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Restoration of saltmarsh as mitigative measure of climate change impact at Chittagong coastal area of Bangladesh

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ABSTRACT

The present study was carried out at Chittagong coastal area of Bangladesh to restore the saltmarsh from the month of December' 2009 to the month of November' 2010. Restoration of existing coastal salt marshes of Bangladesh will enhance the accretion of land in the coastal region by increasing sedimentation and reducing erosion via the establishment of complex root system of salt marsh vegetation in the intertidal zone. The study area was vegetated by salt marsh plant *Porteresia coarctata* with a slope of 1% of plain land topography. In the recent study, there was found significant variations among air temperature, water temperature, soil temperature, sea water salinity, dissolve oxygen, water transparency, tidal height, percentage of sand, bulk density, soil organic carbon and plant biomass with the seasons ($P < 0.05$). Fertilization showed a positive correlation with plant biomass and growth/decay rate of at 5% level of significance and it was negatively correlated with water temperature and soil temperature at 1% and 5% level of significance respectively. From the present study it is evident that in Salt Marsh Restoration Site (SMRS) the remarkable changes in some of the factors studied rather than Reference Site (R) which could be helpful for the coastal environment as well as for the local community in the long run. Restoration, conservation and management of productive albeit degraded saltmarsh needed to cut down piquancy of climate change impacts.

Keywords: Restoration, Saltmarsh, Coastal area, Vegetation, Management, Climate change

1. INTRODUCTION

Salt marsh restoration is an important public pursuit because it provides many services to society and is arguably the most biologically productive features of the landscape. The goal of restoring salt marshes is to bring back their lost functions and values, including the ability to reduce flooding, improve water quality, and provide critical habitat for a host of life forms (http://www.mass.gov/czm/wrp/index.htm). Natural recolonization of areas with restored hydrology, such as reconnected abandoned shrimp aquaculture ponds, occurs quite rapidly if mangrove forests are present in the vicinity and natural production of propagules is sufficient (Stevenson *et al.* 1999). The ability of salt marsh vegetation to reduce wave energy helps to prevent shoreline erosion. Reduction of wave and current energies in salt marshes causes them to trap sediment. As flow velocity decreases, water loses its capacity to carry sediment particles (Nixon 1982). Salt marsh grasses also reduce the velocity of terrestrial runoff. Water leaving the marsh, therefore, carries less particulate material and is less turbid (Niedowski 2000). Wetland soils are well-known as major carbon-storing ecosystems (Chmura *et al.* 2003; Roy and Hossain, 2015). Salt marshes release "negligible amounts of greenhouse gases and store much more carbon per unit area" (Chmura *et al.* 2003) due to salt water soil processes. In central and southern California tidal salt marshes, macrophytes produce about 450g of carbon per square meter per year and the algae productivity adds an additional 340 to 630 g of carbon per square meter per year (Zedler 1980). Experimental addition of nutrients during the growing season showed retention of between 80% and 94% of added nitrogen and phosphorus; in spring and fall retention dropped to between 60% and 75% of added nutrients (Teal 1986). Salt marsh sediments filter and accumulate heavy metals (Teal 1986). In the Cumberland basin, salt marshes make up 53.3% of the total primary productivity, specially 31.7% coming from low marsh and 21.6% coming from the high marsh (Keith 2006). In Bangladesh there is very little information on salt marsh studied by Das and Siddiqui (1985) and Huq (1986). The present investigation was carried out with aim (1) To characterize the place suitable for development of salt marsh before and after the restoration activity (2) To introduce a suitable restoration technique (3) To measure the biomass and organic carbon of salt marsh plant and measure the current velocity (4) To measure the rate of sedimentation and elevation of land (5) To find out the succession of plant and macro benthic faunal community structure as an environmental indicator in the investigated area.

2. MATERIALS AND METHODS

Study area

Figure 1 Geographical location of the study area

The present research was carried out at Fauzderhat coastal area of Chittagong district from the month of December' 2009 to the month of November' 2010. The geographical location of the study area is between latitude 22°24.01' and 22°24.06' N, and longitude 91°44.52' and 91°44.56' E (Figure 1). Two experimental plots (each 100X100 m^2) namely, A & B, was selected in the same area for salt marsh restoration. Among the experimental plots A was considered as Salt Marsh Restoration Site (SMRS) where salt marsh restoration technique was practiced and B was designated as Reference Site (RS).

