 Mangrove Species Diversity

A total of Seven (7) mangroves plant species were identified in the Non salt Pan Zones of both Shengejuu and Kangagani study areas during the wet and dry seasons. These are *Avicenia marina, Pemphis acidula, Rhizophora mucronata, Ceriops tagal, Lumnizera racemosa, Brugeira gymnorrhiza and Xylocarpus granatum.* All seven species were present at the Kangagani study site while four (4) species were observed at the Shengejuu study site. The four (4) species observed at Shengejuu are: *A. marina, C. tagal, R.mucronata and B.gymnorrhiza* (Table 3).*C. tagal* was the dominant mangrove species observed at the Shengejuu study site and constituted 49.59% of the total mangrove species observed. On the other hand, the dominant mangrove species observed at the Kangagani study site was *A. marina* which made up 52.99% of the total species observed.

Table 4. 3: Mangrove species abundance

Mangroves Species	**Kangagani**		**Shengejuu**		
Mangrove	**Number**	**%**	**Mangrove**	**Number**	**%**
Avicenia marina	111070	52.99	*Avicenia marina*	40433	41.89
Pemphis acidula	35	0.016	*Ceriops tagal,*	47857	49.59
Ceriops tagal,	97420	46.48	*Rhizophora mucronata,*	7559	7.83
Rhizophora mucronata	443	0.211	*Brugeira gymnorrhiza*	652	0.675
Lumnizera racemosa	126	0.060	X	x	x
Bruguiera gymnorrhiza	451	0.215	X	x	x
Xylocarpus granatum	47	0.022	X	x	x
Total	**209592**	**100**		**96501**	**100**

The Non salt pan zone of the Kangagani study site has higher numbers of identified mangroves species compared to Shengejuu study site. More mangrove species in terms of numbers were observed during the rainy season than during the dry season in the Kangagani study site with 57122 and15247 numbers of plants (seedlings, saplings or young trees) in the rainy and dry seasons respectively (Figure 4.4)

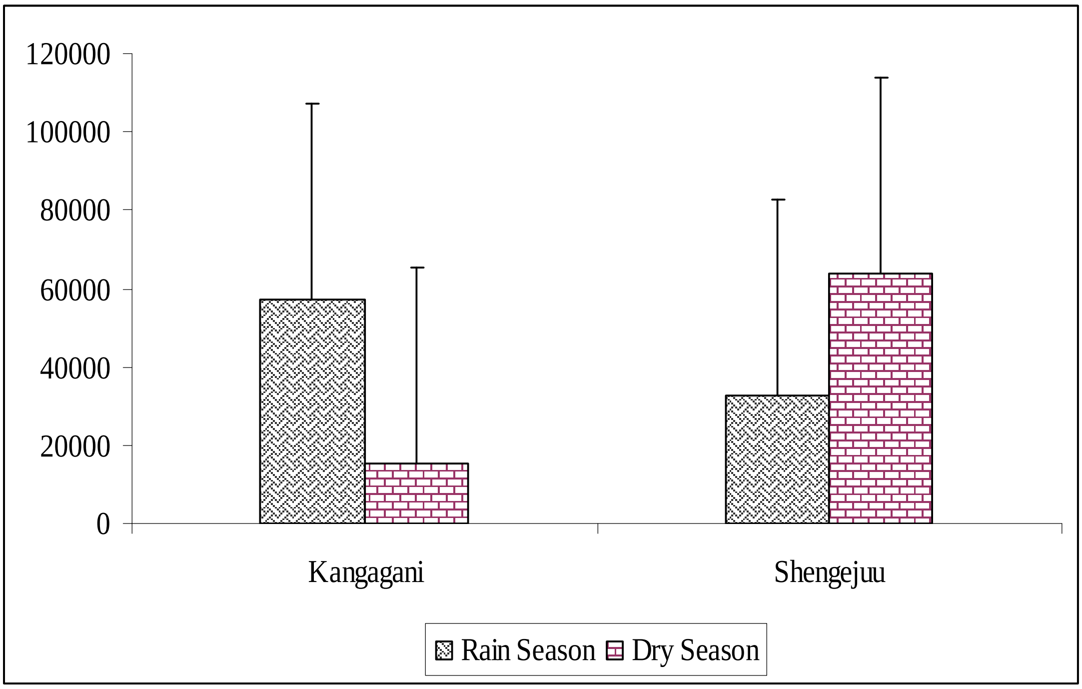


Figure 4. 4: Average numbers of species observed during the Rainy and Dry seasons at the two study sites

Things were different at Shengejuu study sites where 32469 plants were observed during the rainy season and 64032 plants were observed during the dry season (Figure 12). In the Salt Pan Zones of both Study sites, only one mangrove species identified during the Rainy and Dry seasons. This was *A. marina* which was recorded 1986 times (number of trees) at the Shengejuu site. 859recordings were made during the rainy seasons and 1127 recordings during the dry season. At the Kangagani study site, *A. marina* was recorded 624times (number of trees) of which 446 were recorded during the rainy season and 178 recorded during the dry season (Figure 4.5).

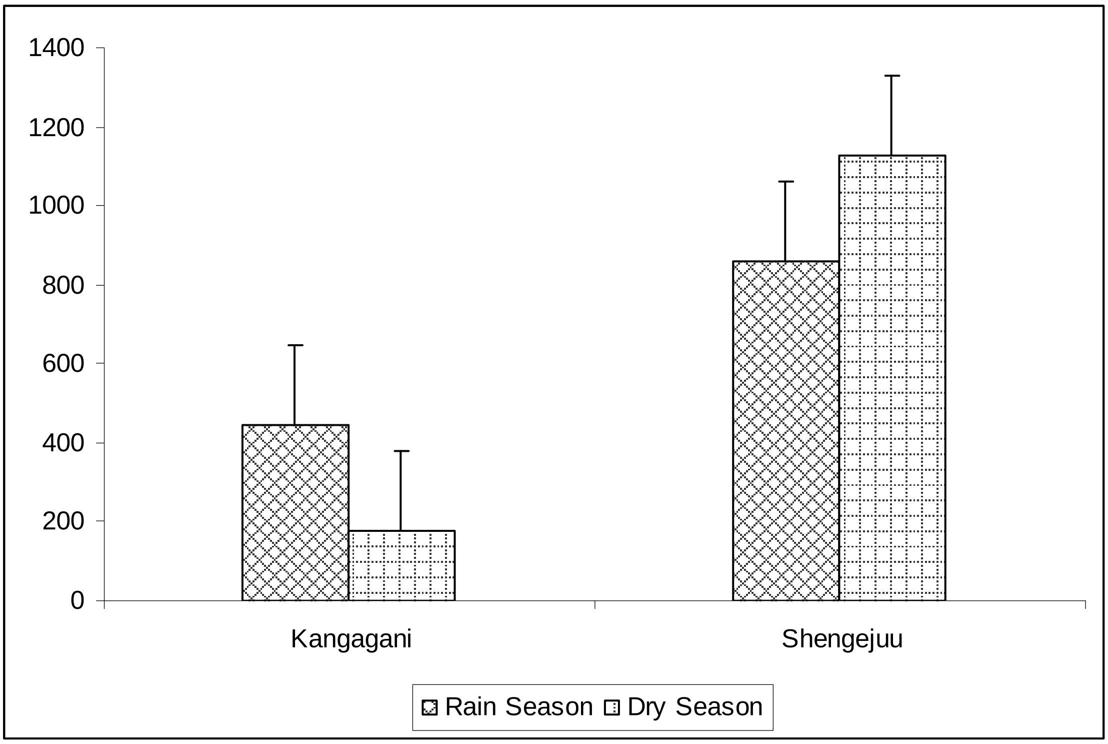


Figure 4. 5: Number of A. marina plants counted at the Study areas

The species diversity index (Hô) in the Non Salt Pan areas was 0.727 for Kangagani and 0.929 for Shengejuu. Analysis carried out for the Salt Pan areas during with values obtained during the Rainy and Dry seasons showed no statistically significant difference for the Kangagani and Shengejuu study sites (two tailed test P = 0.690, t=0.460 df=2 and P = 0.1049, t=2.847 df=2) respectively.

On the other hand the correlation analysis was done between salinity and mangroves abundance at Kangagani site, the results indicated that, there was no correlation between temperature and mangroves abundance where (p ˛ 0.7486, r = -0.1357 and p

0.1374, r = -0.3641) salt and non-salt pan respectively. On contrary at Shengejuu site the results indicated that there was no correlation between salinity and mangroves abundance where (p ˛ 0.1224, r = -0.8776) in salt pan , but in non-salt pan the results indicated that there was significant correlation where (p ’ 0.0152, r = -0.7361).

Also the correlation was done between pH value and Mangroves abundance at Kangagani site, the results showed that statistically there was no correlation relation between pH value and mangrove abundance where (p ˛ 0.8487, r = 0.08948 and p ˛ 0.8487, r = 0.08948) in salt and non- salt pan respectively. At Shengejuu site the results the results indicated that statistically there was no correlation relation between pH value and mangrove abundance in the Salt and non-salt pan where (p ˛ 0.1860, r = 0.5205 and p ˛ 0.1860, r = 0.5205) respectively.

