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RESEARCH ARTICLE

Spatial and Temporal Distribution of Sea Urchins in the Coastal Waters of Massawa, Eritrea

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Abstract

The abundance and distribution patterns of sea urchins, physical and biological parameters were dealt in three study sites, Gurgussum, Tiwalet, Green Island 1 and 2 at the intertidal and subtidal waters for three months (February, March and April 2013). Sea urchins distribution and abundance (no/m^2) varied from site to site during sampling periods. The highest total density of sea urchins was recorded in Gurgussum, with moderate density in Tiwalet and Green island 1 (GI1). However, in Green island 2 (GI2), no sea urchins were recorded during sampling period. Both water temperature and salinity were recorded in all three sites for three months. It was observed that there was negligible temporal and spatial variation with respect to the two physical parameters. The research was done on the hard substratum of the corals.

Keywords: Sea urchins, spatial and temporal distribution, Gurgussum, Tiwalet, Green Island.

Introduction

Echinoderms are exclusively marine phylum, are 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. Echinoderms develop from bilaterally symmetrical larval stages; radial body symmetry is a secondary condition in this phylum. 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. Sea urchins are small, spiny, spherical body animals which, with their close skin, such as sand dollars, constitute the class Echinoidea includes approximately 800 animals commonly called Sea urchins, Heart urchins and Sand dollars of the Echinoderm phylum.

Sea urchins are important grazers in shallow coral reef ecosystem (Sammarco *et al.*, 1974; Sammarco, 1980, 1982; Hay and Taylor, 1985; Carpenter, 1986, 1990 a,b; Foster, 1987; Levitan, 1988). They ingest sediment by scraping the substratum surface on which they live with their teeth although algae are the important food. Most sea urchins are generalist feeders and include wide range of plants and animals in their gut. A frequent observation is that sea urchin are often dominant herbivorous in unprotected coral reefs, while herbivorous fishes such as Parrot-fish and Surgeon-fish are dominant in coral reefs with little or no fishing (Hay, 1984a,b; McClanahun and Shafir, 1990).

Grazing of fleshy and filamentous algae by marine herbivorous is an important factor in controlling the dynamic balance between benthic organisms, because algae are efficient competitors for space. When common grazers are annihilated, dramatic change may occur in the abundance of dominant organisms (Breen and Mann, 1976; Pearse and Hines, 1979; Chapman, 1981; Miller, 1985). They move slowly, feeding mostly on algae. Sea otters, Wolf eels, Trigger fish, Cod and other predators feed on them. Two important bioeroders of coral are the colorful Parrot fishes (Family Scaridae) and sea urchin. Some sea urchins, such as various species of *Diadema*, are among the most important invertebrate bioeroders on coral reefs around the world (Glynn, 1997). 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, usually found on rocks or are associated with coarse sediments (Sumich and Morrissey, 2004). Regardless of the feeding habit employed by benthic animals, the ultimate source of food is the primary producers of the photic zone.

Intertidal and shallow water benthic plants provide direct source of nutrition for the abundant herbivorous algal grazers. Sea urchins use their five-toothed Aristotle lantern to remove algal growth (Sumich, 2004). Variety of physical and biological factors can affect distribution and abundance of sea urchins. These are degree of wave action, salinity and temperature variation, predation and competition in shallow coastal waters. Wave action is an important factor in an open area. Long period ocean swell and storm waves have an effect that can extend to the bottom in the shallow (Nybakken, 2005). So, the waves can disturb the habitat of sea urchin by caring fine sediments and motion of the water can disturb them highly. Those sea urchins which have long spines are restricted to areas which are relatively protected. Salinity in the wavy area is more variable than Deep Ocean, but except for areas where large river discharge massive amounts of fresh water the salinity does not change enough to be of ecological significance (Nybakken, 2005). Salinity could have physiological effects on sea urchins assemblages. Sea urchins are largely stenohaline, lack specific osmoregulatory organs, and are sensitive to salinity fluctuations. Salinity affects sea urchins both with hypo-saline and hyper-saline conditions, reducing larval dispersal and recruitment and leading to morphological deformations with reduced viability in adults (Stickle and Diehl, 1987). Sea-surface temperature, as a proxy for energy available to a system, has been suggested as an underpinning reason for observed diversity patterns. Temperature, however, affects organisms through metabolic and energetic processes, but does not directly influence diversity. As such, taxa with different physiological adaptations and requirements may be differently influenced by temperature, possibly shaping the diversity of an assemblage in multiple ways (Cruz-Motta *et al.,* 2010).