Salt Marsh Restoration

In the present research transplantation of marsh plants along with fencing was applied for salt marsh restoration. The experimental plot A was fenced with bamboo and rope in order to protect transplanted marsh plants from grazing. A regular visit was conducted by caretaker for monitoring the overall activity. Some furrows were made throughout the experimental plot A in order to drain the water during the exposure period. A low-height "breakwater" was produced by making an artificial dike with sack full of sand in the seaward position of the experimental plot A in order to lessen wave energy. After site preparation, seedlings of locally available saltmarsh plant *Porterecia coarctata* were transplanted in the bare zone of plot A with natural vegetation. Transplantation was accomplished by mechanical planting like hand-planting. A soil auger was used for making holes of ~15 cm in depth and 5-7 cm in diameter. Stems or plugs of marsh plants were then inserted into the planting hole. Soil was firmly pressed around the plant to prevent dislodging by waves. A mixture of fertilizer (Urea 25kg+ TSP 25kg=50kg) containing both nitrogen and phosphorous was added in the experimental plot A during planting. After plantation solid urea was put into the experimental plot by placing lines parallel to each other maintaining at equal distance of 30cm. A piece of solid urea was put at every hole (15cm depth) in the lines at every 30 cm distance as a source of slow release nitrogen type fertilizer in each season. It took 25 kg solid urea to cover all the area of restoration site. A total of 75kg conventional type of urea fertilizer was applied as broadcasting method at a rate of 25 kg in every 15 days interval of each season at the site of SMRS throughout the experimental period. Fertilization was done in the extreme low tide condition while the exposure time was greater than inundation period.

Sample collection and processing

Base line data were collected at the initial stage of the proposed research. Samples from each site were collected within two consecutive days after the transplantation of marsh plants for the analysis of biotic and abiotic resources in every month. Plant was harvested from the nine stations of each plot for measuring biomass, density, organic matter and organic carbon. Macro benthic faunal communities was sampled by taking 3 sediment cores (11.5cm diameter, 15cm depth) randomly from the quadrate of 5x5m^2 placing at each of the nine stations of each site. The collected samples was sieved through a 0.5mm mesh and preserved with 10% formalin in seawater containing the vital stain Rose Bengal to aid laboratory storing. In the laboratory, fixed benthic macro fauna was separated systematically from debris in a sorting tray and preserved in 70% alcohol containing 2% glycerol. Additional sediment (by means of a sediment corer) was taken from each station for analysis of abiotic parameters (Soil texture, bulk density, particle density, porosity, pH & soil salinity etc.). The textural class (percent of sand, silt and clay) of sediment, bulk density, particle density & porosity were determined by the method followed by Huq & Alam (2005). Soil pH was determined soil pH meter (DEMETRA, Mo-36, E. M. System Soil Tester, Tokyo, Japan). Free soil water salinity, Salinity, pH, Temperature, Water Transparency were estimated by using Refractometer (TANAKA, New S-100, and Japan), Digital pen pH meter, Centigrade thermometer, Secchi disc (30cm diameter) respectively. Water samples were collected from the near shore area which is very close to the experimental plot as well. Sub surface water was collected for analyzing DO, Salinity, Turbidity, TSS, pH, Temperature etc. DO and TSS were determined followed by Standard Method (APHA 2005). Land topography/elevation/slope was measured by using Topographic Abney Level collected from York Survey Supply. Tidal elevation was measured monthly by "glue stick method" which is developed by (Richter 1997).Water table depth was measured by the installation of shallow PVC wells deep enough into the marsh substrate to intersect the water table during the winter, premonsoon, monsoon and post monsoon period of the year. Wells are typically constructed of PVC pipe with small perforations or slots at their base. Data was collected during low tide as well as in the neap tide condition (Neckles and Dionne 1999). Salt marsh inundation and exposure time was measured seasonally in the extreme high tide condition during full moon. Data were recorded for three consecutive days at day time for getting the highest high water level of that particular lunar phase. For the measurement of current flow velocity, a flow meter was used. Current flow velocity in and around the reference and restored site was observed in order to find out the difference of current flow velocity in both the sites. A buried marker layer of felspar/glitter was set in each station of the reference and restored salt marsh site for measuring sedimentation/ sediment accretion.

Data analysis

To find out the simple correlation within the studied ecological factors of the Salt Marsh Restoration Site (SMRS) and Reference Site (RS), correlation matrix was done by the statistical software (MINITAB 14).

3. RESULTS AND DISCUSSION

The study area was vegetated by salt marsh plant *Porteresia coarctata* with plain land topography and crisscrossed with one major tidal creek and eight small tidal creek connected with nine subs & smaller creeks. The mean width and height of the major tidal creek were 17 and 16.5ft respectively. Average slope of the major tidal creek was 23%. The mean width and height of the small tidal creek were 14.2 ft. and 10ft respectively. The mean width and height of smaller tidal creek were 5.6 ft. and 4.2 ft. respectively. The unconsolidated soil particle was eroded at a high rate during rainy season while the percentage of sand is very high rather than silt and clay. Sedimentation pattern is quite reverse in winter while the percentage of clay is very high rather than sand & silt (Plate 1 & Plate 2). Percentages of gastropod, bivalve, crustacean, polychaete, oligochaete and other macro benthic populations were presented in Table 1 and Table 2.

Variations in air temperatures were found to be statistically significant (ANOVA $F = 14.89$, $P < 0.01$). Air temperature showed a positive correlation with water temperature, soil temperature and a negative correlation with plant biomass, plant growth rate/ plant decay rate, gastropod at 5% level of significance.