Correlation analysis also was done between temperature and mangroves abundance At Shengejuu study site, the results showed that there was significant correlation relation between temperature and mangroves where (p ’ 0.0119, r = -0.6293 and p ’ 0.0119, r = -0.6293) in salt and non-salt pan respectively. Also at Kangagani study site the correlation analysis was done and the results showed that statistically there was correlation relation between temperature and mangrove abundance where (p ˛ 0.0332, r = -0.5512 and p ’ 0.0233, r = -0.4611) salt and non-salt pan respectively.

4.3 Mangrove regeneration numbers

Plant regeneration is the progression whereby seedlings become mature/adult plants that can contribute to conserving the important gene pool of that particular species.

Mangrove seedlings refer to individuals shorter than one meter. A total of 277 and 272 individual seedlings/ha were counted in Kangagani and Shengejuu respectively in the Salt Pan Zones the seedling were counted by placing the quadrant in a different sites, the quadrant were paced for every 5 meters. The study further revealed that, Kangagani study site has higher regeneration numbers compared to Shengejuu. This finding is statistically significant ($X^2 = 301.1$, df = 2, P= 0.0001, $p < 0.05$). The greater regeneration could be due to the disturbances of mangroves forest through utilization of mangrove trees along Shengejuu that affect mangrove species density which are the foundation of new seedlings. Apart from that, degradation of the environment caused by local people residing in and around the Shengejuu area could also contribute to the low regeneration numbers (Plate 4.1)

Plate 5. 1: Destruction of Mangroves by fire

In terms of seasons the Salt Pan Zone, in Shengejuu 18 mangrove seedlings were counted during the Rainy season. This represented 1.87% of total plants encountered. There were 254 mangrove seedlings counted during the Dry season which represented 22.46% of total plants observed during this period. At the Kangagani sites, the mangrove seedlings counted were 202 (48.8%) and 75 (24.58%) for Rainy and dry seasons, respectively. The results show Kangagani having the higher seedling numbers in the rainy seasons as opposed to the dry season unlike Shengejuu where the higher seedling numbers was observed in the dry season compared to the rainy season (Figure 4.6). This observation could be due to the fact that more destruction of mangroves occurred during the dry season for salt pan maintenance (cutting poles for supporting pan walls and also villagers cutting fuel wood saving for rainy season) which left mangroves not intact during the rainy seasons in Shengejuu. But in Kangagani the higher seedling numbers in rainy season could be due to the fact that most of the salt pan wall was destroyed by rain water from the river, which come with more seedling from sea water as a result most of them germinated. On the other side less intact mangroves, favorable conditions such as light, temperatures, nutrients, water provide great chance most seedlings to regenerate and cover the destructed areas.

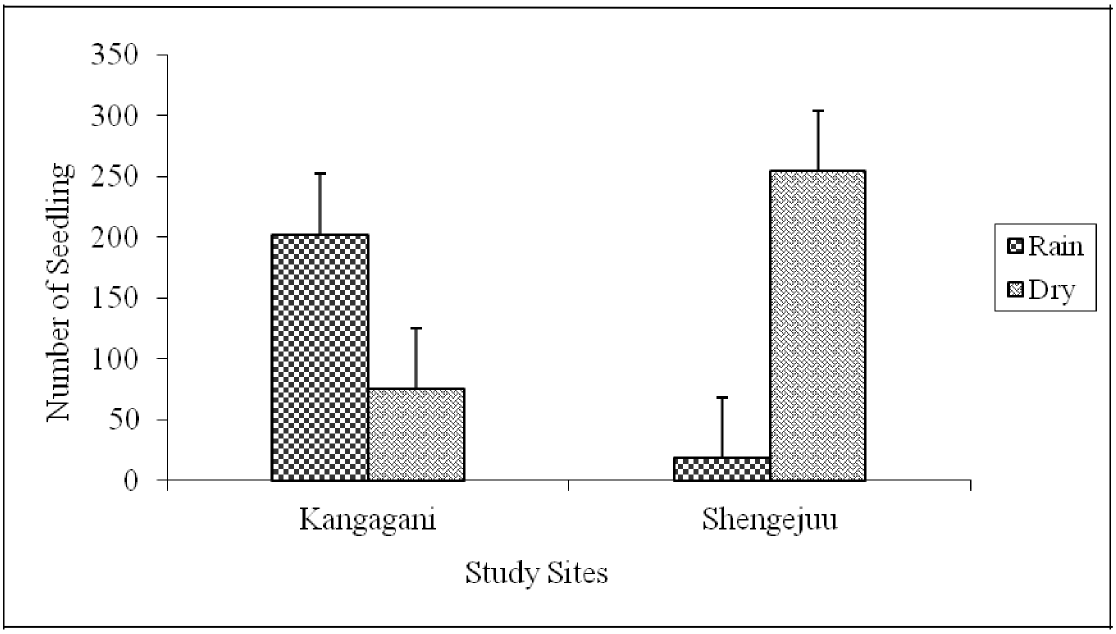


Figure 4. 6: Seedling numbers counted during the dry and rainy seasons

In general the results implies that the dry seasons had higher regeneration (more seedlings) compared to the rain season in Shengejuu study site but different in Kangagani study site. The situation could be explained by the presence of large numbers of mangrove species having high regeneration. Also during the rainy season, the rain water lower physico-chemical parameters like salinity, pH, temperature as well as humidity in the favorable conditions, but according to field data temperature was much higher in the rainy season than the dry season (Figures 9 ï 11) as a result limit some of the species to regenerate such as *A marina*. The statistical test showed that there was a significant difference in regeneration number in mangrove seedlings in Shengejuu between the rain and dry season (One tailed test p= 0.0080, t=4.906 DF=4). The same as Kangagani the statistical results revealed the significance differences between dry seasons and rain seasons of the mangroves regeneration forest (p= 0.0221, t=3.633 DF=4).The study results revealed a higher mangrove regeneration number in the Non Salt Pan Zones than the Salt Pan Zones. There were 55,869 and 21,151 mangroves seedling observed in Kangagani and Shengejuu Non-salt pan zones respectively and 277 and 272 mangrove seedlings observed in Kangagani and Shengejuu Salt Pan Zones respectively. (Figure 4.7).

Statistical analysis revealed that there was significant differences in the mangroves regeneration numbers between Salt Pan and Non Salt Pan zone in the Kangagani and Shengejuu mangroves forest ($P = 0.0001$, $t = 1$, $df = 131.9$: $P < 0.05$).

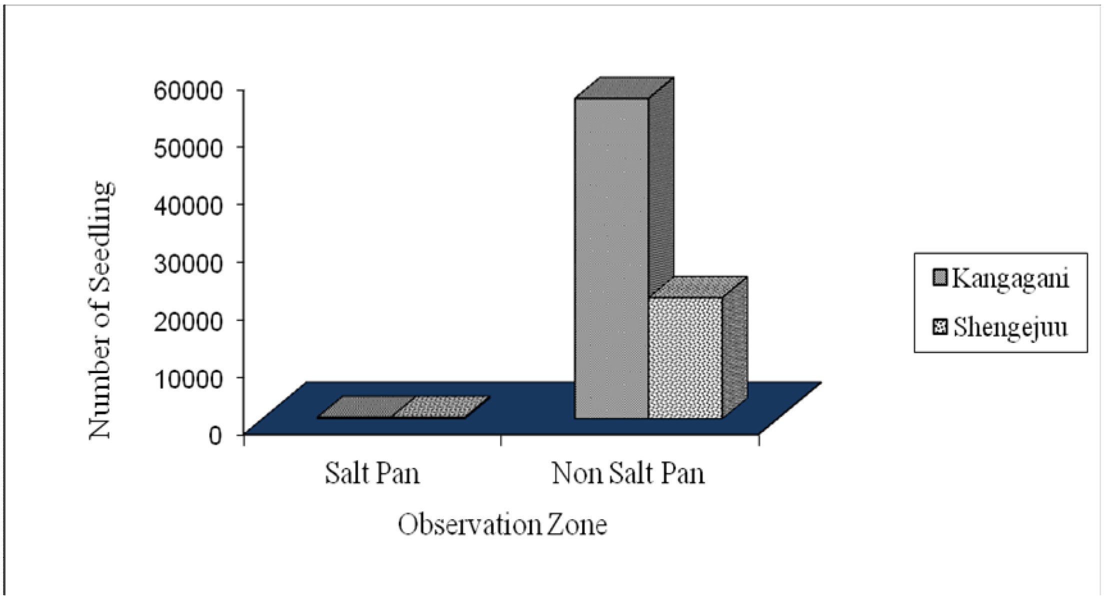


Figure 4. 7: Regeneration number of mangroves in the study site zones

In Non-Salt Pan Zone there were 17,941 seedlings counted during the rainy season in Shengejuu mangroves forest and 37,928 seedlings in the dry season. On the other hand 9,594 seedlings and 11,558 seedlings were observed in Kangagani in the rain and dry seasons respectively. Statistically, the results revealed that there was a significant difference in the regeneration numbers of mangroves between rainy season and dry season in Kangagani and Shengejuu mangroves forests (P=0.0001, t = 1, df1171: P < 0.05

4.4 Environmental Parameters Contributing to Depletion of Crabs

Generally, mangrove crabsô multiplication is influenced by factors such as salinity, types of seedlings, predators, shade, tidal inundation, temperature as well as anthropogenic activities by the local community members living around the coast. The situation may affect natural habitat as well as environmental conditions that are important in supporting proper growth and development of mangrove crabs *Zoea* and *Megalopa* (Fukuyama, 1997).

