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Environmental Conditions of the surface water of the Red Sea Egyptian Coastal Waters; during a decade of EIMP Project

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Abstract

EIMP is the Environmental information and Monitoring programme for evaluation of the water quality of the Red Sea coastal waters, between Hurghada City in the north to Bir Shalatein citiy in the south, distance 600 km. This area is subjected to a rapid increase in man's activities including recreational industrial (mainly phosphate shipping and industry) besides fishing habour activities . From five to six field campaigns were annually carried out during the period from 1998-2008, to visit fifteen selected stations spreading along this distance. The studied water quality parameters were salinity, pH, total suspended matter (TSM), chlorophyll-*a* and N & P forms and silicate. The nutrients (N, P and Si) were generally at concentration levels characterizing a trophic status ranging from oligotrophic and mesotrophic states. In the intermediate distance between Safaga and Quseir phosphate level (especially during the first five years of investigation) experienced enrichment in compared with the other coastal regions. The other regions show N : P ratios indicated that PO_4-P is the limiting factor for phytoplankton growth. All studied parameters refer to a fact that the present study areas are far from the eutrophication phenomenon.

Keywords: Red Sea - coastal water - phyisco-chemical - nutrients -trophic levels.

1. Introduction

The Red Sea Region in general considered relatively undisturbed with human impact due to the low level of population at these regions. However this applied only to discrete areas as demand. Accordingly, the recreational areas are increasing rapidly in several sites of these regions. The existence of a unique ecosystem with highly diversified marine life, including corals and big mammals is great value of recreational, environmental and scientific interests and is in fact what supports and maintains the interest of tourists in visiting the Red Sea Regions. A proper environmental management with respect to the establishment of tourist facilities is highly desired. Further knowledge of the existing coral reef as well as the general environmental conditions is crucial to undertake this process.

Because the economic repercussions on the fishing and tourist trades depend, to a great extent, on the degree of deterioration of environmental conditions, the Environmental Information and Monitoring Program (EIMP) was initiated to assess the aesthetic quality of these coastal areas, due to their importance for the tourism and consequently national income

The previous work on the physical, chemical and biological characteristics of the coastal Red Sea waters were extremely limited, except the investigation performed by the Russian RV Ichthiology during winter 1964-1965 (Beltagy, 1984). An Intensive Data Collecting Program (DCPE), carried out during 1974 - 1977 from aboard the RV Arnona (Hottinger, 1984). It provided basic information on different characteristics of the whole water column of the Red Sea proper throughout few locations and seasons. Environmental Information and Monitoring Programme (EIMP) carried out continuously for seven years of 1998-2004 on the basis of bimonthly successive cruises is the main regular and comprehensive monitoring programme concerned with the hydrography, chemical and microbiological characteristics of the Red Sea proper coastal waters.

2. Materials and methods

2.1. Study area

The coastal zone in the Egyptian Red Sea Side., particularly in the distance between Hurghada and Bir Salatein, along a distance of 600km is interesting from several points of view. In addition to the development of urban areas, ports, oil industry and may be other installations, the major asset of coastal zone is potential for development of tourism. The development of the coastal area with hotels, resorts, villages beaches, pools, diving centers and other tourist facilities has taken place within the coastline, but in many sites as Hurghada the development has included the littoral zone and even part of the reef flat, which has been land filled.

The coastal zone in between Abu Shar (El-Guona) and Bir Shalatein has attracted many investors for establishing their touristic projects along its coast. Some of these plants have been built on the course of wadies, on areas of loose sediments drifted to the wadi mouths by flash floods and torrents from the Red Sea Mountains.

The Red Sea is a natural laboratory for investigating relatively rapid changes of short duration in a restricted marine environment. It covers a wide range of conditions, from normal marine, highly productive to external hypersaline and oligotrophic.

Within the framework of EIMP Program during the period from 1998-2008, the above mentioned fifteen investigated coastal stations were selected to represent different locations situated under the direct effect of human activities, public resort beaches, some protected and reference sites (Table 1 & Figure1).

