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Comparative investigation on physico-chemical properties of the coral reef and seagrass ecosystems of the Palk Bay

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Coral reef and seagrass ecosystems separated by a distance of 25 km in the Palk Bay region were investigated for their physico-chemical properties. Monthly variations of different parameters investigated are as follows; air temperature (27 - 35 ºC), surface water temperature (25.0 - 31.5 ºC), LEC (0.54 - 1.22 k), salinity (28.0 - 36.0 ‰), pH (7.0 - 8.2), DO (3.15 - 6.68 $ml l^{-1}$), nitrate (0.25 - 7.3 µM), nitrite (0.03 - 2.91 µM), inorganic phosphate (0.12 - 4.1 µM), reactive silicate (0.6 - 7.4 µM) and POC (0.28 - 3.25 mg C l^{-1}). There is distinct spatial variation on the above parameters between the stations. The present study had elucidated that the ecosystems like coral reefs and seagrass are prefer specific environmental conditions for their survival.

Key words: Physico-chemical characteristics, coral reefs, seagrasses, water quality, nutrients, Palk Bay

Introduction

Physico-chemical properties of the ambient marine environment will play a pivotal role in determining the type of ecosystem besides several other parameters like geomorphology, tidal amplitude and sediment composition. Coral reef and seagrass ecosystems are unique in embracing a plethora of floral and faunal species with higher biological productivity. The carbonate skeletal structures of coral reefs are effective barriers which dissipate wave energy and create low energy environs in the seas. The reefs also reduce the action of currents on shorelines, thus preventing erosion in those areas and help seagrasses to establish and grow. On the other hand, seagrasses by absorbing the excess nutrients in the water column provide with an ambient environment for corals to flourish well.

Seagrasses play a major role in maintaining the local ecology by stabilizing the sediments and producing particulate organic matter and transporting it to other biological systems thereby promoting secondary productivity in the region. Higher primary production rates of seagrasses are closely linked to the higher production rates of associated fisheries[1] and thus the seagrass communities make significant contributions to the coastal productivity. At the same time, both coral reefs and seagrasses can be strongly influenced by various physical-chemical factors that control the ecosystem processes.

In the open ocean, replenishment of nutrients is provided with principally by water circulation. In contrast to the open ocean, nutrients distribution in the shallow coastal areas like reef waters[2] is primarily due to remineralization which takes place in the top layers of the sediments. Factors such as local rainfall and lagoon morphometry appear to play a large role in determining the water chemistry of the lagoons[3]. Increasing temperature in both coral reef and seagrass environs enhance algal recruitment and growth[4] and it reported that the sea surface temperature in the coastal region of North Indian Ocean is in increasing trend during all the seasons[5], instantly present study area also falls in the same region. There is direct relationship between seagrass density, organic matter remineralization and carbonate dissolution at the shallow sediments[6]. In most cases the land-derived nitrogen loading in the coral reef environs is highly correlated with human activities in the adjacent waters[7].

The information on physico-chemical properties of the seagrass and coral reef environs of the Palk Bay are few[8,9,10]. The coral reef, mangrove and seagrass ecosystems are interlinked by physical, chemical and biological processes and need to be studied in detail.

The present study was carried out to assess the status of the physico-chemical characteristics of coral reef and seagrass environs of the Palk Bay for proper management and sustainable utilization of resources.

Materials and Methods

Study area

In the present study coral reef and seagrass ecosystem of Munaikadu and Devipattinum (Fig. 1) were selected for the study based on the dominant ecosystem prevalent in these sites. Munaikadu is only coral reef site of the entire Palk Bay region where as the Devipattinum is one of the dominant seagrass areas of the Palk Bay. During the onset of northeast monsoon turbulent conditions prevail in Palk Bay. .

The reefs developed around Munaikadu (Station 1) are distributed discontinuously with interrupted distribution of seagrasses. Devipattinum (Station 2) is situated 25 km north of station 1 by sea. The shallow coast is dominated by silt thereby supports luxuriant growth of seagrasses. The predominant seagrasses occurring in this area are *Enhalus acroides*, *Halophila ovalis*, *H. baccarii* and *Cymodocea serrulata*. A thick patch of mangrove dominated by *Avicennia marina* (Forsk.) Vierh, is also present along the northwest side of this station.

