Diet and food preference of sea urchin; *Tripneustus gratilla* (Linnaeus, 1758) in a seaweed cultivated and non cultivated seagrass beds at Kibuyuni-Shimoni, Kenya.

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DECLARATION

This thesis is my original work and has not been submitted to any other college or university for partial fulfillment of a coursework or degree award. Extraction of any part of information from this report by unauthorized persons for purposes other than the objective of this report is strictly prohibited.

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This report has been submitted with my approval as the University supervisor.

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DEDICATION.

This report is entirely dedicated to my dear wife Charity and my children Kellen, Magdaline and Moses for their continuous prayers and patience during my long period of absence from them as a Dad.

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ABSTRACT

A study to compare the diet of the sea urchin *Tripneustus gratilla* (linnaeus, 1758) in seaweed cultivated and non-cultivated seagrass beds at Kibuyuni-Shimoni, Kenya showed that he most preferred food item by sea urchin; *T. gratilla* at Kijiweni seagrass bed was seagrass; *Thalassodendron. ciliatum* (E*= 0.12) while the urchins at the seaweed farm showed no strong preference(E = -ve) for any of the food items found in the gut. Higher densities of sea urchin; *T. gratilla* were found in the seaweed farm compared to the seagrass bed. However, the population density of sea urchin; *T. gratilla* observed in this study was not a threat to the seagrass ecosystem due to overgrazing. There was positive significant correlation (R = 0.225, P = 0.233) between the population density of sea urchin; *T. gratilla* and the relative abundance of the cultivated seaweed *Kappaphycus alverezii*. Similar relationship was observed between the population densities of sea urchin; *T. gratilla* and seagrass; *T. ciliatum i*n seaweed farm. However there was significant negative correlation between the population density of sea urchin; *T. gratilla* and seagrass; *T. ciliatum* in the seagrass bed. Based on the variations in values of relativized index of electivity obtained in this study and the correlation analysis it is concluded that the introduction of cultivated seaweed had influence on the feeding preference of sea urchin; *T. gratilla*. The morphometric measurements of sea urchin; *T. gratilla* at Kibuyuni seaweed farrm were relatively larger and heavier than those at Kijiweni seagrass bed (t-test = P   0.05). However, there was no significant differences in the depth and gut weight of sea urchin; *T.gratilla* between the sites. These results indeed suggest a degree of distinctiveness of the two sites as well as the supported population. Following the revealation that the introduction of cultivated seaweeds in a seagrass bed had effect on growth, this study recommends the conduction of further studies; to determine the the consumed quantities in weight per unit time per area and the chemical composition of seaweed; *K. alverezii* and the their impact on the performance of sea urchin; *T. gratilla.*

CHAPTER ONE

1.0. INTRODUCTION

Key words: *Tripnneusteus gratilla, Thalassodendron ciliatum, Kappaphycs alverezii*, Kibuyuni seaweed farm, Kijiweni seagrass bed, food preference.

Commercial seaweed mariculture is already practiced in seagrass beds of Asian countries such as China and Japan and gradually picking up in East African countries of Tanzania and Kenya. This human activity adds more pressure on an already stressed ecosystem by overfishing. Periodical surveillance, assessments and monitoring of the natural ecological functioning on ecosystems under various pressures have been conducted and recommended for coastal habitats (McClanahan & Mangi, 2001). Commercial seaweed farming in Kenya is currently practiced in small scale in the Kenyan south coast. It has been adopted to provide alternative livelihood to the coastal community as well as relieving the shallow intertidal ecosystems of continuous over-exploitation of important resources. However, it is cautioned that besides selection of sites colonized by local eucheumoid strains that have good growth and carrageenan properties, other factors such as epiphytes and grazers should also be considered in the model in future surveys for potential mariculture sites along the entire Kenyan coast (Wakibia, 2002).

While appreciating the idea and objectives of introducing seaweed farming as an economical adventure it is also important to appreciate that the effects of invasive species on ecosystem processes are much less clear (Levine et al., 2003, Rilov, 2009). Perceived effects of seaweed farming on the ecology and biodiversity of the coastal environment are viewed either as negative or positive but no adequate empirical data or scientific evidence is available to support either of these views (Zemke and Smith, 2006). The sea urchin *Tripnneusteus gratilla* (Linnaeus, 1758) (plate 1) is an epibenthic macroinvertebrate that has been reported grazing on the leaves of seagrass species; *Thalassodendron ciliatum, Syringondium isoetifolium* and *Thalassia hemphrichii* Forskal den Hartog (Herring, 1972, Alcoverro and Mariani, 2002). The sea urchin; *Tripnneusteus gratilla* are reported to normally feed on available seagrass species and algae that are found in their surrounding environment (Klumpp et al., 1993, Beddingfield and McClintock, 1999, Lawrence and Agatsuma, 2001). However large peculiar aggregations of *T gratilla* have recently been observed in newly introduced seaweed culture sites in Shimoni-Kenya (personal observation). Introduction of exotic cultured seaweed species in these habitats could have interfered with the ecological integrity of the ecosystem promoting aggregations of sea urchin; *T. gratilla*. It is apparent that increase in seaweed abundance in the field due to farming adds more food resources for the herbivores accounting for the aggregations of the sea urchins. This study therefore hypothesizes that seaweeds farming alters the food and feeding preference of *T. gratilla*.

Plate.1. A photograph showing the morphometric measurement of *Tripnneustus gratilla*.

1.1. Problem statement and justification

Seaweed farming creates many micro-habitats for many associated organisms. In Kenya aggregations of sea urchin; *T. gratilla* have been reported by seaweed farmers feeding intensively on the cultured species of seaweeds; *Echeuma denticulutum* and *Kappaphycus alvarezii* (plate 2a) at Kibuyuni in Shimoni area. Appreciating that our understanding of invasive algae is limited, the consequences of introducing seaweed mariculture in virgin marine ecosystems cannot be assumed or over emphasized. The research question was thus whether the presence and abundance of cultivated seaweed species may had influenced the population density, food preference and growth of sea urchin *;T. gratilla* in this particular habitat. Studies on examination of the impacts of alien taxa on the fitness of native species is critically required to recognize the ecological effects of invasive species (Wright and Gribben, 2008, Tallamy *et* al., 2010) and are particularly relevant for species with strong ecological and economic roles such as sea urchins.

1.2. Objectives

The main aim of this study was to determine and compare the diet and food preference of sea urchin; *T. gratilla* found in seaweed cultivated site and non cultivated seagrass site at Shimoni Kenya.

1.3. Specific objectives

The following were the specific objectives of the study:

i. To compare the diet composition in the guts of sea urchin; *T gratilla* in cultivated seaweed farm and in non-cultivated seagrass bed at Kibuyuni, Shimoni, Kenya.
ii. To assess the size structure of sea urchin;*T gratilla* in cultivated seaweed farm and in non-cultivated seagrass bed at Kibuyuni, Shimoni, Kenya.
iii. To determine the food selectivity by sea urchin;*T gratilla* in cultivated seaweed farm and in non- cultivated seagrass bed at Kibuyuni, Shimoni, Kenya.
iv. To determine the population density of sea urchin *T gratilla* and the percentage substrate cover of food items (seaweeds and seagrass) in cultivated seaweed farm and in non-cultivated seagrass bed at Kibuyuni, Shimoni, Kenya

1.4. Hypothesis

This study tested the following statistical hypothesis:

i. $H_{O:}$ There is no difference in the diet composition in the guts of sea urchin; *T. gratilla* in cultivated seaweed farm and in non-cultivated seagrass bed at Kibuyuni, Shimoni, Kenya
ii. $H_{O:}$ There is no difference in the size structure of sea urchin; *T. gratilla* in cultivated seaweed farm and in non-cultivated seagrass bed at Kibuyuni, Shimoni, Kenya
iii. H_O: There is no difference in food preference of sea urchin; *T. gratilla* found in seaweeds cultivated seagrass bed and non- cultivated seagrass bed
iv. H_O: There is no difference in density of sea urchin; *T. gratilla* in seaweed cultivated seagrass bed and non- cultivated seagrass bed.