The hydrographic parameters (water temperature, salinity, pH, dissolved oxygen (DO). Transparency, nutrients (NH_4, NO_2, NO_3, PO_4 and SiO_4) the first four parameters were measured *in situ* at each station using CTD (YSI -6000), transparency was measured by Secchi Disk. Water samples for NH_4 measurements were first eluted then fixed, the indophenol blue Technique (IOC-1983) was used. Water samples for some physicochemical and nutrient salts investigation were collected in duplicate from 2m depth at each station using a PVC Nisken's bottle. Nitrite (NO_2), Nitrate (NO_3), DIP and silicate (SiO_4) were determined in filtered (using GF/C filters) sea water samples, following the techniques described by Strickland and Parsons (1972) and total nitrogen and total phosphorus were estimated in unfiltered water samples following the Valderrama (1981) (IOC 1983) technique. Total suspended matter was calculated and chlorophyll-*a* was measured (Strikland and Parsons 1972).

Table 1. Sampling station numbers and geographical positions beside distance from Hurghada-NIOF (km).

St.No	Name	Latitude			Longitude			Distance From Hurgada (km)
Re1	Abu Shar	27	22	41.1	33	41	6.2	20
Re2	Hurghada-NIOF	27	16	59.9	33	46	19.3	0.0
Re3	Hurghada-Public Beach	27	15	34.1	33	49	23.3	5
Re4	Hurghada-Hotel Sheraton	27	11	37.5	33	50	48.4	10
Re5	Acoral reef-Island Gezr.Gifton	27	11	17.8	33	50	10.5	15
Re6	Sahl Hashish	27	2	38.2	33	53	36.5	20
Re7	Safaga	26	47	34.9	33	56	12.6	60
Re8	Safaga middle	26	3	20	34	0	20	65
Re9	Safaga north	26	20	10	34	4	15	70
Re10	El Hamarawein	26	15	9	34	12	5	120
Re11	Quseir	26	12	15	34	13	15	140
Re12	Quseir middle	26	8	30	34	14	30	150
Re13	Quseir south	26	5	55.4	34	16	56.4	160
Re14	Marsa Alam	25	4	6.1	34	54	0.4	275
Re15	Bir Shalatein	23	9	9.9	3	36	48.3	550

Note: Re = Red Sea

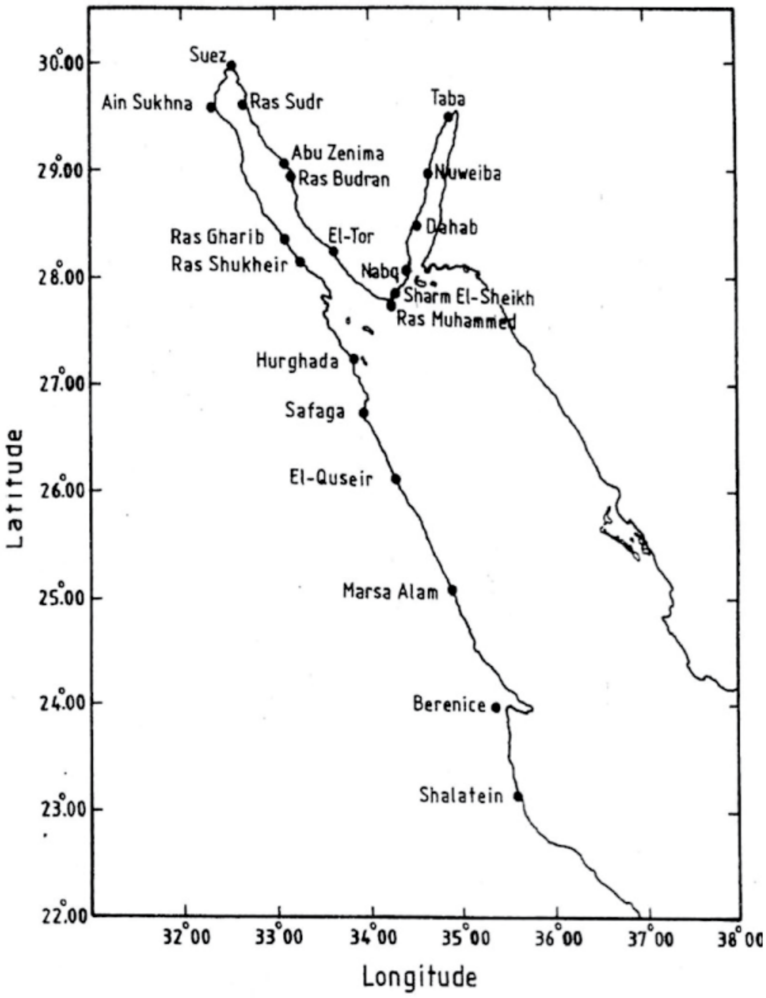

Figure 1. Map showing the locations of sampling sites for study Territional part of the Egyptian Red Sea.

