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Physico-chemical and microbial characteristics of the coral reef environment of the Gulf of Mannar marine biosphere reserve, India

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Abstract: *Investigation on physico-chemical parameters and bacterial characteristics of the coral reef environs of the Gulf of Mannar biosphere reserve was studied. The study found the influence of different physico-chemical parameters on one another and also on the distribution of the total heterotrophic bacteria (THB) in the coral reef areas. Nutrients exhibited considerable seasonal and spatial variations with influence on the bacterial population. Coral reef areas recorded higher bacterial population density both in water (3.5 to 18 X 10^5 CFU ml^{-1}) and sediment (1 to 14 X 10^7 CFU g^{-1}) samples than the non coral reef areas (3.4 to 10.5 X 10^4 CFU ml^{-1} in water and 0.9 to 7 X 10^6 CFU g^{-1}). The study also found the dominance of gram negative groups at all the three stations (64.73, 63,5 and 72.59%) with Pseudomonas contributing maximum number of strains in all the samples. In addition Vibrio, Aeromonas, Flavobacterium, Cytophaga, Enterobacter and Alcaligenes were also recorded. The gram positive group was represented by Bacillus, Micrococcus, Arthrobacter and Corynebacterium. The generic composition of THB isolated from the coral mucus revealed the presence of Vibrio and Micrococcus in all the coral mucus.*

Key words: *Microbial characteristics, Coral reef, Biosphere reserve, Gulf of Mannar*
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Introduction

Coral reef ecosystem in the marine environment is unique in embracing a plethora of microbial populations, especially heterotrophic bacteria which are very important due to their role in the degradation of organic matter and nutrient regeneration. They also serve as an important source of food for a variety of reef organisms which help in sustaining the entire ecosystem.

Activities and relative abundance of the heterotrophic bacteria are controlled by the hydrobiological factors and nutrient levels of the aquatic environment. Abundance and distribution of the heterotrophic bacteria in relation to environmental parameters, such as temperature, salinity, pH, dissolved oxygen and nutrients have been well studied in other parts of the world in the coral reef and other marine environment (Azam *et al.,* 1983; Ducklow and Hill, 1985; D'Elia, 1988). But such studies in the coral reef environment of India, especially from Gulf of Mannar marine biosphere reserve are still scanty (Kannan *et al.,* 1998; Kannapiran *et al.,* 1999; Babu *et al.,* 2004).

Hence, the present investigation was undertaken with a view to record the distribution of total heterotrophic bacteria (THB) and to delineate the relationship of THB population with the physico-chemical parameters of the coral reef environment of the Gulf of Mannar, south-east coast of India.

Materials and Methods

Study area: The Gulf of Mannar biosphere reserve is situated in the southern part of the peninsula of India which extends from the Adam's bridge of Rameshwaram island to Cape Comorin of Kanniyakumari. There are 21 islands forming the 'archipelago' in this Gulf, lying between Rameswaram and Tuticorin. These islands are surrounded by coral reefs in a discontinuous manner over a distance of about 140 km (Wafar, 1986; Ministry of Environment and Forests, 1987). The reefs are mostly of fringing type arising from the shallow seafloor, and the depth here is around 6 meters. This area is remarkable for its richness and variety of flora and fauna and also sustains a good fishery industry.

For the present investigation, three sampling stations, namely Manoli (9^o 14' N lat and 79^o 7'E long), Hare (9^o 12'N lat. and 79^o 5'E long) islands and Mandapam coast were selected (Fig. 1). Manoli island (Station 1), a relatively undisturbed coral environ, exhibits more coral diversity and density. This was compared with disturbed coral environment, the Hare island (Sation 2). Extensive reefs are found on the southwest end of the Hare Island. These reef areas have been damaged due to continuous fishing, boat anchoring and tourism activities (Jeyabaskaran and Lyla, 1996) and long term coral mining activities extended up to early 90s. To compare the coral reef environment with the non coral reef area, samples were also collected from the non coral reef area, the Mandapam coast (Station 3).

Collection of samples of water, sediment and sediment deposited on dead corals was made every month for a period of one year (October 1994 to September 1995) from three different stations to elucidate the incidence and distribution pattern of total heterotrophic bacteria (THB) in relation to the physico-chemical parameters. Through the study was conducted during 94-95, the studies on microbial aspects of coral reefs of Gulf of Manner are scanty.

