



***THE ROLE OF FOOD AVAILABILITY
AND PRESENCE OF PREDATORS ON
POPULATION TRENDS OF THE SEA
URCHIN TRIPNEUSTES GRATILLA (L.)
IN SEAGRASS BEDS OF WATAMU
MARINE NATIONAL PARK AND
RESEARVE, KENYA***

BY

Lillian N. Daudi

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1.0 INTRODUCTION

Seagrass beds are highly productive components of coastal ecosystems with estimated annual primary production comparable to that of tropical rain forests (Duarte, 1999; Hemminga, 2000). They form extensive beds which can either be monospecific (single species) or multispecific (mixed species). Seagrass beds in tropical regions support a large variety of associated faunal organisms of different taxa with several ecological characteristics (Hemminga, 2000).

Seagrass communities are subject to frequent disturbance, whether anthropogenic (e.g. shoreline construction, eutrophication, mechanical damage) or natural (sand wave motion, storms and hurricanes/ typhoons, overgrazing) that lead to alterations in vegetation complexity (Snelgrove, 1997; De Troch, 2001; Gray, 2004). Seagrasses are consumed by a variety of herbivores, and the effects of herbivores on seagrass abundance and productivity are greater than previously thought (Valentine, 1999). Herbivory strongly influences the organisation and functioning of ecosystems through the control of plant community structure and composition (McNaughton, 1989; Hulme, 1996). The herbivores also affect the productivity and abundance of plants in aquatic and marine environments (Mallin, 1994). Grazing, a factor which can influence seagrass production and distribution is a natural disturbance in tropical seagrass meadows (Heck, 2006).

Sea urchins are dominant grazers in a wide range of inter- tidal and sub-tidal habitats within coral reefs, seagrass beds and kelp forests worldwide. Sea urchin population explosions due to high recruitment events have been said to be the cause for seagrass overgrazing episodes (Rose, 1999). Grazing by sea urchins can alter the distribution, relative abundance and species composition of marine plants. Overgrazing of seagrasses by sea urchins may be triggered by reduced predation by fish and eutrophication. In severe cases, such overgrazing could decimate entire seagrass meadows (Eklof et al., 2008).

Decline of seagrasses has occurred as a result of sea urchin grazing where macroalgal kelp forests have been converted to grazer resistant coralline dominated algal pavements in temperate and boreal settings (Lawrence, 1975). In marine kelp forests over harvesting of predatory sea otters was observed to lead to large increases in the density of their sea

urchin prey, which subsequently brought about the loss of kelps as they were overgrazed by the urchins (Duggins, 1980; Estes, 1974).

In the tropical western Atlantic, studies have reported sea urchin overgrazing of large meadows of *Thalassia testudinum* (Camp, 1973) and *Syringodium filiforme* (Macia, 1999; Rose, 1999).

Seagrass grazing is common in East Africa, with herbivorous fish and sea urchins prevailing in protected and fished areas, respectively (Alcoverro, 2004). Sea urchins have been shown to graze on seagrass leaf assays with a high intensity (McClanahan, 1994), while schools of fish generally graze epiphytized leaf tips in a more repeated manner (Dahlgren, 2006).

Thalassia hemprichii (Ehrenberg) Ascherson, one of the predominant seagrasses in the region (Ochieng, 2003), is more resistant to repeated and intensive cropping than other co-occurring species (Alcoverro, 2005), which could explain its dominance in areas intensively grazed by sea urchins (McClanahan, 1994).

The loss of seagrass biomass can also have a substantial impact on animal communities. Changes in plants that occur as a result of herbivore damage are known as induced responses, and these responses can involve both tolerance and resistance traits. For instance, an increase in the relative growth rate of plants as a response to herbivore damage is a particularly widespread compensatory mechanism of plant tolerance in terrestrial systems (Ferraro, 2002).

Seagrasses, on the other hand, are marine vascular plants that possess several of the attributes that favour tolerance and compensatory growth in terrestrial plants, such as the presence of largely inaccessible basal meristems, clonal propagation and physiological integration amongst ramets (Marbà 2002). There were observations of several grazing aggregations of the sea urchin *Tripneustes gratilla* in Kenya which defoliated seagrass patches and seemed to be moving through vegetated areas as small fronts (Alcoverro, 2002).

Echinoids in general might not be restricted to food in situ as they may also feed on captured drift material (Lawrence, 1975). Studies have also shown that echinoids become selective under conditions of abundant and diverse food (Lawrence, 1975) but other

studies have also shown that algal species eaten by *Tripneustes gratilla* are either selected or avoided (food selectivity). The diet of *Tripneustes gratilla* has been found to be composed of mainly seagrasses and this has also been the case for the Caribbean *Tripneustes ventricosus*. Food selectivity of *Tripneustes gratilla* according to some studies has been attributed to the nutrient content of the food in instances where you have the same food source at different sites and urchin of a particular site select a particular food content (Lison de Loma, 2002).

Tripneustes gratilla L. is an Indo-Pacific sea urchin commonly found in shallow lagoons and reef areas within seagrass beds. It was found to dominate the seagrass meadows in Mombasa lagoon, Kenya (Alcoverro, 2002). Preliminary surveys done in the North and South coast of Kenya have shown high densities of *T. gratilla* especially in seagrass beds (Uku, 2005; Zanre, 2004) and previously healthy seagrass meadows of the Watamu Marine Park and Reserve have been degraded over the last few years from a population explosion of the sea urchin *T. gratilla*. Fishermen first reported the population explosions in 2001 and recovery of degraded seagrass beds has been slow (Uku pers. comm.).

The factors that govern the reproductive cycle of *T. gratilla* are both biotic and abiotic. Abiotic factors that affect the reproductive cycle include temperature and photoperiod (Vaitilingon, 2005) as well as lunar periodicity (Muthiga, 2005). *T. gratilla* populations on the Kenyan coast have a reproductive pattern that is continuous throughout the year superimposed on an annual cycle of gonad growth (Muthiga, 2005).

Among the abiotic cues that influence the reproductive cycle, food plays an important role yet little effort has been focused on food availability and its effect on the population trends of *T. gratilla*. Additionally, over fishing of predators in several parts of the Kenyan coast has been cited as the cause of population explosions of sea urchins (McClanahan, 1989) and this may be an additional factor that influences the explosion of *T. gratilla*.

Objective

The objective of the study was to determine the impact of food sources as well as the impact of predator abundance on *T. gratilla* populations by comparing sites in the park and reserve.

Specifically the study aimed

- To establish the population structure and densities of juveniles and adults of *T. gratilla* in the healthy and degraded seagrass beds within the Watamu Marine Park and Reserve
- To establish the seagrass vegetation cover within the sites where urchins were counted including shoot density
- To establish the presence of predators within the park and reserve
- Establish herbivory by *T. gratilla* on *Thalassodendron ciliatum* leaves
- Gut content analysis of the sea urchins

2.0 MATERIALS AND METHODS

Samples were collected for one year from August 2006 to September 2007 on a seasonal basis.

Study Area

Watamu is located in the north coast region of Kenya about 100km north east of the city of Mombasa. Climatic conditions are characterized by two dominant monsoon seasons: the South East Monsoon (March- September) and the North East monsoon (September-March). Watamu Marine National Reserve (WMNR) was protected in 1968 when the Malindi and Watamu Marine Reserves were created to regulate the exploitation of marine natural resources. In 1976, the Watamu Marine National Reserve gained international recognition when UNESCO awarded the reserve a biosphere reserve status (Uku & Kithaka, 2002). At present, a part of the Watamu Marine Reserve has been upgraded into a Marine Park while a part of it remains as a Marine Reserve.

The study focused on both the Marine Park and Reserve and targeted both degraded and healthy seagrass sites. The study was done on three main sites (two in the reserves and one in the Park). The sites were Blue Bay lagoon and Short beach (Mida) and the Marine Park. Sampling strategy involved taking a transect from the beach towards the reef other than in the Short beach (Mida) where the samples were taken randomly since it was at the mouth of Mida Creek. This was done by sampling near shore (near the beach), mid shore (between the near shore and the coral reef) and at the coral reef for comparison purposes.

This area had started experiencing population explosions since 2001 and at the end of 2003 culling of *Tripneustes gratilla* was done.

Blue- Bay lagoon (Reserve) - It was a recovering site for seagrass. Sea urchin removal had been done previously. It is a lagoon that is protected from wave action and is shallow. There was some restricted fishing at this site mainly using spear guns and beach seine nets.

