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Spatial and Temporal Distribution of Echinoderms in the Intertidal Waters of Massawa.

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A B S T R A C T

In this paper distribution patterns of echinoderms, sediment textural analysis and physical parameters were dealt in three study sites, Gurgussum, Hirgigo and Tiwalet at the lower intertidal and upper subtidal waters for three months (February, March and April, 2012). Echinoderms distribution and abundance (no/m2) varies from site to site during sampling periods. The three sites also differ in species composition. The highest total density of Oreasteridae (4/m2) was recorded in Tiwalet and it was nil for the same group in Gurgussum and Hirgigo. The most common groups that were seen in Gurgussum are Ophicomidae (107/m^2) and Echinomertridae (87/m2) and completely absent in Hirgigo and Tiwalet. The highest in diversity of echinoderms was Tiwalet consisting of four families (i.e. Oreasteridae, Ophiuroidae, Scutellidae and Holothuriidae). However, Hirgigo was completely devoid of any of these groups. Both water temperature and salinity were recorded in all three sites for the three months. It was observed that there was negligible temporal and spatial variation with respect to the two physical parameters. Textural analysis of sediment (sand, silt and clay) showed that sand was dominant fraction in Hirgigo than Tiwalet, while silt is comparatively more in Tiwalet than in Hirgigo. The clay fraction was distributed uniformly in very low percentage in both the sites. But, the site Gurgussum is entirely a hard substratum. In general, echinoderms showed negative correlation with sand and silt whereas positive correlation with clay.

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Introduction:

Echinoderms are exclusively marine phylum, widely distributed throughout the sea. They are common in intertidal and are abundant at great depths. Almost all forms are benthic as adults. A calcareous skeleton, external spine or knobs, and five sided or pentamerous radial body symmetry characterize most. Because echinoderms develop from bilaterally symmetrical larval stages, radial body symmetry is a secondary condition in this phylum. This and other aspects of their evolutionary history separate them on the phylogenetic tree of animal groups from these phyla characterized by primary radial body symmetry. A unique internal water vascular system hydraulically operates the numerous tube feet. The tube feet extend through the skeleton to the outside and serves as respiratory, excretory, sensory and locomotors organs.

The echinoderms are familiar group of animals in the lower intertidal. Sea stars, sea urchins, brittle stars and sea cucumbers are all quite sensitive to desiccation and salinity change and seldom seen in abundance above the lower intertidal zone (Sumich and Morrissey, 2004). Echinoderm diversity is typically higher in coastal regions than deeper waters, however, while echinoderms typically are a conspicuous and abundant component within intertidal and shallow subtidal habitats, they often are not overly diverse compared to other phyla (Chenelot*et al.* 2007).

The distribution patterns of benthic plants and animals are strongly influenced by the firmness, texture, and stability of their substrate. These features govern the effectiveness of locomotion or, for non-motile species, the persistence of their attachment to the bottom. The particle size and organic content of the bottom material limit the versatility and distribution of specialized feeding habits. Suspension feeders depend on small plankton or detritus for nutrition. Filtering devices or sticky mucous nets or sheets collect minute suspended food particles from the water. Suspension feeders generally require clean water to avoid clogging their filters with indigestible particles. Therefore, they are usually found on rocks or are associated with coarse sediments (Sumich and Morrissey, 2004).

The number and type of organisms making up any particular benthic community are determined by a variety of physical and biological factors. In shallow coastal water, tidal levels, degree of wave action, salinity and temperature variation will influence the composition and relative abundance of benthic species (Lalli and Parsons, 1993)

Biodiversity assessments in marine systems are of great interest from ecological, public and management standpoints. They are important for understanding ecological patterns and ecosystem functioning and for managing marine resource use and identifying conservation priorities. A particular ecological interest is the identification of biodiversity patterns to investigate possible factors driving diversity, and to serve as context for local ecological studies and in management and conservation (Gray, 1997). It is not always a single echinoderm species or class that contributes to overall ecosystem functioning. Rather, high echinoderm species numbers and abundances contribute significantly to community structure in different regions of the world (Neira and Cantera, 2005).