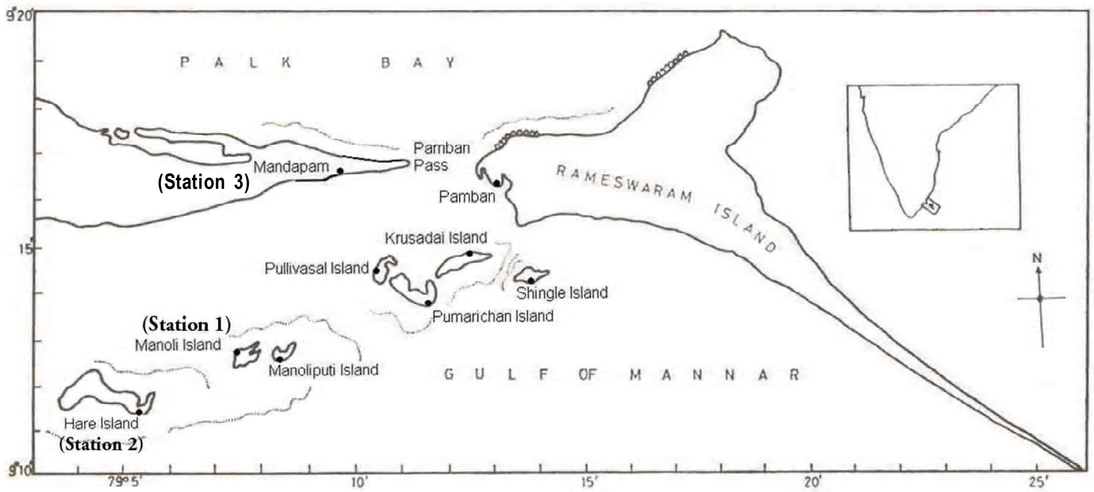

Fig. 1: Map showing the study areas

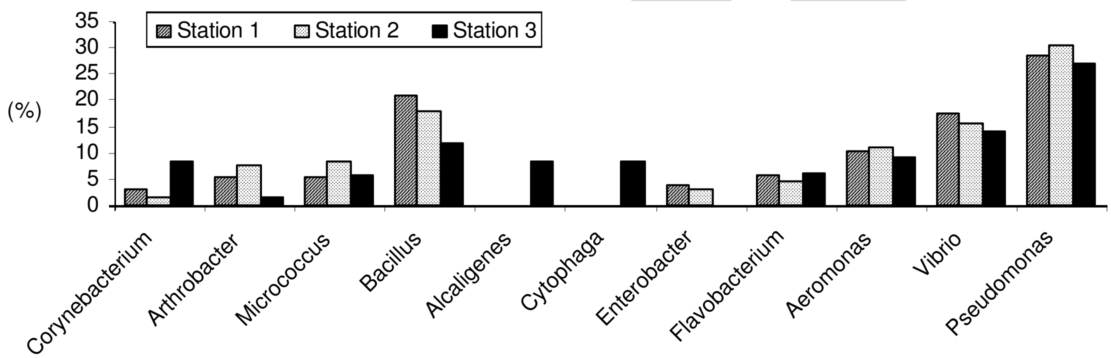

Fig. 2: Percentage composition of THB genera recorded from water, sediments and dead coral sediments of Stations 1, 2 and 3

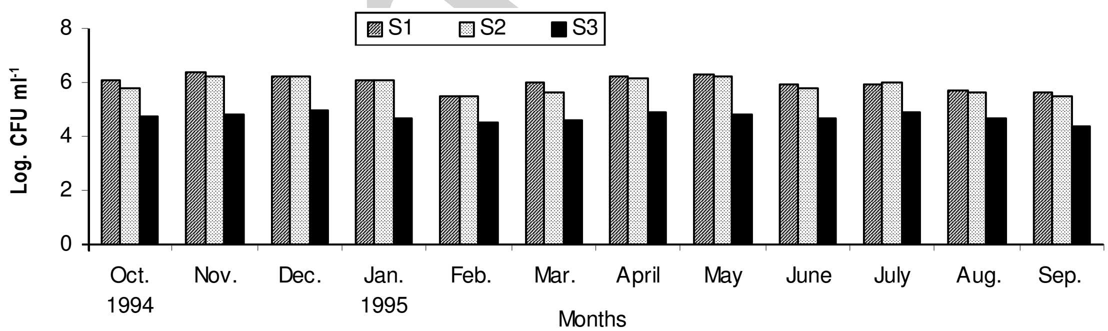

Fig. 3: THB population recorded from the water samples collected from Stations 1, 2 and 3