4.5 Pysico-chemical parameters

Climate change intimidate mangroves through increases in sea level, temperature and salinity, low pH value, changes in precipitation patterns and frequency of storms at the land-sea margins (Kochey; 2008). This leads to their moving further landward so as to have the most favorable habitat condition. Disturbances by human beings at the landward margin, though, could make this landward displacement of Mangroves impossible and as a result, the width of mangrove systems would likely decrease as the sea-level rises. This will significantly affect mangroves and in the face of impending global climate change, the danger of biodiversity reduction is today a reality. Physico-chemical parameters are among the most important factors affecting mangrove ecosystem. There were five physico-chemical variables examined in this study: salinity, temperature, pH, Relative humidity and rainfall. These parameters play a crucial role in the distribution and abundance of mangrove crabs. The physico-chemical parameters examined during the study at the study sites were not statistically different.

4.6 Salinity of Soil Water

Salinity has been identified as a key environmental variable affecting the allocation of marine organisms and influencing critical physiological processes. This is very essential since it represents an ecological master factor for marine organisms. Salinity is the result of local fresh water discharges in other areas like in the estuaries variations (Gibson, 1982).

In this study values obtained for salinity of soil water ranged from 1Be to 4.3Be and 2Be to 3Be for the rainy and dry seasons, respectively, in the Salt Pan Areas in Shengejuu study sites. The values were 1Be to 4Be and 2Be to 3Be for the rainy and dry seasons, respectively at the Kangagani study sites (Figure 4.8).

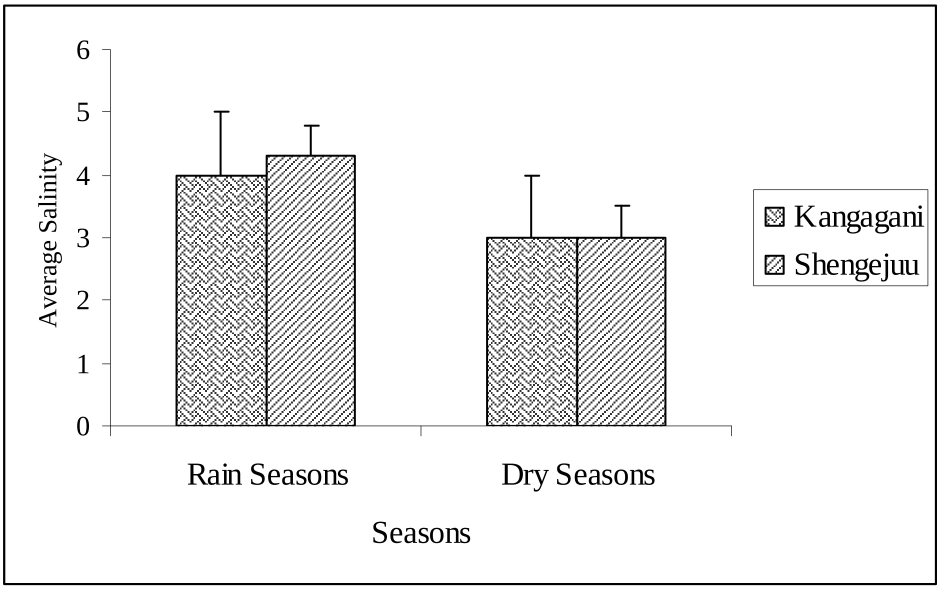


Figure 4. 8: Soil water salinity recorded within salt pans during the rainy and dry seasons of study period

Higher salinity was recorded at Kangagani during the dry season compared to the rainy season. The scenario was the same at the Shengejuu study sites where the higher salinity values were recorded during the dry season than during the rainy season in the Non Salt pan zone (Table 4.4).

Table 4. 4: Average Salinity values recorded at Salt Pan and Non-Salt Pan study sites

Study Site	Salt Pan Area		Non salt Pan area	
	Rainy Season	**Dry Season**	**Rainy season**	**Dry season**
Kangagani	1 Be - 4 Be	2 Be - 3 Be	1 Be - 9 Be	1 Be - 18 Be
Shengejuu	1Be - 4.3Be	2 Be - 3 Be	1 Be - 9 Be	1 Be- 10 Be

High salinity could be the result of high temperature with subsequent evaporation of sea water leading to increased salinity (Zingda et al., 1987). Statistical analysis however showed no significant difference in salinity values between Kangagani and Shengejuu study sites. Non- salt pan zone (One tail p=0.871 t=0.1829 DF=2); the Salt pan zone (p= 0.470, t =0.8835 DF=2). Salinity is the most important abiotic factor that determines the distribution and abundance of crabs along the coast. The Non Salt Pan zones had more numbers of mangroves plants than the Salt Pan zones. The presence of more crab species in the Non Salt Pan zones during the dry seasons than the rainy seasons could indicate crab species preference for habitats having high saline rather than low saline conditions.

On the other hand correlation analysis was done to determine if there is any relationship between salinity of the soil water and crab abundances in the salt and non-salt pan, the results revealed that at Kangagani site there was no correlation hence statistically showed that (two tailed p ˛ 0.4324, r = -0.2283 and p -0.2993, r = -0.7007) salt and non-salt pan respectively. Also the same results occurred at

Shengejuu site where (p =0.1211 r = 0.4519 and p = 0.2632, r = -0.7368) Salt and non-salt pan respectively.

4.7 Soil pH

Soil pH is the second most important abiotic factor that may influence many biological and chemical processes in natural waters (Saad, 1998). The Soil pH values recorded in non-salt Pan area ranged from 3 to 7 during the rainy seasons and 4 to 7 during the dry seasons for the Shengejuu study sites . Kangagani study sites had soil pH values of 3 to 7and 6 to 7 for the rainy and dry seasons, respectively (Table5). The high pH values were recorded during the dry seasons at both Shengejuu and Kangagani sites: 4 - 7 for Shengejuu and 6 ï 7 for Kangagani while the low pH values were recorded during the rainy seasons at both study sites (Figure 4.9)

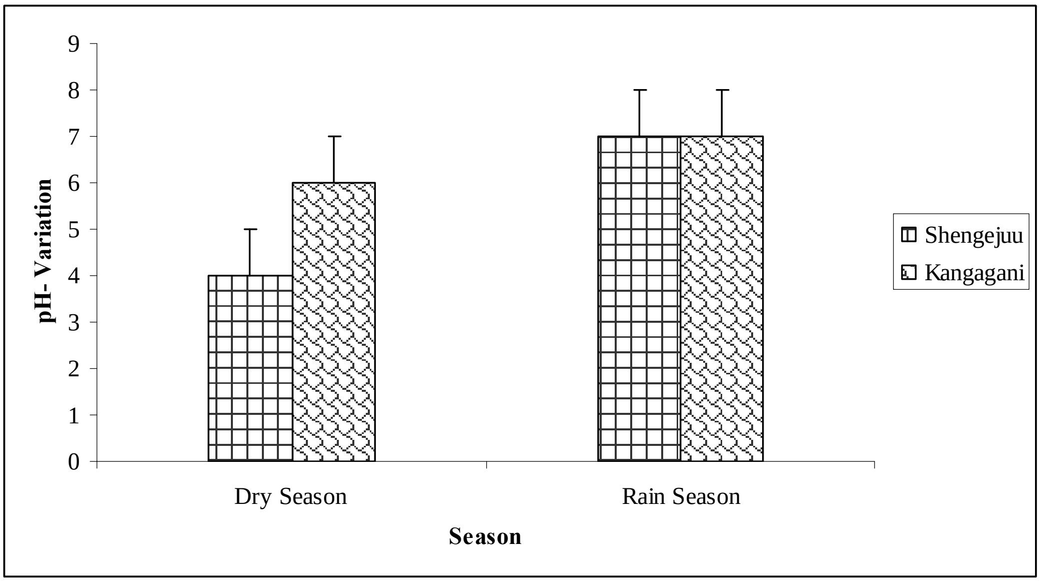


Figure 4. 9: Soil pH variation between the Seasons

The recorded differences in the pH values were not statistically different for the Kangagani and Shengejuu Non-salt pan areas (two tailed test P >0.6985 t = t=0.4472 df=2) and also for the Salt pan areas (p = 0.9999, t=0.0 DF=2).

Correlation analysis also was done to determine the influence of soil pH and crabs abundances at Kangagani site, the results indicated that statistically there was no correlation between crabs abundance and soil pH where (two tailed test p ˛ 0.1242, r = 0.4307 and p ˛ 0.9045, r = 0.03537) salt and non-salt pan respectively. Contrary at Shengejuu non-salt pan site showed that statistically there a correlation of crabs abundance and soil pH where (p ’ 0.0026, r = 0.7374) where in salt pan the results indicated that there is no correlation where (p ˛ 0.9760, r = 0.008870).