Park- A transect was established at this site characterized by healthy seagrass bed towards the beach and some unhealthy seagrass bed towards the middle. At the end towards the reef was the coral garden where there was mainly more of stumps and sand as the major component with less of seagrass cover occurring as patches at the beginning of the study. No fishing was done at this site. The area was generally deeper.

Short beach (Mida Reserve) - The site at the mouth of Mida Creek was made of a rocky substrate and mainly consisted of algae with some patchy seagrass cover also present. No fishing was done at this site and it was also shallow.

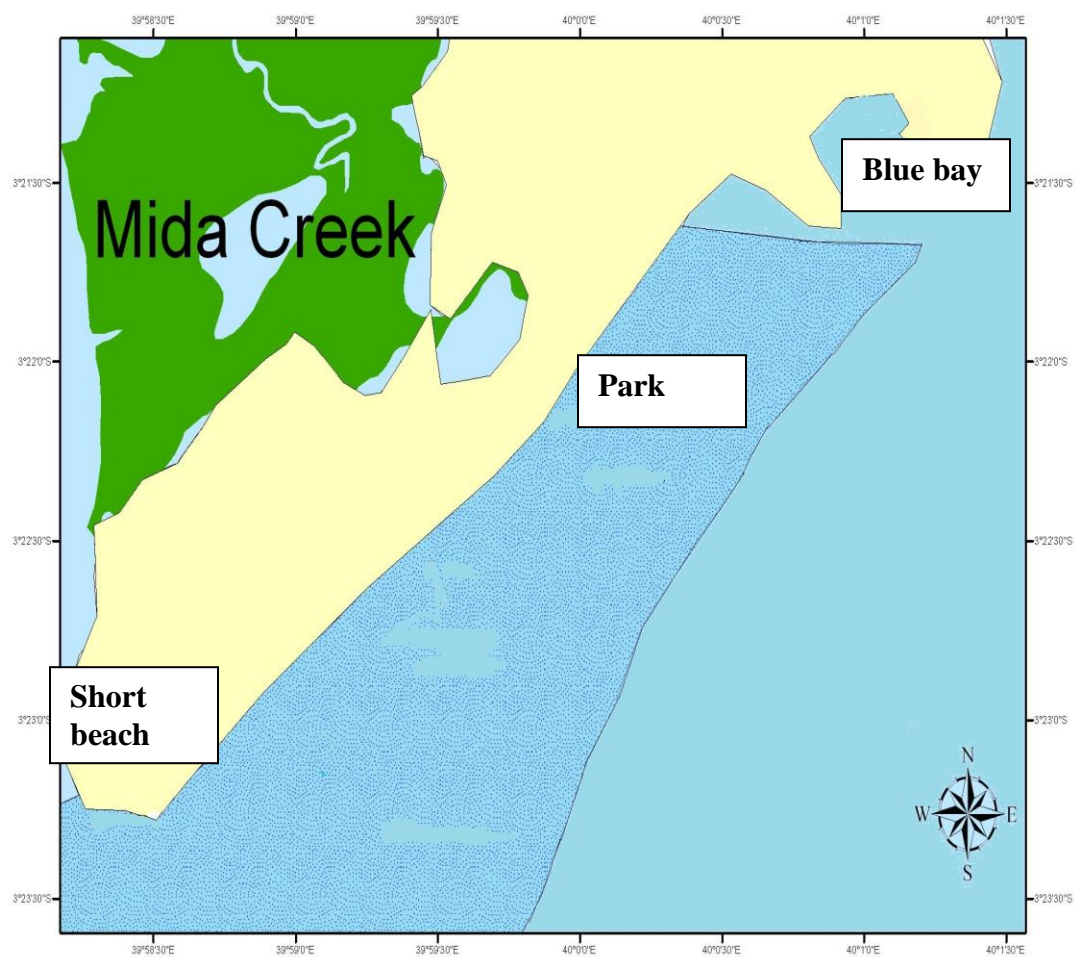


Figure 1: Map of the study site

Field sampling

Environmental parameters

The amount of phytoplankton in seawater was determined by chlorophyll *a* during every sampling period. Samples were collected in 5 litre black bottles and taken to the lab for analysis. Temperature and salinity readings were taken every sampling period using a thermometer and refractometer respectively.

Water samples were collected for nutrient analysis in replicates of 5 for each sampling site. This was done to establish whether there were any variations in nutrient concentrations which influence the phytoplankton densities.

Urchins

The density of urchins was established using circular quadrats (2m) that were randomly taken in the sites both at the Park and Reserves. Juvenile urchins were also counted from all the sites and these were those with diameters of less than 4cm.

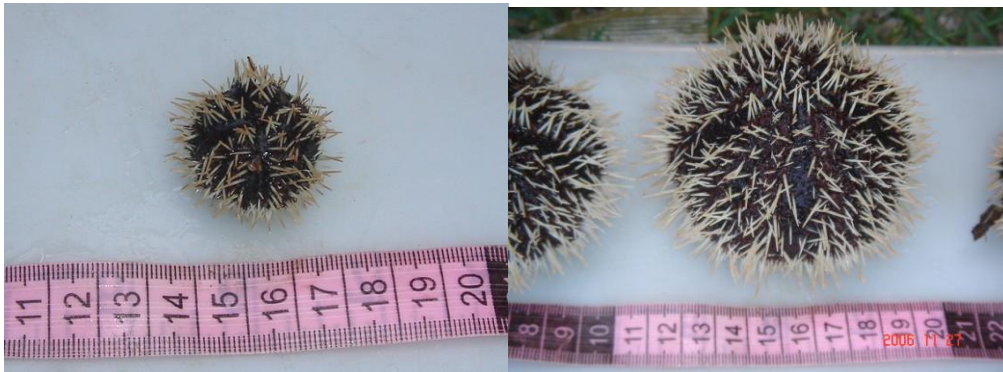


Plate 1: Juvenile *Tripneustes gratilla* **Plate 2:** Adult *Tripneustes gratilla*

Urchins were removed from the field for size determination by measuring body width, length and depth using vernier calipers (Muthiga, 2005). They were dissected for their guts, gonads and jaws and these were measured in the field. The gonads were examined to establish the sex of the urchins only for those that had gonads. This was done by looking at the colour of the gonads (ripe) which are normally creamish for the males and yellowish for females.



Plate 3: Ripe male gonads (creamish)

Plate 4: Ripe female gonads (yellowish)

The developmental stage of the gonads was also established (immature, ripe or spent). The immature urchins were characterized as those not having gonads; the ripe ones as those having ripe and runny gonads (see the plates above) and the spent ones as those with traces of gonads. The guts were collected in sampling containers and preserved in 5% formalin for gut content analysis in the lab. Organ indices were also determined using methods described by (Muthiga, 2005).

It was difficult to observe urchin larvae in the water column since these were very rare to observe.

Benthic vegetation

Percentage cover estimates of seagrasses and macroalgae in the different sites were made using replicate (5) quadrats. This was done using a 1m by 1m quadrat and estimating the percentage cover of the seagrass, algae, rubble or sand within the quadrat. Shoot densities of seagrasses were also determined using a 25 cm by 25cm quadrat and counting all the shoots within the quadrat. Five replicates were done for each sampling point. Within the shoot density quadrat, canopy height was also determined by taking 5 random measurements within a quadrat. Herbivory was also determined for the seagrass *Thalassodendron ciliatum* by collecting some shoots and bringing them to the lab for analysis.

Fish counts

This was done according to standard methods established by REEF CHECK. The different types of fish in the Marine Park and Reserve were determined with emphasis on the presence of Trigger fish which are predators of this sea urchin (McClanahan, 1990).

Laboratory analysis

Environmental Parameters

Chlorophyll *a* determination was done using the Spectrophotometric method (Short, 2001). Phytoplankton data was not observed for all the sampling thus chlorophyll *a* data was used to represent phytoplankton concentration in water. Nutrient determination for Ammonium, Nitrate and Phosphate for water samples was done using methods by (Parsons, 1984).

Gut Content Analysis

This was done to determine food eaten by *T. gratilla* found in seagrass beds. The gut contents were analyzed using a dissecting microscope. Seagrass species found in the guts were identified and the proportions were estimated according to (Hyslop, 1980).

Herbivory

10 shoots were collected from each sampled site and the number of bites was determined starting from the old outer leaves to the inner leaves. Differences of the urchin and fish bites are clearly evident since the urchin bites resemble a razor and those of fish are semi-circular resembling their mouth.