Rainfall data for the Gulf of Mannar (Mandapam region) were obtained from the Central Electro Chemical Research Institute, Mandapam Camp. Air and surface water temperature were measured in the field itself using a good grade mercury filled centigrade thermometer. Salinity was estimated with the help of a salinometer (mode E-2) and pH was measured using an Elico pH meter (model LI-120). For the estimation of dissolved oxygen, Winkler's titration method was followed (Strickland and Parsons, 1972).

Dissolved inorganic phosphate, nitrate and particulate organic carbon were estimated adopting the methods given by Strickland and Parsons (1972). Total phosphorus content in water

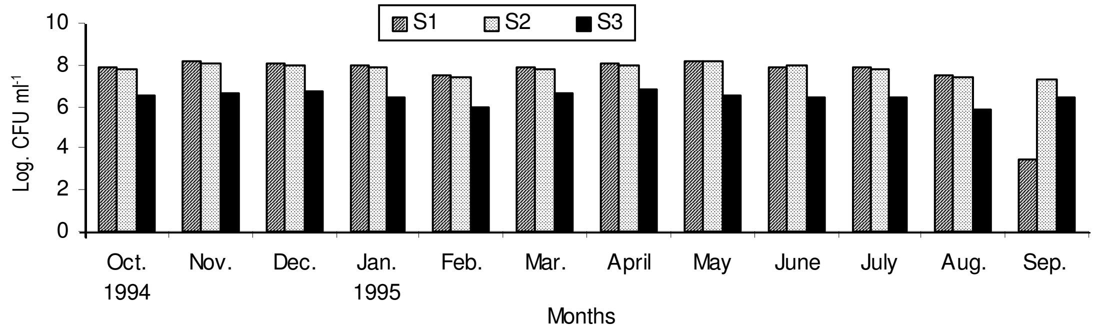

Fig. 4: THB population recorded from the sediment samples collected from Stations 1, 2 and 3

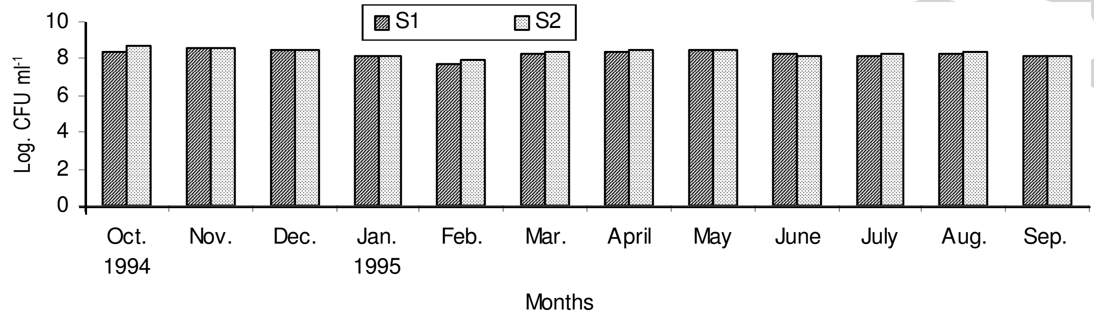

Fig. 5: THB population recorded from the dead coral sediment samples collected from Stations 1 and 2

was determined by the method of Menzel and Corwin (1965). Total nitrogen content in water was estimated by adopting the method of Christopher *et al.* (1977).

The coral mucus (about 50ml) was collected by inverting the coral species in separate sterile finger bowls and the samples were kept in ice-box and transported to the laboratory for further analysis. The enumeration of THB was made using the pour plate method on sterile Zobell Marine Agar medium (2216, HiMedia, Mumbai) with suitable dilutions. After inoculation, the plates were incubated in an inverted position for 72 hr at 28 ± 1°C. Bacterial colonies developed on Zobell marine agar after the incubation periods were counted and their density was expressed as Colony Forming Unit (CFU) per ml or g of water and sediment sample respectively. Identification of the pure culture up to generic level was done with the schemes of Buchanan and Gibbons (1975), Krieg (1984) and Sneath (1986). Simple correlation was made to find out the interrelationship between different physico-chemical parameters and THB.