CHAPTER TWO

2.0. LITERATURE REVIEW

2.1. Introductions of invasive seaweeds

Seaweed farming is often perceived as one of the most sustainable forms of aquaculture. Although the list of advantages (Johnstone and Olafsson, 1995) describes seaweed farming as an environmentally safe activity in the sea, seaweed farming *de facto* introduces macroalgae in habitats where they normally do not occur. In large quantities, seaweeds would negatively compete with other organisms in the habitat for light and space, as well as affecting community composition of associated organisms by attracting mobile species for nutrients provision and aesthetic reasons (Zemke-White and Smith, 2006). Seaweed farms are placed in seagrass beds where vegetation-free areas are lacking or where farmers believe that seagrasses fertilize seaweeds (de la Torre- Castro and Rönnbäck, 2004). While some farmers have been noted initially removing seagrasses to simplify farming (Collén et al., 1995, de la Torre-Castro and Rönnbäck, 2004) and trampling (Eckrich and Holmquist, 2000), others have anchored their boats on seagrasses (Walker et al., 1989).

Over 400 introduction events of invasive seaweeds documented worldwide have caused major global concern (Schaffelke et al., 2006). Although they are known to deeply modify marine ecosystems, that consequently trigger strong detrimental ecological and economic impacts (Schaffelke et al., 2006, Williams & Smith, 2007 and Thomsen et al., 2009), our knowledge of invasive algae herbivore interactions is very limited. According to the Enemy Release Hypothesis (ERH) of Keane and Crawley (2002), an introduced species will successfully spread in a new environment lacking natural predators. Conversely, the Biotic Resistance Hypothesis (BRH) of Elton (1958) suggests that introduced plants are poorly adapted for deterring native consumers, which limits their invasiveness. Since many successful introduced species become integral features of the new ecosystems they invade, it is important to understand how they can potentially modify ecological processes within these systems. This would require assessment of feeding behaviour of native herbivores, and the impacts of alien plants on the survival, growth, and reproductive performance of native herbivores (Wright and Gribben, 2008, Tallamy et al., 2010).

2.2. Interaction of exotic plants and herbivores in marine ecosystem

Sea urchins are one of the most important generalist herbivores in tropical and temperate marine systems (Gaines and Lubchenco, 1982, Lawrence, 2001). They are normally found to feed on a variety of seagrasses and algae that are found in their surrounding environment (Klumpp et al., 1993, Beddingfield and McClintock, 1999, Lawrence and Agatsuma, 2001). They can therefore play a fundamental role in regulating marine invasions (Scheibling and Gagnon, 2006) hence any negative impacts of invasive seaweeds on their performance would require urgent management decisions. According to Parker et al., (2006) generalist herbivores can potentially feed on numerous species, including incorporating exotic plants into their diets thus contributing to invasion control. As a result, plants have evolved numerous strategies to reduce herbivory such as decreasing attractiveness to herbivores and diminishing herbivore performance. Most often such defense mechanisms of the plants function simultaneously and involve morphological, structural, and chemical adaptations (Lubchenco and Gaines, 1981; Duffy and Hay, 1990). Sea urchin feeding habit may be attributed to abundance and preference of food while food selectivity may be due to nutritional value of the food category and/or the presence of chemical substances from the food type which repel the sea urchins (Beddingfield and McClintock, 1998).

2.3. Feeding beahaviour of sea urchins

Many species of sea urchins have been documented to graze on living seagrass tissue. In the WIO region, the most well known species are *T. gratilla* and *Echinometra mathei*. Sea uchin; *Tripneustes gratilla* (plate 1) has been documented in Zanzibar as a primarily grazer on seagrass; *Thalassodendron ciliatum* Forskal den Hartog (Herring, 1972) (plate 2 b). A study carried out in Tanzania by Lyimo et al., (2011) showed that sea urchin; *T. gratilla* generally feeds on available seagrass species. However, in the presence of different types of seagrasses it showed preference to *Syringodium isoetifolium.* Another study on feeding behaviour and performance of the main keystone native herbivore; the sea urchin; *Paracentrotus lividus* (Lamarck) has also been conducted in Mediterranean Sea (Tomas, Box and Terrados, 2010). The results revealed that generalist native herbivore (sea urchin) incorporated exotic plant (*Caulerpa racemosa*) into its diet suggesting the capacity to suppress the spread of exotics Parker et al., (2006) as well as providing biotic resistance to native communities (Elton, 1958). However the high consumption of *C racemosa* by native sea urchin limited its capacity to suppress the invasive species because its performance efficiency was replaced with enhanced escape mechanism.

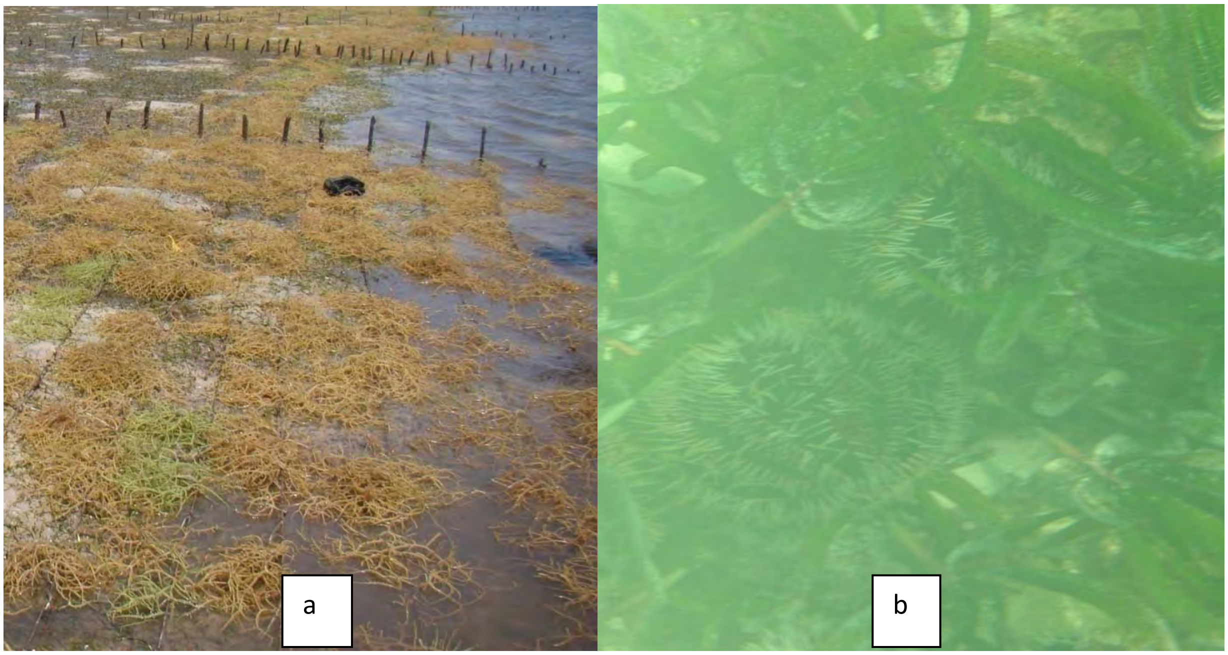

Plate. 2. A photograph of (a) cultivated seaweed, *K. alverezii* and (b) sea urchin, *T. gratilla*, in seagrass bed at Kibuyuni, Shimoni, Kenya. (photo by Kimathi, 2012).

In the tropical western Atlantic, studies have reported sea urchin overgrazing of large meadows of seagrass; *Thalassia testudinum* (Camp *et al*., 1973) and *Syringodium filiforme* (Maciá & Lirman, 1999; Rose *et al*,. 1999). Examining the impacts of invasive taxa on the fitness of native species is therefore critically essential for recognizing the full ecological effects of invasive species (Wright and Gribben, 2008, Tallamy et al., 2010), and is particularly relevant for species with strong ecological and economic roles such as sea urchins.