Variations in water temperatures recorded were found to be statistically significant (ANOVA $F = 6.36$, $P < 0.05$). Water temperature showed a positive correlation with soil temperature and a negative correlation with Plant biomass, Plant growth rate or Plant decay rate at 1% level of significance.

Soil temperatures were recorded found to be statistically significant (ANOVA $F = 9.90$, $P < 0.01$). It showed a negative correlation with plant biomass and plant growth rate or plant decay rate at 1% level of significance.

Table 1 Ecological factors of Salt Marsh Restoration Site (SMRS) recorded from January 2010 to November 2010

Name of Factors	Winter	Premonsoon	Monsoon	Postmonsoon
	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Air temperature (^{0}C)	22.83±1.04	31.83±2.93	31.33±1.53	28.5±1.32
Water temperature (^{O}C)	24.33±4.51	34±2.29	35±3.61	33.5±2.78
Water pH	7.20±0.40	7.23±0.21	6.87±0.12	7.00±0.20
Seawater salinity (ppt)	21.00±1.0	17.33±0.58	2.33±2.08	6.00±1.00
Water Transparency (cm)	10.5±0.5	9.7±0.26	4.70±0.36	5.30±0.26
Tidal height (m)	2.67±0.18	3.43±0.18	3.97±0.21	3.39±0.10
Inundation period (Hr.)	4.47±0.13	5.11±0.26	5.89±0.26	5.02±0.17
Wave velocity	0.046±0.015	0.089±0.019	0.073±0.023	0.065±0.032
Total suspended solids (TSS)(mg/L)	160.33±39.50	776.67±43.11	1123.33±71.47	485.00±60.62
Dissolved oxygen (ml/L)	5.71±0.72	5.44±0.21	5.96±1.09	3.57±0.72
Soil Temperature (^{0}C)	21.50±0.50	31.67±3.06	32.33±4.73	30.00±1.00
Soil pH	6.40±0.10	6.57±0.31	7.13±0.58	6.83±0.29
Soil water salinity (ppt)	24.33±0.58	18.67±3.51	4.00±1.00	10.33±1.52

(%) Sand of soil	11.70±1.35	35.05±7.64	64.68±6.29	38.12±3.21
(%) Silt of soil	63.93±4.72	50.33±4.69	15.71±6.25	52.12±4.77
(%) Clay of soil	24.37±0.95	14.62±2.95	19.50±0.95	9.77±3.59
Water Table Depth (cm)	30.47±1.25	27.37±1.20	20.3±0.62	22.4±0.89
Bulk density (g/cm^3) of soil	1.02±0.03	1.13±0.01	1.38±0.01	1.49±0.01
Particle density (gm/cm^3)	2.65±0.13	2.68±0.11	2.55±0.06	2.63±0.05
Porosity (%)	61.47±2.95	57.79±1.85	45.80±1.29	43.21±0.90
Soil organic carbon (%)	3.59±0.13	2.57±0.69	1.05±0.42	1.55±0.17
Soil organic matter (%)	6.19±0.22	4.43±1.18	1.80±0.72	2.44±0.15
Plant organic carbon (%)	42.36±1.52	43.67±1.31	33.12±2.03	42.53±0.79
Plant organic matter (%)	72.98±2.63	75.17±2.36	56.96±3.49	73.16±1.37
Plant biomass (gm/m^2)	108.00±63.38	93.66±71.62	92.22±4.67	95.67±8.08
Plant Growth/Decay Rate (gm/Week)	19.83	1.04	0.04	4.31
Shoot density(ind/m^2)	193±114	185±74	316±129	459±30
Fertilization (Kg/hactre)	41.67±28.87	25.00±0	25.00±0	25.00±0
Grazing by cattle(invid/day/hr)	0±0	0±0	0±0	0±0
Gastropod ($indiv/m^2$)	270±355	0±0	93±80	139±139
Bivalve ($indiv/m^2$)	21143±20327	9544±9100	14465±10494	5601±2892
Crustacea ($indiv/m^2$)	633±308	6408±10281	409±355	182±206
Polychaete ($indiv/m^2$)	46083±36328	42676±3436	6895±6189	4164±5586
Oligochaete ($indiv/m^2$)	3225±2684	3538±3109	8019±7286	2955±3261
Sipuncula ($indiv/m^2$)	14790±23282	6184±1513	6759±8367	363±276
Other macrobenthic organisms ($indiv/m^2$)	93±80	46±80	46±80	93±80
Gastropod (%)	0.21±0.26	0±0	0.39±0.41	0.80±0.69
Bivalve (%)	17.45±15.27	13.87±12.54	49.10±35.13	49.16±25.60
Crustacea (%)	1.80±2.38	8.36±13.28	1.02±0.48	1.37±1.87
Polychaete (%)	60.93±24.73	63±6.83	16.04±9.37	23.45±19.66
Oligochaete (%)	5.16±3.45	5.75±5.86	19.58±10.35	19.03±9.79
Sipuncula (%)	14.36±20.84	8.96±1.12	13.75±15.95	4.97±6.08

