5.1. Introduction

An ecosystem is a biological environment consisting of all the organisms living in a particular area, as well as all the nonliving, physical components of the environment with which the organisms interact, such as air, soil, and water. Especially, marine ecosystems are among the largest of the earth's aquatic ecosystems and coastal systems constitute the dynamic ecosystems, which contain valuable natural resources and have important environmental values, whose extinction may affect the whole marine environment (Bakri and Kittaneh, 1998). Therefore, study of the physico-chemical properties of the coastal environment is very important. Mostly the marine ecosystems are fueled by the regeneration of nutrients, mediated by the marine microorganisms and these are pivotal for decomposition of organic matter and regeneration of nutrients thereby influencing the productivity of an ecosystem (Cevera et al., 2005).

Microorganisms live in every corner of the ocean and their habitats are diverse and distributed in open waters, sediments, bodies of marine macro and microorganisms, estuaries and hydrothermal vents (Cevera et al., 2005). They are always involved in the important processes of the sea in promoting organic material transformation and mineralization in the sediments and overlying waters (Das et al., 2007b). Microbial communities are structured by temporal and spatial variability of physicochemical and biotic parameters (Hewson et al., 2007).

Microbial distribution, diversity and activities are controlled by various hydro- biological factors and nutrient levels, present in the aquatic environment
and have been well studied in the marine environment (Azam et al., 1983; Ducklow and Hill, 1985). Distribution of microbial diversity further depends on changes in water temperature, salinity and other physico-chemical parameters (Alavandi, 1990) and they play chief roles in maintaining the ecosystems and respond to environmental changes and human activities (Dong et al., 2010)

Importantly, microbial communities readily respond at extremely faster rates (compared to other benthic organisms) to environmental and pollution changes (Thiyagarajan et al., 2010).

Physico-chemical characteristics of water and sediments serve as a useful tool for the ecological assessment and monitoring of different coastal ecosystems (Sankar et al., 2010). In general, factors like temperature, salinity and DO together with sediment characteristics have great influence on the abundance and distribution of benthic organisms and no single factor by itself has a controlling effect (Jayaraj et al., 2007). Physico-chemical parameters of the coastal waters and sediments would form a useful tool for further ecological assessment and monitoring of the coastal ecosystems (Saravanakumar et al., 2008). Good quality of coastal water resources depends on a large number of physicochemical parameters and the magnitude and source of the pollution loads and to assess these, monitoring of these parameters is essential (Reddi et al., 1993). Therefore, the present study was carried out to examine the influence of the physico-chemical parameters on the distributional variations of culturable actinobacterial population density in the Havelock Island coast of the Andamans.
5.2. Material and Methods

5.2.1. Collection of samples

Field collections were made at six stations of the Havelock island to record various ecological characteristics (physico-chemical parameters) and to collect sediment samples for actinobacteriological analysis, during November 2011.

Sediment samples were collected at a depth of 25 cm from six locations of the Havelock islands using a sterile spatula. The samples were placed in sterile polythene covers and brought to the field laboratory immediately and after arrival, necessary dilutions were made to carry out further microbiological analysis.

5.2.2. Physico-chemical parameters

Physico-chemical parameters viz. air temperature, surface water temperature and sediment temperature were recorded using a mercury thermometer having ±0.02°C accuracy. Salinity of water and sediments was recorded using a refractometer (Erma Company, Japan); pH of water was measured by a calibrated pH pen (pH Scan 1 Tester-Eutech Instruments, Singapore) and sediment pH was measured by a soil pH tester Model DM-13, Takemura Eletric Works Ltd, Tokyo, Japan. Electrical conductivity was also measured by Pye Unicam model 292 meter.

Water samples collected for dissolved oxygen estimation were transferred carefully to BOD bottles. The dissolved oxygen was immediately fixed and the samples were brought to the laboratory for further analysis. The modified Winkler's method, described by Strickland and Parsons (1972) was adopted for the estimation of dissolved oxygen.
5.2.3. Sediment nutrients

Powdered and digested sediment samples were used for the estimation of nitrogen, phosphorus and potassium, using Kjeldahl method (Subbiah and Asija, 1956) and colorimetric method (Olsen et al., 1954), in the Sugarcane Breeding Research Institute, Cuddalore. Total organic carbon was determined using potassium chromate as an oxidizing reagent (El-Wakeel and Riley, 1956).