2.4. Ecology of seagrass in marine ecosystems

Seagrasses are worldwide distributed marine angiosperms which form the basis of marine primary production. They are found extending below the mean mid tidal level and are always submerged. Seagrasses do not have strong structural support like terrestrial angiosperms hence thrive best in high nutrient environment such as soft muddy substrates. Their presence causes a dramatic increase in diversity and productivity of both plants and animals (Larkum et al., 1989, Duarte, 2002), and they form one of the main components within the tropical seascape (Moberg and Rönnbäck, 2003). Seagrass beds are of great social and economic value within the WIO region (Gullström et al., 2002; Ochieng & Eftermeijer, 2003), and past studies have shown that they form a key component in coastal community development (de la Torre Castro & Rönnbäck, 2004; De la Torre-Castro, 2006). Upon death seagrasses decay slowly but faster than the terrestrial macrophytes thus enhancing natural aquatic nutrient regeneration. In the tropics, *in siu* species of *Thalassia* leaves may lose 10-20% of their initial dry weight per week and hence they would be completely decomposed in less than one year thus entering the planktonic system (Barnes, R.S.K. 1982).

The seagrass community of the East African coastline is composed of 12 species, belonging to 8 genera, and each of the living leaves and stems are hosts for numerous types of both macroscopic and microscopic epiphytic algae (Isaac, 1968a; Bandeira, 1995; Lindow & Brandl, 2003, Nduku 2009). It is this softer, more digestible algae that support the abundant grazers associated with the meadows. Direct beneficiaries of seagrass meadows are all the herbivores; mammals, reptiles, fishes and invertebrates (sea urchins). Indirect beneficiaries are all the detritivores. They include the Annelids; Polychaetes, Heterotrophs; Nematodes and the Carnivores; Decapod crustaceans, starfish, crabs, lobsters etc, (Barnes, R.S.K, 1982).

In seagrass meadows sea urchin; *T gratilla* densities of 1.6 individuals m^{-2} in the Mombasa Marine Park, Kenya have been reported by Alcoverro and Mariani (2002; 2004) and non at Malindi and Watamu Marine Parks (Alcoverro & Mariani 2004). Rapid population outbreaks of sea urchins in overfished areas (with up to 500-600 individuals m^{-2}) have been reported in various places across regions e.g the Caribbean, Florida Bay (USA), Moreton Bay (Australia) and Kenya (Camp et al.. 1973; Heck & Valentine, 1995; Rose et al.,1999; Peterson et al., 2002; Alcoverro & Mariani, 2002) leading to extensive loss of seagrass biomass.

2.5. Characteristics of suitable site for seaweeds mariculture.

Introduction of open water cultivation of macroalgae (seaweeds) in East Africa was started in the late 1970s in Tanzania by Mshigeni (1976). By the late1980s, seaweeds; *Eucheuma denticulutum (*N. L. Burman) F. S. Collins & Hervey and *Kappaphycus alvarezii* Doty, were imported from Philippines and introduced to Unguja Island, Zanzibar (Lirasan and Twide, 1993). The algae are farmed in shallow coastal areas for extraction of carrageenan.

Highly productive farms for seaweeds are usually located in shallow lagoons characterized by good water movement (current and/or moderate wave action), appropriate salinity levels and depth at low tide, diverse flora and fauna; clear, fertile and unpolluted water, and appropriate substrate. These areas are most often colonized by dense seagrass beds that form abundant food sources for herbivores especially the generalized grazers. Favourable ecological conditions are indicated by high unit production of seaweeds. In areas where these favourable environmental conditions are maintained throughout the different cropping seasons, seaweeds show very high growth rates and form thick ground cover, which attract associated fauna (fish and invertebrates) and flora species. The farm support system also provides additional substrate on which the associated seaweed species grow. Thus biodiversity appears to be enhanced in farmed areas. It is apparent, however, that changes in the level of biodiversity is affected by the farming cycles, being comparatively lower during the start of cropping (planting) and harvest periods and high during the grow-out period.

CHAPTER THREE

3.0. MATERIALS AND METHODS

3.1. Study sites

The study was conducted at Kibuyuni seaweed farm (S: 04. 64 225^0 _ E 039 33.853^0) and Kijiweni seagrass bed (S: 04 64118^0- E: 039 34 280^0), in the southern coast of Kenya (Fig. 1). Kibuyuni is a village whose coastal belt is a site for seaweed farms owned by various families. Kijiweni is on the northern coast of Kibuyuni about 500 m from the seaweed farm (Fig1.).

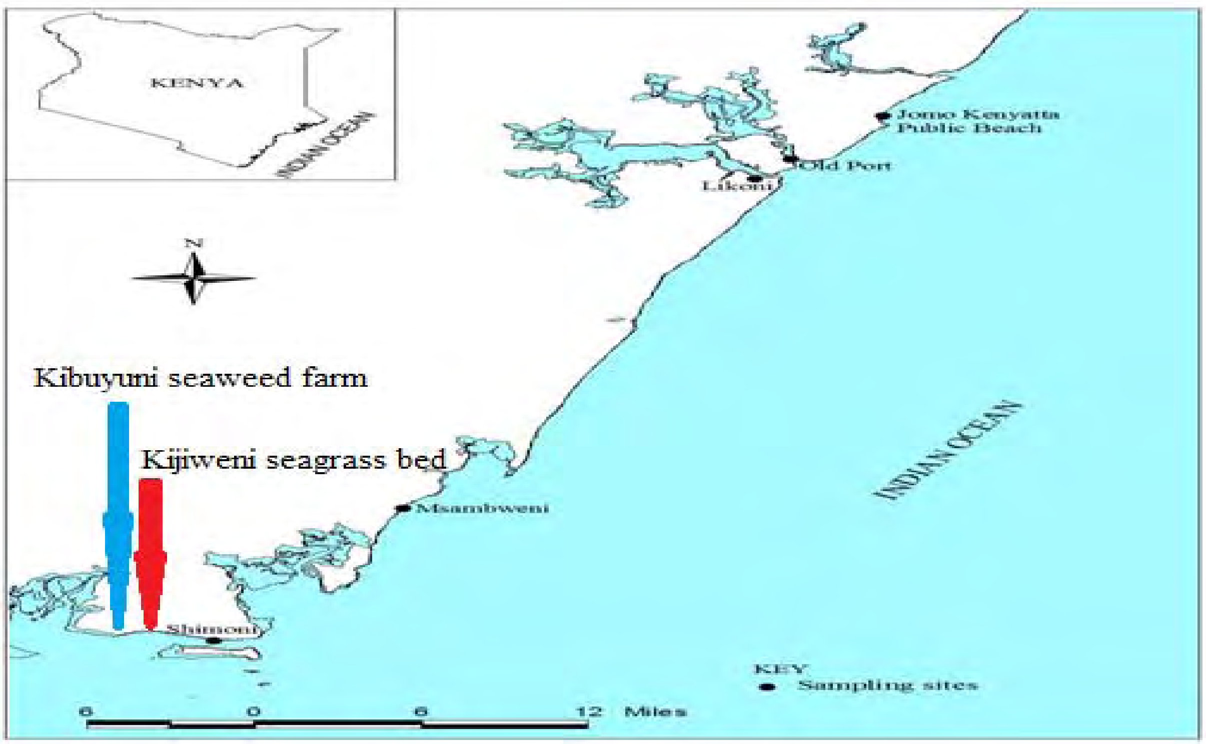

Fig. 1. Kenyan coastline showing Kijiweni and Kibuyuni study sites

Kibuyuni seaweed farm is a long but narrow intertidal reef flat covered by a belt of seagrasses; *Thalassodendron ciliatum* (Forsskal) Hartog and patches of seaweed; *Echeuma denticulatum* and *Kappaphycus striatus* (Schmitz) Doty (Wakibia et. al., 2006). The reef-flat is covered with 10 cm of seawater at the lowest tide and 3.2 m at the highest tide. The dominant animals are soft corals, large sponges, starfishes, brittle stars, sea urchins and rabbit fishes. Kijiweni (S: 04 64118^{0}- E: 039 34280^{0}) is on the northern coast of Kibuyuni, about 500 meters away. The sublitoral zone is a shallow lagoon colonized by a dense healthy seagrass species dominated by seagrass; *Thalassodendron ciliatum*. Species of sea urchin such as sea urchins; *T. gratila* and *Echinometra sp* are abundantly found in the seagrass meadow.