Other macrobenthic organisms (%)	0.08±0.07	0.06±0.10	0.11±0.19	1.22±1.23

Table 2 Ecological factors of Reference Site (RS) recorded from January 2010 to November 2010

Name of Factors	Winter	Premonsoon	Monsoon	Postmonsoon
	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Air temperature (^{0}C)	22.83±1.04	31.83±2.93	31.33±1.53	28.5±1.32
Water temperature (^{O}C)	24.33±3.22	34±1.80	34.50±1.00	33.67±2.31
Water pH	7.07±0.42	7.20±0.20	6.77±0.38	6.90±0.10
Seawater salinity (ppt)	21.00±1.0	17.33±0.58	2.33±2.08	6.00±1.00
Water Transparency (cm)	10.5±0.5	9.7±0.26	4.70±0.36	5.30±0.26
Tidal height (m)	4.44±0.09	5.10±0.32	5.84±0.25	4.97±0.16
Inundation period (Hr.)	2.66±0.18	3.41±0.21	3.88±0.14	3.38±0.12
Wave velocity (km/hr)	0.046±0.018	0.087±0.021	0.071±0.021	0.064±0.031
Total suspended solids (TSS)(mg/L)	160.33±39.50	776.67±43.11	1123.33±71.47	485.00±60.62
Dissolved oxygen (ml/L)	5.71±0.72	5.44±0.21	5.96±1.09	3.57±0.72
Soil Temperature (^{0}C)	21.67±1.76	31.67±2.25	31.83±3.79	30.17±1.61
Soil pH	6.40±0.26	6.53±0.15	7.07±0.57	6.90±0.53
Soil water salinity (ppt)	23.67±2.08	18.67±4.04	3.83±1.61	10.33±1.44
(%) Sand of soil	11.10±3.03	30.53±5.63	61.46±3.03	35.29±5.97
(%) Silt of soil	63.81±1.95	55.19±3.02	18.92±6.29	52.56±7.55
(%) Clay of soil	25.10±1.22	14.28±2.69	19.35±3.03	12.15±1.68
Water Table Depth (cm)	30.53±0.51	27.60±0.78	20.47±0.47	23.13±1.19
Bulk density (g/cm^3) of soil	1.01±0.03	1.12±0.02	1.37±0.02	1.47±0.02
Particle density (gm/cm^3)	2.63±0.13	2.66±0.11	2.54±0.06	2.61±0.05
Porosity (%)	61.59±2.78	57.97±2.05	46.10±1.39	43.67±0.31
Soil organic carbon (%)	3.60±0.10	2.54±0.70	1.04±0.40	1.54±0.17

Soil organic matter (%)	6.16±0.21	4.39±1.18	1.80±0.70	2.43±0.15
Plant organic carbon (%)	42.34±1.52	43.65±1.31	33.09±2.02	42.52±0.80
Plant organic matter (%)	72.96±2.63	75.15±2.35	56.94±3.49	73.15±1.37
Plant biomass (gm/m^2)	106.67±58.38	50.33±4.51	11.50±4.09	52.00±25.24
Plant Growth/Decay Rate (gm/Week)	15.56	2.33	1.43	3.77
Shoot density(ind/m^2)	186±102	89±23	72±31	148±106
Fertilization (Kg/hactre)	0.00±0.00	0±0.00	0.00±0.00	0.00±0.00
Grazing by cattle(invid/day/hr)	7±1.53	8±1.15	9±1.53	15±3.51
Gastropod (indiv/m^2)	224±239	8±7	89±29	66±114
Bivalve (indiv/m^2)	18926±20233	4137±3782	7227±3137	4206±2744
Crustacea (indiv/m^2)	459±263	4867±7580	328±168	135±96
Polychaete (indiv/m^2)	29861±24362	20270±6196	4090±3349	1812±1627
Oligochaete (indiv/m^2)	9691±3241	11244±6118	14990±5864	3944±2376
Sipuncula (indiv/m^2)	15562±18588	10730±2904	6354±6278	580±284
Other macrobenthic organisms (indiv/m^2)	93±53	78±70	151±128	93±70
Gastropod (%)	0.29±0.18	0.01±0.01	0.30±0.16	0.60±1.05
Bivalve (%)	18.65±19.27	8.06±7.16	24.46±15.22	37.43±21.79
Crustacea (%)	1.22±1.51	8.93±13.80	1.03±0.45	1.28±0.84
Polychaete (%)	33.28±17.38	39.81±13.23	11.78±8.54	15.98±9.45
Oligochaete (%)	24.73±29.07	21.77±11.38	45.15±8.96	37.16±15.61
Sipuncula (%)	21.70±16.72	21.25±7.11	16.68±12.51	6.51±4.34
Other macrobenthic organisms (%)	0.13±0.03	0.16±0.15	0.60±0.69	1.03±0.76