Table 4. 5: Soil pH values for Salt pan and Non Salt pan zones

Study sites	**Soil pH Values**			
	Non Salt pan Zone		**Salt Pan Zone**	
	Rainy Season	**Dry Season**	**Rainy season**	**Dry season**
Kangagani	3 - 7	6 - 7	3 - 7	4 - 7

Shengejuu	3 - 7	4 - 7	3 - 7	4 - 7

4.8 Water temperature

Water temperature also plays an essential role in the distribution and abundance of crabs in a particular area. The major observable consequence of incompatible temperature is the absence of certain species from that particular habitat (Choudhuryet al. 1984). Inappropriate temperature may affect growth rates, length of life, reproductive capacity as well as intra and inter specific competition. In fact, such effect may have some impact, directly or indirectly, on the distribution of mangrove crabs. In this study, the results indicated that in there corded water temperatures values for Shengejuu Non Salt pan zone ranged from 23.5ęC to 34.5ęC in the rainy season and from 21.5ęC to 33.5ęC in the dry season. At the Kangagani study sites the values recorded were from 23.5ęC to 34.5ęC in the rainy season and from 21ęC to 34ęC in the dry season (Figure 4.10)

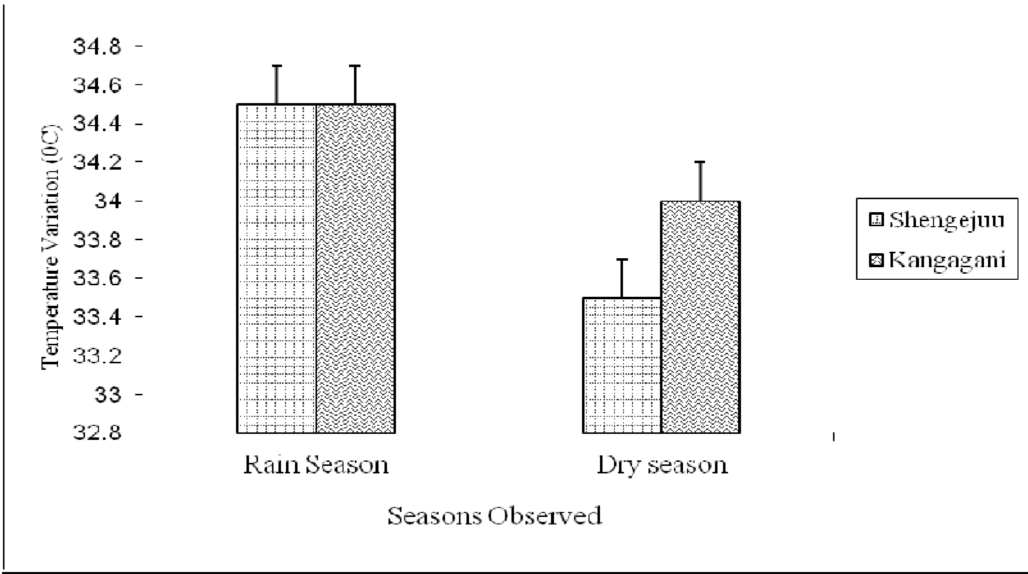


Figure 4. 10: Variation of temperature in Non-Salt Pan areas

The highest temperature recorded in the Non Salt pan zone was 34.5ęC and the lowest temperature was 21ęC. These values are for both study sites at Kangagani and Shengejuu. The highest temperature recorded at both Shengejuu and Kangagani non salt pan zone sites could be explained by the free open space where local community members were observed utilizing mangrove trees for poles, construction salt pans, fuel wood, aquaculture, lime and charcoal making. These activities are major threats to the mangrove community. Generally, surface water temperature is influenced by the intensity of solar radiation, evaporation and fresh water influx.

The results obtained at both study sites showed that the rainy season revealed slightly much higher temperatures than the dry season, these differences it may be one among the impact of salt production in Pemba that cause temperature fluctuation even during rainy season. In relation to the distribution and abundance of crabs, the large numbers of crabs were observed during the dry season when relatively low temperatures were recorded.

The results obtained at the Salt Pan Zone showed the temperature recorded in Shengejuu study site ranging from 27ęC to 44.5ęC in the rainy season and 21ęC to 34.5ęC for the dry season. At the Kangagani study site the water temperature recorded ranged from 27ęC to 44.3ęC in the rainy season and 21ęC to 34.5ęC in the dry season. The highest temperature recorded in Kangagani was 44.3ęC in the rainy season and the lowest temperature was 21ęC in the dry season while the highest temperature recorded at the Shengejuu study site was 44.5ęC in the rainy season and the lowest temperature was 21ęC in the dry season (Figure 4.11)

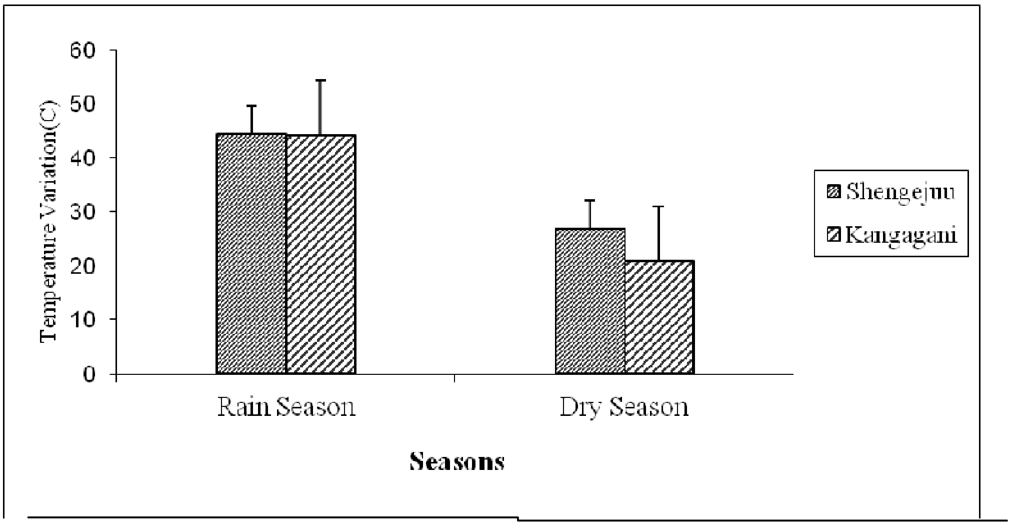


Figure 4. 11: Variation of temperature at Salt Pan Zones

Statistical analysis indicated that there was no significant difference in temperature variation between Kangagani and Shengejuu Non- Salt Pan zones (P =0.698, t = 0.447, df =2). Similarly there was no significant difference between Kangagani and Shengeju Salt Pan Study site Zones (P=0989, t =0.989, df =2).

The presence of large numbers of crabs in the dry season could be explained by the presence of low temperature that reduces water loss or desiccation of macro fauna. Extremely high or low temperature may have negative effect like mortality, low numbers of hatching, desiccation and under severe conditions animals can migrate from one habitat to another. Therefore moderate temperature plays an important role for the proper growth and development of crabs. Steele (1991) reported that no eggs hatched at 5ęC and 15ęC and also no eggs hatched above 35ęC. However all eggs that was kept between 20ęC and 30ęC hatched. These findings justify the influence of temperature on the distribution of Crabs.

Generally, study results indicated that the water temperature recorded in Kangagani Non Salt Pan zone and Salt Pan Zone in the rainy and dry seasons ranges from 21ęC to 34.5ęC and 27ęC to 44. 3ęC respectively, the temperature recorded in Shengejuu ranges from (23.5ęC to 34.5ęC and 27ęC to 44.5ęC) Non Salt Pan and Salt Pan Zones respectively (Figure 4.12).

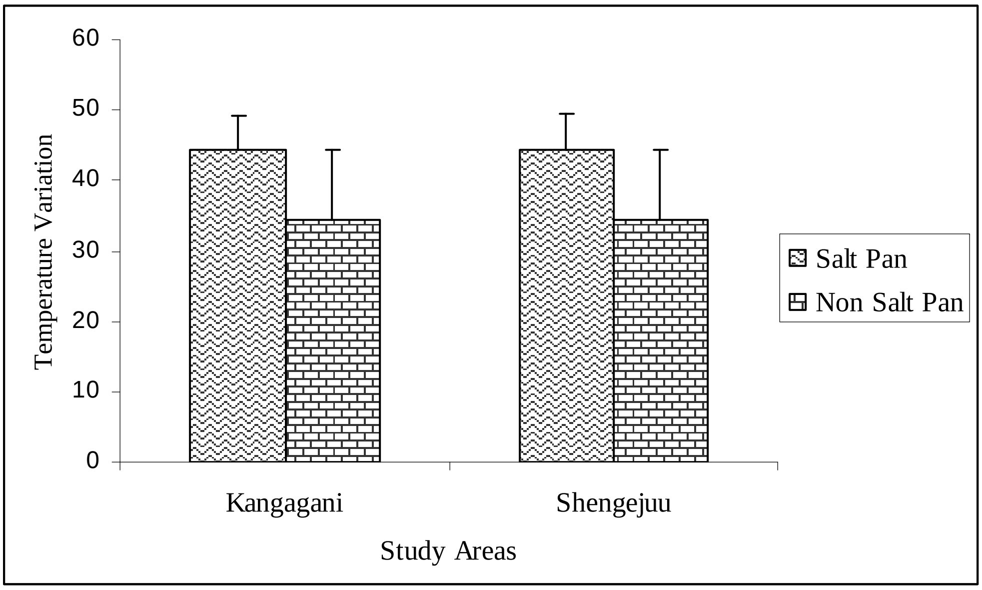


Figure 4. 12: Temperature variations in Study sites

Statistical analysis the results of this study observed that there is no significant differences between the temperatures recorded at the Shengejuu and Kangagani study sites at both the Non salt and Salt Pan Zones ($p = 0.98$, $t = 0.014$, $df = 2$: $P < 0.05$).

In spite of the absence of statistically significant difference in the variation of the physico-chemical parameters between the study areas great variation in crabs distribution and abundance was observed between Kangagani and Shengejuu study sites. Other factors could possibly be contributing to the lower distribution of Crabs observed at Shengejuu rather than the environmental factors. It is likely that low distribution of crabs at Shengejuu mangrove forest may be due to the clearing of mangroves plants for different purposes like poles, fuel wood, and charcoal.