3.2. The coastal climate of Kenya

The coastal climate of Kenya is influenced mainly by large-scale pressure systems of the Western Indian Ocean and Monsoon winds. The Monsoons blow from the northeast between December and March (kaskazi) and from the southeast from May to October (kusi), with the 1 to 2-months transition periods characterized by variable and weaker winds. The two seasons are characterized by distinct differences in physical and chemical conditions of the coastal waters (McClanahan, 1988). Coupled with other geomorphological and hydrological factors, these conditions become ideal for seaweed mariculture in the coast. Mean annual rainfall along the Kenyan coast range from 500–900 mm at the North Coast to 1000–1600 mm in the wetter areas south of Mombasa (UNEP, 1998). Rainfall occurs during two distinct periods; the long rains (kusi) between March and May and the short rains (kaskazi) usually between October and December (Mutai and Ward, 2000; Camberlin and Philippon, 2002). Mean minimum and maximum temperatures at the Kenyan coast range between 24 °C and 30 °C. Sea surface temperatures are highest during the North-East Monsoon, averaging 28.4 °C (maximum 29 °C) and lowest during the South-East Monsoon, averaging 26 °C (minimum 24 °C) (UNEP, 1998; Obura, 2001).). Salinity variation of the EACC waters is low, ranging between 34.5 and 35.4 ppt (UNEP, 1998). In estuaries and tidal creek systems such as Gazi Bay, Mtwapa, Mwache/Port Reitz and Tudor, there are significant seasonal salinity variations, particularly in the inshore waters. During the dry season, salinity can rise to 38 ppt while in the rainy season it can be as low as 19 ppt (Kitheka, 1996). The Kenya coast experiences mixed semi-diurnal tides, with approximately two tidal cycles every 24 hours. The reference tidal stations for tidal observations in Kenya are Kilindini (Port of Mombasa), and Lamu Island where the maximum tidal range generally does not exceed 3.8 m.

3.3. Sampling design and methods

Simple random sampling was done within the perimeters of the seaweed cultivated seagrass bed at Kibuyuni and non seaweed cultivated seagrass bed at Kijiweni. Sampling dates were set to coincide with spring low tides of December, 2012 and January, 2013, for ease of access to the sites. Access to the sites involved walking and snorkeling depending on the water depth at each habitat. Raw data was recorded with a pencil on a waterproof slate in the water and later transferred into a note book before processing and analysis. Each site was visited twice for sampling.

3.4. Estimation of seagrass, seaweeds and sea urchin parameters

A quadrat measuring $0.5m^2$ was thrown randomly at each site to visually describe and estimate the percentage substrate cover of seagrases and seaweeds in *situ* according to Duarte and Kirkman (2001). The frame of the quadrat was a metallic rod coiled systematically and welded to form a square. Three strings of 2.5mm thickness were tied from each side of the frame to the opposite sides crossing each other to form small squares inside the quadrat. Each small square represented a 6% substrate cover of the substrate. For each of calculation this cover was recorded as 5%; (5-100%). A total of 20 quadrats were sampled for each site during each visit for two visits per site.

Using the method described by McClanahan and Shafir (1990), sea urchin; *T. gratilla* abundance and population density in the field were determined for each sampling habitat. This method involved random throwing of one meter rope attached to a weight. The tip of the rope was held by one hand and a circular quadrat of 1m radius was formed by swimming or squatting around the weight and counting the individual numbers of sea urchins; *T. gratilla* within the area. The circular quadrat formed an area of $3.14m^2$.

A total of 20 sea urchins; *T gratilla* specimens were collected from each site within the circular quadrats. Those were taken to the laboratory for gut analysis. Where sea urchins; *T. gratilla* were not included in the quadrat they were collected by random searching to yield 20 specimens per site per visit. Each site was visited once in the spring tides of December and January, 2012/2013. This resulted to a total of 40 sea urchins; *T. gratilla* from each site.

3.5. Laboratory gut analysis for sea urchin; *T. gratilla*

The collected 40 specimens of sea urchins were immersed in a bucket of seawater and carried to the beach. The total weight of each specimen to the nearest gram was taken at the beach by use of a top loading analytical balance. The length, width, depth measurements were done using Vanier caliper. Each urchin was split open longitudinally (oral to aboral) into halves. From each half visual estimate of percentage food composition to the stomach fullness in the gut was done and the gut weighted. Samples were preserved in plastic bottles and taken to Kenya Marine and Fisheries Research Institute (KMFRI), Mombasa laboratory for microscopic verification. The food items are categorized into dominant seagrass (*Thalassodendron cilliatum*), and seaweed species (*Eucheuma* and *Kappaphycus*), others (macrophytes that could not be easily identified) and sediments and percentage estimates of the composition observed. A field guide to the seaweeds and seagrasses by Oliveira et al., (2005) was used to distinguish species of seagrass and seaweeds in the undigested and partially digested diets.

3.6. Data analysis

3.6.1. Descriptive statistics

The collected data was entered into excel spreadsheet for organization to provide descriptive statistics. The means, standard deviations and variances of total weight, length, width and depth for sea urchins, and percentage cover of seaweed and seagrass were determined. Graphs and table were used to show the patterns of species based on the relative abundance, density and percentage composition. The abundance of sea urchins was expressed as a number per unit area. Linear correlation between percentage cover of seagrass and seaweed and population densities of sea urchin; *T gratilla* were determined using Spearmans rank correlation. The significance of the differences of the means; total weight, length, width and depth for sea urchins, and percentage cover of seaweed and seagrass between the two sites was done using two sample t-test.

3.6.2. Food preference of sea urchin;Tripneustus gratilla.

Food preference by sea urchin; *Tripneustus gratilla* in the two habitats was tested by application of the relativised electivity indices (*E**) (Vanderploeg and Scavis, 1979) which was calculated from the mean percent food items in the gut and mean percentage food items abundance in the field. The relativised electivity indices (E^*) equation is as follows:

$E^* = (Wi - (1/n)) / (Wi + (1/n))$

Where: $W = (ri/pi)/(\Sigma ri/pi)$;

ri = % proportion of the food i in the diet of the animal;

pi = % proportion of food i in the environment;

n = number of kinds of food items in the gut.

When the value of E^* tends towards +1, it indicates that food category is more abundant in the diet (preferred), while E* tends towards -1 indicates that food category is more abundant in the field but not in the diet (avoided). When E^* equals 0 (zero), it indicates that the food is consumed in proportion to its availability in the field.

CHAPTER FOUR.

4.0. RESULTS

4.1. Substrate composition of the study sites

The mean percentage of the main substrate covers; macrophytes (seagrasses and seaweeds) and coarse sand, are summarized in Table 1. A total of sixteen genera/species of macrophytes distributed among five families of Chlorophyta, Cymododoceacea, Hydrochaitaceae, Rodophyta and Phaeophyta were identified as substrate covers at Kibuyuni seaweed farm and Kijiweni seagrass bed (Table 1). While 50% of species of these Families were present in both sites others were only present in one site. Seaweed; *Kappaphycus alverezii* was only present at Kibuyuni seaweed farm while seagrass; *Thalassodendron ciliatum* was abundant in both sites. Coarse sand substrate covered 18% and 21% for Kibuyuni seaweed farm and Kijiweni seagrass bed, respectively.