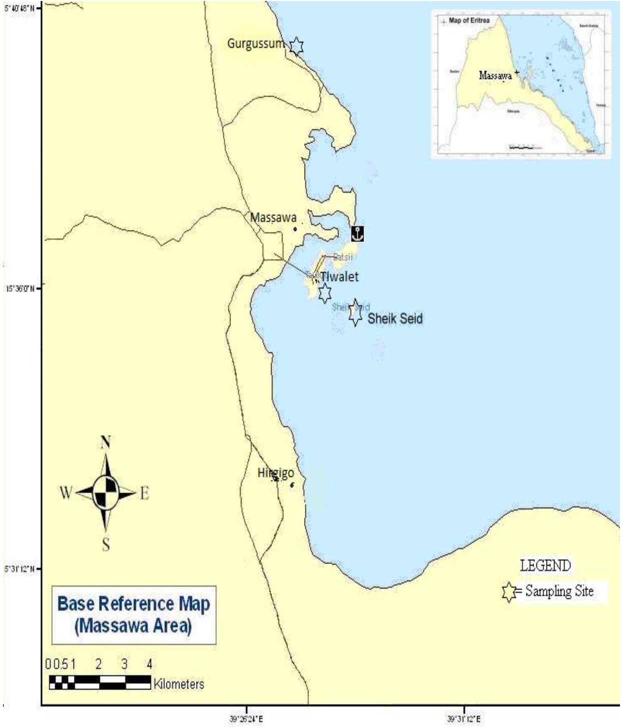
Biodiversity assessments in marine systems are of great interest from ecological, public and management stand points. They are important for understanding ecological patterns and ecosystem functioning and for managing marine resource use and identifying conservation priorities. A particular ecological 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 sea urchin species that contributes to overall ecosystem functioning. Rather, high sea urchin species numbers and abundances contribute significantly to community structure in different regions of the world (Neira and Cantera, 2005). Predation is one of the most factors that affect the distribution and abundance of sea urchin. Large fish predators may also have limited sea urchin population. With the decline of coastal predators, sea urchin populations denuding kelp from vast coastal areas thereby reducing coastal productivity and habitat structure for other organism (Bologna and Steneck, 1993).

Fishing has the potential to influence species composition and ecological process of coral reefs by changing the abundance and species composition of predators and competitors (Hay, 1984a,b; Mcclanahan and Shafir, 1990; Mcclanahan, 1992; Mcclanahan, 1994a,b,c). Heavily fished reefs have high sea urchin abundance (Hay, 1984; Mcclanahan and Muthiga, 1998; Hughes, 1994; Waston and Ormand, 1994) that is frequently attributable to reduction in populations of their predators, such as Trigger fish and terminal male Wrasses (Mcclanahan and Shafir, 1990; Mcclanahan, 1995a). High sea urchin abundance may also suppress fish growth and the recovery of fish population once fishing effort is reduced or eliminated (Mcclanahan, 1994; Mcclanahan, *et al*., 1994). Sea urchins are economically important, in the late 1980's sea urchins become a targeted fisheries species for their highly valued Roe, which is marketed in Japan, and this crated a "gold rush" and resulted in classic boom-bust fishery. Under intense fishing pressure, sea urchin population densities dropped and kelp beds expanded throughout the gulf of Maine. This occurred because of sea urchins are the dominant herbivore in those costal zones. As their densities decline, rate of herbivory decreased and kelp abundance increased markedly. All of this suggests those food webs are changing due to cascading effects of fishing down food webs. Food webs prior to intense fishing activity were probably dominated by large predatory fish and an abundance of kelp. Considering the above facts, this study was aimed to study the spatial and temporal distribution of sea Urchin in relation to physical parameters of coastal water of Massawa.