On the side of correlation analysis, the results indicated that statistically there was no correlation between crabs abundance and water temperature in non-salt pan area at Kangangani where (two tailed test p ˛ 0.5587, r = 0.1711). But in salt pan area there was correlation between temperature and crabs abundance where (p ’ 0.0016, r = -0.5971). Also at Shengejuu the results indicated that statistically there was no correlation between temperature and crabs abundance in non- salt pan where (p ˛ 0.5729, r = 0.1726). Contrary to the salt pan area the results showed the correlation between temperature and crabs abundance where (p’ 0.0010, r = -0.6170).

4.9 Relative Humidity

Relative Humidity plays a vital role in the distribution and abundance of crabs in a particular area. This is the ratio of the partial pressure of water vapor to the equilibrium vapor pressure of water at the same temperature. Relative humidity depends on temperature and the pressure of the system of interest (Choudhury et al., 1984). Along with the proper temperature, adequate humidity in the tank is vitally important to crabs. Since crabs "breathe" via gills, the proper exchange of oxygen by the crabs depends on the humidity in the air, so if the tank air is too dry the crabs will essentially suffocate. They need a relative humidity of around 70-80% and since this is so important to the crabs, air that is too dry will actually dry out their gills, making it increasingly difficult to breathe and finally suffocating (Pearson 2007)

The numbers of water loss from the sub tidal crab *Portunus marmoreus* and the shore crab *Carcinus maenas* is influenced by relative humidity. Unsuitable temperature and Relative Humidity may affect reproductive and growth capacity of the crabs. Relative humidity may have some impact on the distribution of mangrove crabs. Relative humidity values recorded at the Shengejuu Non Salt Pan zone ranged from 66% to 94% in the rainy seasons and 73% to 81% in the dry seasons. The values recorded at the Kangagani site was from 66% to 94% in the rainy seasons and 72% to 81% in the dry season (Figure 4.13).

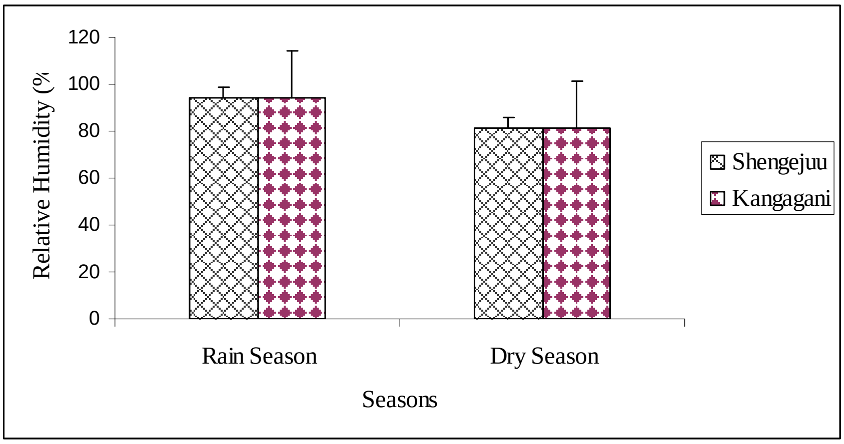


Figure 4. 13: Variation of Relative Humidity according to the Seasons

Statistically the results of this study revealed no significant differences between the relative humidity recorded at the Kangagani and Shengejuu study sites in the Rainy and Dry seasons ($P = 0.999$, $t = 0.0$, $df = 2$).

The highest relative humidity value recorded at the Shengejuu study site was 94% in the rainy season and the lowest was 42% in the dry season. The highest relative humidity value recorded at Kangagani study site was 94% in the rainy seasons and the lowest was 46% in the dry season. More crabs were observed during the rainy seasons than the dry season indicating that the relative humidity was adequate for the growth and survival of the crabs. There was no statistically significant differences between the relative humidity at the Kangagani and Shengejuu Non salt Pan and Salt Pan Zones (P= 0.837, t = 0.232, df = 2) implying that the study sites at the two localities had similar Relative Humidity. On the other sideôs it shows that differences of relative humidity might cause differences number of crabs between study sites and different seasons (rainy and dry).

Also correlation analysis was done to determine if there is positive correlation between humidity and crabs in both study sites, the results indicated that there is positive correlation between crabs and humidity at Kangagani where (p <0.0001, r =-0.7474). Whereas Shengejuu the study indicated the positive correlation where (p ’ 0.0001, r = -0.8338).

4.10 Rainfall

Rainfall plays an important role in the distribution and abundance of crabs in a particular area. Heavy rains periods can lead to flooding in some estuaries (mainly on coastal lagoons), and thus, affect interactions between species. It is true that a lot of rain push crabs out of creeks (Albert *et al*., 2007).

The total average rainfall recorded during this study at the Shengejuu Non Salt Pan zone was 220.93mmduring the rainy season and 24.26mm during the dry season. The values for the Kangagani sites were 194.13mm in the rainy season and 19.53mm in the dry season (Figure 4.14). The maximum rainfall recorded at the Shengejuu site 286.2mmwas during the month of May while the minimum rainfall recorded was

15mm during the month of June. The maximum rainfall recorded at the Kangagani site was 279mm in May and the minimum rainfall recorded, 11mm, was in June.

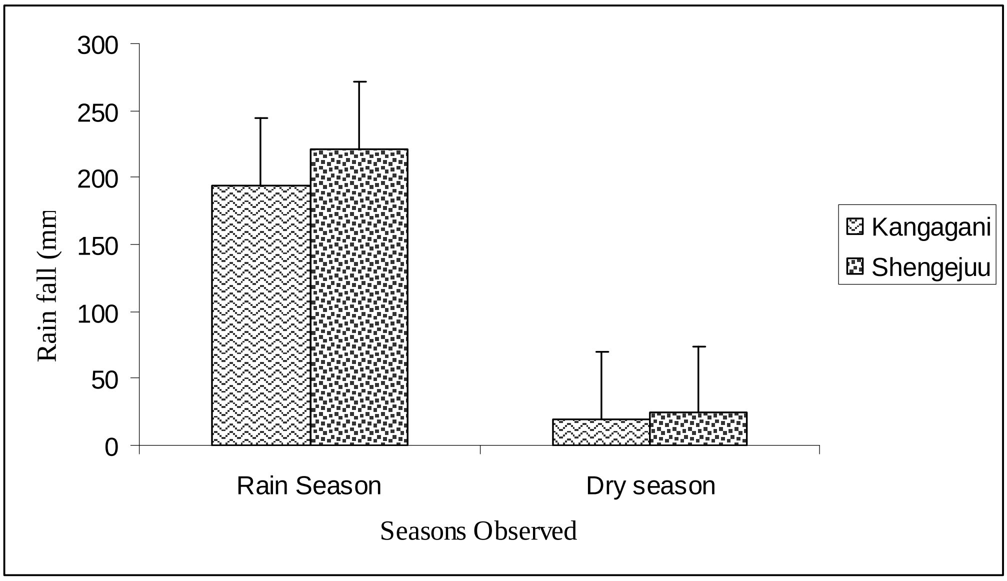


Figure 4. 14: Rainfall variation between Seasons

Statistical analysis done in this study showed no significant differences in the rainfall parameter at the Non salt pan sites at Kangagani and Shengejuu in the rainy and dry seasons (P=0.131, t=1.89 df=4) implying similar amounts of rainfall in the Non Salt Pan study areas On the other hand the amount of rainfall recorded in the Salt Pan Zone at Kangagani averaged 205.2mm in the rainy season and 21.8mm in the dry season. The recorded rainfall values for the Shengejuu sites averaged 210.23mm in the rainy season and 21.8m in the dry season (Figure 4.15). The maximum amount of rainfall recorded in the Shengejuu study site was 264.4mm during the month of May and the minimum amount of rainfall recorded was 16mm in June. The maximum amount of rainfall recorded for Kangaganiwas 272.7mm in May and the minimum amount recorded was 21.86mm in June

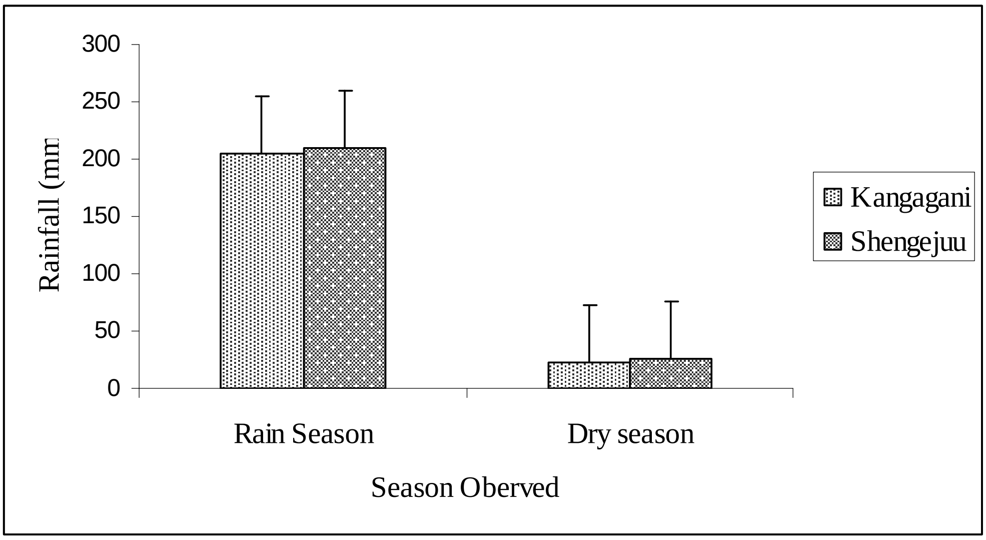


Figure 4. 15: Rainfall variations in the seasons

Statistical analysis of the results for the Non Salt Pan and Salt Pan Zones of both study sites at Kangagani and Shengejuu showed no significant differences in the amount of rainfall recorded during the dry and rainy seasons (P= 0.986, t = 0.019, df = 2,: P > 0.05). Hence there was 118.26mm and 113.56mm of rainfall in the Non Salt Pan Zones and 122.59mm and 109.19mm in the Salt Pan Zones at Kangagani and Shengejuu respectively (Figure 4.16).