The mean percentage composition of the main substrate types at Kibuyuni seaweed farm were seagrass; *Thalassodendron ciliatum* (20.83± 24.35), Coarse sand (18.3 ± 18.16), brown strain of seaweed; *Kappaphycus alverezii* (44.5 ± 24.29) and brown strain of seaweed; *Echeuma denticulutum* (9.67 ±22.51). It is clear from the results that the substrate of seaweed cultivated site was dominated by the cultivated seaweed species; *Kappaphycus alverezi*. Similarly, seagrass; *T. ciliatum* dominated the substrate (48.28± 33.94) at Kijiweni seagrass bed. Other main components of substrate at Kijiweni seagrass bed included *Syringondium isoetifolium* (10.33± 25.92), and coarse sand (21.5 ± 25.86) (Table 1).

Table 1. Percentage cover of substrate types at Kibuyuni seaweed farm and Kijiweni seagrass bed.

Common name	**Family name**	**Genera/ species**	**% cover at seaweed farm**	**% cover at seagrass bed**
Algae	Chlorophyta	*Enteromorpha sp*	-	0.5 ± 2.01
Algae	Chlorophyta	*Halimeda sp*	0.67 ± 2.17	1 ± 2.42
Algae	Chlorophyta	*Ulva spp*	-	0.83 ± 3.73
Algae	Chlorophyta	*Chaetomorpha sp*	0.67 ± 2.53	-
Seagrass	Cymodoceaceae	*Syringondium sp*	-	10.33 ± 25.92
Seagrass	Cymodoceaceae	*T ciliatum*	20.83 ± 24.35	48.28 ± 33.94
Seagrass	Hydrochaitaceae	*H ovalis*	-	0.5 ± 2.01
Algae	Phaeophyta	*Dictyota sp*	0.33 ± 1.26	0.67 ± 2.17
Algae	Phaeophyta	*Padina sp*	0.5 ± 2.01	0.17 ± 0.91
Algae	Phaeophyta	*Sargassum sp*	1.33 ± 3.45	10.33 ± 19.91
Algae	Rodophyta	*Amphiroa sp*	0.5 ± 2.01	-
Algae	Rodophyta	*Gracillaria sp*	0.167 ± 0.91	1± 2.75
Algae	Rodophyta	*Hypnea sp*	0.33 ± 1.82	0.52 ± 2.04
Algae	Rodophyta	*Jania sp*	0.17 ± 0.92	0.67 ± 2.17
Algae	Rodophyta	*Green E. denticulutum*	1.33 ± 5.71	-
Algae	Rodophyta	*Brown E. denticulutum*	9.67 ± 22.51	-
Algae	Rodophyta	*Brown K alverezii*	44.5 ± 24.29	-
Coarse sand	-	-	18.3 ± 18.16	21.5 ± 25.86

4.2. Relative abundance of the shoots of the main seagrass species

Analysis of the relative abundance of shoots for seagrass species at Kibuyuni seaweed farm and Kijiweni seagrass bed revealed that seagrasses; *T. ciliatum* and *S. isoetifolium* were the most bundant species (Fig 2). The highest relative abundance for seagrass; *T ciliatum* was at Kijiweni seagrass bed (87.9%) and compared to 50.5%. at Kibuyuni seaweed farm. Seagrasses; *Thalassia hemprichii* and *Cymodocea rotundata* were only found at seagrass bed and at relatively lower percentages (10%) than other seagrass species found in both sites (Fig 2).

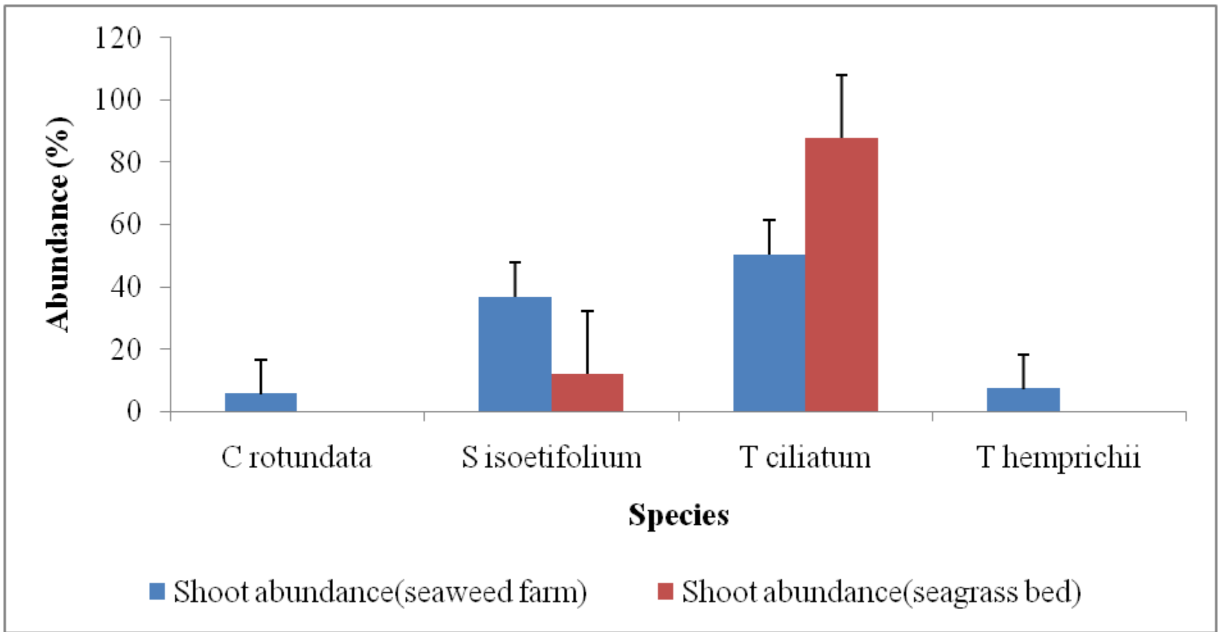

Fig.2. Relative abundance of shoot for seagrass species at Kibuyuni seaweed farm and Kijiweni seagrass bed.

The mean canopy height (± S.D) of seagrass; *Thalassodendron ciliatum* at Kibuyuni seaweed and Kijiweni seagrass bed were 24.609 ±10.11 and 24.774± 8.15, respectively. However, there was no significance difference between the mean canopy height of seagrass; *T ciliatum* from the seaweed farm and from the seagrass bed ($t = 0.0645$, $p = 0.949$).

The population density of sea urchin; *T. gratilla* was correlated with the percentage cover of seagrass; *T. ciliatum,* and seaweed*; K. alverezii* in the two habitats (Table 2). Results of the correlation analysis revealed that there was insignificant positive correlation between the population density of sea urchin; *T. gratilla* and the percentage cover of seaweed; seaweed; *K.*

Table 2. Correlation between the population density of sea urchin; *T. gratilla* and percentage cover of seagrass and seaweed species.

Correlated variables	**R - value**	**P - value**
Population density of *T. gratilla* and percentage cover of *K. alverezii* in seaweed farm	0.225	0.233
Population density of *T. gratilla* and percentage cover of *T. ciliatum* in seaweed farm	-0.319	0.086
Population density of *T. gratilla* and percentage cover of *T. ciliatum* in seaweed farm	0.126	0.507

alverezii in seaweed farm and also between the percentage cover of seagrass; *T. ciliatum* in the seaweed farm. There was a negative but insignificant correlation between the population densities of sea urchin; *T. gratilla* and the percentage cover of seagrass; *T. ciliatum* in the seagrass bed (Table 2).