Results and Discussion

Coral reefs are exposed to various physical and chemical conditions in the marine environment. The coral reef growth is controlled by primary ecological factors, such as light intensity, temperature and nutrients or by environmental signals (*e.g.* photoperiod). In recent times, there has been increasing interest in the study of potential perturbations due to physical and chemical pollution that might exert influence on the water quality and in turn affect the metabolic rates of coral reefs. Hence, it becomes important to study the various ecological factors that influence the growth of corals and the results are given in Tables 1-3.

Temperature is one of the most important factors controlling the physiological activities of corals and all the other related organisms. Every species has its maximal, optimal and minimal temperature requirement for growth and development. Hence, recording of temperature would be very useful in the study of coral reef communities. Air temperature recorded during the present study period showed seasonal variation at all stations investigated. Station 3 recorded highest temperature as compared to Stations 1 and 2. In general, the high temperature was recorded during the summer and premonsoon seasons whereas during the monsoon seasons, low temperature was noticed at all the three stations. This could be attributed to ocean's large thermal inertia which causes a lag between the absorption and the subsequent release of solar energy to the atmosphere during the summer season. Further, the summer maximum recorded in the present study may be due to the high solar radiation and clear sky conditions. But during the monsoon season, rain fall brought down the air temperature to the minimum.

Like air temperature, surface water temperature was also lower during the monsoon season and higher during the summer and premonsoon seasons at all the stations investigated. Seasonal pattern of minimum and maximum during monsoon and summer is a common phenomenon which has been reported by other workers from the southeast coast of India (Thangaraj *et al.,* 1979; Rajapandian *et al.,* 1990).

Coral reefs thrive at a water temperature ranging from 17°C to 34°C (Guilcher, 1988) with the most optimum growth occurring between 25 and 29°C (Clansen and Roth, 1975). Mayer (1914)

Table - 1: Variation in physico-chemical parameters recorded at Station 1

Parameters/ Months	Rainfall (mm)	Air temp. (°C)	S.W.T. (°C)	Salinity (‰)	pH	DO (mgl^{-1})	IP (μM)	T P (μM)	Nitrate (μM)	T N (μM)	POC (mgl^{-1})
Oct. 1994	250	28.0	28.4	30.2	8	4.4	0.27	0.95	1.1	3.9	0.05
November	365	24.5	28.1	29.1	8.3	5.3	0.36	1.03	1.32	4.1	0.06
December	120	35.4	25.0	26.9	7.8	4.8	0.29	1.00	1.25	4.5	0.05
Jan. 1995	100	28.0	28.0	27.0	8.1	5.0	0.04	1.00	1.10	4.9	0.05
February	55	28.4	26.2	30.1	8.3	4.9	0.005	0.65	0.7	2.5	0.03
March	0	30.1	27.2	34.8	8.4	5.6	0.09	0.56	0.65	1.9	0.04
April	60	30.4	33.0	33.5	8.7	7.2	0.1	0.23	0.55	1.8	0.02
May	60	31.5	31.0	34.0	8.6	8.5	0.15	0.3	0.46	1.3	0.03
June	65	31.0	32.1	34.5	8.3	7.6	0.15	0.35	0.5	1.5	0.03
July	0	30.0	32.2	34.0	8.6	7.0	0.15	0.36	0.55	1.9	0.04
August	0	30.1	32.5	30.2	8.2	6.0	0.2	0.45	0.75	3.6	0.04
September	10	29.4	29.0	31.0	7.9	4.6	0.16	0.61	1.1	4.2	0.03