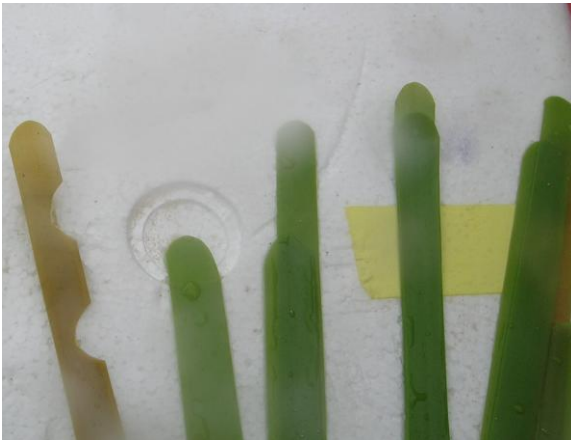


Plate 5: Example of a fish bite

3.0 RESULTS AND DISCUSSION

The data is represented in seasons. The seasons have been classified using the East African Coastal Current (EACC) regime as South East Monsoon (SEM) from April to October and North East Monsoon (NEM) from November to March.

3.1 Environmental parameters

The values of Chlorophyll *a* were different for the sites and seasons as shown below. Blue bay had the highest values for the SEM while Mida had the highest for the NEM. Factorial ANOVA showed statistical significance between seasons but not between sites.

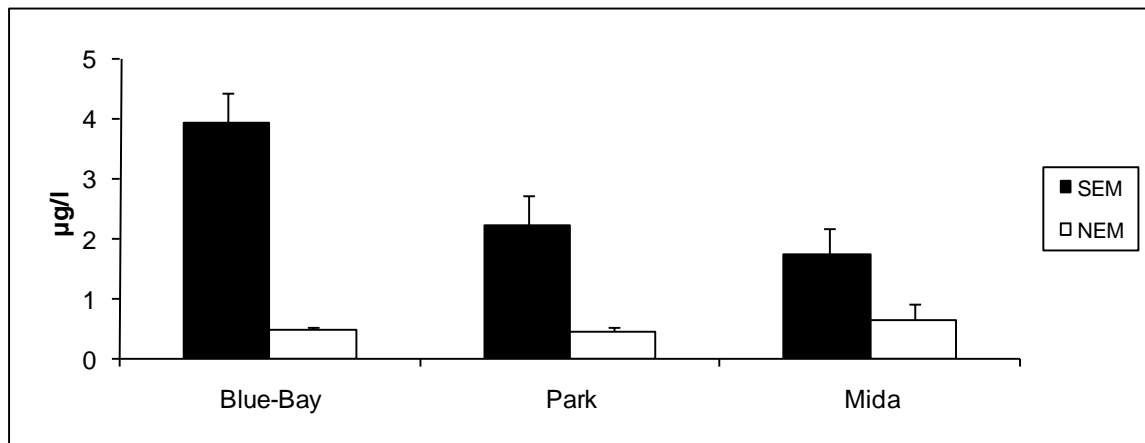


Figure 2: Chlorophyll *a* in the different sites

The nutrient concentrations are as shown below. There were no statistical significant differences observed for these parameters.

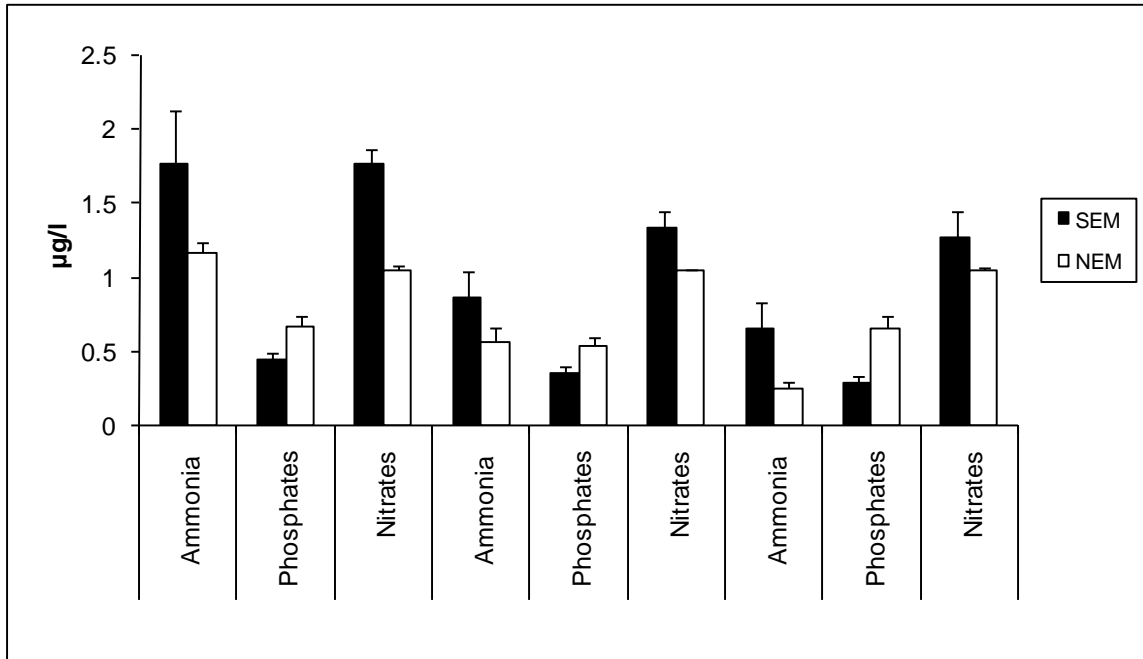


Figure 3: Figure showing nutrient concentrations at different sites and in the different seasons

3.2 Urchin Densities

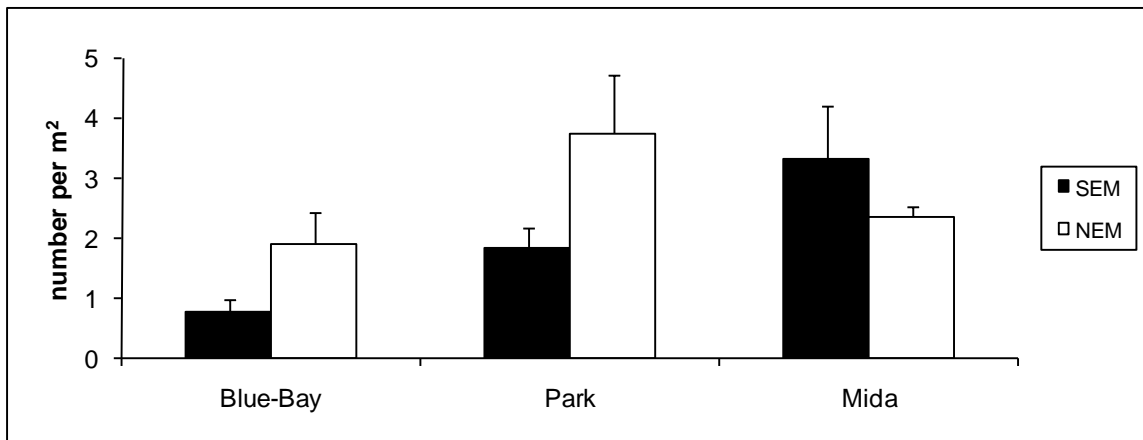


Figure 4: Urchin densities in the three sites

Urchin densities were expressed as individuals per square metre. In general, the urchin populations of *Tripneustes gratilla* were highest in the Park and Mida and least at Blue Bay. At Mida and the Park the urchins were mainly found occurring in aggregations. In the Blue Bay lagoon at the start of the study there were hardly any urchins and this may

have been as a result of the culling of the urchins in the year 2003. At Mida, the urchins were found occurring in aggregations within *Thalassodendron ciliatum* patches since the vegetation structure here was mostly algal dominated. Higher aggregations were also generally observed in grazed sites in the Park towards the coral areas. In healthy seagrass sites aggregations were low or sometimes absent.

Non parametric statistical tests were done to look at the differences in the urchin populations between the sites. Kruskal Wallis tests done showed significant statistical differences ($p=0.0002$). Dunn's multiple comparison test showed extreme significant difference between Park and Blue Bay ($p<0.001$) and a significant difference between Mida and Blue Bay ($p<0.01$). No significant difference was observed between the Park and Mida.