3. Results and discussion

3.1. Physicochemical Characteristics

The ranges as well as average values of different studied physicochemical characteristics of the Red Sea surface coastal waters are listed in Table 2. Their annual and regional average values are graphically presented in Figure 2 .

Based on the regional and annual average values of physicochemical characteristics, one can noticed that, water temperature was accompanied with their geographic and temporal variations i.e. they followed seasonal changes in air temperature at different regions of the present study. Temperature varied from 22.19 °C at Re1 during winter of 2000 to 33.05 °C at Re15 during summer of 2008. A slight increase in water temperature was observed moving southward. The spatial distribution of salinity, pH and DO did not display clear changes. Salinity fluctuated between 39.32ppt at Re10 in the 2002 to 40.54 ppt at Re1 during 1998. The general distribution of DO indicated high values and the presence of well oxygenated waters where it ranges from 6.04 mg/l at Re9 during 1998 to 8.24 mg/ l at Re3 in 2008. Minor changes of these variables reveal that the effect of human impact on the distribution pattern of different hydrographical conditions in the Red Sea coastal waters are still limited. This was expected due to the low population there, the absence of fresh water sources and the limitation of land based sources (i.e. sewage, agriculture and / or industrial effluents). Accordingly, these conditions could be principally controlled by the circulation pattern of seawater in the Red Sea Regions. The hydrochemical characteristics of the Red Sea depend on the dynamics of its water as well as on the geographical location (Beltagi, 1984).