Table - 2: Variation in physico-chemical parameters recorded at Station 2

Parameters/ Months	Rainfall (mm)	Air temp. (°C)	S.W.T. (°C)	Salinity (‰)	pH	DO (mgl^{-1})	IP (μM)	T P (μM)	Nitrate (μM)	T N (μM)	POC (mgl^{-1})
Oct. 1994	250	28.4	28.1	30.0	8.1	4.1	0.32	1.1	1.4	5.0	0.04
November	365	27.0	29.5	27.5	8.4	5.2	0.39	1.34	1.6	4.9	0.07
December	120	26.4	24.5	27.2	7.9	4.5	0.38	1.19	1.38	5.0	0.05
Jan. 1995	100	28.2	28.0	30.1	8.3	4.5	0.05	0.98	1.2	5.5	0.06
February	55	29.0	26.0	32.4	8.0	4.4	0.007	0.95	0.95	3.0	0.04
March	0	30.6	27.0	35.0	8.2	6.8	0.1	0.62	1.7	2.2	0.05
April	60	30.1	34.0	34.4	8.6	7.0	0.12	0.28	0.52	2.1	0.03
May	60	33.0	30.4	35.7	8.5	7.9	0.1	0.32	0.6	2.0	0.04
June	65	30.1	32.0	35.0	8.4	7.2	0.13	0.43	0.6	1.6	0.04
July	0	30.0	31.4	34.2	8.2	6.9	0.17	0.44	0.6	2.0	0.05
August	0	29.6	31.7	29.5	8.0	5.6	0.23	0.5	1.0	3.5	0.05
September	10	28.4	28.1	31.2	8.4	5.7	0.28	0.62	1.25	4.35	0.04

had reported physiological stress in a number of corals at a temperature between 31.8 and 36.4°C and death at a temperature exceeding 35.8°C. Neudecker (1987), showed that corals suffer from sub lethal effects, such as expulsion of zooxanthellae (bleaching) and reduced growth rates at 3-4°C and near total mortality at 4-6°C, above the ambient temperature. In the present study, the temperature in the reef waters (Stations 1 and 2) (24.5 to 33.0°C) observed was within the maximal level *i.e.* 36.4°C as reported by Mayer (1914). In the non coral reef area (Station 3), slightly higher temperature was observed than the reef waters.

During the present study period, there was not much seasonal fluctuation in water pH. There was also not much of variation in pH between the three stations. The pH remained alkaline throughout the study period. During the monsoon season, low pH was observed while during the summer season, high pH was noticed. Higher pH recorded in the present study could be due to the removal of CO_2 by the photosynthesizing coral community and the lower pH could be attributed to the dilution of seawater by freshwater inflow during the monsoon season. Higher pH in water during the summer season would help in the precipitation of calcium carbonate which in turn would help in the formation of interstitial lime paste, most useful for the coral development (Vacelet, 1984).

Corals flourish in salinities which are approximately close to optimal salinity value of about 35‰ (Bakus, 1973). However, many coral species found in such localities show significant variation in mean or extreme salinity. Coles and Jokiel (1992) reviewed field and laboratory data on the responses of corals and other reef organisms to salinity and they reported that natural reef communities seem to do well within a salinity range of 25-40‰. Salinity maintained below 20‰. for longer periods (more than 24 hr) is lethal to corals and the lethal response is more rapid at low salinities. Sub lethal responses to salinity include expulsion of zooxanthellae from the corals and alteration of their metabolic rates.

In the present study, salinity showed narrow range of fluctuation at all three stations. Summer season recorded higher salinity (30.6 to 34.5‰.) when compared to other seasons. Lower salinity (24.5 to 29.9 ‰.) was observed during the monsoon season at all three stations. This could be ascribed to the precipitation that occurred during the monsoon season in the study area. In the present study, salinity values were well within the required range of 25 to 40‰. (Coles and Jokiel, 1992) for coral growth and there would be no damage to the coral reefs in the study area due to the prevailing salinity.

Table - 3: Variation in physico-chemical parameters recorded at Station 3

Parameters/ Months	Rainfall (mm)	Air temp. (°C)	SWT (°C)	Salinity (‰)	pH	DO (mgl^{-1})	IP (µM)	T P (µM)	Nitrate (µM)	T N (µM)	POC (mgl^{-1})
Oct. 1994	250	28.5	28.2	31.8	8.6	5.1	0.39	1.35	1.85	5.1	0.06
November	365	26.0	30.0	30.0	7.9	4.2	0.42	1.68	1.8	6.8	0.09
December	120	25.9	25.5	29.73	8.4	5.0	0.46	1.42	2.0	8.3	0.06
Jan. 1995	100	27.0	28.1	32.5	8.2	4.1	0.1	1.40	1.8	7.5	0.06
February	55	28.6	26.5	34.0	8.0	4.0	0.12	1.15	1.1	5.9	0.05
March	0	30.0	28.0	35.5	8.0	4.4	0.13	1.3	1.0	5.2	0.06
April	60	29.6	34.5	34.6	8.9	6.0	0.13	0.85	0.85	4.8	0.04
May	60	33.5	32.1	36.4	8.3	5.3	0.11	0.56	0.9	4.2	0.05
June	65	30.3	32.4	33.7	8.1	5.0	0.16	0.62	0.65	4.1	0.05
July	0	30.2	32.0	34.2	8.4	4.2	0.19	0.81	1.0	4.0	0.06
August	0	29.8	33.1	30.0	8.5	4.8	0.3	1.05	1.25	4.1	0.04
September	10	30.0	29.2	32.8	8.3	4.1	0.31	1.3	1.85	4.2	0.06