Sea water salinity showed high significance between seasons (ANOVA F = 143.07 & P = 0.00). It showed a positive correlation with water transparency at 1% level of significance and with soil water salinity, porosity, soil organic carbon, soil organic matter, polycheate, percentage of polycheate and a negative correlation with soil pH, percentage of bivalve, percentage of oligocheate at 5% level of significance. The salinity was found to be high during winter & premonsoon season and low during the monsoon season at the site. The recorded higher values could be attributed to the low amount of rainfall, higher rate of evaporation and also due to neritic water dominance (Balasubramanian 2005; Sridhar *et al.* 2006; Asha 2007). During the monsoon season, the rainfall and the freshwater inflow from the land moderately reduced the salinity as reported by (Mitra *et al.* 1990); in the Bay of Bengal and coastal waters of kalpakkam by (Satpathy 1996). Soil water salinity showed high significance between the seasons (ANOVA F = 60.39 & P = 0.00). It showed a positive correlation with water table depth at 1% level of significance and with soil organic carbon, soil organic matter at 5% level of significance. Soil water salinity is one of the important controlling factors and it certainly has an impact on vegetation distribution. Experimental evidence (Adam 1990; Mahall and Park 1976) indicates that soil salinity increases with soil elevation, it reaches a maximum just above mean high sea level (MHSL) and then decreases beyond it. These observations, indirectly linking the presence of halophytes to topographic elevation, have been explained that duration of evaporation periods (occurring when the marsh is not flooded) increases with elevation and thus salts become increasingly concentrated (Adam 1990). The salinity gradient increases during the dry and warm season, which usually (at mid-latitudes) coincides with the plant growing season, while it is less important during rainy periods. During dry periods, salinities in the marsh increase as evaporation occurs and there is no tidal flushing or rainfall to dilute salt build-up (Nordby 1991). Conversely, during wet periods *(e.g.*, rainfall, flooding, spring melt events, pulses of fresh water from sewer overflows), salinities decrease as salt content is diluted and not replenished by tidal inundation. Similar result was observed in case of salt fluctuations at the site.

Water pH showed a positive correlation with water salinity, water transparency, percentage of polycheate and a negative correlation with soil pH, percentage of bivalve, percentage of oligocheate at 5% level of significance. Soil pH showed a positive correlation with percentage of sand at 5% level of significance and a negative correlation with soil water salinity at 1% level of significance and soil organic carbon, soil organic matter, soil organic carbon, soil organic matter at 5% level of significance.

Dissolved oxygen variation was found to be statistically significant (ANOVA F = 6.25, $P < 0.05$). It showed a negative correlation at 5% level of significance at the site. It is well known that the temperature and salinity affect the dissolution of oxygen (Saravanakumar *et al.* 2008). In the present investigation, higher values of dissolved oxygen were recorded during monsoon season which might be due to the cumulative effect of higher wind velocity coupled with heavy rainfall and the resultant freshwater mixing (Govindasamy *et al.* 2000; Rajasegar 2003; Saravanakumar *et al.* 2008). (Paramasivam 2005) attributed that seasonal variation of dissolved oxygen is mainly due to freshwater flow and terrigenous impact of sediments. In accordance with earlier findings (Upadhyay 1988; Subramanian & Mahadevan 1999) high values of DO were recorded during pre-monsoon and monsoon.

Water transparency, Tidal height, Percentage of sand, Bulk density, Soil organic carbon, Plant biomass, showed high significance variations between the seasons.

Inundation period showed high significance between the seasons (ANOVA F = 23.26 & P = 0.00). It showed a positive correlation with percentage of sand at 1% level of significance and with TSS at 5% level of significance and a negative correlation with percentage of silt at 5% level of significance. The duration of inundation at a particular elevation influences the vegetation found there. (Seneca *et al.* 1985) studied the influence of duration of inundation on development of a planted *Spartina alterniflora* marsh. They found that through the first several growing seasons, *S. alterniflora* exhibited maximum well-being in the 7- and 4-hour inundation zones, but for the remaining period through 12 growing seasons *alterniflora* demonstrated a shift in maximum well-being to the 11- and 9-hour inundation zones, and dominated these zones for the duration of the study. The upper zones (7- and 4-hour inundation) became a mixed species marsh over the 12-year period, and by the twelfth year *Phragmites australis* came to dominate the uppermost, 4-hour inundation zone (Seneca *et al.* 1985). However, it shows that the inundation period found in the present study coincides with the works of previous researchers.

Plant biomass showed very simple relation between the seasons (ANOVA F = 0.07 & P = 0.976). It showed a positive correlation with Plant growth rate or plant decay rate at 1% level of significance and fertilization at 5% level of significance. Cartaxana and Catarino (1997) found 41.71 % carbon in the leaf of salt marsh plant, Spartina maritime, while the plant biomass was 105.64g/m^2 in their study which is very similar with the results of the present study. Plant growth rate/ plant decay rate showed high significance between the seasons (ANOVA F = 60.58 & P = 0.00). Shoot density showed significance between the seasons (ANOVA F = 5.53, P < 0.05). It showed a positive correlation with percentage of gastropod at 5% level of significance.