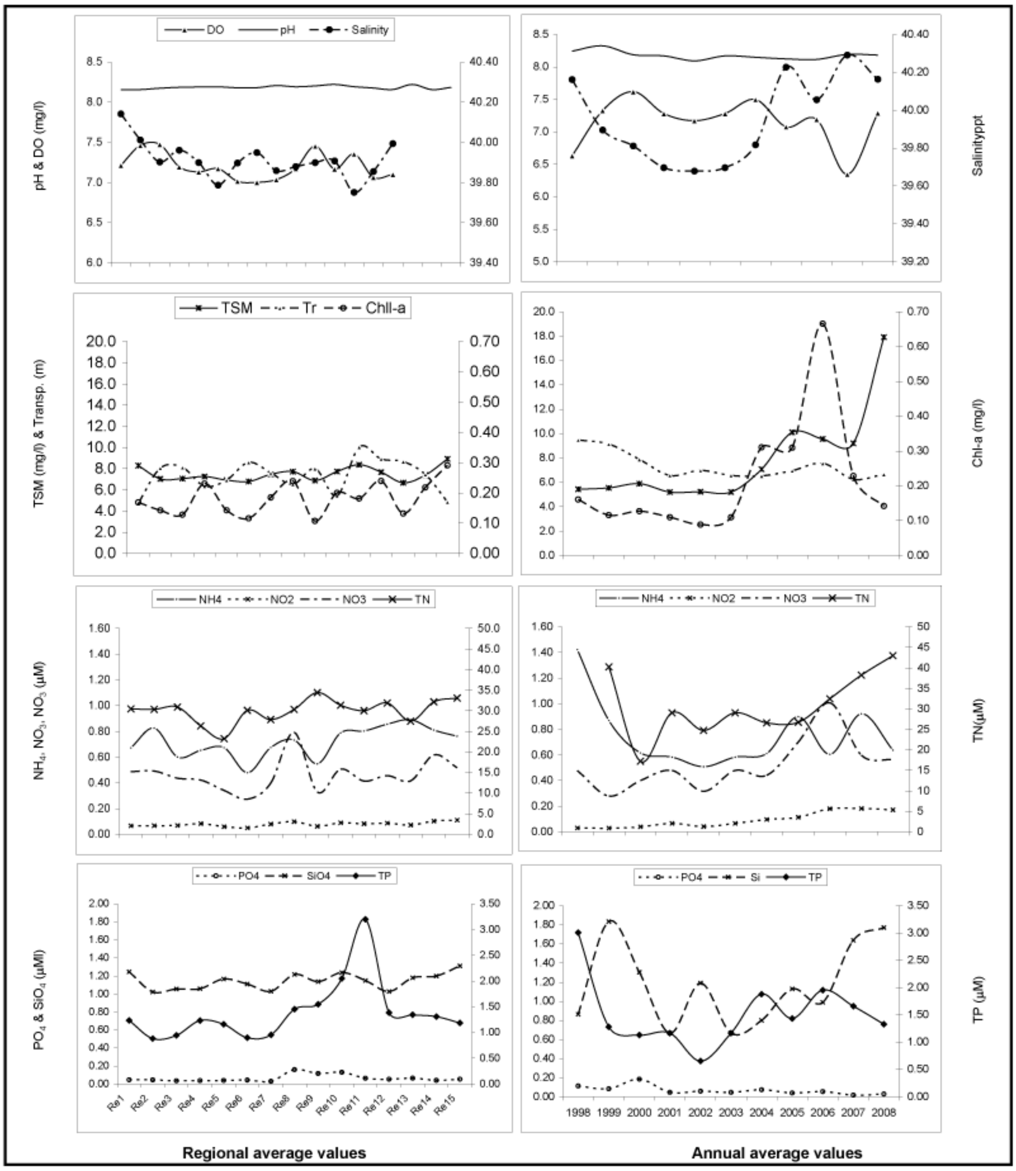

Figure 2. The distribution pattern of regional and annual average values for hydrographical and nutrient salt characteristics of the Red Sea Coastal Waters during 1998-2008.

3.2. Trophic State Variables

3.2.1. Chlorophyll-a, Total Suspended Matter and Secchi Disk Depth

Ranges and regional average values of Chl-*a*, TSM and Secchi Disk depth are reported in Table 2 and graphically illustrated in Figure 2. Low Chl-*a* and TSM concentrations and high transparency were generally encountered at most stations which indicate that the effect of human impact in the investigated Red Sea coastal waters is still insignificant. This can be highlighted by ranges and annual average values, at which Chlorophyll-a ranged from 0.06 µg/l at Re6 and Re13 in 1999 and 2002 to 0.98 µg/l at Re12 in 2006. Total suspended matter ranged from 4.16 mg/l at Re3 in 1998 to 20.25 mg/l at Re12 in 2008. Finally, Secchi Disk transparency reached bottom depth at most stations. These results are further confirmed by the comparison with the average Chlorophyll-*a* concentrations for the Red Sea Coastal waters by Halim (1969) in which the average value was 0.15 µg/l .

Table 2. Ranges and regional average values of physicochemical parameters of th e Red Sea Coastal waters during 1998-2008.