The study principally carried out to investigate intertidal and upper subtidal distribution patterns of echinoderms in coastal waters of Massawa. It emphasized mainly on species composition of the echinoderms in the intertidal zone of Massawa coastal waters. Simultaneously, sediment texture analysis conducted to determine animal sediment interaction.

Materials and Methods:

Study Sites:

The Red Sea sandwiched between Arabian Peninsula and African continent is one of the warmest seas in the world (Alasdair and Stephen, 1987). This area is noted for its high salinity, as exchange of water with neighbouring water bodies is limited. Another factor is the absence of permanent terrestrial runoff discharging into the sea and due to exceedingly high evaporation relative to precipitation (Elhag and AbdalGodir, 1988). Evaporation from the water amounts to about 235 mm/year (Fishelson, 1971) and mean salinity was 40.35 $^{o}/_{oo}$ (Marcos, 1984).

Massawa coast, which is part of the Eritrean coastline, is part of the different coasts that surrounds the Red sea. Like other parts of the Eritrean Red Sea coast, it gets little inflow of fresh water from the terrestrial areas. In the present study, three sites were selected (Fig.1) assuming that, these three sites can represent the intertidal coast around Massawa (sandy, muddy and rocky) and based on its accessibility under most weather condition. These three sites are:

- Gurgussum located at (15^{o}39'.364 N, 39^{o}28'.364 E), east of Hamassien Beach Hotel, experiences a considerable amount of wave action and tourist pressure. In addition, this site has rock dominated substrate.
- Hirgigo located at (15o32'.927 N, 39o27'.761 E), around the jetty area, eastern side of the hirgigo village, is mangrove dominated site.
- Tiwalet located at (15o35'.813 N, 39o27'.933e), western side of green island, is relatively protected area, free from wave action and human disturbance.

Fig: 1. Map showing study sites.

Sampling:

Samples were collected using transect and quadrat method from three sites namely, Tiwalet, Gurgussum and Hirgigo. The sampling was done monthly for a period of three months that is February, March, and April, 2012. It was conducted in the intertidal and upper subtidal zone of each site. By determining the time of lowest of low tide of each site, a transect line was set at a distance of 100 meters starting from 25 meter sea ward from the low water line to the upper part of the intertidal zone. Along with the transect method, a quadrat of 1m^2 (1m x1m) was used at every 25m interval on the transect line. With quadrats, some forms of stratified random sampling usually gave estimates that were closer to known values than simple random placement (Miller and Ambrose, 2000). The quadrat itself was divided into 25 sub-sections (grids) of each $0.4m^2$. The number of sample to be taken can be determined on the basis of the desire degree of inclusiveness or precision of the data (Brower and Zar, 1997).

Temperature:

The water temperature of the intertidal water was recorded every month during the sampling period by using ordinary thermometer.

Salinity:

Salinity of tidal pools of the three areas was measured monthly for about three months with the help of a refractometer.

Sediment collection and textural analysis:

Sediment samples were collected from each quadrat in every month in all three sites. From each quadrat, sediment was collected from two randomly selected grids. The sediment samples were collected in polyethylene bags and brought to the laboratory for further textural analysis. To determine the sediment particle size, the sediments were air dried for 10 days to remove the moisture content. After air drying, 100g of sub samples were taken and soaked in water with $Na_2H_2PO_4$ (Sodium hexameta-phosphate) dispersant over night. 50% of HCl was added into the sediment in order to dissolve the shells. Wet sieving was carried out using a sieve of mesh size 62.5µm to separate silt and clay from sand and later retentions in the sieve was dried in oven at 60ºC. The clay components were separated from silt by Standard pipette analysis method (Carver, 1971).