Table - 4: Generic composition and mean population density of THB isolated from the mucus of the four coral species

Genus	*Gonestrea* sp	*Favites abdita*	*Acropora formosa*	*A. difitifera*
Bacilus	+	-	+	-
Vibrio	+	+	+	+
Micrococcus	+	+	+	+
Pseudomonas	+	-	-	+
Arthrobacter	-	+	-	-
Aeromonas	-	+	-	-
Flavobacterium	+	-	+	-
Population density (x 10^4 CFU ml^{-1})	40.8	39	21.2	32.3

In general, photosynthetic productivity in the coral areas is high. Photosynthesis and respiration in the coral reef community can be determined by oxygen or carbon dioxide changes in water. In the present study, the reef waters (Station 1, 2) showed higher dissolved oxygen concentration than the non coral reef waters (Station 3). Dissolved oxygen concentration was high during the summer season, probably due to the photosynthetic activity of zooxanthellae (Johannes and Webb, 1970) and the reef phytoplankton (Untawale and Parulekar, 1976). Lower dissolved oxygen concentration recorded during the monsoon was due to the low rate of photosynthesis, high rate of oxidation of detritus and respiration of bottom communities along with the slow diffusion of dissolved gases.

Availability of nutrients is one of the primary factors regulating the growth and development of corals. In subtropical regions availability of inorganic nutrients has been implicated as the most important factor limiting the productivity of the coral reef ecosystem. Further, nutrient dynamics in the coral reef ecosystem is complex, since the corals and other organisms are able to utilize the nutrients either from the sediments or from the water column (D'Elia, 1988). In the present study, higher concentration of dissolved inorganic phosphate (DIP) was observed at the time of monsoon seasons and this was due to the rainfall and subsequent land run off. This was followed by a sudden decrease of DIP during postmonsoon and summer seasons as a result of increased utility of DIP by phytoplankton and zooxanthellae. It is interesting to note that the population of phytoplankton was found to be more during these seasons in this part of the sea. This is substantiated by the fact that the corals containing zooxanthellae have been found to readily absorb inorganic phosphorus even at low nutrient concentration (D'Elia, 1988). Further, these algae within the coral tissue use the inorganic phosphorus from the coral tissues for their photosynthetic process. As this inorganic phosphorus is thus depleted, more inorganic phosphorus diffuses into the coral tissues from the surrounding environment (D'Elia, 1988), there by reducing the nutrient concentration in the surrounding waters.

Total phosphorus concentration was also higher in water during the monsoon season at all the stations due to the terrestrial run–off and the release of organic phosphorus from the mud. Deposition and release of phosphate from the sediments into the overlying water column has been reported by Carritt and Goodgal (1954) and Sykes and Boney (1970). The same has been attributed to the buffering action of the sediments, controlled by the variations in salinity, pH *etc.* In the present study, a maximum of 0.36 µM and 0.39 µM of inorganic phosphorus has been recorded at Station 1 and 2 respectively. These concentrations are slightly higher than those reported by Wafar *et al.* (1985) from the Lakshadweep coral reef environment.

In the present study, high levels of nitrate were observed during the monsoon season at all the three stations. Though the increase in nitrogen concentration in reef waters is often correlated with the nutrient input from terrestrial run-off (Marsh, 1985), sewage discharge (Johannes, 1975) and ground water seepage (Marsh, 1977; D'Elia *et al.,* 1981), the terrestrial run-off holds good in the present study. The lower concentration of nitrate recorded during the summer season could be due to the maximum photosynthetic activity of phytoplankton and zooxanthellae (D'Elia, 1988). Assimilation of dissolved inorganic nitrogen by photosynthetic organisms and other microbes during mineralization and oxidation and reduction of nitrogenous nutrients are the chief factors controlling the distribution of inorganic and organic nitrogen compounds as well as their interaction in the marine environment.