Fertilization showed a positive correlation with plant biomass and growth/decay rate of at 5% level of significance and it was negatively correlated with water temperature and soil temperature at 1% and 5% level of significance respectively. (Levine *et al.* 1998) studied the effects of nutrient availability in a New England salt marsh, considering competitive interactions and zonation. They compared fertilized with non-fertilized plots of various halophytes and found that fertilization increased the biomass of the inferior competitor while the biomass of the dominant competitor was decreased which coincides with the present study.

Number of gastropod and Percentage of gastropod showed very simple relation between the seasons. Grazing, caused by herbivore insects, cattle and other grazing mammals is usually considered as a biotic, potentially zonation-contributing, factor (Ellison 1987; Adam 1990). Grazing, by introducing spatial disturbances, was observed not only to modify vegetation density but also to influence diversity and plant abilities to survive, colonize new sites and compete. This phenomenon was also observed with comparing the other sites which were grazed by cattle throughout the study period whereas the situation was reverse in the salt marsh restoration site which was protected from grazing by fencing (Plate 1).

4. CONCLUSION

From the present study it is evident that Salt Marsh Restoration Site (SMRS) which was controlled and managed with some artificial inputs showed not only elevated levels of plant biomass & their shoot density but also it was noticed the remarkable changes in some of the factors studied rather than other sites which could be helpful for the coastal environment as well as for the local community in the long run.