Echinoderms collection and analysis:

Echinoderms were collected from each quadrat laid in 100m length transect line starting from 25m offshore of the low water line mark. Most of the echinoderms were very friendly in their collection. In a sense, majority solely could be picked up by hand. However, there were also other members which require some instruments to detach the organisms from their excavations. Sand dollars, sea stars and sea cucumbers collected manually (by hand picking)**,** whereas sea urchins and brittle stars collected by using a scrapper. The specimens of the echinoderms which have been collected in the study area were kept in polyethylene plastic containers to avoid the atmosphere borne deterioration that bears unpleasant putrid smell. Therefore, after death to deter this rotten egg like smell, 5% formalin solution was poured into each container holding the specimens. Along with the collection of the sediment and echinoderms, the presence of other organisms (plants and animals) and other important characteristics of each site during the sampling period were recorded. The preserved specimens were identified to the possible lower taxon under their respective families. Their density was expressed as number of organisms per quadrat.

Data analysis: ANOVA:

In order to determine whether there exists a variance on the distribution patterns of the identified families in the three sites, a statistical Analysis of Variance (ANOVA) was tested based on the data collected from the three sites during the sampling period.

t-Test:

The textural variation of sediment among the three sites (i.e, Hirgigo, Tiwalet, Gurgussum) was assessed using t-Test.

Result & Discussion:

The textural analysis of sediment was carried out to determine the variation in composition between the three sites. The sediment texture was grouped as: sand its allies (62.5µm and above), silt (between 62.5 µm and 3.9 µm), and clay (less than 3.9 µm). The preserved echinoderms were sorted out to six families and expressed their abundance as number of organisms per quadrat (no/m^2) in all three sites during the study period.

Physical parameters:

The average water temperature of Gurgussum, Hirgigo and Tiwalet was recorded as, 29^{o}C, 30.7^{o}C and 30.33^{o}C respectively (Table 1). Salinity of the study sites was also measured monthly. The highest average salinity (42$^o/_{oo}$) was observed in Hirgiogo followed by Gurgussum (41.7 $^o/_{oo}$) andTiwalet (41 $^o/_{oo}$)

Table: 1. Water quality Parameters of the Intertidal waters of the three sites

Sites	GURGUSSUM				HIRGIGO				TIWALET			
Parameters	Feb.	Mar.	Apr.	**Ave.**	Feb.	Mar.	Apr.	**Ave.**	Feb.	Mar.	Apr.	**Ave.**
Water temperature (^{o}C)	29	30	28	29	31	31	30	30.7	30	30	31	30.33
Salinity ($^o/_{oo}$)	41	42	42	41.67	43	42	42	42.3	41	41	41	41

Substrate nature of the study sites:

During the present study, there was a variation in the substrate nature and this is mainly due to the topographic difference among the sites. In Gurgussum, almost whole sampling area was hard substrate. This hardness is mainly due to the dead corals that extend from the shore line toward the lower part and having a gentle slope with slightly elevated than the surrounding areas and is densely populated with seaweeds especially in the subtidal areas.

In the second site (Hirgigo) the sediment was dominated by relatively fine sand, followed by silt and with negligible amount of clay (Table 2). Within the site, sediment texture was analysed among the quadrates. Among the quadrats, however, a significant difference was not found.

In Tiwalet, the sediment type was dominated by sand followed by silt and the percentage of clay was very little amount (Table 2). Although, the sediment nature of Tiwalet exhibited a relatively lower percentage of sand and higher percentage of silt than that of Hirgigo, no difference was observed in the percentage of clay. The relatively protected nature of the area leads to high deposition of sediment and a number of dead shells. In addition, there were dominant sea grasses in the lower parts and patchy seaweeds in the upper zone.

Table: 2. The percentage composition of sand, silt and clay in Hirgigo and Tiwalet.