3.3 Gut, Gonad and Jaw indices

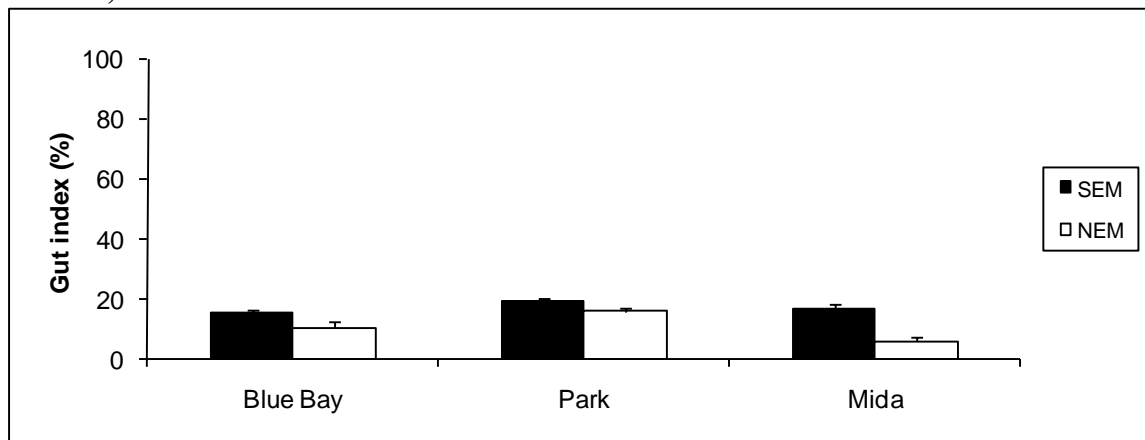


Figure 5: Figure showing Gut indices for the sites for the different seasons

Gut indices were below 20% for all the sites and seasons as shown in the figure above. They were however slightly higher in the SEM as compared to the NEM. Non parametric tests done showed an extremely significant difference ($p<0.0001$) between the reserves and the park. No significant difference was observed for reserves (Blue-bay and Mida). There was also an extremely significant difference between the seasons ($p<0.0001$).

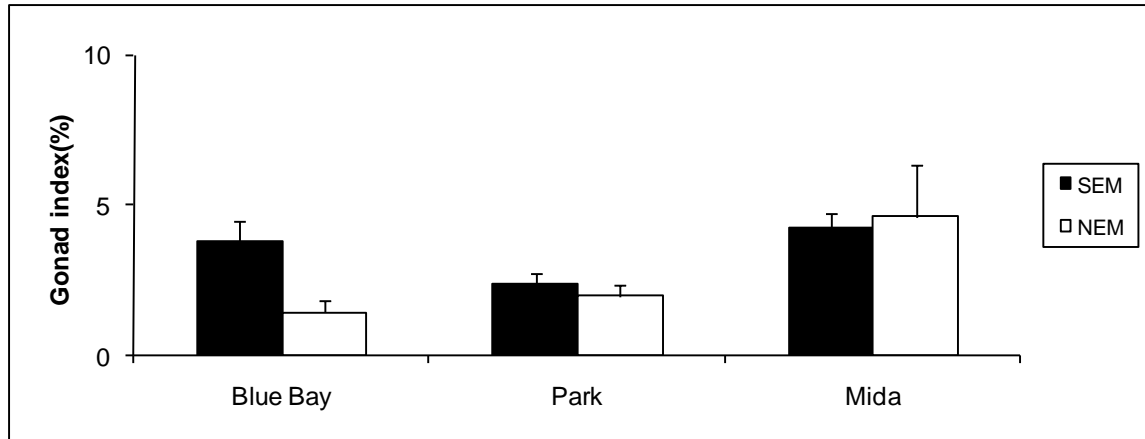


Figure 6: Figure showing Gonad indices for the sites for the different seasons

The gonad index ranged from 1-5% for all the sites and seasons. The values were higher at Mida for all the seasons and generally low in the Park. The variation of seasons was considered to be significantly different from non parametric tests done ($p < 0.0001$). However, variation among sites was not significant.

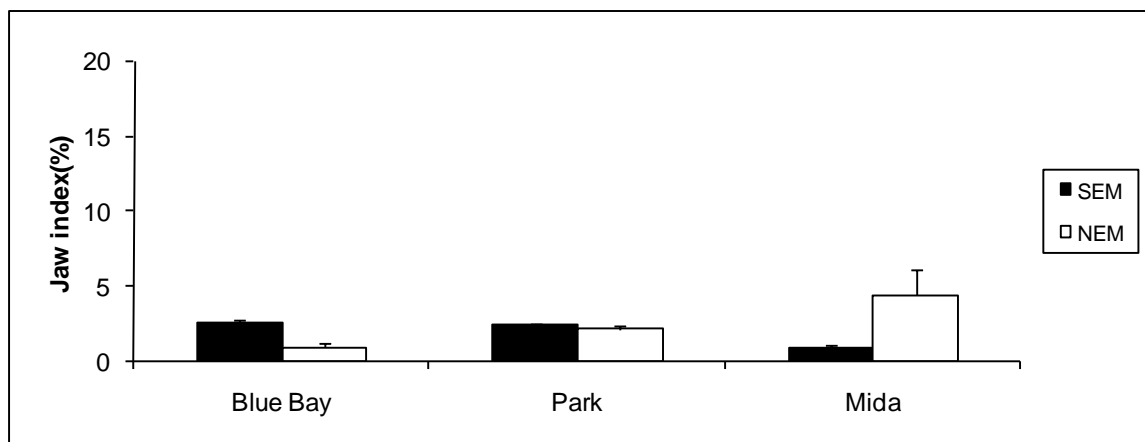


Figure 7: Figure showing jaw indices for the sites for the different seasons

The values for the jaw indices are as shown in the figure above. Mida during NEM had the highest value as compared to the other sites. The values seemed to be higher in the SEM for Blue-Bay and the Park but at Mida they were higher during the NEM. The variation among seasons was considered extremely significant $p < 0.0005$ while the variation among the sites was considered significant ($p < 0.05$).

3.4 Urchin Diammeter

Juveniles were mainly observed in healthy sites in the Blue Bay lagoon. The urchins with diameters less than 4cm observed in Mida seemed to be mature since they already had gonads.

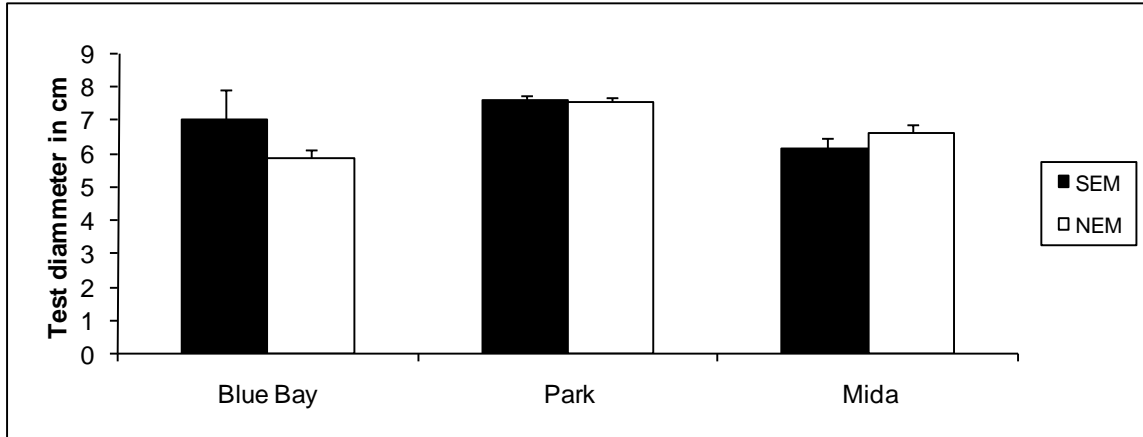


Figure 8: Diameter distribution of Urchins

Test diameter was higher at the Park as compared to the reserves as shown in the figure above. Non parametric tests showed statistical differences for the seasons ($p < 0.05$) and extremely significant difference between for Blue Bay and Park; Park and Mida ($p = 0.0001$).