5.2.4. Sediment texture

Sample weighing 100g was taken and sieved through a mesh (62 µ) for ten minutes in a sieve shaker. The samples remained in the sieve was weighted and treated as sand. Sediment samples which passed through the 62 µ sieve were the silt and clay. The silt and clay were then separated by means of the pipette method, described by Lindholem (1987).

5.2.5. Enumeration of actinobacterial population density

For actinobacterial assessment, the sediment samples were collected by inserting a polyvinyl corer (10 cm dia.) into the sediments. The corer was sterilized with alcohol before sampling at each station. The central portion of the top 2 cm sediment samples was taken out with the help of a sterile scoop. The sediment was then transferred to a sterilized polythene container and labeled. The sediment samples thus collected were air-dried aseptically. After a week, the sediment samples were mixed with equal weight of CaCo₃ (1:1) and incubated at 55°C for 5 min (Balagurunathan, 1992).

Actinobacterial population density was enumerated by adopting the spread plate method using Kuster’s agar medium (Appendix).

One gram of pretreated sediment sample was serially diluted using sterile seawater and 0.1 ml of serially diluted samples was added to the petriplates
containing Kuster's agar medium (Appendix) (Kuster and Williams, 1964) and spread using a ‘L’ shaped glass spreader. The plates were incubated at 37°C for seven days in an inverted position. Leathery colonies of actinobacteria that appeared on the petriplates were counted from the 5th day onwards upto 28th day. Population density of actinobacteria has been expressed as colony forming units (CFU) per gram of the sample (Hogg, 2005). All the colonies that grew on the petriplates were separately streaked and sub-cultured so as to ensure axenicity and were maintained in the slants.

5.2.6. Statistical analysis

Graphical representation of the physico-chemical parameters of the water and sediments values of graphical diagram were prepared using MS office excel 2007 software. Statistical analysis was performed to find out the relationship between the physico-chemical parameters of the water and sediments with actinobacterial population density, using SPSS version 11.5. Principal Component Analysis (PCA) and cluster analysis were used to identify the trends between the highly correlating physicochemical parameters and actinobacterial population density using PRIMER software.

5.3. Results

5.3.1 Analysis of physico-chemical parameters

Air temperature (Fig. 5.1): Air temperature varied from 29°C to 23°C, during the present period of study. Lower temperature value (23°C) was recorded at station 5 and the higher temperature value (29°C) was recorded at station 3.
Fig. 5.1 Air temperature recorded at six stations of the Havelock island.

**Surface water temperature** (Fig. 5.2): Surface water temperature varied from 26°C to 24°C, during the present study. Lower surface water temperature (24°C) was recorded at station 5 and the higher value (26°C) was recorded at stations 1, 3 and 6.

Fig. 5.2. Surface water temperature recorded at six stations of the Havelock island.
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**Sediment temperature** (Fig. 5.3): Sediment temperature varied from 27°C to 23°C, during the present period of study. The lower sediment temperature (23°C) was recorded at station 4 and the higher sediment temperature (27°C) was recorded at stations 3 and 6.

![Sediment temperature graph](image1)

Fig. 5.3. Sediment temperature recorded at six stations of the Havelock island.

**Water salinity** (Fig. 5.4): Water salinity fluctuated from 18 psu to 35 psu, during the present period of study. The lower water salinity was recorded at station 4 (18 psu) and the higher water salinity was recorded at station 6 (35 psu).

![Water salinity graph](image2)

Fig. 5.4. Water salinity recorded at six stations of the Havelock island.
**Sediment salinity** (Fig. 5.5): Salinity of sediments fluctuated from 17 psu to 34 psu, in the present study. The lower sediment salinity (17 psu) was recorded at station 4 and the higher sediment salinity (34 psu) was recorded at stations 5 and 6.

![Sediment salinity graph](image)

Fig. 5.5. Sediment salinity recorded at six stations of the Havelock island.

**Hydrogen-ion concentration (pH) in water** (Fig. 5.6): A narrow range of fluctuation in pH of the water was exhibited and it varied from 6 to 8 during the present period of study. The maximum pH value (8) was recorded at stations 3, and 6 and the minimum pH value (6) was recorded at station 1.
Fig. 5.6. Hydrogen-ion concentration (pH) of water recorded at six stations of the Havelock island.

**Hydrogen-ion concentration (pH) of sediments** (Fig. 5.7): A narrow range of fluctuation in pH of the sediments was exhibited and it varied from 7.6 to 8.7 during the present period of study. The maximum pH value (8.7) was recorded at station 6 and the minimum pH value (7.6) was recorded at station 1.