	HIRGIGO			TIWALET		
Quadrat No	Sand %	Silt %	Clay%	Sand %	Silt %	Clay%
1	97.00	2.95	0.05	91.37	8.58	0.05
2	95.56	4.40	0.04	90.61	9.36	0.03
3	94.49	5.42	0.09	90.67	9.27	0.06
4	94.53	5.42	0.05	93.00	6.95	0.05
Average	95.40	4.55	0.05	91.41	8.54	0.05

Species Composition andtheir Distribution Pattern:

Species composition of the three study area all in all sharing six families (i.e. Holothuriidae, Ophicomidae, Echinomertridae, Scutellidae, and Oreasteridae), was identified to the species level (Table 3 & 4, Fig.2). Gurgussum was completely dominated by families of Ophicomidae and Echinomertridae (Fig.3), while in Tiwalet all the groups other than Echinomertridae and ophicomidae were common (Fig.4). Unlike the two sites, complete absence of the six groups was observed in Hirgigo. In order to determine if there exists variation on the distribution patterns of the identified families among the three sites, a statistical Analysis of Variance (ANOVA) was tested based on the data collected from the three sites during the sampling period. Based on the calculation carried at 5% level of significance, there was a considerable variation among the three sites in the distribution patterns of the six families of echinoderms. And also, there was a significant difference in the distribution patterns of the six families within each site.

Table: 3. Species composition of the three sites (presence and absence indicated by '+' and '- ')

CODE	SPECIES NAME	COMMON NAME	GURGUSSUM	HIRGIGO	TIWALET
	Oreasteridae				
01	*Culcitaschmideliana*	Star fish	-	-	+
	Ophicomidae				
02	*Ophiocomascolopendrina*	Brittle star	+	-	-
	Ophiuroidae				
03	*Ophiothrix*sp.	Brittle star	-	-	+
	Echinomertridae				
04	*Echinomertamathaei*	Sea urchin	+	-	-
	Scutellidae				
05	*Echinodiscus*sp.	Sand dollar	-	-	+
	Holothuriidae				
06	*Holothuriaatra*	Sea cucumber	-	-	+