Station	Salinity ppt	Transparency m	pH	DO mg/l	Do %	Chl-a µg/l	TSM mg/l
	39.90-40.54	3.75-5.40	8.00-8.21	6.82-7.65	102-111	0.12-0.32	5.57-20.18
1	40.14	4.74		7.21	107	0.17	8.29
	39.84-40.32	7.00-10.08	8.05-8.29	7.00-7.99	105-119	0.11-0.24	4.72-16.62
2	40.01	8.05		7.46	112	0.14	7.04
	39.68-40.26	6.16-10.72	8.03-8.26	6.97-8.24	106-122	0.08-0.29	4.16-18.72
3	39.90	8.11		7.47	113	0.13	7.06
	39.62-40.28	4.88-8.24	8.12-8.34	6.34-7.62	94-115	0.08-0.83	4.39-17.30
4	39.96	6.34		7.19	108	0.23	7.26
	39.75-40.28	6.10-8.18	8.12-8.33	6.13-7.60	94-113	0.09-0.28	4.56-16.93
5	39.90	6.92		7.13	108	0.14	6.91
	39.48-40.19	6.29-17.70	8.07-8.34	6.24-7.70	96-116	0.06-0.26	4.39-17.13
6	39.79	8.60		7.17	109	0.12	6.79
	39.50-40.31	6.00-11.40	8.10-8.37	6.48-7.42	96-112	0.07-0.38	4.17-17.61
7	39.9	7.59		7.02	106	0.18	7.46
	39.72-40.36	4.63-8.20	8.13-8.32	6.15-7.50	91-114	0.09-0.65	4.82-17.90
8	39.95	6.25		7.00	105	0.24	7.72
	39.64-40.14	5.66-12.00	8.12-8.33	6.04-7.51	93-114	0.07-0.15	4.50-17.10
9	39.86	8.00		7.04	107	0.11	6.89
	39.32-40.36	4.75-6.13	8.10-8.36	6.23-7.72	93-119	0.09-0.49	4.95-16.70
10	39.88	5.44		7.17	109	0.2	7.73
	39.56-40.29	7.50-14.88	8.12-8.40	6.76-8.03	88-123	0.09-0.53	4.75-18.87
11	39.9	10.04		7.45	111	0.18	8.37
	39.56-40.30	6.60-12.63	8.12-8.40	6.23-8.21	90-125	0.07-0.98	4.39-20.25
12	39.91	8.91		7.17	107	0.24	7.67
	39.54-40.10	6.75-10.90	8.08-8.38	6.96-7.99	108-117	0.06-0.21	4.34-17.21
13	39.75	8.66		7.35	112	0.13	6.67
	39.46-40.25	6.20-8.18	8.06-8.31	6.07-7.70	90-119	0.11-0.64	4.81-16.25
14	39.85	7.54		7.06	108	0.22	7.39
	39.64-40.42	4.00-5.45	8.10-8.29	6.32-7.78	94-121	0.10-0.82	5.49-19.26
15	39.99	4.85		7.1	109	0.29	8.92
	39.90-40.54	7.50-17.70	8.13-8.40	7.00-8.24	108-125	0.12-0.98	5.75-20.25
Max	40.22	10.04		7.47	113	0.29	8.92
	39.32-40.10	3.75-5.40	8.00-8.21	6.04-7.42	88-111	0.06-0.15	4.16-16.25
Min	39.63	4.74		7.00	105	0.11	6.67
Range	39.32-40.54	3.75-17.70	8.00-8.40	6.04-8.24	88-125	0.06-0.98	4.16-20.25
Average	39.81	7.35		7.21	109	0.18	7.51

3.2.2. Nutrient Salts

The Red Sea does not receive any significant nutrient supply from river out flow. Therefore, the replenishment of these elements in the Red Sea depends upon the inflow of Indian Ocean water through Bab El Mandab, (12.5 x 10^3 K^3 Y^{-1}) (Beltagi, 1984) and the mixing of surface with deeper waters. Ranges as well as regional average values of different nutrients are listed in Table 3 and illustrated in Figure 2. The present data indicated that, dissolved inorganic nitrogen concentrations were quite low. This evident was found from both ranges and regional average values. They ranged from 0.31-2.76 µM NH_4-N at Re2 during 2002 and 1999, respectively for ammonium; 0.01 µM NO_2-N in 1998 at Re5 and Re12 during 1999 and 2000 at Re6 and Re7 to 0.30 µM NO_2-N during 2007 at Re15 for nitrite, from 0.12 µM NO_3-N during 1999 at Re6 and Re9 to 2.65 µM NO_3-N during 2006 at Re8 for nitrate and from 12.15 to 72.16 µM N during 2000 and 1999 at Re4 and Re10, respectively for total nitrogen.

Based on the mean annual values, the concentrations of dissolved inorganic nitrogen forms followed the order NH_4 > NO_3 $\geq$ NO_2. The relative increase in NH_4 concentration, which is the preferred N form for phytoplankton uptake, is unclear. These concentrations, based on the classification reported by Skrivance and Strin (1982) and Franco (1983), allow classifying the Red Sea coastal waters as oligotrophic to mesotrophic state. They indicated that as oligotrophic, seawater displaying concentrations of 0.5 µM for each NH_4 and NO_3. Whereas, in eutrophic waters the concentration of these nutrients are usually in order of 2.0 µM for NH_4 and 4 µM for NO_3.