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 Godir, 1988). Evaporation from the water amounts to about 235 mm/year (Fishelson, 1971) and mean salinity was 40.35 ppt (Marcos, 1984). Massawa coast, which is part of the Eritrean coastline, is different from other sea coasts that surround the Red sea. The same as other parts of the Red sea, it gets little inflow of fresh water from the terrestrial areas. In the present study, three sites were selected 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^o39'.364 N, 39^o28'.364 E) West of Hamassien Beach Hotel that experiences a considerable amount of wave action and indirect tourist pressure. In addition this site has dead coral dominated substrate.

Fig. 1. Map showing the study area and sampling stations.



Tiwalet located at (15^{o}35'.813 N, 39^{o}27'.933 E) Western side of Green Island, which is relatively protected area, free from wave action. Green Island sheltered (GI 1) East side of Tiwalet, which are sheltered and have low wave action. Green Island exposed (GI 2) East side of Tiwalet, which is characterized by high wave action and free from human disturbance.

Sampling: Samples were collected using transect and quadrat method from three sites namely, Tiwalet, Gurgussum and Green Island 1 and 2 (Fig.1). The sampling was done monthly for a period of three months (February, March and April 2013). It was conducted in the intertidal and sub-tidal zones 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 m starting from 25 m seaward from the low water line to the upper part of the intertidal zone. Along with the transect method, a quadrat of 1 m^{2} (1 m x 1 m) was used at every 25 m interval in 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 0.4 m^{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 Zarf, 1977).

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 three months with the help of a refract meter.

Sea urchins collection and analysis: Sea urchins were collected from each site. Sea urchins are difficult to collect because of their morphological structure (spines). They are collected using a scrapper. The specimens of the sea urchins which have been collected in the study area were kept in polyethylene plastic containers to avoid the atmosphere born deterioration that bears unpleasant putrid smell. Therefore, after death to deter this rotten egg like smell, 10% formalin solution was poured into each container holding the specimen. Since the body tissues of most of them are not well developed, their preservation in formalin solution is carefully carried out. The presence of other organisms (plants and animals) and other important over all characteristics of each site during the sampling period was recorded, especially brittle star, seaweeds and algae. The preserved specimens were identified to the possible lower taxon under Echinoidae. Their density was expressed as number of organisms per m^{2}.

Data analysis: In order to determine whether there exist a variance or not on the distribution patterns of the sea urchins 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 was used to see whether there is a significant difference in abundance among the three sites (i.e., Green Island 1 and 2, Tiwalet and Gurgussum).

Results

Sea urchin abundance and distribution were assessed as number of organisms per no/m^{2} in each of the three sites for three months (February-April). Physical parameter that affects their abundance and distribution were also recorded.

Physical parameters: The average water temperature of Gurgussum, Green island and Tiwalet was recorded as, 29, 30 and 30.33°C respectively. Salinity of the study sites was also measured monthly. The highest average salinity (41.33^{o}/oo) was observed in Tiwalet followed by Gurgussum (41^{o}/oo) and Green Island (40^{o}/oo) (Table 1).

Sea urchin abundance and distribution patterns: Sea urchin abundance and distribution in the three sites were very different. The highest abundance has been recorded in Gurgussum while comparing it with other two sites (Tiwalet and Green Island 1 and 2). In which, Green island 2, abundance was nil (Table 2). In order to determine if there exists variation on the distribution patterns of the sea urchin 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 (Table 3).

Table 1. Physical parameters of the intertidal waters of the three sites.