Fig. 5.7. Hydrogen-ion concentration of sediments recorded at six stations of the Havelock island.
**Dissolved oxygen concentration (DO)** (Fig. 5.8): Dissolved oxygen concentration of water ranged between 4.60 to 2.10 ml l⁻¹. At station 1, the minimum DO concentration (2.10 ml l⁻¹) was recorded and the maximum DO concentration (4.60 ml l⁻¹) was recorded at station 5, during the present study period.

Fig. 5.8. Dissolved oxygen concentration recorded at six stations of the Havelock island.

**Electrical Conductivity** (Fig. 5.9): Electrical conductivity of the sediments fluctuated at all the stations investigated. It ranged from 2 dSm⁻¹ to 5.5 dSm⁻¹, registering the lower value (2 dSm⁻¹) at station 3 and higher value (5.5 dSm⁻¹) at station 1, during the present study.
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**Fig. 5.9.** Electrical conductivity recorded at six stations of the Havelock island.

**Total Organic Carbon (TOC)** (Fig. 5.10): Sediment TOC content exhibited wide variations at all the stations investigated, registering the lower value (0.55 mg g\(^{-1}\)) at station 6 and higher value (8 mg g\(^{-1}\)) at station 4.

**Fig. 5.10.** Sediment TOC content recorded at six stations of the Havelock island.

**Sediment nitrogen** (Fig. 5.11): Sediment nitrogen content varied from 2.63 mg g\(^{-1}\) to 10.88 mg g\(^{-1}\), recording the lower value at station 2, and higher value at station 4, during the present period of study.
Fig. 5.11. Sediment nitrogen content recorded at six stations of the Havelock island.

**Sediment phosphorous** (Fig. 5.12): Sediment phosphorous content recorded the higher value (4.50 mg g\(^{-1}\)) at station 3 and lower value (3.13 mg g\(^{-1}\)) at station 4, during the present period of study.

Fig. 5.12. Sediment phosphorous content recorded at six stations of the Havelock island.
**Sediment potassium** (Fig. 5.13): Sediment potassium content showed fluctuation, registering higher value (60.88 mg g\(^{-1}\)) at station 4 and lower value (11.88 mg g\(^{-1}\)) at station 2.

![Sediment potassium](image)

Fig. 5.13. Sediment potassium content recorded at six stations of the Havelock island.

**Sediment texture** (Fig. 5.14): Sediment texture in terms of sand, silt and clay was in the range of 65-95 %; 3.5 -9.4 % and 1.2-30 % respectively. Minimum content of sand (65%) was recorded at station 4 and maximum content of sand (95%) was recorded at station 6. Minimum silt content (3.5%) was noticed at station 1 and maximum content of silt (9.4%) was noticed at station 5. Minimum content of clay (1.2%) was recorded at station 6 and the maximum (30%) was recorded at station 4.
5.3.2. Actinobacterial population density

Actinobacterial population density ranged from $8 \times 10^3$ to $21 \times 10^3$ CFU g$^{-1}$. Higher actinobacterial population density ($21 \times 10^3$ CFU g$^{-1}$) was recorded at station 4, followed by moderate actinobacterial population density, recorded at stations 5 ($19 \times 10^3$ CFU g$^{-1}$), 1 ($18 \times 10^3$ CFU g$^{-1}$) and 2 ($13 \times 10^3$ CFU g$^{-1}$). Lower actinobacterial population density ($8 \times 10^3$ CFU g$^{-1}$) was recorded at station 3 (Fig. 5.15).
Fig. 5.15. Sediment actinobacterial population density recorded at six stations of the Havelock island.