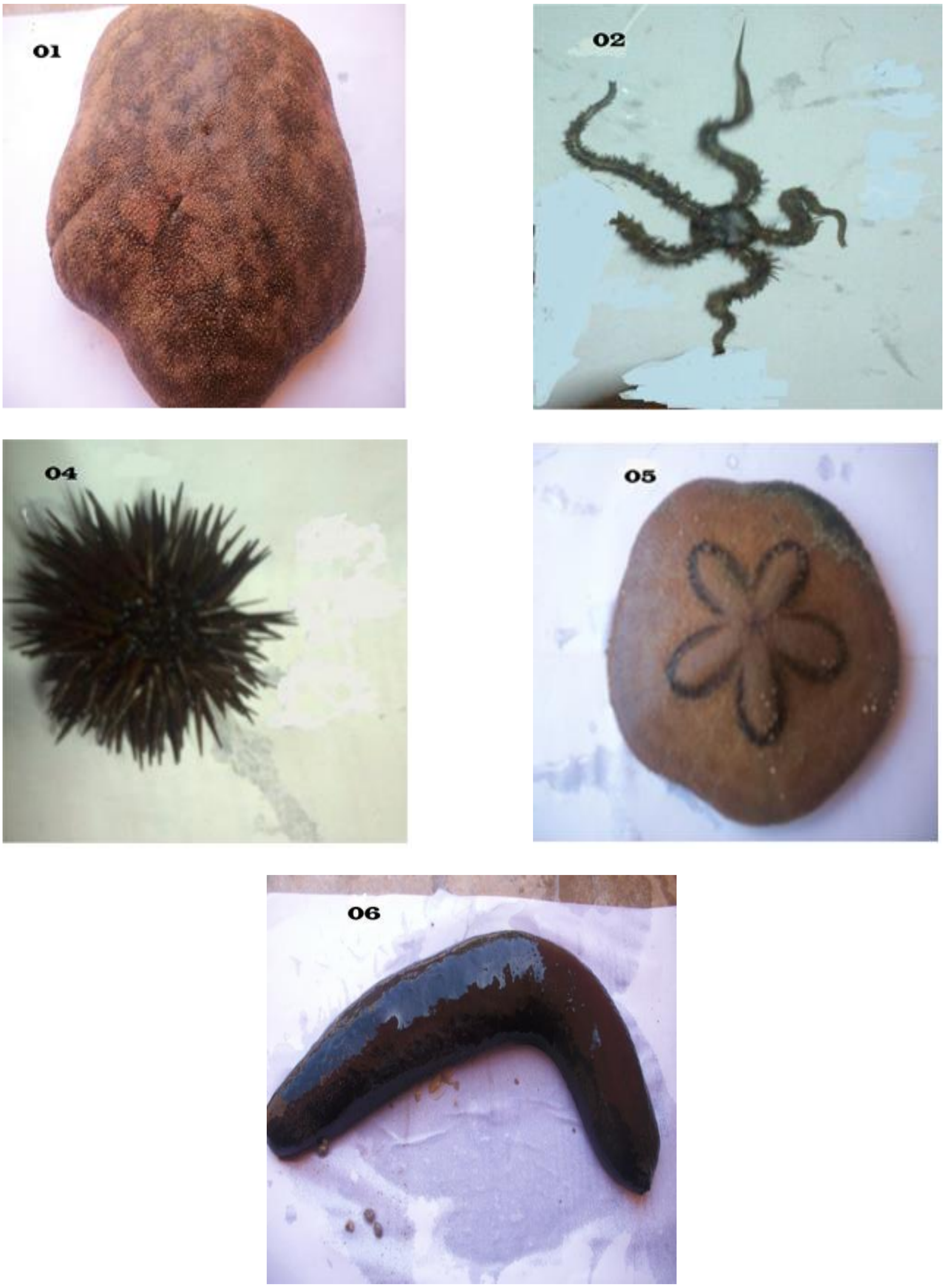

Photo by Kidane and Michael

Fig: 2. Photos of the identified species

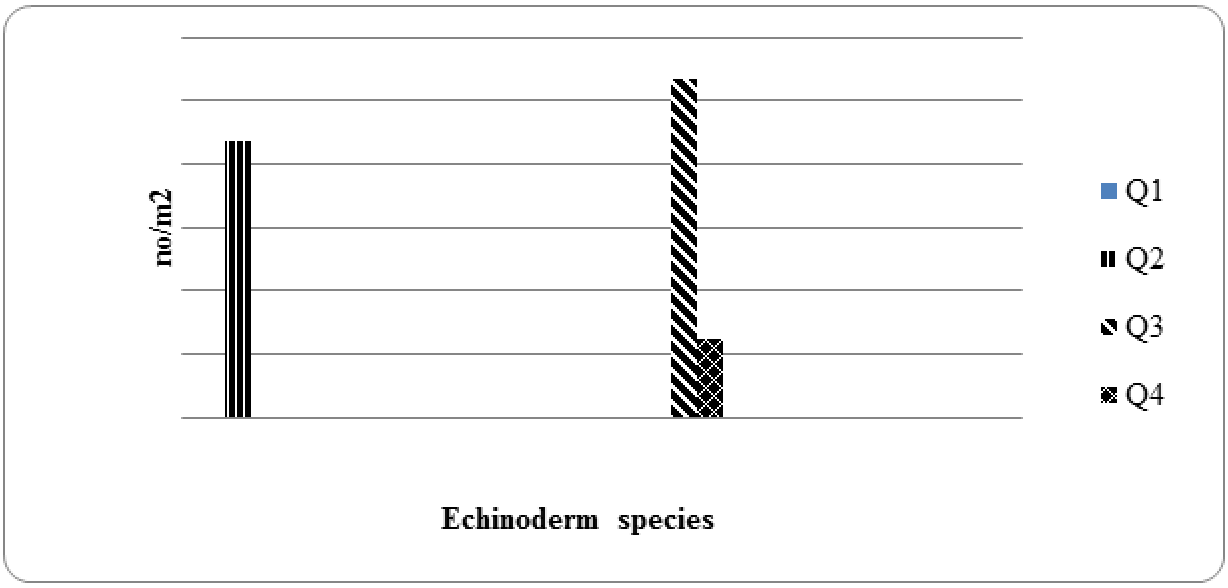

Fig: 3. Spatial distribution of echinoderms (no/m^2) in Gurgussum

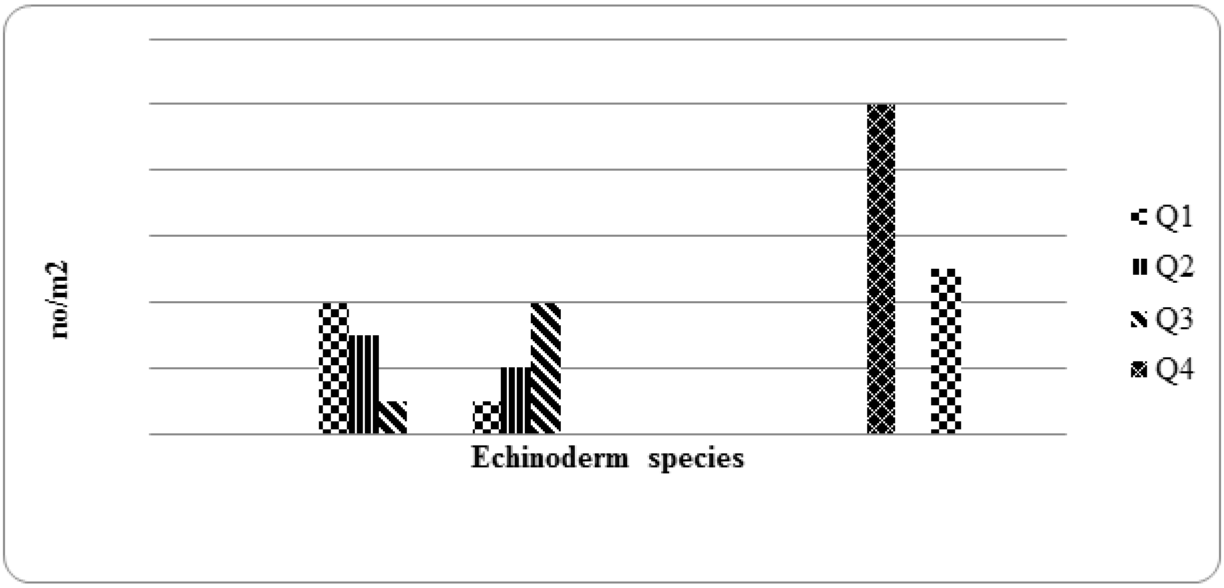

Fig: 4. Spatial distribution of echinoderms (no/m^2) in Tiwalet

Table: 4. Population density (no/m^2) of the six families of echinoderms with respect to the three sites of the intertidal areas of Massawa

FAMILLY	GURGUSSUM				TIWALET				HIRGIGO				
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	TOTAL
Oreasteridae	0	0	0	0	1	2	4	0	0	0	0	0	7
Ophicomidae	0	0	107	25	0	0	0	0	0	0	0	0	132
Ophiuroidae	0	0	0	0	5	0	0	0	0	0	0	0	5
Echinomertridae	0	87	0	0	0	0	0	0	0	0	0	0	87
Scutellidae	0	0	0	0	0	0	0	10	0	0	0	0	10
Holothuriidae	0	0	0	0	4	3	1	0	0	0	0	0	8
TOTAL	0	87	107	25	10	5	5	10	0	0	0	0	249