3.5 Gut composition

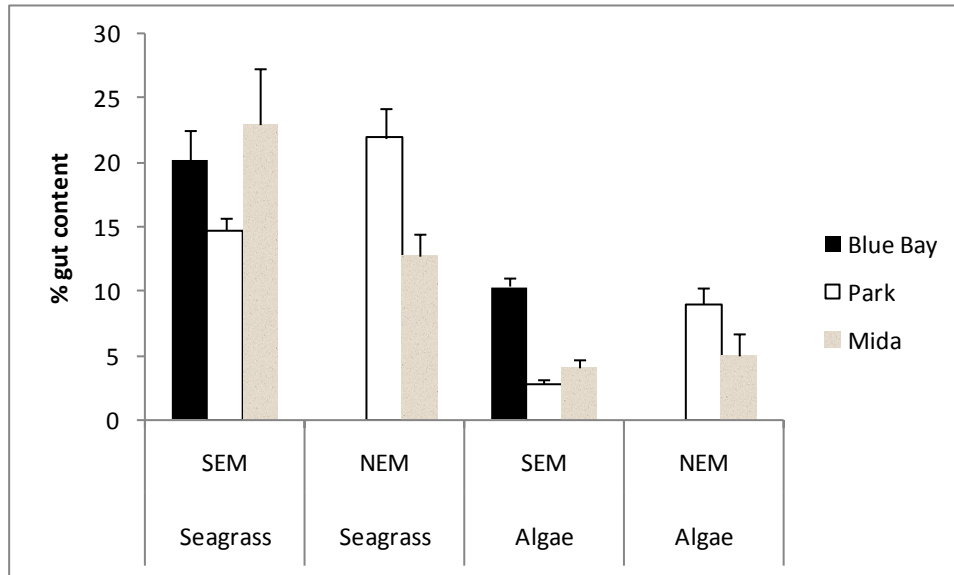


Figure 9: Composition of the gut for the urchins at all sites (only seagrass and algae considered; sand was omitted)

There was a high proportion of seagrass within the guts of the urchins at all the sites as shown in the figure above. The gut content also contained a higher percentage of fresh leaves (live seagrass) as compared to old leaves. Algae, sand and molluscs were also present within the guts analyzed but were lesser in abundance as compared to the seagrass.

ANOVA did not show any significant difference between sites or season ($p > 0.05$).

3.6 Benthic Vegetation (Percentage cover)

The data comprises of all the quadrats sampled. Sampling was done at the same sites though it was random. It did not involve going back to the same quadrats sampled (no fixed quadrats).

The main emphasis of the study was on the seagrass *Thalassodendron ciliatum* which seemed to be the favourite seagrass for *Tripneustes gratilla*.

The data is presented separately for the three sites.

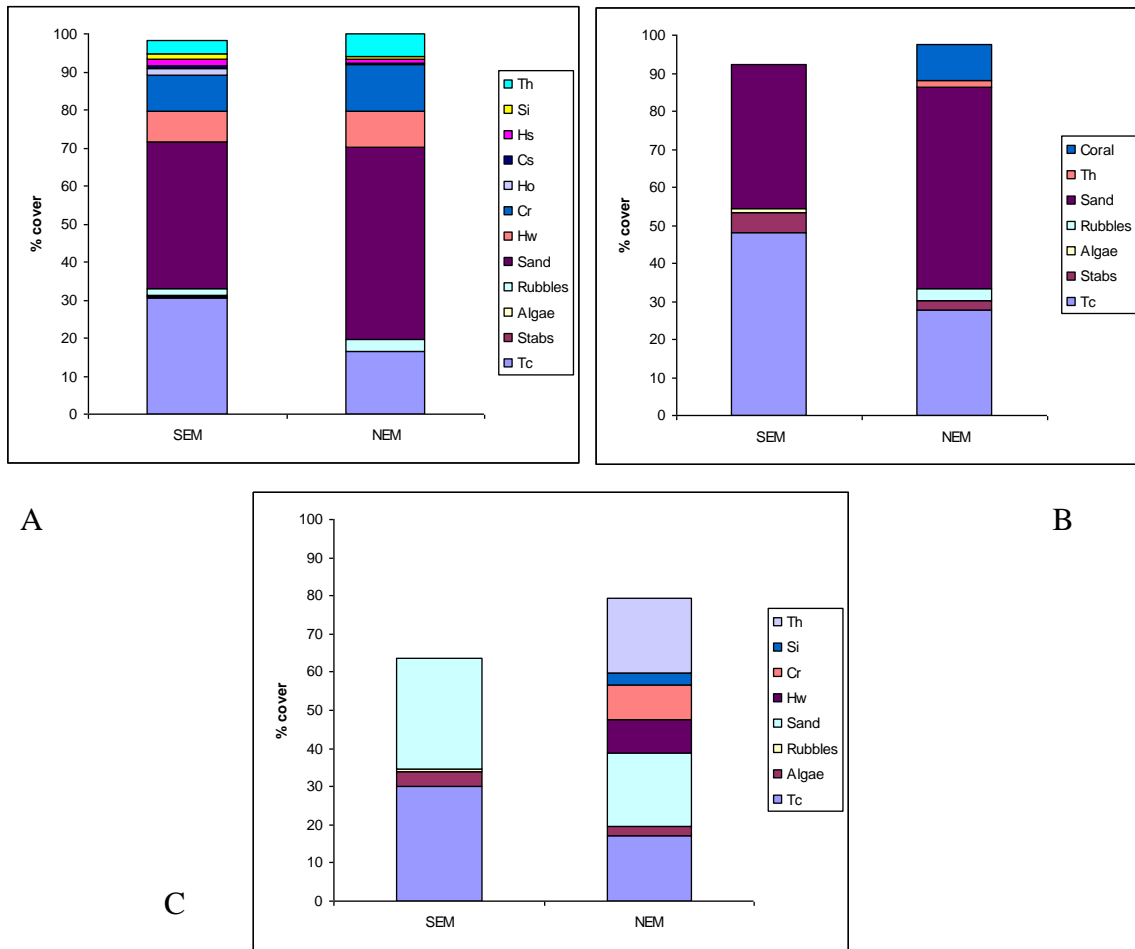


Figure 10: Relative abundance of seagrass species, algae, sand and rubble in the three sites (A-Blue Bay; B- Park; C- Mida). TH- *Thalassia hemprichii*, Si- *Syringodium isoetifolium*, HS- *Halophila stipulacea*, CS- *Cymodocea serrulata*, HO- *Halophila ovalis*, CR- *Cymodocea rotundata*, HW-*Halodule wrightii*, TC-*Thalassodendron ciliatum*. SEM-Southeast Monsoon, NEM-Northeast Monsoon

In Blue Bay lagoon, *Thalassodendron ciliatum* occurred at the middle and the end of the lagoon. The middle part of the lagoon was deeper thus could allow for the growth of this species. The area had been recovering from a culling event in the year 2003 hence by the time of the study there were healthy areas of *Thalassodendron ciliatum* at the end and also at the middle of the lagoon. The percentage cover is represented for the two broad seasons (SEM and NEM). Succession was evident at the Blue Bay lagoon. At the beginning of the sampling the climax vegetation was *Thalassodendron ciliatum*. However, from observation during the study period *Thalassia hemprichii* which is also a climax vegetation was observed in areas that previously were dominated by

Thalassodendron ciliatum beds. Pioneer species including *Halodule wrightii*, *Halophila ovalis*, *Halophila stipulacea* as well as intermediate species like *Cymodocea rotundata*, *Cymodocea serrulata* and *Syringodium isoetifolium* were also observed.

The Park represented deeper waters and *Thalassodendron ciliatum* was still the dominant species. There was patchy distribution of *Thalassodendron ciliatum* from field observations and these patches were healthy but adjacent to them areas of bare sand were also evident.

At Mida the cover represented several species comprising of *Halodule wrightii*, *Syringodium isoetifolium*, *Cymodocea rotundata*, *Thalassia hemprichii*, *Thalassodendron ciliatum* and algae. It was hard to establish a transect as was done for the other sites hence sampling was random. The most abundant algae was *Sargassum* sp. *Thalassodendron ciliatum* was present but in patchy distributions and the relative abundance was similar as that in Blue Bay. There was clear grazing evidence represented by the percentage cover of stabs both in Blue Bay and the Park which was higher in NEM than SEM corresponding to the higher urchin densities in the NEM than in the SEM. Mida reserve had high sand cover than the rest of the sites studied. In general, *Thalassodendron ciliatum* was most abundant at the park as compared to the two reserves.