Field trips were undertaken for a period of one year from April 2002 to March 2003 at monthly intervals to record various physico-chemical parameters at the two selected stations. To confirm the consistency of data of the first year, seasonal collections were also made during the second year period (April 2003 to March 2004) at both the stations. Five sampling points were fixed for each station with an interval of 200 m on the respective ecosystems and the mean values were taken for the present study.

Air and surface water temperatures were measured using standard mercury filled centigrade thermometer. Light penetration in the water column was measured with the help of a secchi disc and the light extinction co-efficient (LEC) was calculated using the formula of Pool & Atkins[11]. Salinity was estimated with the help of a hand held refractometer (Model E-2) and pH was measured using a Elico pH meter (Model LC-120). Dissolved oxygen was estimated by the modified Winkler's method as described by Strickland & Parsons[12].

For the analysis of nutrients, surface water samples were collected in clean polypropylene bottles and kept in an icebox and transported immediately to the laboratory. Water samples were filtered using a millipore filtering system (MFS) and analyzed for dissolved inorganic phosphate, nitrate, nitrite and reactive silicate by adopting the standard methods[13]. POC was determined by wet ashing method[14] with the mixture of potassium dichromate and concentrated sulphuric acid.

For the sake of convenience and easy interpretation, a calendar year of study was divided into four seasons viz. Autumn (January to March), summer (April to June), southwest monsoon (July to September) and northeast monsoon season (October to December) based on the northeast monsoon which is prevalent during October–December months along the Tamil Nadu coast including the present study area. Seasonal mean, simple correlation co-efficient (r) and ANOVA were employed for the statistical interpretation of data.

Results

Air and surface water temperatures recorded at the two stations were ranged from 27 to 35 ºC and 25.0 to 31.5 ºC (Fig. 2) respectively with the maximum during the summer and southwest monsoon seasons and minimum during the northeast monsoon season. LEC values varied from 0.54 to 1.22 (k) at the two stations during the study period (Fig. 3). Station 2 recorded comparatively higher LEC values owing to the fact that the station is more shallow and turbid than station 1.

Salinity at the two stations varied from 28.0 to 36.0 ‰. The maximum salinity of 36‰ was recorded at station 2, in general station 1 registered higher salinity consistently than station 2 (Fig. 4) throughout the year. Water pH varied from 7.0 to 8.2 (Fig. 4) at both the stations, however, with clear spatial and temporal variations. The trend of pH is much resembles with that of variations in salinity while dissolved oxygen concentration ranged from 3.15 to 6.68 mll^{-1}. In general station 1, the coral reef water registered higher DO concentration throughout the study period (Fig. 5).

All the nutrients recorded higher values at the seagrass environment (station 2) expect the POC content. Likewise all the nutrients except inorganic phosphate were registered higher values during the northeast monsoon and minimum values during summer seasons. Concentration of different nutrients were recorded at different ranges, nitrate ranged from 0.25 to 7.3 µM; nitrite ranged from 0.03 to 2.91 µM; inorganic phosphate ranged from 0.12 to 4.1 µM and reactive silicate varied from 0.6 to 7.4 µM

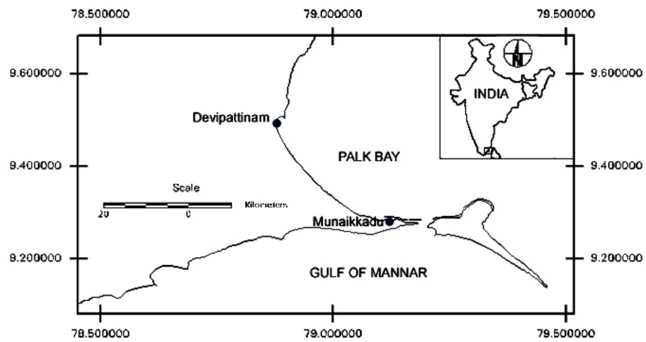

Fig. 1—Map showing the study areas in the Palk Bay

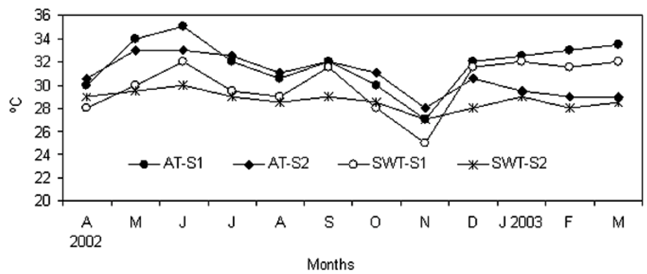

Fig. 2—Monthly variation in the air and surface water temperatures recorded at stations 1 and 2