Table: 5. t-test two tail:

	Sand		Silt		clay	
Quadrat	Hirgigo	Tiwalet	Hirgigo	Tiwalet	Hirgigo	Tiwalet
1	97	91.37	2.94	8.41	0.05	0.05
2	95.56	90.61	4.4	9.35	0.04	0.03
3	94.49	90.67	5.42	9.27	0.09	0.06
4	94.53	93	5.42	6.96	0.05	0.05
Mean	95.395	91.4125	4.545	8.4975	0.0575	0.0475
S.d	1.17905	1.113145	1.17307	1.109816	0.02217	0.01258306
Variance	1.39017	1.239092	1.3761	1.231692	0.00049	0.00015833
S-square	1.75284		1.73853		0.00043	
t-test	6.0161		-5.9953		0.96077	

From the Table 5 of t-test statistical analysis, there is significant difference between the two sites with respect to sand and silt percentage composition. The t-calculated values for sand (6.016) and silt (5.995) are greater than the t- tabulated value (2.354). But, in case of clay composition between the two sites there is no significant difference, which is the calculated value (0.960) is less than the tabulated value (2.354).

Animal sediment relationship:

The present study mainly focused on distribution patterns of echinoderms and sediment texture analysis to understand animal sediment relationship. This study shows that the distribution of different families of echinoderms in the intertidal waters of the three sites around Massawa is significantly different. This difference is mainly due to nature of substrate, seagrass and seaweed coverage, variation in sediment composition and other physical factors such as wave action.

All six groups of echinoderms were correlated with sediment grain size to understand the animal sediment relationship. The distribution patterns of the different groups of echinoderms in general are slightly influenced by sediment texture. By and large, the clay fraction is directly related to the abundance of echinoderms whereas sand and silt showed negative correlation. The *Echinodiscus* sp. showed positive correlation with increasing sand and clay percentage. But, with respect to silt, density is inversely related. *Holothuriaatra*showed a considerable degree of positive correlation with increasing clay percentage composition. The brittle star, *Ophiothrix*sp., it is negatively correlated with increasing percentage of sand composition while in silt and clay exhibited zero correlation.

Gurgussum, which has a dead coral constituted hard substrate, is dominated by families of Echinomertridae and Ophicomidae residing in the lower intertidal zone. The extensive coverage of seaweeds supports the herbivorous *Echinomertamathaei*during their feeding. According to McClanahan and Muthiga (2001), two basic feeding modes are adapted by both juvenile and adult *Echinometra*and these vary with species and environment: 1) catching algal drift, and 2) benthic grazing. The filtering mode is common in shallow waters along shorelines, but also occurs in areas with currents such as reef channels, or shallow tops of patch reefs or reef flats. Therefore, in Gurgussum where there is vigorous wave action the sea urchin can benefit from wave drifted seaweeds while feeding. They are well adapted to wave exposure possessing short and stout spines actually excavates shallow depressions in dead coral by continually scrapping the rock surface with its short spines (Vine, 1986). *Ophiocomascolopendrina* inhabit in the immediate vicinity of sea urchin. This may be due to the accessibility to wave driven suspended matter. Suspension feeders generally require clean water to avoid clogging their filters with indigestible particles. Therefore, they are usually found on rocks or are associated with coarse sediments (Sumich and Morrissey, 2004).

The study site, Tiwalet was represented by four species of echinoderms,*Culcitaschmideliana*, *Holothuriaatra*, *Ophiothrix*sp., and *Echinodisscus*sp. But, the most common is sea star *Culcitaschmideliana*,andsea cucumber, *Holothuriaatra*. The presence of C*ulcita*specie is mainly attributed to its feeding habit. According to Lane, *et al.* (2003), *Culcita*species evert their stomachs over immobile animals or even on sediments to eat the organic particles found there. According to Gosliner, *et al.* (1996), *Culcita* species gains at least part of their nutrition from eating coral polyps as well as seaweeds. The percentage of silt and clay fraction is comparatively more in Tiwalet than other two sites which is source of detritus food to the star fish and also site is adjacent to Green Island, rich in coral polyps. It has been reported that they eat live corals similar to the feeding habits of the dreaded Crown-of-thorns sea star (*Acanthasterplanci*).