3.7 Shoot Density

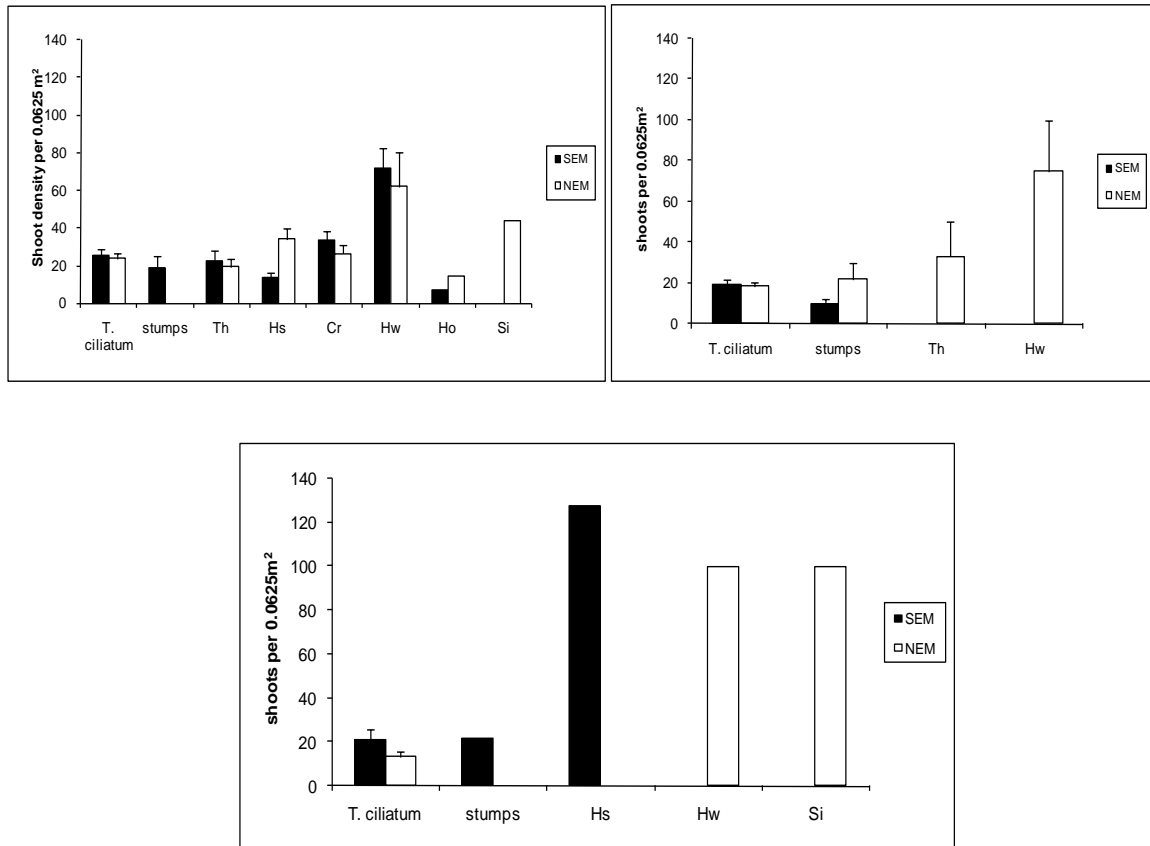


Figure 11: Shoot densities for different seagrass species at Blue Bay lagoon (A), Park (B) and Mida (C). TH- *Thalassia hemprichii*, Si- *Syringodium isoetifolium*, HS- *Halophila stipulacea*, CS- *Cymodocea serrulata*, HO- *Halophila ovalis*, CR- *Cymodocea rotundata*, HW-*Halodule wrightii*, TC- *Thalassodendron ciliatum*. SEM-Southeast Monsoon, NEM-Northeast Monsoon

At the start of the study there were no shoots of pioneering species were observed but these were observed later *Halodule wrightii* being the abundant one in Blue Bay and park. *Halophila stipulacea* was the abundant species in Mida (Short beach). Other species like *Cymodocea rotundata* and *Syringodium isoetifolium* which could be regarded as intermediate species were also observed especially at Blue bay in both seasons. The climax species *Thalassodendron ciliatum* and *Thalassia hemprichii* shoots were observed thought all the seasons.

3.8 Herbivory

Leaf analysis for bites was done by counting the bites of urchins and fish and getting the relative abundance of the urchin, fish; urchin and fish marks on a leaf for each of the leaves. Their standard deviation was also determined. Shoots were collected randomly to represent the whole site in Blue bay and Mida but for the Park they were collected at the beach, middle and end (reef). Leaves are represented from the younger leaves (1) to the older ones. At least 10 shoots were collected for the analysis at each site each sampling time.

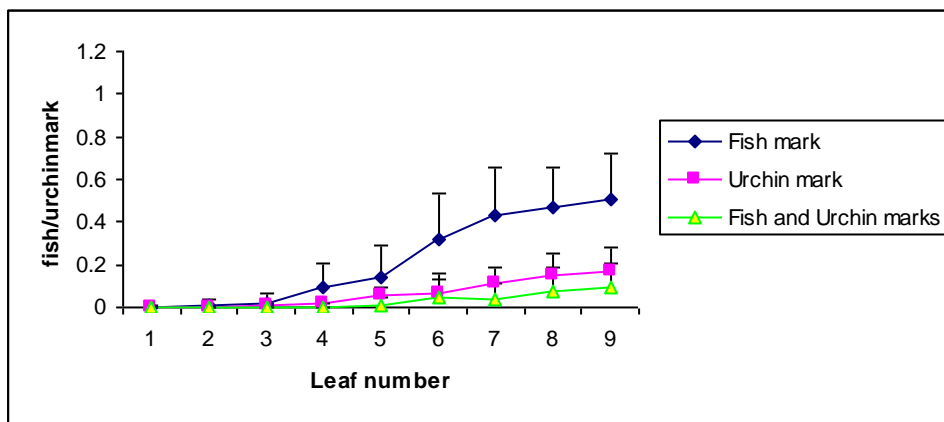


Figure 12: Herbivory on leaves by urchins and fish in Blue bay lagoon (0=no bites to 1=all leaves browsed)

In Blue bay urchin marks were much lower than fish marks. Leaves with both the urchin marks and fish marks are also shown in the figure above. Herbivory tended to increase with leaf age as the older outer leaves were the most impacted compared to the younger leaves. Herbivory started to be seen from the 4th leaf.

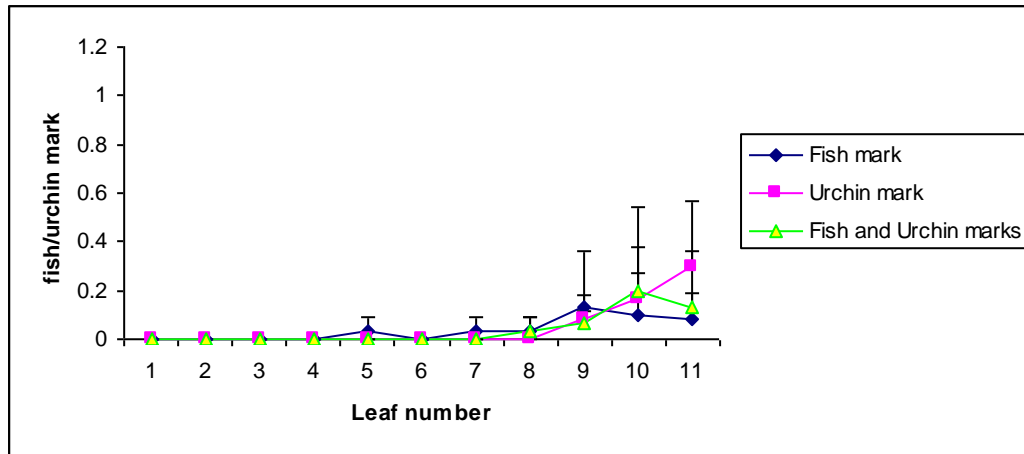


Figure 13: Herbivory on leaves by urchins and fish in Mida (0=no bites to 1=all leaves browsed)
 At Mida, grazing on leaves by both urchins and fish were much lower compared to Blue bay. Herbivory started to be seen from the 8th leaf. In the older leaves urchin marks were more abundant than fish marks.