4.3. Morphometrics and densityof sea uchin; *Tripneustus gratilla* at the study sites

A comparison of means of various morphometric variables of sea urchin; *T. gratilla* specimens from Kibuyuni seaweed farm and Kijiweni seagrass bed are represented in Tables 3. The results also showed higher values of morphometric variables of sea urchin; *T. gratilla* from Kibuyuni seaweed farm when compared to those from Kijiweni seagrass bed. All specimens of *T gratilla* analysed from Kibuyuni seaweed farm were significantly heavier (236.582 ± 65.500) than those from Kijiweni seagrass bed (179.763 ±48.854) (P 0.05). The t- test analysys also showed significant differences in the mean length, and width of the seaurchin; *T. gratilla*,(p 0.05) when compared between the two sites. However, there were no significant differences in the body depth, and gut weight(g) betweeen the two sites, (P > 0.05) (Table 3). The mean population density of sea ur chin;*T. gratilla* was higher (7.03 ±5.66 individuals m^{-2}) at Kibuyuni seaweed farm and lower at Kijiweni seagrass bed where 3.07 ±2.36 individuals m^{-2} were recorded.

Significant difference (t =3.5425, p = 0.00079) in the mean density of the sea urchins from the two sites was revealed.

Table 3. Comparative means of various parameters measured on sea urchin; *T. gratilla* specimens at Kibuyuni seaweed farm and Kijiweni seagrass bed.

	***T. gratilla* at Kibuyuni**	***T. gratilla* at Kijiweni**	**T- test**	
Parameter	**seaweed farm**	**seagrass bed**	**t- value**	**P-value**
Total wt (g)	236.582 ± 65.500	179.763 ±48.854	4.5034	2.31E-05
Length(cm)	7.88 ± 0.699	7.132 ±0.741	4.834	6.56E-06
Width(cm)	7.777 ± 0.687	7.016 ±0.727	4.9213	4.69E-06
Depth(cm)	6.304 ± 8.154	4.458 ±0.564	1.4387	0.1581
Gut weight (g)	33.27± 11.49	29.995 ±9.151	1.4102	0.1624
Population density (no. urchins/1m radius quadrat (SD ±)	7.03 ± 5.66	3.07 ±2.36	3.5425	7.90E-04

All differences were considered significant at P 0.05.

4.4. The composition of food items in guts of the sea urchin; *Tripnneustus gratilla*

The guts of sea urchin; *T gratilla* from Kibuyuni seaweed bed were dominated by a seaweed species; *Kappaphycus alverezii* (61%), while the guts of seaurchin; *T. gratilla* from Kijiweni seagrass bed were dominated by a seagrass species; *Thalassodendron ciliatum* (69%) (Fig. 3). The sea urchins from both sites also had different percentage compositions of sand/sediment and other microscopic materials that could not be easily identified (Fig. 3). At Kibuyuni seaweed farm the guts of the urchins had 10% sand and 10% other materials while, the same species of urchin at Kijiweni seagrass bed had 10 % sand and 20% other materials (Fig. 3).

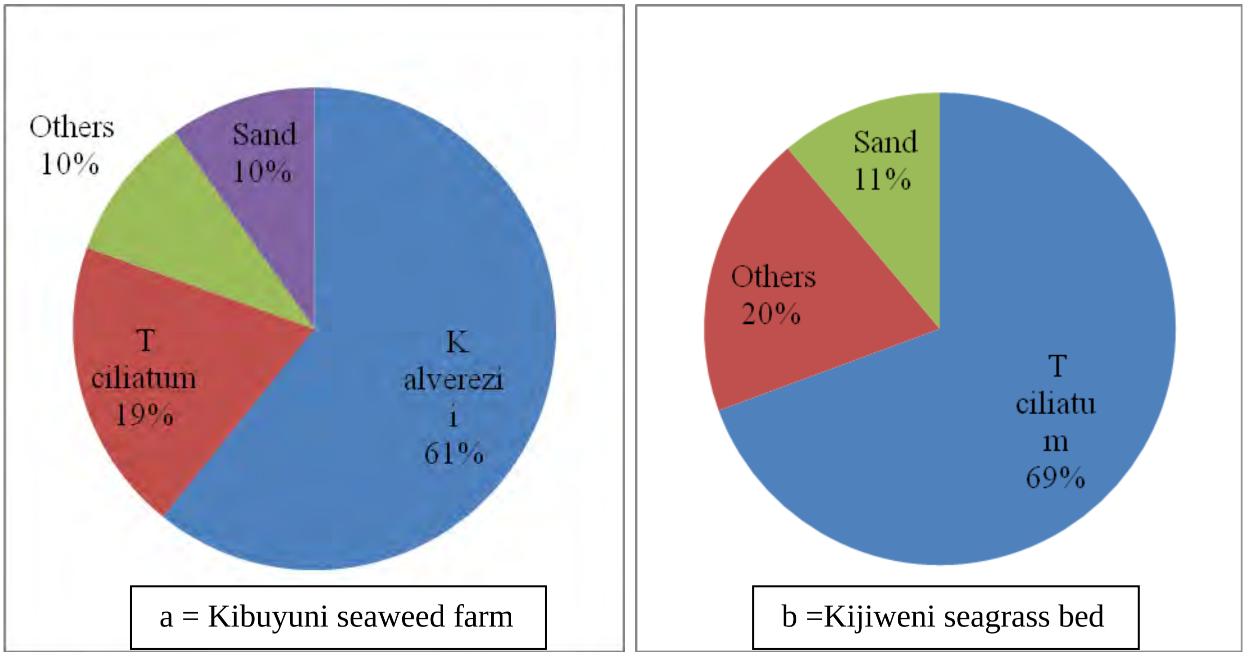

Fig. 3. The mean percentage composition of the main food items in guts of *T gratilla* at (a) Kibuyuni seaweed farm and (b) Kijiweni seagrass bed.

4.5. Food preference (selectivity)of sea urchin; *Tripnneustus gratilla* at Kibuyuni seaweed farm and Kijiweni seagrass meadow.

The calculated relativized index of selectivity E* for all the food items in the guts of sea urchin; *T. gratilla* from Kibuyuni seaweed farm tended towards negative one (-1), (Fig.4) an indication of less preference for any of food category. However , the mostly avoided food item was coarse sand (E*= -1.2), followed by seagrass species; *T. ciliatum* (E* = -0.6), seaweed species; *Kappaphycus alverezii* (E* = -0.1) while other unrecognized macrophyte were least avoided (E* = -0.5) perhaps indicating the sand was in the gut accidentally and the urchin feeds more on the other macrophytes.

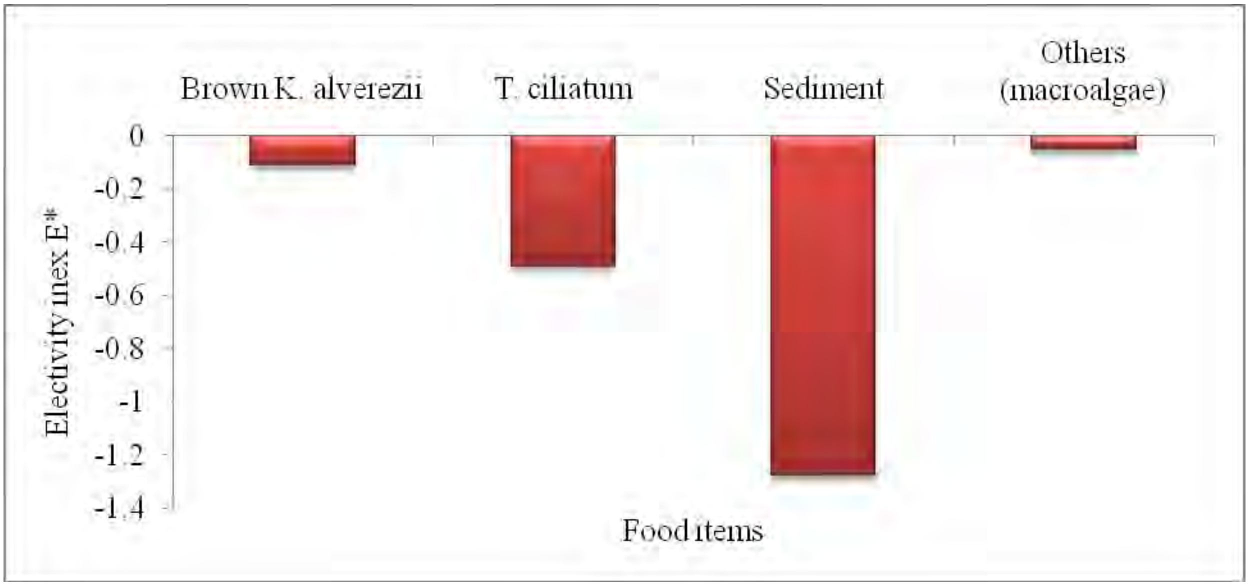

Fig. 4. Relativized index of electivity E* of food items of sea urchin; *Tripnneustus gratilla* at Kibuyuni seaweed farm.