Sites	Gurgussum				Green Island				Tiwalet			
Parameter	Feb	Mar	Apr	Ave	Feb	Mar	Apr	Ave	Feb	Mar	Apr	Ave.
Water temperature (^{o}C)	29	30	28	29	-	30	-	30	30	30	31	30.33
Salinity ($^{o}/_{oo}$)	40	42	41	41	-	40	-	40	41	42	41	41.33

Table 2. Population density (no/m^2) of sea urchins with respect to the three sites of the coastal waters of Massawa.

Site/Species	Gurgussum				Tiwalet				Green island 1				Green island 2			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Diademasetosum	22	24	10	25	18	15	12	13	6	4	7	2	0	0	0	0

Table 3. One way analysis of variance of descriptive abundances of three sites.

Stations	N	Mean	Std. Dev.	Std. Error	95% Confidence interval for mean		Min	Max
					Lower bound	Upper bound		
Tiwalet	12	4.8333	1.33712	.38599	3.9838	5.6829	3.00	7.00
Gurgussum	12	6.7500	2.73446	.78937	5.0126	8.4874	1.00	11.00
Green Island 1	4	4.7500	2.21736	1.10868	1.2217	8.2783	2.00	7.00
Green Island 2	8	.0000	.00000	.00000	.0000	.0000	.00	.00
Total	36	4.3889	3.11932	.51989	3.3335	5.4443	.00	11.00

Table 4. Sample T-test showing significant difference between Tiwalet and Gurgussum.

		Levene's test for equality of variances		t-test for equality of means						
		F	Sig.	T	Df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	95% confidence interval of the diff.	
									Lower	Upper
Abundance	Equal variances assumed	2.645	.118	-2.181	22	.040	-1.91667	.87869	-3.73896	-.09438
	Equal variances not assumed			-2.181	15.976	.044	-1.91667	.87869	-3.77963	-.05370

Table 5. Sample T-test showing no significant difference between Gurgussum and Green Island 1.

		Levene's test for equality of variances		t-test for equality of means						
		F	Sig.	T	Df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	95% confidence interval of the diff.	
									Lower	Upper
Abundance	Equal variances assumed	.047	.831	1.316	14	.209	2.00000	1.51971	-1.25946	5.25946
	Equal variances not assumed			1.470	6.366	.189	2.00000	1.36098	-1.28430	5.28430

Based on the calculation carried at 5% level of significance, there was a considerable variation between Gurgussum and Tiwalet in the distribution patterns of sea urchins. Based on the number of observation in three months [Gurgussum and Tiwalet (N=12) and Green Island 1 (N=4)], statistical analysis showed a clear significant difference in the abundance of sea urchins between Gurgussum and Tiwalet (significance of 2 tailed is 0.040) (Table 4). In contrast there is no significant difference between Gurgussum and Green Island 1 (it gives significant of 0.209) (Table 5).

Discussion

Result and observations of the study indicated the difference in abundance and distribution of sea urchin with habitat. Many factors could influence the distribution of sea urchins. Some of this are, seabed composition, the presence of herbivores fish and predators (Hay, 1984 a,b; Mcclanahn and Shafir, 1990), temperature, salinity, wave action and current flow (Lissner, 1980, 1983; Cower *et al*., 1982). Heavily fished reefs have high sea urchin abundance (Hay, 1984a,b; Mcclanahn and Muthiga, 1988).