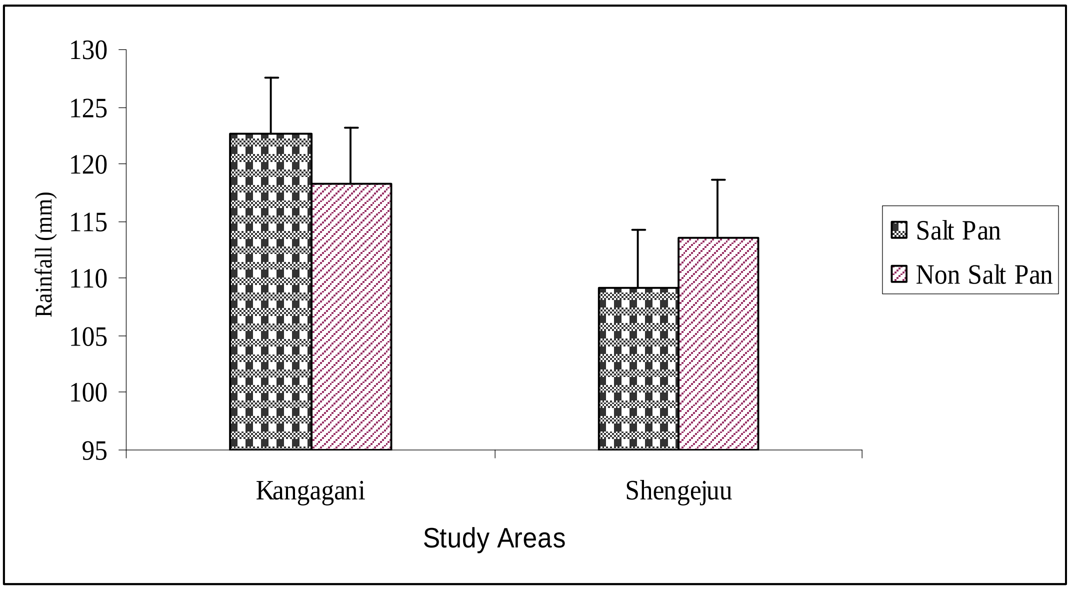


Figure 4. 16: Rainfall variation with respect to Zonation

Statistically no significant differences were observed on the amount of rainfall recorded at Kangagani and Shengejuu Saltpan and Non Salt Pan zones ($P = 0.983$, $t = 0.023$, $df = 2$: $P > 0.05$). This means that there was the same amount of rainfall in these two study sites.

CHAPTER FIVE

DISCUSSION OF FINDINGS

5.1 Mangrove Crab Species diversity in Salt and Non Salt Pan Zones.

A total of 14 mangrove Crab species were identified in Non-Salt Pan Zone while four (4) species of Crabs were observed and identified in the Salt Pan Zone at Kangagani and Shengejuu study sites. The presence of more crabs in the Non Salt Pan Zone could be the result of less anthropogenic influence in the area. These findings are in line with those of Kipyegon, (2008) who reported that few species (but high abundance of animals in each species) live in the salt marsh. However, species composition can fluctuate with the seasons. Generally, peak densities of marsh fauna occur in the spring or fall, with lowest species diversity occurring during the summer due to predation and competition (Colwell and Lees, 2000). Typically, biodiversity is low in the salt marsh and animal populations are usually selected specialized species (Teixeria,et al., 2006).

During this study, it was observed that *N. smithii* was the dominant species at the Kangagani site. This species accountedfor 15.0% of the total mangrove Crab species identified. At the Shengejuustudy site *N. africanum* was the dominant species making up 15.7% of the total mangrove Crab species identified. There was one crab species *Cardisoma spp*found at the Kangagani study site but not found at the Shengejuu study area.

Higher mangrove crabs diversity occurred in the Non Salt Pan zone compared to the Salt pan areas. The species diversity index (Hô) was 2.48 and 1.17 respectively for the Non- Salt Pan and Salt Pan Zones at the Kangagani study site. Hô was 2.40 and 1.17 respectively for the Non Salt Pan and Salt Pan Zones at the Shengejuu study sites. Statistical analysis showed significant differences in mangrove crab diversity for the Non Salt and Salt Pan zones at Kangagani and Shengejuu study sites respectively (P = 0.0001, t=16.78 DF=10) and (P = 0.0350, t=2.318 DF=15).

This could be the result of factors such as physical tolerance to temperature, salinity, oxygen, relative humidity and pH (Varadharajan et al., 2013) that determine the distribution of the crab species. It is probable that, there were other factor such as trophic mode, predators, social behavior, territoriality and association of species that could influence low presence of mangrove crab in the Salt Pan Zone. This low abundance was likely due to environmental disturbance in the Salt Pan Zone, like a contamination of toxic compounds from petroleum hydrocarbons as well as heavy metals, has been reported in other studies as influencing the distribution of macro benthos (Surugiu, 2005; , Pearson and Rosenberg, 2003; and Hatje et al.,2008) Elements, such as Arsenic; Lead ,Manganese and Zinc, that are mobile under acidic conditions can be toxic to flora and fauna. When released into water, Aluminium hydroxide can be damaging in the presence of an acid as it is toxic to crabs, hamper mangroves growth, damages root systems and affect natural ecosystems. Acid sulphate soils are unconsolidated estuarine mud and clay with gel -like and low load-bearing capacity, earth works activities may settle in the soil (Silva etal.1990; Tam and Wong, 2000)

5.2 Mangrove Regeneration

A total of 255 and 244 individual seedlings/ha were counted in Shengejuu and Kangagani, study sites, respectively. Statistical tests showed a significant difference in regeneration at the study sites with higher regeneration numbers of mangrove seedlings at Non Salt Pan zones at the Shengejuu and Kangagani study sites (X^2 = 301.1, df = 2, P = 0.0001, $p < 0.05$). These findings can be attributed to the greater disturbances of mangrove forest through utilization of mangrove trees at the study sites as this affect mangrove species density, the basis of new seedlings.. The findings of our study corroborates the findings of Hamad,et al., (2014), who explained that lower regeneration in one Study area could be attributed to the fact that the area was highly disturbed compared to the other area. Thus, in one area there was less competition for basic requirements such as light and air between the mangrove trees (species) that provide maximum opportunity for tree regeneration.

The results of our study showed higher mangrove regeneration numbers in the Non Salt Pan Zone than the Salt Pan Zone where 55,869 and 277 mangroves seedlings were respectively observed at the Kangagani study sites and 21,151 and 272 mangroves seedling were observed at the Non Salt Pan and Salt Pan areas at the Shengejuu study sites respectively. Statistical analysis showed significant difference in mangrove seedling counts between Salt Pan and Non Salt Pan zones with Kangagani having higher seedlings compared to Shengejuu sites. This situation can be explained by the disruption of mangroves at Kangagani site. Studies by Lewisand Streever, (2000) reported that regeneration or rehabilitation of mangroves is often recommended when the ecosystem has been degraded to such an extent that it cannot regenerate numbers naturally. However, the concept has not been analyzed or discussed much in mangrove and as a result, those managing mangrove restoration frequently emphasize planting of mangroves as the primary tool in restoration. Mangrove habitat can regenerate naturally in 15-30 years if the normal tidal hydrology is not disrupted (Spaldinget al., 2010). If the mangroves are disturbed, then, restoration may be successfully established by planting (Lewis, 2005).

5.3 Environmental Parameters contribute to depletion of Crabs.

The results of the study found that salinity of the soil water; water temperature, soil pH, rainfall and humidity are the physico-chemical parameters which affect crabsô presence and distribution at different areas. The average soil water salinity value at Shengejuu Salt Pan Study site ranged from 1Be to 4.3Be for the rainy season and 2Be to 3Be for the dry season. At the Kangagani Salt Pan Study site the salinity values recorded were between 1Be to 4Be for the rainy season and 2Be to 3Be for the dry season. At the Non Salt pan study sites, values obtained for the Shengejuu areas ranged from 1Be to 9Be for the rainy season and 1Be to 18Be for the dry season while the Kangagani area had values ranging from 1Be to 9Be and 1Be to 10Be for the rainy and dry seasons respectively.(Table 4) The results show changes in salinity ranges at the salt Pan Zone and Non- salt Pan Study sites due to seasonal variation from rainy to dry season and impact of solar salt production which degraded both salt pans and nearby non salt pans sites.

The changes in salinity affect the presence and distribution of crabs because of the different salinity requirements at the different stages of the crabôs life - juvenile and adult, male and female.