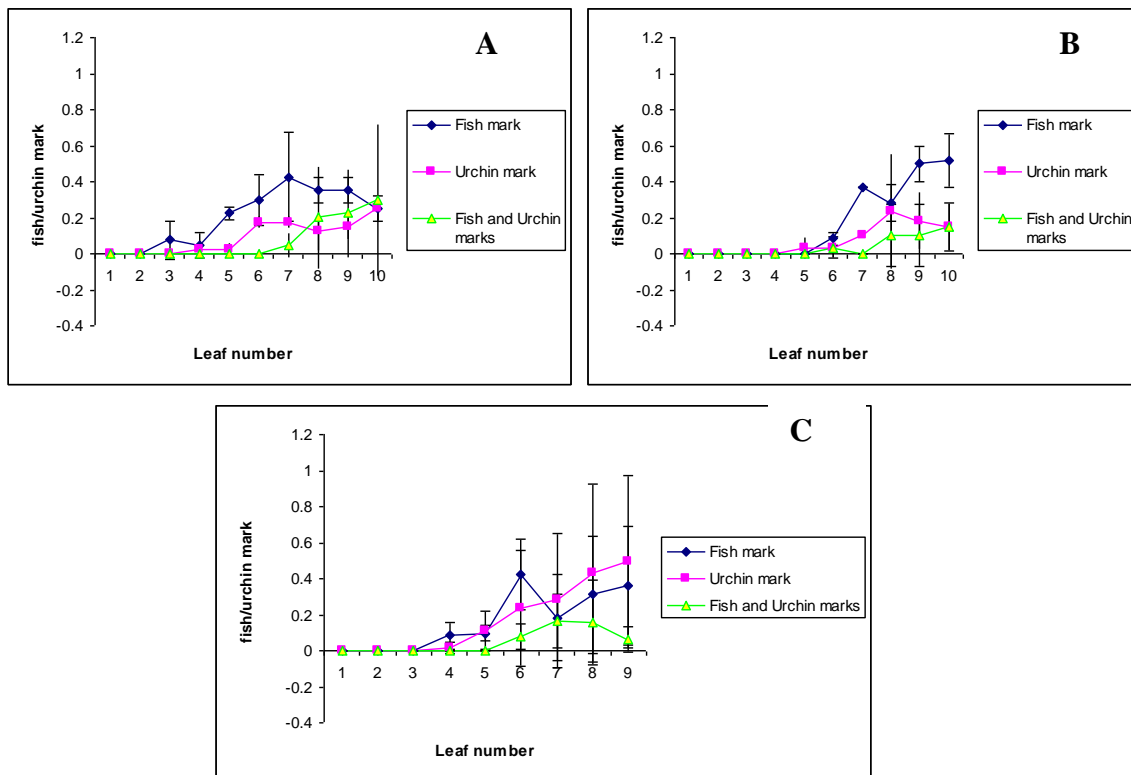


Figure 14: Herbivory on leaves by urchins and fish in the Park. A-Beach; B- Middle; C- End (reef)
 (0=no bites to 1=all leaves browsed)

In the park fish bites were generally higher towards the beach than the reef (end) where urchin bites were more than fish bites from the 7th leaf. Herbivory on the leaves started from the 3rd leaf at the beach mainly by fish, 6th mark mainly by fish at the middle and from the 4th leaf mainly also by fish towards the end (reef).

3.9 Fish Counts

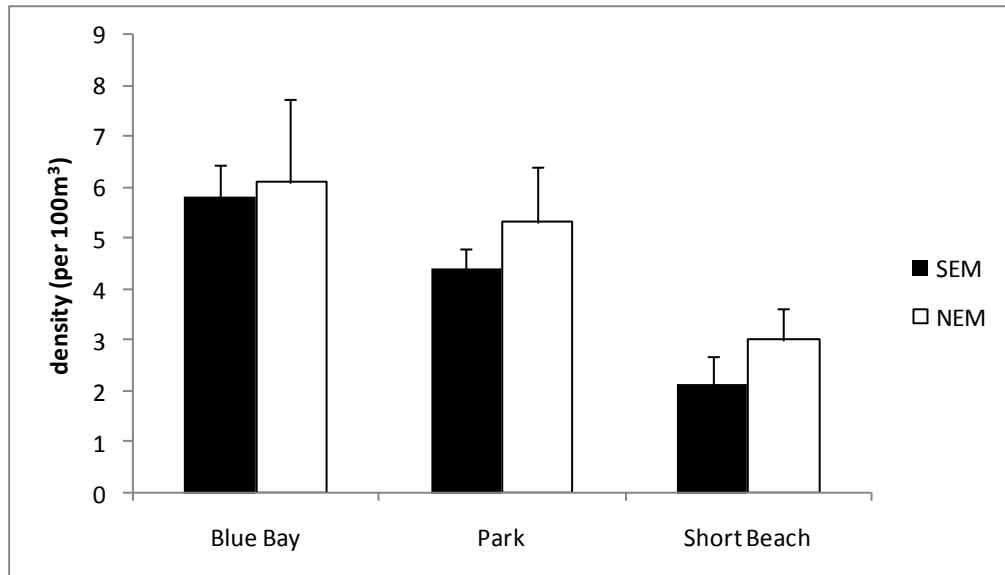


Figure 15: Densities adult fish in Blue Bay, Park and Mida

Fish counts were done during low tide when other parameters were collected. Transects 5m wide and 20m long were taken at low tide approximately 1-1.5m water depth. Juveniles were assumed to be less than 10cm with an exception of few species (*Amphiprion allardi*, *Dasyllus sp*, *Apogon sp*) whose adults are 8-13 cm. More fish densities were observed in the Park followed by the Blue Bay lagoon then Mida for the adults but in Mida and Blue Bay there were more Juveniles than the Park (see figure above). High fish densities at Blue Bay also corresponded to the high fish herbivory observed. The family Pomacentridae (6-12 per 100m³) had the most abundance but the other families were ranging between (0-6 per 100m³).

Factorial ANOVA of adult fish showed statistical differences on the interaction of seasons and sites for adult fish as shown in the table below.

Table 1: ANOVA results for Adult fish

Effect	df	SS	MS	F	p
Intercept	1	1330.94	1330.945	56.36782	0.000000
Season	1	12.01	12.013	0.50877	0.475974
Site	2	93.76	46.882	1.98554	0.138288
Season*Site	2	301.02	150.510	6.37436	0.001833
Error	551	13010.09	23.612		
Total	556	13532.59			

Parametric tests done on log transformed densities did not show any significant difference of juvenile densities between the three sites.

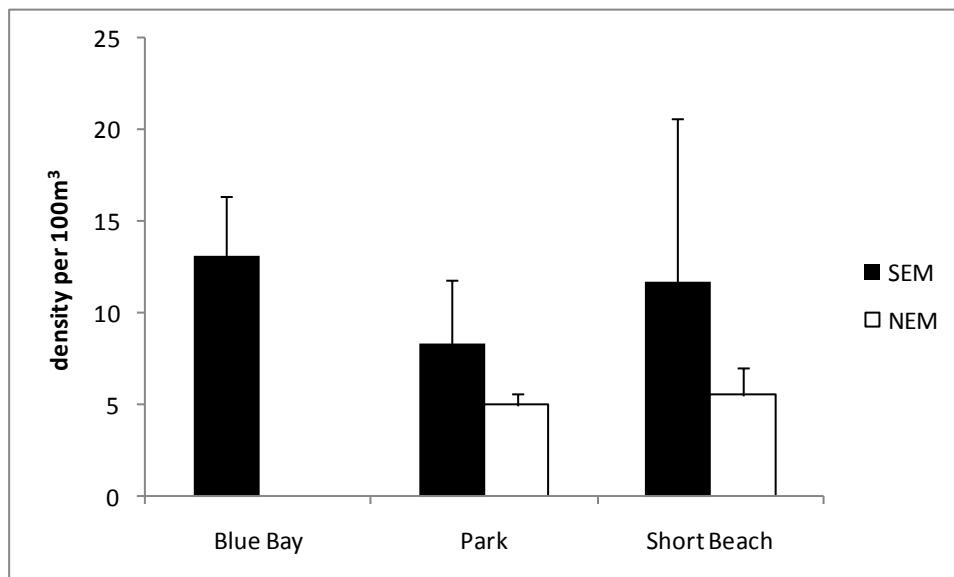


Figure 16: Juvenile fish densities at the three sites

At Blue Bay no juveniles were observed during the NEM. Densities of juveniles were higher during the SEM as compared to the NEM as shown on the figure above.

The fish known to prey upon the urchins are from the family Balistidae (commonly known as trigger fish) and some Labridae. *Suflamen frenatus* and *Rhinecanthus aculeatus* were the only fish counted from the Balistidae family during the study. These were mainly observed in the Park and Mida though the juveniles were also seen in Blue Bay.