This is frequently attributable to reduction in population of their predators such as Tiger fish and terminal-male Wrasses (Mcclanahn and Shafir, 1990; Mcclanahn, 1995a). In exposed area, where there is no fishing, no sea urchins are present. Some studies indicated that high sea urchins in coral reefs are frequently due to total reduction in their predators and absence of disease. Large fish predators limited sea urchins populations with decline of costal predators. Sea urchins population may have expanded their population denuding kelp from vast costal area there by reducing costal productivity and habitat structure for other organisms (Bologna and Steneck, 1993). Sea urchins will out compute herbivorous fishes for food and space. Herbivorous fishes such as Parrot fish have a great bit depth in the thalli of coralline algae which potentially make them superior competitors (Steneck, 1983, 1988), but fishing can stop Parrot-fish from competing effectively with sea urchin. Habitat type and time of a year can also influence sea urchin distribution (Mattison *et al.,* 1977). Sea urchins population density has been shown to vary depending to habitat, with higher density at Gurgussum and lower at Green Island exposed (GI2). On the protected side of Tiwalet and Green Island sheltered (GI1), high density was observed. This may be due low storm or calm area is attractive for sea urchin distribution (Lissner, 1980, 1983).

Many studies have illustrated the importance of attached and drift micro-algae (i.e. habitat type) to community structure, particularly food availability has been shown to influence sea urchin density (Dean *et al.,* 1984; Harold and Reed, 1985; Sala *et al.,* 1980; Russell, 1988). Exposed sites may not be possibly good habitat for sea urchins due to excessive wave action and higher current flows that may affect distribution of seaweeds. The studies have shown that the distribution of sea urchins was found to be restricted by wave action and exposure (Lisser, 1980, 1983; Cower *et al.,* 1982; Himmetman, 1984; Ebling *et al.,* 1985). The high movement of algal fronds by wave action in exposed localities was shown to deter sea urchin grazing (Himmelman, 1984). He had noticed that the duplicated structure of *Desmarestia virdis* species allowed it to be washed about by even the slight test water motion. At that site, sea urchins were abundant and relatively distributed on vertical reef surface sea urchin noticeably absent on surface where *Divirdis* species was swept about the wave surge. Gurgussum, which has a dead coral constituted hard substrate, is dominated by families of Echinomertridae and Ophicomidae residing in the sub-tidal zone. The extensive coverage of seaweeds supports the herbivorous sea urchin (*Echinomertamathaei* spp.) during feeding. According to McClanahan and Muthiga (2001), two basic feeding modes are adapted by both juvenile and adult and these vary with species and environment: (1) catching algal drift and (2) benthic grazing. The presence of sea urchins in Gurgussum restricted to the sub-tidal area.

The intertidal areas are dominated by sea stars, sharp discontinuity of sea stars in the border of sub-tidal area was observed the reason can be out compute by sea urchins. Sea urchin doesn't live in the tidal exposed zones. Average density along depth gradients at wave exposed sites in tropical and temperate regions, showing the scarcities of sea urchin in the shallow zone where hydrodynamic forces imposed by wave shock and follow speeds are highest. The ability of sea urchins to bore into the substrate and inhabit depression they create undoubtedly reduces their risk of dislodgment from hydrodynamic forces, enabling sea urchin to persist in shallow physically stress full sub-tidal habitats. Although they are dislodged in large number during extreme hydrodynamic conditions in exceptional storms (Witman, 1996), sea stars seem able to feed more effectively in shallow wave exposed habitat (as it had recorded in Gurgussum) than sea urchins (Menge, 1979; Hulbert, 1980). This may be due to the combination of low profile drag and high attachment strength of sea stars (Denny, 1995). Generally there is high abundance of sea urchins in Gurgussum comparing with other two sites. The reason can be vigorous wave action in which sea urchin can be benefited from wave drifted seaweeds during 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). And almost there is low predation because relatively there is fishing of sea urchins predators. The presence of high seaweeds in this area also can be a reason for abundance of the sea urchins since they graze on them.

Conclusion

Sea urchins play a great role in both ecological and economical aspects. They are principal members of the herbivore level, reduction in its abundance and distribution causes dramatic and immediate change to costal food webs. This shift also has caused numerous other changes to the costal ecosystems. Even though it is not eaten by our society, it has great market demand especially in Japan. So, it is necessary to know their habitat preferences and distribution in the marine ecosystem to get export earnings. Therefore, this study needs to be extended to the other coastal and Island waters of the Eritrean Red Sea.

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