Adult male crabs live in the low-salinity waters upstream, while adult female crabs live in the higher-salinity waters near the mouth of the estuary (NOAA, 2008). The crabs mating from May to October and high-salinity preferences of the female overlaps with the lower salinity preference of the male, after mating, female crabs move offshore, sometimes up to 200 m, to high-salinity waters to incubate their eggs. The females release their larvae, called *zoeae* (first larval stage) during spring high tides.

Soil pH recorded at both study sites -.Non salt Pan and Salt Pan Zones-showed that the Salt Pan Zones of both study sites had higher pH values during the dry season than the rainy season. It means that the salt Pan Zoneȏs pH value during the rainy season was lower than in the dry season. This is due to the high influx of rain water from rainfall in the rainy season. In spite of this, statistical analysis showed no significant difference (p = 0.9999, t=0.0 DF=2).Similar result has been reported by Donahue (2014), who indicated that the average pH of mangrove area (Non - Salt Pan zones) varied from 6.6pH to 7 pH while the salt pan area had an average pH range of 6.8pH to 7pH. The average salinity levels were higher in the salt pan than in the non- salt pan zone which is most likely due to how the salt pans collect high amounts of rainfall during the rainy season while the Non- Salt Pan zones, though they too, collected lots of rain water, were still affected by tidal inundation which raised the Be values. The salt pans, in the rainy season recorded a lower pH values;, this is due to the fact that during rainfall seasons heavy metals like irons are eroded from the land to the salt pan mixing with carbonic acid from the rain to react to provide some sort of acid which lower pH.

The temperature recordings for the Non Salt pan zones ranged from 21°C to 34.5°C at both study sites and the Salt Pan Zones values were from 21°C to 44.3°C for both sites Shengejuu and Kangagani. Comparing the seasons this study found that the average temperature was higher during the rainy season than the dry season. From the stand point of zones the Salt Pan zone had a higher average temperature than the Non Salt Pan Zone at 44.3°C and 34.5°C respectively.

These results are similar to the study conducted by Donahue (2014Unpubl.) who indicated that Water temperatures were slightly cooler and fluctuated slightly within the non- salt pan than in the salt pan zones. The Non Salt Pan zone was a constantly changing environment during the duration of the study having experienced rainfall almost daily with tidal inundation, especially spring tides, and the changing of sun exposure caused by the cloud cover of the rainy season. Also, mangrove trees provide canopy cover, especially in densely populated mangrove forests. The lower water temperatures within the non- salt pan compared to salt pan areas was due to less light availability, which suppressed the ability of the sun to warm the ground water, unlike the entirely exposed salt pans where there was little or no tree coverage. Generally, the surface water temperature is influenced by the intensity of solar radiation, evaporation, freshwater influx and cooling and mixing up with ebb and flow from adjoining neurotic waters. The water temperature during December was low because of strong land sea breeze and precipitation and the recorded higher value during summer could be attributed to high solar radiation (Prabu et al. 2008). Temperature range is equally as important because if too high will cause irreversible heat damage, and too low temperatures will alter crabs metabolism (Dehnel, 2006)

The relative humidity recorded during this study ranged from 66% to 94% at the Salt Pan Zone and Non Salt Pan Zone at both study sites at Kangagani and Shengejuu. The averages for the relative humidity readings changed throughout the sites within 60% to 70%. The weather conditions were constantly changing from dry to rainy which caused the humidity to fluctuate quite frequently and sometimes more than 10% to 20% (Donahue2014).

The relative humidity increased during monsoon due to the cloud cover and heavy precipitation, which act like a blanket to restrict the water vapor near the earthûs surface. The high humidity throughout the year is considered as perfect for enhancing the establishment and growth of mangroves. The greater extent and maximum diversity of mangroves occurs in the humid tropical and sub-tropical regions between 28° N and 32°S, though they extend in the latitudinal belt of 32° N and 38°S (Walter, 1977).

The amount of rainfall received in the study areas Non-Salt Pan zones and Salt Pan Zones of Kangagani and Shengejuu were slightly different. The Non Salt Pan study site at Kangagani received 118.26mm of rainfall while the Salt Pan zone received 122.59mm. The rainfall values for Shengejuu study areas were 113.56mm for the Non Salt Pan area and 109.19mm for the Salt Pan Zone.

Various abiotic factors, such as annual rainfall, seasonal variations in rainfall, temperature extremes, wind exposure, soil type, soil texture, topography, pH, sunlight and availability of nutrients, influence the diversity, distribution and populations of species within the mangrove ecosystem (Satheeshkumar and Khan, 2009). Those factors initially suspected of being most influential upon mangroves are localized topography, which determines the frequency and duration of inundation by tidal waters (Srilatha et al., 2003)

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

This study based on crabs and mangroves species diversity in salt pan and non- salt pan areas on the eastern Wete district of Pemba, Zanzibar. Mangrove crabs are the organisms that play a significant role in the dynamics of the mangrove ecosystems in the world.

With regards to mangrove Crab Species diversity, different crabs were identified in both Salt Pan and Non- salt Pan Zones - located at Kangagani and Shengejuu study sites. The species diversity index (H') of the two mangrove forests was higher in the Non Salt Pan Zone (Mangroves community) than in the Salt Pan Zone whereby the diversity index (Hô) were 2.42 and 1.17 respectively. Further analysis to compare the seasons, Rainy and Dry seasons revealed statistically significant difference of species between seasons at both study sites (tailed test P = 0.0016, t=7.333 df=4 and P = 0.0149, t=4.097 df=4) where by species diversity and density were more pronounced in the rainy season than the dry season.

On mangrove regeneration, more seedlings were found at the Kangagani study sites than Shengejuu, with higher mangrove seedling numbers in the Non - Salt Pan Zone than that of the Salt Pan Zone: 38,510 and 2,774 seedling respectively. These differences could be attributed to the disturbances of mangroves community in Shengejuu which affects the mangroves because the light can penetrate easily in mangrove forest which allows germination of seedling hence leads to the greater seedling numbers. Also environmental degradation by users residing by the study areas such as excavation, digging, and cutting mangroves could be the cause of the low regeneration and hence low seedling numbers obtained during this study. Physico-chemical parameters of the study areas such as water temperature, salinity, soil pH, relative humidity and rainfall were found the contributing factors to depletion of Crabs availability. The water salinity results indicated that there was higher salinity in the Salt pan zone than the non- salt pan zone according to field dataôs and was changing due to the variation of seasons.

The average salinity levels were higher in the Salt Pan zone than in the non-salt pan which is most likely due to how the salt pans collect high amounts of rainfall during the rainy season thereby diluting the salt content of the area while the mangroves, though they, too, collected lots of rain water, were still affected by tidal inundation which raised the Be values thus increased salinity.

The pH of the Salt Pan Zones at both study sites at Kangagani and Shengejuu were higher due to high influx of rainfall. The average pH range was 6.8 to 7. Normally the salt pans during the rainy season had lower pH value due to the increasing of acidic caused by rain water which reacts with heavy metals from run- off. The Non Salt pan zone recorded temperature range from 21°C to 34.5°C at both study sites, while the Salt Pan Zone had temperature range of 21°C to 44.3°C.

The average temperature was higher during the rainy season than the dry season with the higher temperature in the Salt Pan Zone than in the Non Salt Pan Zone at 44.3°C to 34.5°C respectively. The lower water temperatures within the mangrove were due to less light availability which suppressed the ability of the sun to warm the ground water. Surface water temperature is influenced by the intensity of solar radiation, evaporation, freshwater influx and cooling and mixing up with ebb and flow from adjoining neurotic waters.

Relative humidity increases during the monsoon rain season due to cloud cover and heavy precipitation, which act like a blanket to restrict water vapor near the earthôs surface. The high humidity throughout the year is considered perfect for enhancing the establishment and growth of mangroves. The greater extent luxuriance and species richness of mangroves from the tropics can be used to explain the recorded values of 66% to 94% in the Salt Pan Zone and Non Salt Pan Zone at the study sites of Kangagani and Shengejuu study sites.

The amount of rainfall received in the Non Salt Pan and Salt Pan Zones at Kangagani and Shengejuu were slightly different. The amount of 118.26mm and 122.59mm were received at the Non Salt Pan Zones at Kangagani and Shengejuu respectively and 113.56mm and 109.19mm of rainfall were received in the Salt Pan Zones at Kangagani and Shengejuu respectively.

The extremes temperature, wind exposure, soil type, soil texture and topography which determine the frequency and duration of shower by tidal waters could be the reasons for the rainfall received.

6.2 Recommendations

The following recommendations are made following the results of the present study:

To prevent high degradation of mangroves ecosystem by manӧs activities salt production which lowers the abundances and species diversity of fauna and flora such as crabs, mangroves, mollusks and others for now and future generation. Salt production costs should be put into consideration by using the suitable modern techniques selected by the government through ministry of fisheries to reduce environmental degradation.

Mangroves forest should be replanted the same species after destruction by salt producers and others environmental degradation. Seedlings of different mangrove species should be used for reforestation, efforts should be restricted to mangrove tree species.

Wide-ranging monitoring and evaluation are needed to ensure that restoration project succeeds. Mangrove rehabilitation has often been carried out simply by planting mangrove seedlings without adequate site assessment, or subsequent evaluation of the success of planting at the ecosystem level.