4.0 Discussion

Sea urchin grazing was always present in the Park and the two reserves (Blue bay and Mida) but fish herbivory was also present and mostly higher than for urchins. This could suggest that fish herbivory also impacts seagrass production in fishing protected habitats (Alcoverro, 2004). However, urchin herbivory is destructive compared to fish herbivory leading to the clearing of previously healthy patches. Urchins were observed to occur in the bare areas (sand) in aggregations and in seagrass patches singly and it seemed that the urchins were moving to seagrass patches for food and then to the bare areas especially in the Park where there was a patchy distribution of healthy *Thalassodendron ciliatum*. High herbivory by urchins was in the Park (towards the reef) and at Mida which corresponds to the high urchin numbers observed at the same sites. The rest of the areas had higher fish herbivory than urchins as expressed by fish and urchin bites. The urchins from this study seemed to like *Thalassodendron ciliatum* species as food evidenced by the high portion of this seagrass species in their guts. It has been observed in other studies that *Thalassodendron ciliatum* seems to be more vulnerable to sea urchin grazing than other seagrasses (i.e. *Thalassia hemprichii*, *Cymodocea serrulata*, *Cymodocea rotundata* and *Syringodium isoetifolium*) whose apical meristems are partially protected in the sediment (Alcoverro, 2002). *Thalassodendron ciliatum* also had high epiphytization as compared to other seagrass species from field observations and this could also have been a possibility for the preference of this species for the others. There was also a preference of live seagrass as compared to the old leaves. This is also the case that was observed in Papua New Guinea where *T. gratilla* grazes on living seagrass leaves (Mukai, 1985).

Other studies done in other areas have shown the favourite food preference for *T. gratilla* to be *Syringodium isoetifolium*. It was suggested to be partly related to the higher availability of that particular seagrass species in the area of that study (Vaitilingon, 2003). This is different as compared to this study where *T. ciliatum* was the food preferred and shows that the urchins could be choosing their preferred food with regard also to its abundance in an area.

The type of grazing matters as the urchins are destructive grazers compared to fish since they are even known to move in fronts clearing whatever cover they find on the way leaving bare areas that were initially vegetated. The recovery rate of *Thalassodendron ciliatum* is also slow and if intensely grazed on this poses a problem of bouncing back after disturbance. In Blue bay lagoon *Tripneustes gratilla* had been culled before the study was started hence there were healthy beds of seagrass mainly comprising of *Thalassodendron ciliatum* but after some time the urchins came back and grazed heavily on the seagrass beds leaving bare areas at the end of the lagoon towards the reef. Studies done elsewhere have shown that the reason why abundances of prey decline amongst sparse seagrass is that individuals move to better cover, not that they are more easily preyed upon (Bell, 1986).

There was therefore a change in the seagrass species showing a succession that was geared towards the development of *Thalassia hemprichii* and *Syrigondium isoetifolium* as the climax communities. This was the case for Blue Bay which is a shallow lagoon but not the case at the Park which is much deeper and Mida comprising of a rocky substrate.. *Thalassodendron ciliatum* was also seen at Blue Bay but mainly at the middle of the lagoon which was deep. Lots of stumps of *T. ciliatum* were observed during the NEM and this was reflected by the high urchin numbers then.

Towards the end of the lagoon it was a bit shallower and *Thalassia hemprichii* and *Syrigondium isoetifolium* were developing as the climax communities. In other studies high urchin densities have been known to cause a transition from macroalgal forests to coralline barrens, i.e., bare rocks with encrusting algae (Tegner, 1981; McClanahan, 1990; Sala, 1998), with repercussions for rocky-reef ecosystem structure and functioning (Sala, 1998).

Catastrophic mortality as a result of large scale disturbances has been invoked as a mechanism which promotes species diversity and prevents a system from achieving equilibrium or becoming a climatic successional stage (Huston, 1994). Species diversity may be enhanced as the abundance of a dominant competitor is reduced or resource regimes are altered due to the loss of the dominant species or by physical changes to the environment. This could be due to the fact that quick colonizers take advantage of empty space. This could explain the case in Blue Bay lagoon where at the beginning of the study

the most dominant species was *Thalassodendron ciliatum* but by the end of the study there were several species recolonizing the area and also the nature of the lagoon, being shallow. This may eventually depending on the biology of the species involved alter even the climax community. In this study in the end of the lagoon *Thalassia hemprichii* was the species taking over as the climax community. It could be because the recovery rate of *Thalassodendron ciliatum* is also slow and the shallowness of the lagoon which could also favour existence of *Thalassia hemprichii* which is mainly an intertidal seagrass species compared to *Thalassodendron ciliatum*, a subtidal species. The fact that *Thalassia hemprichii* is also resistant to herbivory by urchins (Alcoverro, 2005) could mean that there is a possibility of it to replace *Thalassodendron ciliatum* if its recovery is slow. In other studies large-scale loss of seagrass biomass has been seen to initiate community-wide cascading effects that altered resource regimes and species diversity (Peterson, 2002). Successional studies in seagrass communities have also shown that recolonization is directed by seed banks, vegetative propagules, and ramet expansion. The ramets would originate from isolated island patches within the bare area, or from the edges surrounding the disturbance. Major constraints on plants colonizing disturbed areas include access to the disturbed region, availability of limiting resources, and continual mortality.

The lack of seeds and seedlings in the overgrazed areas presumably due to erosion and sediment resuspension which would remove the seeds and uproot the germinating seedlings could be a cause for lack of recovery of some areas in the period studied (Peterson, 2002). This study however did not look at the seedlings or seeds of the species found.

Predators can affect density, behaviour and population structure of sea urchins (McClanahan, 1990) hence they may indirectly influence the structure of benthic communities by mediating urchin grazing pressure (Shears, 2002).

The main predators of sea urchins generally are from the Balistidae family. In this study *Suflamen frenatus* and *Rhinecanthus aculeatus* were the only species in the Balistidae family counted. The fish data was only limited to low tide and mainly in seagrass areas. Previous studies done in coral reef areas indicated a low abundance of *Balistapus*

undulatus relative to *Rhinecanthus aculeatus* which largely feeds on juvenile sea urchins (McClanahan, 1994).

Cheilinus trilobatus was observed in the Park towards the reef (adults) and in the Middle part of the Park (juveniles). This species is known to feed on adult sea urchins (McClanahan, 1994). The species was however not very common and the observed densities were low (2 per 100m²). Adult Scavengers such as *Lethrinus harak* and *Lutjanus fulviflamma* were also observed mainly in the Park and the juveniles in Mida. These two mainly prey upon juveniles or injured urchins (McClanahan, 1994). The densities of the fish that mainly prey upon sea urchins from the observed counts were rather low. This however may be due to the fact that the fish counts were done during low tide with water levels of 1- 1.5m in height.

The fact that *Tripneustes gratilla* are able to move from one place to another makes them able to maintain their large densities since after clearing one seagrass patch they are able to move to another patch in search for food. Their ability to move in fronts in this case had an impact on seagrass distribution at the park where they left areas totally cleared and fragmented healthy patches of *Thalassodendron ciliatum*. The three sites represented different impacts where at Blue Bay there was clear evidence of the possibility of the most dominant species, *Thalassodendron ciliatum* being replaced by *Thalassia hemprichii* which could be due to its long recovery time and also the shallowness of the lagoon favouring the latter species.

At the Park which is deeper representing a more subtidal environment there was only a decline in the cover of *Thalassodendron ciliatum* and no succession by other species. This however led to a fragmentation which could influence the diversity of other species. Mida which mainly had a rocky substrate and comprised mainly of algae and the urchin maturity as at small test diameter.

5.0 Conclusion

Seagrass beds are valued for the services they provide to the overall function of coastal marine ecosystems (Hemminga, 2000). They increase coastal biodiversity by providing habitat for many organisms and by functioning as nursery and foraging areas for many animals. In addition, they improve water quality by reducing suspended sediments and by absorbing nutrients, and they stabilize sediments. From the study especially in the Park if the trend increases and there is no full recovery then these services may be lost.

Disturbance also in this study has shown that it can alter the community structure of the seagrass ecosystem as observed in the Blue Bay lagoon. This may lead to a totally different system that may function but probably lead to a loss in the ecosystem function.

Food therefore may not really affect much the populations of urchins as observed in the study since they always can move to other potential areas with food source and even come back to overgrazed areas after disturbance. The presence of the predators on the other hand may affect the urchin populations but this needs a further survey of the population densities of the urchin predators since this was done in the study sites and only limited in low tide. Most of the predators inhabit the coral reefs and move to seagrass beds to feed.

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