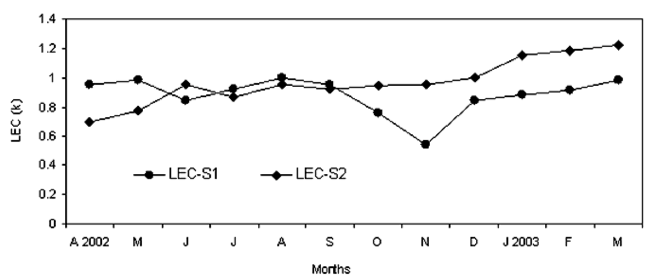

Fig. 3—Monthly variation in the LEC recorded at stations 1 and 2

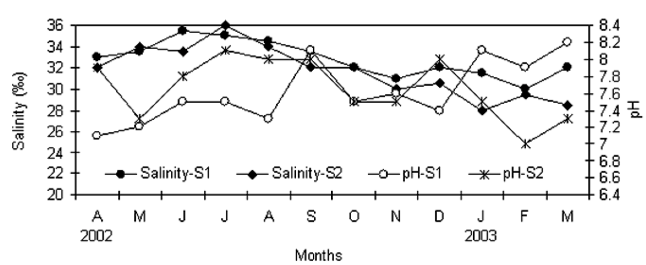

Fig. 4—Monthly variation in salinity and pH recorded at stations 1 and 2

(Figs 6-9) while POC ranged from 0.28 to 3.25 mg C l^{-1} (Fig. 10) at both the stations. Seasonal means of various hydrographical parameters recorded during the period of 2002-2003 and 2003-2004 were given in Tables 1 and 2.

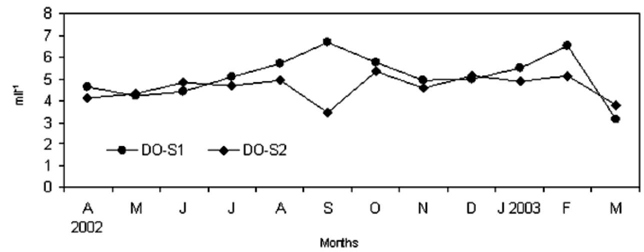

Fig. 5—Monthly variation in the dissolved oxygen recorded at stations 1 and 2

Discussion

The present study areas viz. Munaikadu and Devipattinam are situated within 25 km distance in the Palk Bay. They differ in floral and faunal composition, governed by hydrographical variations. Though the two stations showed clear spatial variations, both the stations exhibited more or less similar temporal variations in the physico-chemical characteristics of water. Temperatures recorded at both the stations showed more or less similar pattern of variations. The temperature was minimum during the northeast monsoon season and the maximum during the summer season. The monsoonal clouds prevalent during October – December months would reduce the air temperature. Surface water temperature showed the similar trend of variations as that of air temperature. This indicates that the surface water temperature is largely influenced by the air temperature. This is supported by the significant positive correlation obtained between the air temperature and surface water temperature ($r = 0.882$; $p < 0.001$ at station 1 and $r = 0.809$; $p < 0.001$ at station 2). Such seasonal behavior in temperature was reported[19] earlier from the Palk Bay.

The present range of 27–35°C of air and 25–31.5 °C of surface water temperature recorded at the station 1 (coral reef environment) is high when compared to the optimum temperature (30°C) for the better coral growth[14]. This increasing trend of temperature found in this study and also by the other studies[4] confirms that life of corals in this part of the sea is going to be challenge in the years to come. Air temperature at station 2, varied between 28 and 33 °C and surface water temperature ranged between 27 and 29.5 °C and these ranges are less as compared to that of station 1. This might have favoured the growth of extensive seagrass meadows at this station.