5.4. Discussion

Along with the physical, biological and chemical parameters that define microbial niches in marine sediments, hydrodynamic forces play a pre-dominant role in the shallow nearshore environment (Rusch et al., 2003) and they are directly related to microorganisms and productivity of water bodies. Some organisms can survive in a wide range of conditions and some are very sensitive to the changes in conditions (Raibole and Singh, 2011). So, in this direction, present objective was to investigate the important physico-chemical parameters (air temperature, surface water temperature, sediment temperature, water salinity, sediment salinity, water pH, sediment pH, electrical conductivity, dissolved oxygen, sediment nitrogen, potassium and phosphorus, total organic carbon and soil texture) of the coastal wetlands of the Havelock Island of the Andamans to find out their influence on the marine actinobacterial population density.
Generally, surface water temperature will be influenced by solar radiation, evaporation and fresh water influx (Ajithkumar et al., 2006). Temperature changes may cause great variations in the seawater properties and correspondingly in the life it supports. Variations in water density, salinity, and dissolved oxygen are caused by temperature changes. Growth and reproduction of aquatic life are also temperature dependent (Davis, 1977). Surface water temperature will be higher than that of the sediment temperature (Muraleedharan et al., 2010) because it decreases steadily from the surface to deep waters and sediments (Das et al., 2007b). Supporting this view, in the present study, air temperature was higher than that of the surface water and sediments in the Havelock island. This also lends support to the study of Ramaraju et al. (1981) who reported that the surface water temperature varied from 27.5°C to 28.5°C in the southern Andaman Sea, during winter and the temperature decreased gradually from the sea surface to depth. Statistically, air temperature showed positive correlation with surface water temperature ($r=0.944<0.01$), sediment temperature ($r=0.817<0.05$) and sand ($r=0.756<0.05$).

Salinity is one of the most important factors that determines the composition of biological elements in the marine environment (Manivasagan, 2009). Salinity fluctuation would definitely affect the biological characteristics of the marine environment. In the present study, water salinity fluctuated from 18 psu to 35 psu and salinity of sediments fluctuated from 17 psu to 34 psu. Lower water and sediment salinity was found at station 4 and it could be presumably due to the influence of fresh water prevailing in this mangrove creek area as compared to other stations. Maximum water and sediment salinity was found at station 6, which could be attributed to the high degree of evaporation and...
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dominance of neritic waters, from the open sea (Senthilkumar et al., 2002). Statistically, water salinity showed positive correlation with sediment salinity ($r=0.992<0.01$) and sediment pH ($r=0.796<0.05$). Sediment salinity exhibited positive correlation with sediment pH ($r=0.808<0.05$) and potassium content ($r=0.740<0.05$).

Water pH (Hydrogen-ion concentration) plays an important role by influencing all the aquatic organisms including microbes (Gnanam et al., 2013). pH (water and sediments) values, ranging from 6 to 8 observed in the present work might favour the growth and survival of many types of microorganisms, as reported by Jay (1996). In the present study, sediment pH was higher (average 8.2) than that of water pH (average 7.4). Generally, fluctuation in pH values is attributed to factors like removal of CO$_2$ by photosynthesis through bicarbonate degradation, dilution of seawater by freshwater influx, reduction of salinity and temperature and decomposition of organic matter (Rajasegar, 2003). In addition, pH might often change with time due to temperature-salinity changes and biological activity (Srilatha et al., 2012). Statistical analysis revealed that the water pH had significant positive correlation with sediment pH ($r=0.922<0.01$).

Dissolved oxygen concentration in water fluctuated from 4.60 ml l$^{-1}$ to 2.10 ml l$^{-1}$. Higher DO content was recorded at station 5, followed by station 6 due probably to neritic influence. Lower dissolved oxygen concentration was recorded at station 1. This could be due to higher microbial utilization of DO. Dissolved oxygen showed an inverse relationship with temperature and salinity and it is well known that temperature and salinity would affect dissolution of oxygen in seawater (Vijayakumar et al., 2000).
Electrical conductivity is an indicator of higher concentration of trace metals, which are capable of conducting electricity at much higher levels (Chaudhuri et al., 2009). The range of EC was 1.7 dSm\(^{-1}\) to 6.4 dSm\(^{-1}\) in the post tsunami period in the Andaman waters (Nayak et al., 2010). In the present study, EC of the sediments fluctuated from 2 dSm\(^{-1}\) to 5.5 dSm\(^{-1}\). Station 4 had higher EC level (5.5 dSm\(^{-1}\)) as this station is a dense mangrove habitat with more decomposed soil and station 3 (sandy beach) had lower EC level (2 dSm\(^{-1}\)). Swarnakumar (2010) reported that based on the nature of the chemical characters of the soil, there will be significant variations in the electrical conductivity.