The level of particulate organic carbon (POC) recorded in the water was maximum during the monsoon season *i.e.* 0.06, 0.07 and 0.09 mgl^{-1} at Stations 1,2 and 3 respectively. The lower level of POC was observed during the summer season at all the three stations. In general, there was an increase in POC content during the monsoon season at all three stations. The higher POC content in water was mainly due to the organic matter brought in from the land through run-off. It could be also due to the presence of plant (seagrasses and seaweeds) and animal organic matter within the reef ecosystem and/or exported from the adjacent ecosystem. In addition, the seasonal variation in POC content in the water could be related to the plankton productivity (Sankaranarayanan and Panampunnayil, 1979).

Reef ecosystem is the most active centre for the growth of heterotrophic bacteria (Disalvo and Gunderesan, 1971) which are important in the recycling of nutrients and as food for many species of reef animals. These bacteria decompose particulate organic matter of local origin as well as imported from the surrounding ocean and from other reef area and convert it into high quality biomass. This in turn serves as food for different consumers ranging from protozoa, meiofauna, sea cucumber and to the coral species (Bakus, 1973; Moriarity, 1982; Moriarity *et al.,* 1985).

From the bacterial strains isolated from water, sediments and sediments deposited on dead corals, from all the three stations were randomly selected, sub cultured and identified up to generic level and 11 genera (*Pseudomonas, Vibrio, Aeromonas, Flavobacterium, Cytophaga, Enterobacterium, Alcaligenes, Bacillus, Micrococcus, Arthrobacter* and *Corynebacterium*) were recorded. The gram negative group (64.73, 63.5 and 72.59 % at Stations 1, 2 and 3 respectively) was generally more as compared to the gram positive group (35.27, 36.5 and 27.41 at Stations 1, 2 and 3 respectively). In general, the gram negative bacteria showed a higher proportion (65.7%) than the gram positive bacteria (34.3%).

Present study revealed the fact that the population density of heterotrophic bacteria (3.5 to 18 X 10^5 CFU ml^{-1}) in the coral reef waters and in the sediments (1 to 14 X 10^7 CFU g^{-1}) was much higher than in the surrounding coastal waters and sediments. In the present study, slightly higher density of THB in reef waters as compared to that of the reef waters of the coconut Island, Hawaii (10 X 10^3 ml^{-1}) (Sorokin, 1973) and lower density in sediments as compared to that of Kaneohe Bay, Hawaii (1 to 3 X 10^9 CFU g^{-1}) (Disalvo, 1973) have been recorded. In another reef environment of India, the microbial population density was around (3.2 X 10^5 CFU g^{-1}) in the sediments of Port Blair, Andaman Nicobar Islands (Neudecker, 1987).

In the present investigation, maximum density of THB population was noticed during the monsoon and summer seasons at all the three stations as well as in all the samples (water, sediments an dead coral sediments). The detritus particles that enriched the reef waters due to land run-off largely increased the distribution of organic matter as suggested by Sreepada *et al.* (1993) during the monsoon season thereby increasing the bacterial population. Likewise, THB population density was higher during the summer season when the plankton population density was higher (86,000 Cellsl^{-1}) of phytoplankton and 56,000 organisms $l^{-1}$of zooplankton. Dissolved organic matter released into the water from the plankton was probably the main source of nutrients that increased the bacterial population as suggested by Moriarity *et al.* (1985). This would support the finding of Larsson and Hagstrom (1979), who calculated that up to 45% of planktonic production is secreted as dissolved organics and much of this is utilized by the bacteria. Increase in bacterial population during or after the plankton bloom has also been reported by Ramsay (1976) from New Zealand waters.

Statistical analysis revealed the positive correlation (r = 0.8089, 0.6771 respectively) between the THB populations of water and dead coral sediments at Stations 1 and 2. At Station 3, a positive correlation (r = 0.6676) was noticed between the THB populations of water and sediments. A significant positive correlation was observed between the inorganic phosphorus and nitrate (r = 0.9504, 0.9858, 0.6204) and total nitrogen (r = 0.7824, 0.9421, 0.8470) at Stations 1, 2 and 3 respectively. A positive correlation was observed between the THB population of water and salinity (r = 0.6230) and dissolved oxygen (r = 0.5308) at Station 3. Salinity showed a positive correlation with THB of sediments at station 3 (r = 0.5823). At Station 2, THB population in sediments showed a positive correlation with inorganic phosphorus (r = 0.5138).