Values of the calculated relativized index of selectivity E*for the food items of sea urchin; *T. gratilla* from Kijiweni seagrass bed highly contrasted with those of Kibuyuni seaweed farm (Fig 5). The E* value for seagrass; *T. ciliatum* (E*= 0.12) and other macrophtes (E*= 0.04) tended toward positive one (+1), indicating higher preference for them. Just like the sea urchins of Kibuyuni seaweed farm those of Kijiweni seagrass bed also strongly avoided coarse sand (E* =.-1.22) (Fig. 5).

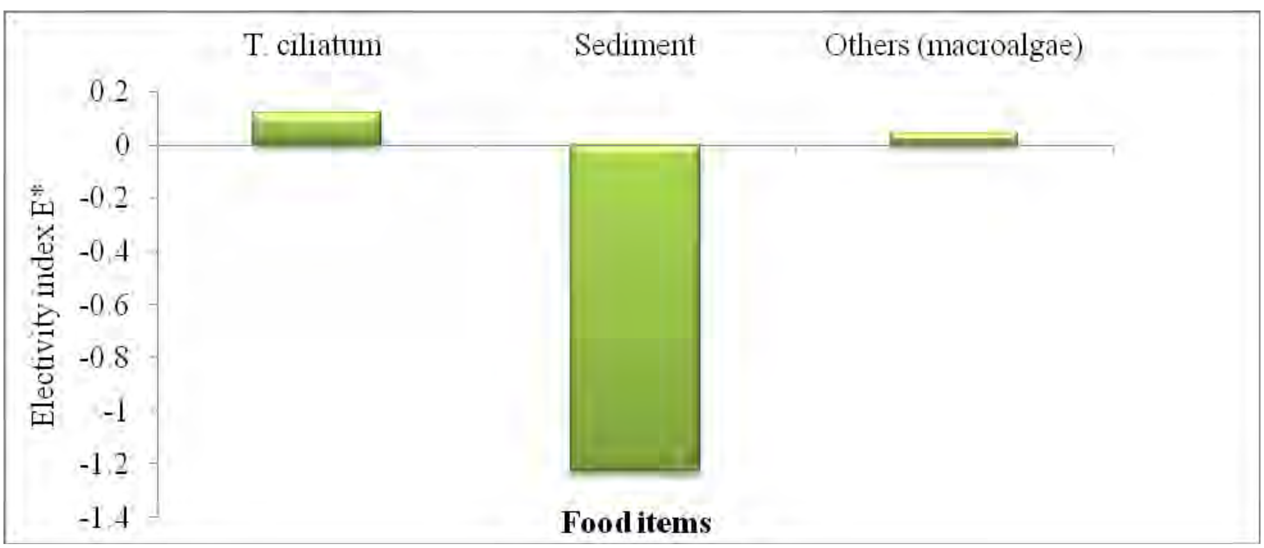

Fig 5. Relativized index of electivity E* of food items of *T. gratilla* at Kijiweni seagrass bed site.

CHAPTER FIVE

5.0. DISCUSSION

Out of the sixteen macrophytes recorded in the study sites, more than 50% of them appeared in both habitats. However, seaweed; *Kappaphycus alverezii* was only found at Kibuyuni seaweed farm dominating a substrate cover of 44%. The absence of this food category (*Kappaphycus alverezii)* in the seagrass bed suggests that all the other recorded food categories in the seagrass bed could be available for sea urchin; *T. gratilla* apart from the seaweed; *Kappaphycus alverezii.*

The values obtained in this study for percentage cover, relative abundance, shoot density and canopy height of seagrass are within the ranges documented by other authors in the Western Indian Ocean region and other tropical countries (de la Torre-Castro and Rönnbäck, 2004; Uku and Björk, 2005, Mamboya et al., 2009). The highest percentage cover in the seagrass bed was seagrass species; *Thalassodendron ciliatum* (48.28± 33.94%) which could be attributed to availability of extensive and evenly distributed coarse sand substrate along the entire Kibuyuni area and the sheltering effect by the Mpunguti and Wasin Islands. These factors could therefore not only make the two habitats suitable for growth of seagrass; *T.ciliatum* but for other species of seagrasses, native and the cultured seaweeds found in the site.

Relatively lower shoot abundance for seagrass species at Kibuyuni seaweed farm than at Kijiweni seagrass bed could be due to human disturbance on the seagrasses during seaweed cultivation. The relative abundance of seagarss; *T. ciliatum* showed negative correlation with the density of sea urchin; *T. gratilla* in the seagrass bed. This means that the population density of seaurchin; *T. gratilla* decreased with increase in percentage cover of seagarass; *T. ciliatum*. The explantion to this scenario could be that the highest percentage cover of seagrass; *T. ciliatum* in a seagrass meadow is found at a deeper transition zone of seagrass and coral gardens that support growth of seagrass; *T. ciliatum* with the long canopy height (> 0.5m), lower shoot density, and structurally stronger and tougher leaves and stems than those in shallower zones (personal observation and opinion). These characteristics consequently could render the typical seagrass not only inaccessible to the sea urchin; *T. gratilla*, but also make them dificult for ingestion and digestion. Secondly, the coral gardens are within foranging ground for potential predators of sea urchin; *T. gratilla* such as theTrigger fish which will predate on the sea urchins.

Higher densities of sea urchin; *T. gratilla* were found in the seaweed farm compared to the seagrass bed. The variation could have been due to additional food item seaweed; *K. alverezii* that was only available in the seaweed farm. However, the values in this study were far below the 500-600 individuals m^{-2} reported in various places such as Caribbean, Florida Bay (USA), Moreton Bay (Australia) and Kenya (Camp et al., 1973; Heck & Valentine 1995; Rose et al.,1999; Peterson et al., 2002; Alcoverro & Mariani, 2002) that led to extensive loss of seagrass biomass. It can therefore be concluded that the population density of sea urchin; *T. gratilla* observed in this study was not a threat to the seagrass ecosystem due to overgrazing.

Coarse sand comprised a significant proportion of substrate in both habitats and in the guts of sea urchin; *T. gratilla* suggesting that the typical urchins spend considerable period of time in bare sand environments as well. The presence of sediment in the guts of these urchins could probably indicate that they do not primarily ingest it as food *per se* but accidentally as they source for diverse micro algae films that provide them with other essential nutrients (Klumpp et al., 1993). These include microalgae that may be abundant and sometimes form visible bio-films or microbial mats on sediment surfaces in coastal waters (Lugomela et al., 2005).

Significance tests for comparative means of various parameters measured on sea urchin; *T. gratilla* specimens at Kibuyuni seaweed farm and Kijiweni seagrass bed showed that the sea urchins at Kibuyuni seaweed farm were heavier and larger than at Kijiweni seageass bed. However there was no significant differences in the body depth and gut weight of sea urchin; *T. gratilla* between the sites. The results suggest a degree of distinctiveness of the two habitats. Although seaweed farming has been previously described as an environmentally safe activity in the sea, Johnstone and Olafsson, (1995), seaweed farming *de facto* introduces macroalgae in habitats where they normally do not occur (Zemke-White and Smith, 2006). Proliferation of these macro and micro algae species can dramatically or gradually alter the ecological conditions of an aquatic ecosystem (Schaffelke et al., 2006, Williams & Smith, 2007 and Thomsen et al., 2009).