LEC values are tend to reduce from southwest monsoon upto northeast monsoon season. This indicates that the land-runoff at station 1 during the

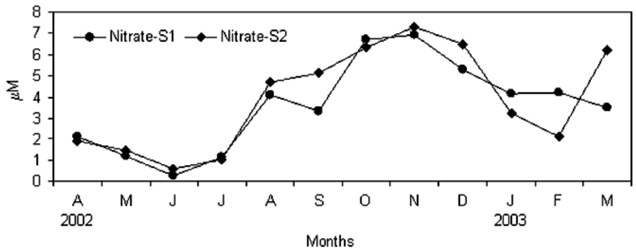

Fig. 6—Monthly variation in nitrate concentration recorded at stations 1 and 2

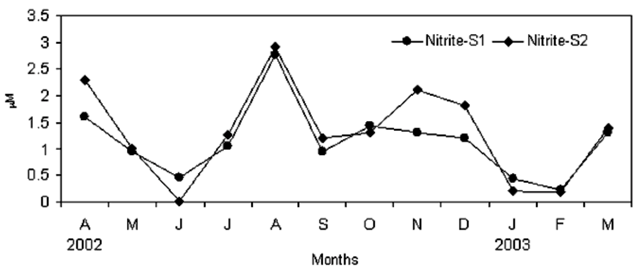

Fig. 7—Monthly variation in nitrite concentration recorded at stations 1 and 2

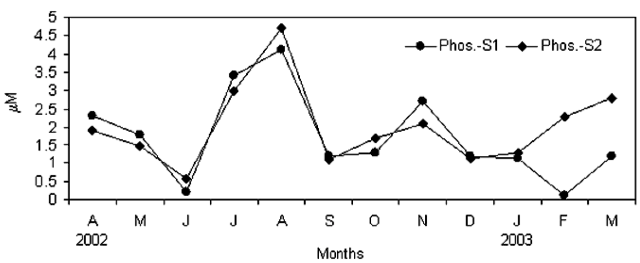

Fig. 8—Monthly variation in inorganic phosphate concentration recorded at stations 1 and 2

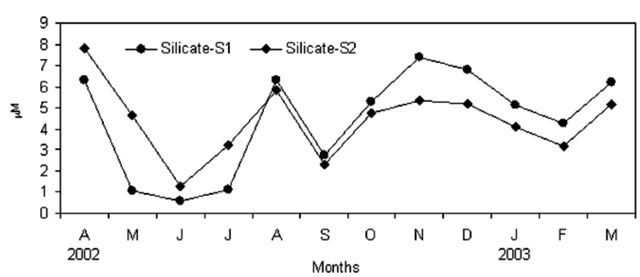

Fig. 9—Monthly variation in reactive silicate concentration recorded at stations 1 and 2

northeast monsoon season made observable impact on the turbidity of the water column. The turbidity is caused due to the mixing up of the turbid waters form Gulf of Mannar which usually tend to be highly turbid during the summer and southwest monsoon season. The LEC was lower during the summer season and it

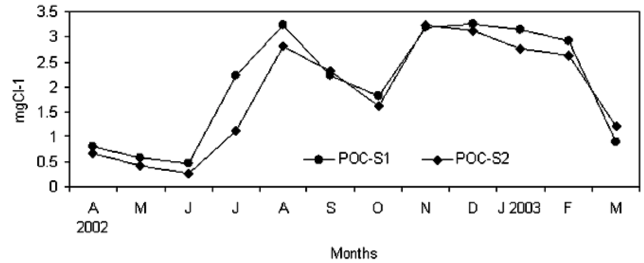

Fig. 10—Monthly variation in particulate organic carbon recorded at stations 1 and 2

was higher during the autumn season at station 2. Mixing of mangrove waters and the silt laden mudflat areas prevalent here might have increased the turbidity of the water column.

Natural reef community seems to do well within a salinity range of 25-40 ‰. The salinity range (28.0 to 35.0 ‰) recorded at station 1 (coral reef environment) was well within the optimum range. The significant positive correlation obtained between salinity and air temperature ($r = 0.824$; $p < 0.001$) at station 2 indicates that the salinity is largely influenced by the temperature at this station. It is generally agreed that the distribution of temperature, salinity, density and dissolved oxygen of surface waters of the Palk Bay is largely influenced by the Bay of Bengal waters entering through the Palk Strait.