In the present study, Total Organic Carbon (TOC) content closely followed the sediment type i.e. sediments low in clay content had lower amount of total organic carbon and as the clay content increased, TOC content also increased, as reported by Reddy and Hariharan (1986). TOC value was lower at station 6. It was higher at station 4 followed by station 1, as these stations are mangrove habitats. Therefore, higher organic carbon content in the mangroves could be due to the mangrove and terrestrial detritus present in the suspended matter (Jagtap, 1987) and a higher rate of sedimentation, in addition to the fine nature of sediments (Clayey and silt sediments) (Raghunath and Sreedhara Murthy, 1996). Decomposition of mangrove foliage and other vegetative remains in the sediments would also contribute to higher TOC (Ramanathan, 1997). Statistically, TOC exhibited positive significant correlation with clay (\(r=0.922<0.01\)) and actinobacterial population density (\(r=0.785<0.05\)) and negative significant correlation with sand (\(r= -0.872<0.05\)).
Nutrients would promote the growth and metabolic activity of the microbial communities in the marine environment (Trupti and Dave, 2010). This could be true in the coastal habitats of the Havelock island where sediment nitrogen (2.63 mg g\(^{-1}\) to 10.88 mg g\(^{-1}\)), phosphorus (3.13 mg g\(^{-1}\) to 4.50 mg g\(^{-1}\)) and potassium (11.88 mg g\(^{-1}\) to 60.88 mg g\(^{-1}\)) were recorded. Statistical analysis revealed that the sediment nitrogen content had a significant positive correlation with the TOC \((r=0.906<0.01\), clay \((r=0.884<0.01\) and phosphorus \((r=0.777<0.05\). Phosphorus content also had significant positive correlation with the TOC \((r=0.936<0.01\) and clay \((r=0.905<0.01\).

Sediment soil texture also plays an important role in the distribution and abundance of marine microorganisms. A significant correlation between actinobacteria and clay fraction of the sediments has revealed the positive relationship between the microbes and sediments. Higher microbial population density mainly coexists with clayey sediments than the sandy sediments (Nair et al., 1978). Similarly, in the present study, actinobacterial population density was higher at station 4 followed by stations 5 and 1 which stations had more clay content. Correlation matrix also revealed that the sand content showed negative significant correlation \((r=-0.907<0.01)\) whereas the clay content had a significant positive correlation \((r=0.932<0.01)\). It is worth mentioning here that the clayey sediments would contain sufficient nutrients and organic matter content for the propagation of microbes including actinobacteria (Gnanam et al., 2013).

In this study, hierarchical cluster analysis was performed to investigate the similarities or dissimilarities between the stations and physico-chemical parameters. Dendrogram of the analyzed stations and physico-chemical parameters provides with a visual summary of the clustering process (Figs. 5.16
Three clusters were observed in the dendrogram (Fig. 5.16). Cluster 1 corresponds to station 4. Cluster 2 corresponds to stations 3, 2, and 6 and Cluster 3 corresponds to stations 1 and 5.

Cluster 1 (station 4) corresponds to a dense mangrove habitat with favorable physico-chemical conditions, supporting higher actinobacterial density, than the stations of the other clusters 2 and 3. In the Cluster 2 (stations 3, 2, and 6), station 3 clade showed a very close distance similarity with the station 2 (8.929) and station 6 (9.599). These stations are coral and sandy habitats, having similar physico-chemical features. In the cluster 3 (stations 1 and 5), station 1 clade showed a close distance with station 5 (17.482), where there is the occurrence of monospecific stands of seagrasses (station 5) and station 1, occupied by patches of mangroves (station 1). Such vegetated situation in stations 1 and 5 could be reason for having similar physico-chemical features and actinobacterial density.

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**Hierarchical Cluster analysis**

*Group average*  

*Resemblance: D1 Euclidean distance*

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**Fig. 5.16.** Dendrogram of the cluster resemblance between physico-chemical parameters and six stations of the Havelock island.
Though the dendrogram can reveal the dataset structure, it does not allow the interpretation of the observed patterns in terms of the original parameters. Therefore, the target physico-chemical parameters dataset was subjected to Principal Component Analysis (PCA analysis) in order to determine which parameters influence the variation in the quality of the actinobacterial density at the six stations of the Havelock island. Principal Component Analysis (PCA) (Ter Braak, 1986) was used to identify the trends between the highly correlating physicochemical parameters and microbial density. PCA revealed the distinct relationship between the stations and the physico-chemical parameters with the actinobacterial population density.