Promotion and awareness campaigns through different media such as showing films, seminar organization, distributing publicity materials should be conducted not only to the communities of Shengejuu and Kangagani mangroves forest areas but to all coastal communities living along the coastal areas. This will help increase community knowledge on environmental conservation which is important in supporting many biological resources.

The government should give priority to ensuring that the different policies formulated by the Ministry of Fisheries which involve environmental protection and environmental considerations are incorporated into the planning and execution of all major projects. In addition, comprehensive and more environmental bylaws should be formulated and enacted to enable the relevant bodies to enforce such legislation. Projects which deal with and encourage environmental conservation efforts in both mangroves forested villages should be established. This is due to the presence of a variety of biological resources which can contribute to make the living conditions of communities better and the economy healthier.

6.3 Suggestions for Further Research

The purpose of this study was to assess the influence of environmental factors on species diversity in Wete District Pemba; Zanzibar. The researcher based only in two sites of Pemba (Shengejuu and Kangagani) while in Pemba have several areas where mangroves and crabs are found such as Ngezi vumawimbi nature forest, Uchozini, Makoongwe. Therefore, there is a need for another research of the rest areas of Pemba so as to have varieties of data concerning mangroves and crabs. The researcher believed that the result will be different this is because other areas number of mangroves and crabs are less compared to another areas.Despite man made disturbances such as excavation salt pans, overexploitation of mangroves for charcoal, fuel wood, there are other anthropogenic factors which influenced depletion of crab and Mangrove diversity.

Climate Change Threats: Mangroves are also threatened by natural factors mainly the Global climate change, which has concomitant effects on rising of temperature, increasing level of carbon dioxide, change in precipitation pattern, storminess and sea-level rise. However, gradual sea level rise in recent years poses significant threat to the mangroves of Zanzibar, if the rising trend will exceed the limit of which mangroves can cope. (Paramitaet al., 2015)

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APPENDICES

APPENDIX 1: ENVIRON=MENTAL PARAMETER –DATA SHEET: 1

SITE………………………………… DATE ……………

RESEARCHER …………………………………………..

TRANSECT LINE NUMBER ……………………………

GPS POINT ……………………

SALINITY (Be)																					
SOIL Ph																					
WATER TEMPERATURE ($^{\circ}$C)																					
RELATIVE HUMIDITY (%)																					
RAINFALL (MM)																					

APPENDIX 2 CRABS-DATA RECORD SHEET: 2

SITE………………………………… DATE ……………

RESEARCHER …………………………………………..

TRANSECT LINE NUMBER ……………………………

GPS POINT ……………………

SPECIES	SPECIES CODE	SWAHILI NAME	CRABS NUMBERS	%	CRABS BORROWS	%	COMMENTS

APPENDIX 3: MANGROVEFOREST - RECORD SHEET: 3

SITE………………………………… DATE ……………

RESEARCHER …………………………………………..

TRANSECT LINE NUMBER ……………………………

GPS POINT ……………………

SPECIES	SPECIES CODE	SWAHILI NAME	SEEDLINGS (SE) NUMBERS	%	SAPLINGS (SA) NUMBERS	%	YOUNG TREE (YT) NUMBERS	%	COMMENTS

APPENDIX 4 - CORRELATION ANALYSIS

Correlation of Salinity and Crabs at Kangagani (Salt and Non Salt pan)

Pearson r		Pearson r	
R	-0.2283	R	-0.7007
95% confidence interval	-0.6769 to 0.3439	95% confidence interval	-0.9930 to 0.7974
R squared	0.05213	R squared	0.4910
P value		P value	
P (two-tailed)	0.4324	P (two-tailed)	0.2993
P value summary	ns	P value summary	ns
Significant? (alpha = 0.05)	No	Significant? (alpha = 0.05)	No
Number of XY Pairs	14	Number of XY Pairs	4

Correlation of salinity and crabs at Shengejuu (Salt and non-salt pan)

Pearson r		Pearson r	
R	0.4519	R	-0.7368
95% confidence interval	-0.1320 to 0.8029	95% confidence interval	-0.9940 to 0.7685
R squared	0.2042	R squared	0.5428
P value		P value	
P (two-tailed)	0.1211	P (two-tailed)	0.2632
P value summary	ns	P value summary	ns
Significant? (alpha = 0.05)	No	Significant? (alpha = 0.05)	No
Number of XY Pairs	13	Number of XY Pairs	4

Correlation of pH value and crabs at kangagani (Salt and Non salt pan)

Pearson r		Pearson r	
r	0.4307	R	0.03537
95% confidence interval	-0.1295 to 0.7825	95% confidence interval	-0.5047 to 0.5555
R squared	0.1855	R squared	0.001251
P value		P value	
P (two-tailed)	0.1242	P (two-tailed)	0.9045
P value summary	ns	P value summary	ns
Significant? (alpha = 0.05)	No	Significant? (alpha = 0.05)	No
Number of XY Pairs	14	Number of XY Pairs	14

Correlation of pH and crabs at Shengejuu(Salt and non-salt pan)

Pearson r		**Pearson r**	
R	0.7374	**R**	-0.008870
95% confidence interval	0.3397 to 0.9114	**95% confidence interval**	-0.5369 to 0.5242
R squared	0.5437	**R squared**	7.868e-005
P value		**P value**	
P (two-tailed)	0.0026	**P (two-tailed)**	0.9760
P value summary	**	**P value summary**	ns
Significant? (alpha = 0.05)	Yes	**Significant? (alpha = 0.05)**	No
Number of XY Pairs	14	**Number of XY Pairs**	14

Correlation of Temperature and Crabs at Kangagani (Salt and Non -Salty)

Pearson r		Pearson r	
r	0.1711	R	-0.5971
95% confidence interval	-0.3954 to 0.6433	95% confidence interval	-0.8028 to -0.2643
R squared	0.02927	R squared	0.3565
P value		P value	
P (two-tailed)	0.5587	P (two-tailed)	0.0016
P value summary	ns	P value summary	**
Significant? (alpha = 0.05)	No	Significant? (alpha = 0.05)	Yes
Number of XY Pairs	14	Number of XY Pairs	25

Correlation of Temp and crabs at Shengejuu (salt and non -salt pan)

Pearson r		Pearson r	
r	0.1726	R	-0.6170
95% confidence interval	-0.4182 to 0.6607	95% confidence interval	-0.8138 to -0.2934
R squared	0.02978	R squared	0.3807
P value		P value	
P (two-tailed)	0.5729	P (two-tailed)	0.0010
P value summary	ns	P value summary	**
Significant? (alpha = 0.05)	No	Significant? (alpha = 0.05)	Yes
Number of XY Pairs	13	Number of XY Pairs	25

Mangroves correlation Salt and non- pan at Kangagani (salinity)

Pearson r		Pearson r	
r	-0.1357	R	-0.3641
95% confidence interval	-0.7670 to 0.6291	95% confidence interval	-0.7103 to 0.1238
R squared	0.01842	R squared	0.1326
P value		P value	
P (two-tailed)	0.7486	P (two-tailed)	0.1374
P value summary	ns	P value summary	ns
Significant? (alpha = 0.05)	No	Significant? (alpha = 0.05)	No
Number of XY Pairs	8	Number of XY Pairs	18

Mangroves correlation of salinity at Shengejuu (salt pan)

Pearson r	
r	-0.8776
95% confidence interval	-0.9974 to 0.5334
R squared	0.7701
P value	
P (two-tailed)	0.1224
P value summary	ns
Significant? (alpha = 0.05)	No
Number of XY Pairs	4

Pearson r	
R	-0.7361
95% confidence interval	-0.9332 to -0.1984
R squared	0.5418
P value	
P (two-tailed)	0.0152
P value summary	*
Significant? (alpha = 0.05)	Yes
Number of XY Pairs	10

Mangroves correlation Kangagani (salt and non-salt pan) pH

Pearson r	
r	0.08948
95% confidence interval	-0.7115 to 0.7893
R squared	0.008007
P value	
P (two-tailed)	0.8487
P value summary	ns
Significant? (alpha = 0.05)	No
Number of XY Pairs	7

Pearson r	
R	0.08948
95% confidence interval	-0.7115 to 0.7893
R squared	0.008007
P value	
P (two-tailed)	0.8487
P value summary	ns
Significant? (alpha = 0.05)	No
Number of XY Pairs	7

Mangroves correlation at Shengejuu temperature (salt and non- salt)

Pearson r	
r	-0.6293
95% confidence interval	-0.8633 to -0.1727
R squared	0.3960
P value	
P (two-tailed)	0.0119
P value summary	*
Significant? (alpha = 0.05)	Yes
Number of XY Pairs	15

Pearson r	
R	-0.6293
95% confidence interval	-0.8633 to -0.1727
R squared	0.3960
P value	
P (two-tailed)	0.0119
P value summary	*
Significant? (alpha = 0.05)	Yes
Number of XY Pairs	15

Correlation Mangroves at Kangagani temperature (salt and non- salt)

Pearson r	
r	**-0.5512**
95% confidence interval	**-0.8293 to -0.05421**
R squared	**0.3038**
P value	
P (two-tailed)	**0.0332**
P value summary	*
Significant? (alpha = 0.05)	**Yes**
Number of XY Pairs	**15**

Pearson r	
R	-0.4611
95% confidence interval	-0.7289 to -0.07085
R squared	0.2126
P value	
P (two-tailed)	0.0233
P value summary	*
Significant? (alpha = 0.05)	Yes
Number of XY Pairs	24