The variety of food items found in the guts of sea urchin; *T. gratilla* from both habitats portrays the characteristics of a generalized herbivore. The presence of *T. ciliatum* (seagrass) and *K. alverezii* (seaweed) as the dominant food items in the guts of sea urchin; *T. gratilla* from the seagrass bed and seaweed farm, respectively agrees with earlier observation which showed sea urchin; *Tripneustes gratilla* as the primarily grazer on seagrass; *Thalassodendron ciliatum* in Zanzibar (Herring, 1972). Also a study carried out in Tanzania by Lyimo et al., (2011) showed that sea urchin; *T. gratilla* generally feeds on available seagrass species. This observation had previously been demonstrated in laboratory experiments (Beddingfield and McClintock, 1999; Stimson et al., 2007). On the other hand the observed dominance of seaweed; *K. alverezii* in guts of sea urchin; *T. gratilla* from seaweed farm could partly be attributed to existence of seaweed; *K. alverezii* as the dominant substrate cover in the habitat and partly because the typical urchin, being a generalist herbivore, is pre-adapted to feed on a wide variety of plants (Bernays and Minkenberg, 1997) and can often expand its food range to include new species.

The largest food composition in the gut of sea urchin; *T. gratilla* from Kibuyuni seaweed bed was seaweed; *Kappaphycus alverezii* (61%) while the gut of sea urchin; *T. gratilla* from Kijiweni seagrass bed was dominated by seagrass; *Thalassodendron ciliatum* (69%) which was significantly higher than 19% found in the guts of sea urchin; *T. gratilla* from Kibuyuni seaweed farm. It was also found out that these food categories also dominated in the field suggesting that the feeding behaviour of sea urchin; *T. gratilla* has a relationship with the abundance of food categories in the field.

The calculated relativized index of selectivity E* for all the food items in the guts of sea urchin; *T. gratilla* from Kibuyuni seaweed farm tended towards -1, an indication of less preference for any of the food categories. These values contrasted highly with those of Kijiweni seagrass bed where the E* value forseagrass; *T ciliatum* (E*= 0.12) and other macrophtes (E*= 0.04) tended toward +1, showing some degree of food preference. The mostly avoided item in the field by sea urchin; *T. gratilla* in the seaweed farm was coarse sand (sediment) (E*= -1.2), followed by seagrass; *T. ciliatum* (E* = -0.6), seaweed; *Kappaphycus alverezii* (E* = -0.1) while other unrecognized macrophyte (E* = -0.5) were least avoided. If we were to base the measure of preference on the value of relativized index of electivity E*, then we would conclude that the most preferred food item was the least avoided . In this case unrecognized macrophytes(Others) were the most prefered food item by urchins in the seaweed farm, followed by cultivated seaweed; *K. alverezii.* Macropyhtes (Others) were least avoided probably because of their significant abundance in the field and perhaps because they could provide the soft essential epiphytic algae to the urchins. The avoidance of seaweed; *K. alverezii* by sea urchin; *T. grailla* could be due to the fact that marine generalist herbivores appear to globally avoid invasive seaweeds as documented for *Caulerpa taxifolia* (Boudouresque et al., 1996; Gollan and Wright, 2006), for *Codium fragile spp* (Scheibling and Anthony 2001; Scheibling et al., 2008) and for *Sargassum muticum* (Monteiro et al., 2009). However, in an indoor experiment *Caulerpa. racemosa* was highly consumed in a preference experiments (Ruitton et al., 2006, Bulleri et al., 2009; Cebrian et al., in press). In that experiment there was no apparent relationship found between feeding choices and nutritional characteristics of the different species, suggesting that reduction of feeding preference is not driven by nutritional quality (Cruz-Rivera and Hay, 2001) but by both chemical and structural defense mechanism of exotic seaweeds (Verge´s et al., 2007, Vadas, 1977). Given that seagrass blades are tougher than the thin filamentous thallii of seaweed; *K. alverezii*, differences in feeding behaviour of sea urchin; *T. gratilla* are likely to be driven by chemical and structural characteristics of food items.

The most preferred food item by sea urchin; *T. gratilla* at Kijiweni seagrass bed was seagrass; *T. ciliatum* and this could be attributed to its dominancy in abundance in the field and probably its potential to host palatable epiphytic algae required by the sea urchins. Indeed, epiphytic algae have been reported from other areas to be more palatable to herbivores than vascular plant tissues (Klumpp et al., 1993). Just like the sea urchins of Kibuyuni seaweed farm those of Kijiweni seagrass bed also strongly avoided coarse sand(E* =.- 1.22). This could signify that the essential micro algae scrapped by the urchins from the sediment could be adequately provided by the epiphytes from the abundant seaweeds and the seagrasses within their vicinity.

5.1. Conclusions

Following the results of this study, the following conclusions have been made:

i. The population density of sea urchin; *T. gratilla* in the seaweed farm was relatively higher than in the seagrass bed. Also there was positive significant correlation between the population density of sea urchin; *T gratilla* and the relative abundance of the cultivated seaweed (*K alverezii*). Similar relationship was observed between the population densities of sea urchin; *T gratilla* and seagrass; *T. ciliatum i*n seaweed farm. However, there was significant negative correlation between the population density of sea urchin; *T. gratilla* and seagrass; *T. ciliatum* in the seagrass bed.

ii. The most preferred food item by sea urchin; *T. gratilla* at Kijiweni seagrass bed was seagrass; *T. ciliatum* while the urchin at seaweed farm showed no strong preference for any of the food items found in the gut. Although one would expect the sea urchin to show strong preference for cultivated seaweed; *Kappaphycus averezii* due to its dominant relative abundance in the field, it was slightly avoided. However, based on the variations in values of relativized index of electivity obtained in this study and the correlation analysis it can be concluded that the introduction of cultivated seaweed had influence on the feeding preference of sea urchin; *T. gratilla*.

iii. The total weight and the morphometric measurement of the sea urchin; *T gratilla* at Kibuyuni seaweed farrm were relatively higher than those at Kijiwenni seagrass bed. However, there was no significant differences in the depth and gut weight of sea urchin; *T. gratilla* between the sites. These facts indeed suggests a degree of distinctiveness of the two habitats as well as the supported population. Introduction of cultivated seaweeds in a seagrass bed therefore has effect on growth of sea urchin; *T. gratilla.*

5.2. Recommendations

The following recommendations are made following this study:

i. Farm preparation for seaweed mariculture involves clearing the benthic cover to limit organism that compete for resources with culture species or graze on it. This human activity therefore results to massive loss of seagrass species and epibenthic invertebrates such as sea urchin; *T gratilla*. This practice should be discouraged as these organisms play significant roles in maintaining a stable and productive ecosystem on which the cultured seaweed depend for growth.

ii. During grow out period of cultivated seaweeds, sea urchin species such as *T. gratilla* are killed by various methods by farmers claiming of intensive gazing on the cultured seaweeds. This study has however demonstrated that the population densities of sea urchin; *T. gratilla* in both seagrass and seaweed habitats are not a threat to the seagrass habitats. Any attempt to bring this density down could pose a serious ecological imbalance in the area.

iii. This study quantified the amount of seaweed consumed by the typical urchin on the basis of percentage visual estimates of the gut composition. Further research need to be conducted to determine the consumed quantities in weight per unit time per area. This assessment will help to determine if indeed the quantity consumed by the urchin is significant enough to warrant suggestions for management of sea urchin; *T. gratilla* in a seaweed farm.

iv. There is need to conduct a study on the chemical composition of seaweed; *K. alverezii* and assess their impact on the performance of sea urchin; *T. gratilla*..

v. Any introduction of seaweed mariculture in marine ecosystem must be preceded by conduction of a complete environmental impact assessment (EIA) by authorized institutions. This will not only document the aquatic resources that may be threatened or affected by the project but will also address the interests of the local community.

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