In PCA, higher correlation component score was obtained between the actinobacterial population density and the physicochemical parameters at station 4 (118), followed by station 1 (32.2) and station 5 (28.1). In the PC1 axis, these three stations had positive significant correlation with clay, TOC, potassium (K), actinobacterial population density, nitrogen content and EC. It could be due to the fact that these stations are occupied by mangroves (stations 4 and 1) and seagrasses (station 5). Whereas, stations 3, 2 and 6 had negative correlation component scores (-53, -57.3 and -68.2 respectively), thus proving that these three stations had positive significant correlation with sand, phosphorus, and temperature. It could be ascribed to the fact that the two stations (stations 3 and 6) are sandy beaches and station 2 is a coral reef environment. In addition, at these three stations, very poor vegetation exists, as compared to stations 4 and 1 (mangrove habitats) and station 5 (seagrass habitat).
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**Principal Component Analysis**

![PCA plot](image)

**Fig. 5.17. PCA plot of the physicochemical parameters and actinobacterial population density recorded at six stations of the Havelock island.**

Microbial populations can tolerate and grow under varying environmental conditions. During the present investigation, higher population density of actinobacteria \((21\times10^3\text{ CFU g}^{-1})\) was recorded at station 4, followed by stations 5 \((19\times10^3\text{ CFU g}^{-1})\) and 1 \((18\times10^3\text{ CFU g}^{-1})\). Station 4, a dense mangrove habitat, had higher density of actinobacterial population, since mangroves would act as a major nutrient transformation system, responsible for more microbial activity (Alongi *et al.*, 1993; Holguin *et al.*, 2001). Further, microbial colonies can appear after the mangrove litter fall, grow quickly and reach very high densities (Kathiresan, 2007), taking part in biomineralization and biotransformation of minerals (Gonzalez-Acosta *et al.*, 2006). Sediment nutrients especially total organic carbon can significantly influence the actinobacterial population density (Das *et al.*, 2008) and the actinobacteria can survive well as they are saprophytic, depending on the availability of carbon (Promod and Dhevendaran, 1987).
Correlation matrix also showed that actinobacterial population density had positive significant correlation with clay ($r=0.932<0.01$), electrical conductivity ($r=0.811<0.05$), nitrogen ($r=0.809<0.05$) and total organic carbon ($r=0.785<0.05$) (Table 5.1).

At stations 5 and 1, there was moderate population density of actinobacteria ($19\times10^3$ CFU g$^{-1}$ and $18\times10^3$ CFU g$^{-1}$ respectively), correlating with the occurrence of monospecific stands of seagrasses (station 5) and patches of mangroves (station 1), as revealed by the average cluster analysis where both the stations fell under the same cluster (cluster 3) (Fig. 5.16). Next to the mangrove and seagrass habitats, station 2 (coral reef environment) recorded a fair actinobacterial population density ($13\times10^3$ CFU g$^{-1}$). It could be possible because corals can secrete mucus, which makes up the surface mucopolysaccharide layer, a medium high in organic compounds, which constantly traps microbes of all varieties from seawater and develops a higher concentration community of bacteria than that of ambient seawater (Ritchie, 2006). Stations 3 and 6, sandy beaches, with organic carbon content, 1-2 order lower than that of the muddy sediments, showed only a lower density of actinobacteria ($8\times10^3$ CFU g$^{-1}$ and $9\times10^3$ CFU g$^{-1}$ respectively), compared to other habitats. In Hierarchical cluster analysis (Fig. 5.16) also, these three stations (3, 2 and 6) fell under the same cluster (cluster 2) with close resemblance distance.

Present study has thus found that the physico-chemical parameters (air, surface water and sediment temperatures, water and sediment salinity, water and sediment pH, electrical conductivity, dissolved oxygen, sediment nutrients, total organic carbon and soil texture) have influenced the actinobacterial population density directly or indirectly, in the different coastal habitats of the
Havelock island. Mangrove environment has favoured higher density of actinobacteria than the other habitats. However, it should be noted that these environmental factors and their influence are specific and applicable only to the microbial populations of the study areas of the Havelock island and should not be generalized.
Table 5.1. Pearson correlations coefficient ($r$) values of the actinobacterial population and physico-chemical characteristics of Havelock island.

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** (Correlation is significant at 1% level ($p<0.01$)); * (Correlation is significant at 5% level ($p<0.05$)), Air temperature (AT), Surface water temperature (SWT), Sediment temperature (ST), Water salinity (WS), Sediment salinity (SS), Water pH (WpH), Sediment pH (SpH), Dissolved oxygen (DO), Electrical conductivity (EC), Nitrogen (N), Phosphorus (P), Potassium (K), Total organic carbon (TOC), Actinobacterial population density (APD).