The seasonal mean fluctuation recorded in the hydrogen-ion concentration was less and the pH remained alkaline throughout the study period. There was not much of spatial difference in pH between the two stations. Seasonal pH values recorded in the coral reef environment of the Munaikadu (Station 1) varied between 7.25 and 8.2. The minimum pH value recorded at this station during the summer season was quite contrast to the earlier[15] with higher pH values during the summer season in the coral reef environment of the Gulf of Mannar. But the seasonal studies conducted during the subsequent year found the higher pH values during the summer season. The station 2 registered higher pH values during southwest monsoon season and showed significant positive correlation ($r = 553$; $p < 0.05$) between pH and salinity.

In general, monthly and seasonal values of DO concentration were higher at station 1, the coral reef environment. This higher dissolved oxygen concentration in the coral reef environment is a common feature. This ecosystem represents one of the most productive ecosystems in the marine

Table 1—Seasonal variations in physical-chemical parameters recorded during 2002-03 at stations 1 and 2

Parameters	Summer		Southwest Monsoon		Northeast Monsoon		Autumn	
	S1	S2	S1	S2	S1	S2	S1	S2
Air Temp. (°C)	33.0	32.16	31.5	31.83	29.66	29.83	36.8	29.16
S.W. Temp. (°C)	30.0	29.5	30.0	28.80	28.16	27.83	31.8	28.5
LEC (K)	0.92	0.8	0.95	0.91	0.71	1.06	0.92	1.18
Salinity (‰)	33.33	33.16	34.33	34	31.66	30.83	31.16	28.5
pH	7.26	7.56	7.63	8.03	7.5	7.66	8.1	7.26
DO (ml l^{-1})	4.4	4.4	5.82	4.34	5.21	5.11	5.05	4.6
PO_4 (μM)	1.43	1.31	2.9	2.92	1.73	1.65	0.82	2.12
NO_3 (μM)	1.17	1.31	2.5	3.6	6.29	6.7	4.01	3.18
NO_2 (μM)	1	1.11	1.59	1.79	1.31	1.74	0.66	0.6
SiO_4 (μM)	2.66	4.58	2.73	3.79	6.5	5.06	5.2	4.16
POC (mg Cl^{-1})	0.61	0.46	2.56	2.08	2.75	2.64	2.32	2.19

Table 2— Seasonal variations in physical-chemical parameters recorded during 2003-04 at stations 1 and 2

Parameters	Summer		Southwest Monsoon		Northeast Monsoon		Autumn	
	S1	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
Air Temp. (°C)	36.0	35.0	27.0	32.0	26.0	30.0	30.0	29.0
S.W. Temp. (°C)	34.0	34.5	26.0	31.0	25.0	28.0	29.0	28.0
LEC (K)	1.85	1.42	1.25	0.68	0.72	0.68	1.54	1.35
Salinity (‰)	35.0	35.5	33.0	32.0	28.0	29.0	32.0	30.0
pH	8.2	8.3	7.25	8.1	7.8	7.5	8.15	8.0
DO (ml l^{-1})	5.67	3.7	3.84	5.48	4.58	6.0	7.15	6.48
PO_4 (μM)	3.15	0.64	4.78	5.1	9.38	8.25	4.52	4.25
NO_3 (μM)	0.05	0.05	0.15	1.01	2.34	3.28	0.12	0.15
NO_2 (μM)	0.04	0.14	5.48	2.15	4.15	5.28	1.28	3.18
SiO_4 (μM))	3.15	2.15	5.28	7.84	10.40	12.48	2.68	8.15
POC (mg Cl^{-1})	0.34	2.29	1.85	3.15	2.18	4.75	0.64	0.46

environment. The lower dissolved oxygen concentration recorded during the summer season may be due to the higher surface water temperature recorded during this season.

The seagrass environment (station 2) was also recorded higher DO values during the northeast monsoon and autumn seasons. This reflects the higher seagrass productivity[10]. The summer and southwest seasons have registered more seagrass biomass and productivity. However the subsequent dissolution of oxygen might have been reduced due to the higher surface water temperature recorded during these seasons. Coral waters are appears to be more productive than the seagrass waters in terms of DO. It is evidenced by the significant difference in DO between stations (ANOVA at 5% level). This could be due to the combined production of phytoplankton, zoozanthalae, seaweeds and seagrasses present in the coral reef area while in the seagrass environment it is only by seagrass and phytoplankton alone.