In the present study, total heterotrophic bacterial count from the reef sediments was very high (2.2 to 14 X 10^7 CFU g^{-1}) and the bacterial activity within the reef regenerative spaces would help in the precipitation of calcium carbonate thereby helping in coral reef building. In the present study, coral reef samples (Stations 1, 2) recorded higher bacterial population density than the non coral reef waters (Station 3). Analysis of variance revealed that the THB population varied significantly between the stations in water, sediments and sediments collected from dead corals. Likeswise, Westrum and Meyers (1978) had shown that the bacterial population density was 10 times higher in water flowing off the back reef than over the reef front at the Lizard Island. Moriatity (1979) was also of the opinion that the bacterial numbers increase when the water flows across the reef too rapidly, due to the suspension of particulate matter containing bacteria over the reefs.

In many reef waters, corals on the reef flats support bacterial growth by extruding mucus. In the present study also, higher bacterial number was observed at Station 1 due to release of mucus from a variety of corals than at Station 2 where no such coral diversity and distribution was noticed. Mucus is a glycopeptide and can be utilized by the marine bacteria as a carbon and nitrogen source (Mitchell and Chet, 1975). Even prior to its release from the coral surface, secreted mucus serves as a habitat and substrate for viable heterotrophic bacteria (Rublee *et al.,* 1980), thus suggesting that mucus would form the basis for microbial food-chain.

A total of 42 strains of bacteria were isolated from the mucus of the four coral species from which, 7 genera (*Pseudomonas, Aeromonas, Vibrio, Flavobacterium, Bacillus, Micrococcus* and *Arthrobacter*) were recorded (Table 4). *Vibrio* and *Micrococcus* occurred in the mucus of all coral species studied. *Arthrobacter* and *Aeromonas* occurred only in the mucus of *F. obdita*, while *Flavobacterium* was present in the mucus of *Gonestrea* sp and *A. formosa*. The number of genera found in the mucus of various coral species varied from 3 in *A. digitifera*, 4 in *A. formosa* and *F. abdita* and 5 in *Gonestrea* sp. Total viable counts of bacteria encountered from the mucus of *Gonestra* sp and *F. abdita* were more than that of the mucus of other two coral species. This change in bacterial counts in different coral species could be attributed to the change in mucus production by different coral species (Ducklow and Mitchell, 1979) and organic carbon content in the mucus (Pascal and Vacelet, 1981). Wild *et al.* (2004) reported that *Acropora* sp exudes up to 4.8 liters of mucus per square meter of reef area per day and about 56 – 80% of this mucus dissolved in water there by acting as energy carrier in the reef ecosystem.

From the present study it is concluded that the physico-chemical parameters largely fluctuate in association with the seasonal changes. As most of the global coral reef impacts are caused by the stress induced by the change in temperature and salinity (Pittock, 1999) this coral reef ecosystem has to be monitored closely. Nutrients exhibited considerable seasonal and spatial variation. In general, lower concentration of nutrients was recorded during the summer season, possibly due to the maximum utilization of the nutrients by zooxanthellae, bacteria, phytoplankton and other reef organisms. The primary peak of THB was noticed during the monsoon season when higher concentration of water nutrients was observed. This might be due to continuous availability of organic matter through decomposition of seaweeds and seagrasses and also from the land run-off. The secondary peak of THB was observed during the summer season, coinciding with the release of dissolved organic carbon from phytoplankton. Mucus exudation by the coral reef also plays major role in determining the microbial ecology. Present results and previous reports also suggest that bacterial population in the reef environment are virtually responsible for the decomposition of all organic materials reaching the coral reef environs thereby supplying essential nutrients, in addition to serving as a direct food source for a variety of reef organisms and to the corals. Above all, investigation on microbial characteristics of the Gulf of Mannar is scanty and the papers directly dealing with the microbiology of the coral reef waters of Gulf of Mannar after 1996 were restricted with the studies on coral reef microbial flora (Kannan *et al.,*1998), magneto bacteria (Kannapiran *et al.,* 1999) and molecular identification of bacteria associated with the coral reef ecosystems (Babu *et al.,* 2004). Under this condition, the present results are of paramount importance in undertaking long term monitoring of microbial characteristics of the Gulf of Mannar.

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