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APPENDIX

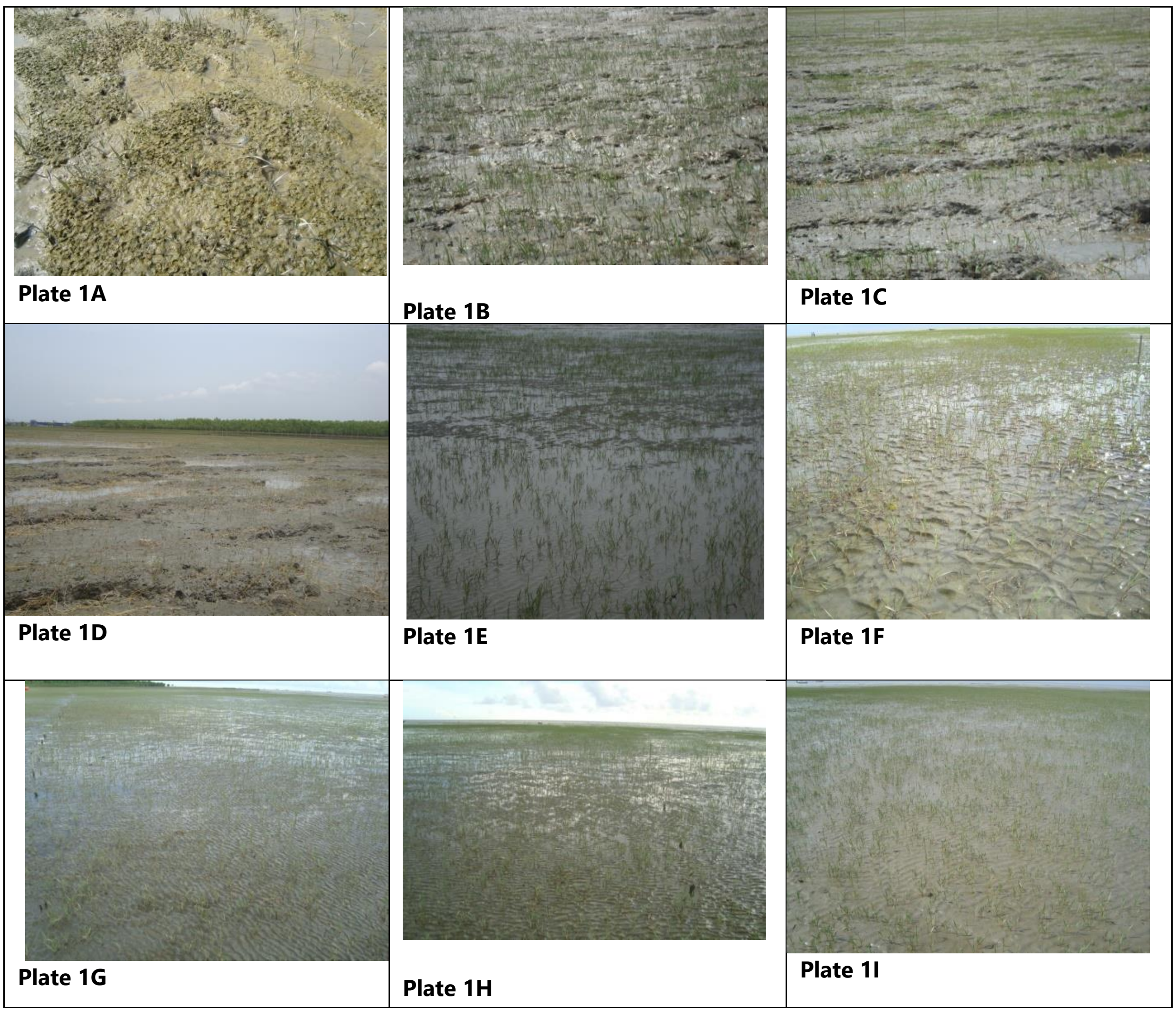

Plate 1. Succession of salt marsh plant, *Portereciacoarctata* at Salt Marsh Restoration Site (SMRS) from February 2010 to October 2010 (Plate 1A-February; Plate 1B-March; Plate 1C-April; Plate 1D- May; Plate 1E-June; Plate 1F-July; Plate 1G-August; Plate 1H-September & Plate 1I-October).

Plate 2A

Plate 2B

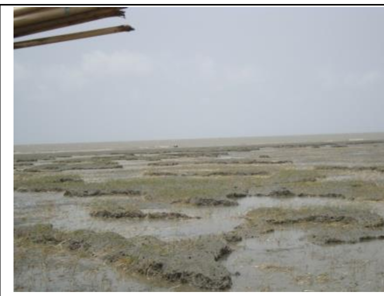

Plate 2C

Plate 2D

Plate 2E

Plate 2F

Plate 2G

Plate 2H

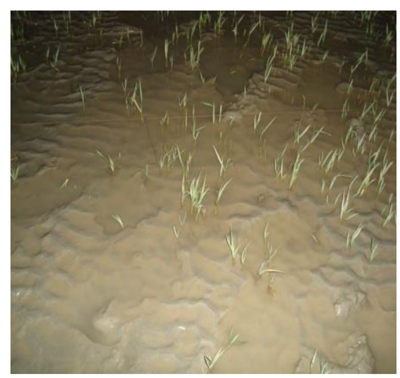

Plate 2I

Plate 2. Succession of salt marsh plant, *Portereciacoarctata* at Reference Site (RS) from February 2010 to October 2010 (Plate 1A-February; Plate 1B-March; Plate 1C-April; Plate 1D- May; Plate 1E-June; Plate 1F-July; Plate 1G-August; Plate 1H-September & Plate 1I-October).

Plate 3A

Plate 3B

Plate 3C

Plate 3D

Plate 3. Photographs of field visit and sampling activities (Plate-3A: Filed visit at February, 2010; Plate-3B: Marking experimental plot with bamboo & flag by the researchers; Plate-3C: Data collection by researchers, Plate-3D: Measuring soil temperature and pH in situ).

Plate 3A

Plate 3B

Plate 3C

Plate 3D

Plate 3. Photographs of field visit and sampling activities (Plate-3E: Plant sample collection; Plate-3F: Survey of experimental plot condition at May, 2010; Plate-3G: Protection of Restoration plot by making fence by the caretaker; Plate-3H: Plate-3D

REFERENCES

1. Adam, P. 1990. *Saltmarsh Ecology*. Cambridge University Press, Cambridge UK, 461p.
2. Asha, P. S. And R. Diwakar, 2007. Hydrobiology of the inshore waters off Tuticorin in the Gulf. J. Mar. Biol. Ass. India, 49: 7 -11.
3. APHA. 2005. Standard Methods for the examination of water and wastes water. 14th ed. Broadway, New York, U. S. A. 10019.
4. Balasubramanian, R. and L. Kannan. 2005. Physico-chemical characteristics of the coral reef Environs of the Gulf of Mannar Biosphere Reserve, India. Int. J. Ecol. Environ. Sci. 31: 265- 271.
5. Cartaxana, P. and F. Catarino. 1997. Allocation of nitrogen and carbon in an estuarine salt marsh in Portugal. Journal of Coastal Conservation, 3: 27-34.
6. Chmura, G. L., S. C. Anisfeld, D. R. Cahoon and J. C. Lynch. 2003. Global carbon sequestration in tidal, saline wetland soils. Glo. Biogeoche. Cycles, 17: 1111. doi: 10.1029/2002GB001917.