The POC value at station 1 was low during the summer season and high during the northeast monsoon season at station 1. The seagrass environment (station 2) recorded lower POC value during summer and autumn seasons, and high during the northeast monsoon season. There is significant difference in POC content between stations (ANOVA at 5%) with higher POC values. This difference could be attributed to the contribution of seagrass biomass at station 2. The higher POC values were recorded at station 2 during the northeast monsoon season since the land-runoff derived detritus and mangrove detritus[16] of this area. The seaweed biomass of station 1 is higher enough to contribute to the POC values of this station. The station 2 (Devipattinam), a shallow backwater like environment might allowed the seagrass biomass to settle there itself for decay.

The nutrients can have consistent impact on both the coral reef and seagrass ecosystems. Coral reef ecosystems are more sensitive to the changes in the nutrient levels in the ambient environment, especially of nitrogen and phosphorous, which are the limiting nutrients for coral growth[17]. The seagrass ecosystems are capable of withstanding higher nutrient levels when compared to the coral reef ecosystems, whereas the former could be affected by persistent higher nutrient levels for longer periods. The world's most frequent seagrass disappearances are associated with the nutrient enrichment from various sources including seawage and agriculture discharges[18].

During the northeast monsoon season nutrients recorded high values. This is due to land runoff caused by the monsoonal rains. The nutrient value is less during summer season. This could be ascribed to the greater phytoplankton population density recorded during the summer season and reduced addition of nutrients from the external sources like land runoff. ANOVA worked out for various nutrients has revealed that there is no significant variation in the nutrient concentrations in water column at both the stations. This would have caused the faster disappearance of corals coupled with faster encroachment of seaweeds and seagrasses in station1.

Most of the nutrient levels except phosphate were higher at Station 2, in the seagrass environment. This could be due to the higher utilization of phosphate by the seagrasses and phytoplankton. The above process plays a major role in the flux of carbon and nutrients in the sediments. The higher concentration of phosphate recorded at station 1 might have caused the growth of seaweeds at this station. Generally, coral reef environment will have low phosphate concentration[19] and increase in phosphate levels will suppress the calcification of corals, thereby affecting the coral growth.

Both nitrate nitrogen and nitrite nitrogen equally influence the blooming of algal population in the reef environment, thus affecting the coral reef ecosystem. Higher nitrate and nitrite concentrations recorded at the seagrass environment (Station 2), is a common feature as it is reported that nitrogen metabolism is generally more active in the seagrass bed sediments rather than the carbonate sediments of the coral reef environment.

Significant positive correlation ($r = 653$; $p < 0.01$ at station 1 and $r = 0.638$; $p < 0.01$ at station 2) obtained between nitrate and particulate organic carbon clearly indicates that the decaying seaweed / seagrass biomass might get finally mineralized and release the nutrients in to the ambient water column. Different groups of bacteria such as ammonifers, nitrate reducers, N_2 fixers, phosphate-solubilizers and phosphate-producers which are abundant in the reef ecosystem[21] would help in the regeneration of nutrients. In addition, they would take part in the decomposition of particulate organic matter of local origin as well as the imported ones and convert them into high quality biomass to sustain the food for different consumers dwelling in the coastal systems.

Reactive silicate is not an essential nutrient for coral species and seagrasses but an essential element for the associated organisms especially diatoms which often encrusts the seagrass leaves. However the increasing trend of temperature and nutrient levels in both coral reef and seagrass environs has to be checked otherwise such climatic change, europhication and food-web alterations have independent effects and potential for synergistically enhancing the development of macro-algal blooms in coastal ecosystems[22]. In the coral reef ecosystem, nutrient enrichment and / or silt sedimentation would tend to decline the corals and replace them with seagrasses while persistent excessive nutrients in the seagrass ecosystem make phase shift from seagrasses to macro-algae[23]. Hence, it is imperative to control the nutrient enrichment in these fragile ecosystems.

Conclusion

The temperature and nutrient concentration of Palk Bay had increased compared to the previous years. The increase in nutrient levels in the coral reef waters would affect the coral skeleton formation and causes the micro and macro-algal blooming. The above process would affect the coral reefs by decreasing the light availability to the zooxanthellae. The temperature would directly affect the corals. The increase in the nutrient levels in the seagrass environment would favour the epiphytes to grow and affect the photosynthetic efficiency of the seagrasses. All these would adversely affect the coral reef and seagrass ecosystems in the long run.

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