Dissanayake and Stefansson, (2012) found that, the habitat variables, such as mean grain size, organic content, gravel, silty–mud and depth, influences the habitat preference of sea cucumbers. They opined that the shallow water seagrass habitat with sediments characterized by 2–3.5% organic content, 15–25% of gravel and coarse sand (0.7–1.2 mm) were the most preferred conditions by ***H.atra.*****The *Holothuriaatra*is represented only in**Tiwalet site and it could be due to nature of substrata. The sediment consists of sand and allied particles (> 90.00%) and good representation of sea grass (visual observation).**The** *Ophiothrix*sp.**lives in association with sponges.**Ophiuroids, brittle stars occupy a range of habitats associated with the reefs. Many live in crevices among coral rubble while others may live in association with sponges and gorgonians or with coralline (Vine, 1986). Scutellids (sand dollars), are common on sandy beaches, are generally detritus feeding animals (Nybakken and Bertness, 2003). Therefore, in this site, sand dollars can benefit from the wave protected environment because suspension and resuspension of detritus matter is minimal.

The Hirgigo bay characterized is by low wave action and rich in mangroves but very poor in echinoderms population. The soils of mangrove forests are low in oxygen, high in salt content, and fine grained, with a high organic content (Nybakken and Bertness, 2003). Though higher organic matter could be advantageous to deposit feeders like sea cucumbers, the higher concentration of salt may create problem to these ionic change sensitive species.

In Tiwalet, the distribution patterns of the different groups of echinoderms in general are not strongly influenced by sediment texture. This is because there is no considerable variation in sediment composition within the site (Tiwalet). The overall distribution pattern in relation to clay is direct whereas with respect to sand and silt the distribution is negatively correlated. In particular, *Echinodiscus*sp. shows positive correlation with increasing sand and clay percentage. But, with respect to silt, density is inversely related. According to Nybakken and Bertness (2003), these species usually burrow through the sand and as they do so, the finer organic particles (but not sand grains) fall down between these short spines are trapped. *Holothuriaatra*showed a considerable degree of positive correlation with increasing clay percentage composition. This may be due to increased amount of organic matter is favourable during their feeding. The brittle star, *Ophiothrix*sp., it is negatively correlated with increasing percentage of sand composition while in silt and clay exhibited zero correlation. The strong negative correlation is not because of increase in sand percentage but may be due to presence of sponges which they have an association.

Conclusion:

According to the study conducted in the three sites for a period of three months, about six species of echinoderms belonging to four different classes have been identified. From the result obtained in the three sites, it can be concluded that the variation in sediment composition among the sites is not considerable except for Gurgussum which is exclusively hard substrata. The clay percentage of the two soft bottom sites was varied between 0.05 and 0.06% in Tiwalet and Hirgigo respectively. The study site Tiwalet recorded comparatively more percentage of silt (8.50%) than Hirgigo (4.55%). The distribution of the different echinoderm species varies among and within the study sites. This variation is mainly due to difference in substrate nature, sediment texture, seaweed and seagrass coverage, presence and absence of crevices and wave action. In terms of abundance, Gurgussum has more abundance and Tiwalet has a great array of echinoderms diversity. The animal sediment relationship is observed to be very weak, except for

*Echinodiscus*sp., where it is observed to have positive correlation towards increasing sand and clay percentage. But, with respect to silt, density is inversely related.The preference towards the specific habitat characteristics seems to be associated with their feeding and protection. An understanding of habitat preference would be useful to improve the management of echinoderm populations and enable more precise stock assessment.

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