7. Govindasamy, C, L. Kannan and I. J. Azariah. 2000. Seasonal variation in physico- chemical properties and primary production in the coastal water biotopes of Oromandel coast, India. J. Environ. Biol., 21: 1- 7.
8. Das, S. and Siddiqui, N. A. 1985. The mangroves and mangrove forests of Bangladesh, Bangla. Forest Res. Instit. 3: 142.
9. Ellison, A. M. 1987. Effects of Competition, Disturbance, and Herbivory on *Salicornia europea*. Ecology, 68: 576-586.
10. Huq, A. M. 1986. Plants names of Bangladesh (Native and Scientific). Bangladesh National Herbarium (BARC), Dhaka, 228p.
11. Huq, S. M. I. and M. D. Alam. 2005. A hand book on analysis of soil, plant and water, 246 p.
12. Keith, S. 2006. Workshop report: Salt marsh restoration as a community adaptation to climate change and sea level rise in maritime Canada. School for Resource and Environmental Studies at Dalhousie University in Halifax, Nova Scotia, Canada. 5: 64.
13. Levine J.M., J. S. Brewer and M. D. Bertness. 1998. Nutrients, competition and plant zonation in a New England salt marsh, Journal of Ecology, 86: 285-292.
14. Lewis, R.R. and M.J. Marshall. 1997. 'Principles of successful restoration of shrimp aquaculture ponds back to mangrove forest', Programa/resumes de Marcuba '97, September 15/20, Palacio de Convenciones de La Habana, Cuba. 23: 126.
15. Mahall, B. E. and R. B. Park. 1970. Characteristics of *Spartina* marsh which is receiving treated municipal sewage wastes. In: Studies of marine estuarine ecosystems developing with treated sewage wastes, H. T. Odum and A. G. Chestnut (Eds.). Univ. of N.C., Chapel Hill, N. C. 14: 59.
16. Mitra, A., K. C. Patra and R. C. Panigrahy. 1990. Seasonal variations of some hydrological parameters in a tidal creek opening into the Bay of Bengal. Indian J. Mar. Sci. 28: 429-433.
17. Neckles, H. and M. Dionne. 1999. Regional standards to identify and evaluate tidal wetland restoration in the Gulf of Maine. Wells National Estuarine Research Reserve Technical Report, Wells, Maine.
18. New Hampshire Coastal Program (NHCP). 1998. Draft monitoring requirements for salt marsh restoration projects. State of New Hampshire Office of State Planning.
19. Niedowski, N. L. 2000. New York State Salt Marsh Restoration and Monitoring Guidelines prepared for the New York State Department of State Division of Coastal Resources & New York State Department of Environmental Conservation Division of Fish, Wildlife and Marine Resources. P.147.
20. Nixon, S. W. 1982. The ecology of New England high salt marshes: a community profile. Technical report FWS/OBS-81/85. US Fish and Wildlife Service, Office of Biological Services, Washington, DC. 23: 70.
21. Nordby, C.S. and J.B. Zedler. 1991. Responses of fish and macro benthic assemblages to hydrologic disturbances in Tijuana Estuary and Los Penasquitos Lagoon, California. Estuaries 14: 80-93.
22. Paramasivam, S. And L. Kannan. 2005. Physico-chemical characteristics of Muthupettai mangrove environment, Southeast coast of India. Int. J. Ecol. Environ. Sci., 31: 273-278.
23. Richter, K.O. 1997. A simple gauge for water-level maxima and minima. Restoration and Management Notes, 15: 60-63.
24. Rajasegar, M. 2003. Physico-chemical characteristics of the Vellar estuary in relation to shrimp farming. J. Environ. Biol., 24: 95-101pp.
25. Roy TK, Hossain ST. Role of Sundarbans in Protecting Climate Vulnerable Coastal People of Bangladesh. Climate Change, 2015, 1(1), 40-44
26. Stevenson, N. J., R. R. Lewis and P. R.B. Bur. 1999. 'Disused shrimp ponds and Mangrove rehabilitation', in W. J. Streever, ed., An International Perspective on Wetland Rehabilitation, The Netherlands: Kluwer Academic Publishers, 21: 277-297.
27. Saravanakumar, A., M. Rajkumar, J. SeshSerebiah and G. A. Thivakaran. 2008. Seasonal variations in physico- chemical characteristics of water, sediment and soil texture in arid

zone mangroves of Kachchh Gujarat. J. Environ. Biol. 29: 725- 732.

28. Satpathy, K. K. 1996. Seasonal distribution of nutrients in the coastal waters of Kalpakkam, East Coast of India. Indian. J. Mar. Sci, 25: 221-224.
29. Seneca, E.D., S.W. Broome, & W. W. Woodhouse. 1985. The influence of duration-of-inundation on development of a man-initiated *Spartina alterniflora* Loisel. Marsh in North Carolina. J. Exp. Mar. Biol. Ecol. 94: 259-268.
30. Sridhar, R., T. Thangaradjou, S. S. Kumar and L. Kannan. 2006. Water quality and phytoplankton characteristics in the Palk Bay, southeast coast of India. J. Environ. Biol., 27: 561 -566.
31. Subramanian, B. and A. Mahadevan. 1999. Seasonal and diurnal variation of hydro biological characters of coastal waters of Chennai. Ind. J. Mar. Sci. 28: 429-433.
32. Teal, J. M. 1986. The ecology of regularly flooded salt marshes of New England: A community profile. Prepared for the National Coastal Ecosystems Team, Division of Biological Services, U.S. Fish and Wildlife Service, U.S. Department of the Interior, Washington, DC.
33. Upadhyay, S. 1988. Physicochemical characteristics of Mahanadi Estuarine Ecosystem, East Coast of India. Ind. J. Mar. Sci., 17: 19-23.
34. Zedler, J. B. 1980. Algae mat productivity: Comparisons in a salt marsh. Estuaries 3: 122-131.