The punctual average levels of PO_4, ranged from ND to 0.68 µM PO_4-P in 2007 and 1998 at Re4 and Re8, respectively. TP ranged from 0.41 to 7.34µMP in 2002 and 2004 at Re7 and Re11, respectively. A remarkable increase of PO_4 concentration was observed in the middle Red Sea stations as compared to the southern and northern stations. Since the middle area represents the main shipping and industry of Phosphate Company and El Hamrawe in main phosphate shipping Harbour. In the other stations PO_4 concentrations were very low. Low phosphate contents could be mostly related to their short life cycle, sorption and deposition on iron born dust conveyed to the basin from the surrounding deserts. Suzumura *et al.,* (2000) reported the effect of composition and physicochemical characteristics of natural particles on phosphate adsorption-desorption processes under various aquatic environment. The typical concentrations for eutrophic coastal waters are above 0.15 µM and for highly eutrophic system will be beyond 0.30 µM Franco, (1983). Accordingly the obtained results are consistent with the oligotrophic characteristics of the Red Sea coastal waters. Beltagi (1984) reported phosphate concentrations of 0.12-0.14 µM PO_4-P in the surface Red Sea waters. These values are higher than those reported in the present study, except in the middle region. The geographic and temporal distribution pattern of TP displayed a large variability during the investigation period, they fluctuated between 0.41to 7.34 µMP at stations Re7 and Re11 during 2002 and 2004, respectively.

DIN/P ratio amounted between (1.3 : 1) and (332 : 1) with an regional average value of (62.88 : 1) for Red Sea coastal waters These values when compared with those of normal Redfield's (16:1) suggest phosphate as a limiting nutrients for phytoplankton growth in different investigated regions (Table 3).

The distribution pattern of reactive silicate concentrations displayed small spatial and temporal variations. Punctual and annual average values ranged from 0.44 µMSiO_4-Si in 2001 and 2003 at Re2 to 2.73 µM SiO_4-Si in 1999 at Re13. A slight increase in SiO_4 concentration was observed in the northern side of Red Sea coastal water. Beltagi (1984), reported out that primary producers of the northern Red Sea are mainly composed of blue green algae (*Trichodesmium erythrium*) and to a lesser extent by diatoms, the main consumer of SiO_4. The main factors controlling SiO_4 distribution in the Egyptian Red Sea coastal waters are mainly: 1) the supply of SiO_4, which flows in the Red Sea through the straight of Bab El Mandab, 2) biological consumption, 3) organic matter decomposition and 4) the partial dissolution of quartz particle transported to the sea from the surrounding desert during sand storms.

Statistically, correlation coefficient technique was applied between different measured variables to evaluate the relationships betwe en them (Table 4).

The Red Sea is cleaning Region and no human impact, so no noticeable variations occurred and consequently the correlations between variables were fluctuated between moderate and low association, moderately negative association between salinity with DO (r= -0.40) positive correlation with TSM, (r= 0.56), all nutrient salts NH_4, NO_2, NO_3,TN, TP and SiO_4 (r> 0.32), pH with transparency, NH_4,TN, and SiO_4 (r> 0.30), DO was negatively correlated with TN (r= -0.40) Chl-*a* was correlated NO_2 and NO_3 (r= 0.52 & 0.43) TSM was correlated with NO2 and SiO4 (r=0.73 & 0.45) NH_4 was correlated with TN (r= 0.55) NO_2 with NO_3(r= 0.54).

Table 3: Ranges and regional average values of nutrient salts (mM) and their different ratios in the Red Sea Coastal waters d uring 1998-2008

Stations	NH_4-N	NO_2-N	NO_3-N	DIN	(NO3+NO2)/DIN	TN	(NO3+NO2)/TN%	PO_4-P	TP	PO4/TP%	SiO_4-Si	N:P	N:Si	Si:P
1	0.48 0.85 0.67	0.02 0.19 0.07	0.22 0.66 0.49	0.96 1.61 1.23	0.22 0.54 0.45	14.88 57.28 30.45	0.59 4.10 2.07	0.02 0.07 0.05	0.53 4.49 1.24	1.01 9.01 5.15	0.66 1.91 1.25	15.8 75.5 34.3	0.6 1.7 1.1	14.6 89.6 34.9
2	0.31 2.76 0.83	0.03 0.19 0.07	0.31 0.72 0.49	0.67 3.20 1.38	0.14 0.59 0.46	20.62 52.19 30.34	1.05 2.47 1.91	0.02 0.08 0.05	0.48 1.76 0.88	1.39 8.85 5.29	0.44 1.81 1.02	14.0 60.9 36.3	0.6 2.5 1.5	9.6 55.2 29.2
3	0.38 1.12 0.60	0.02 0.17 0.07	0.33 0.56 0.44	0.88 1.70 1.11	0.34 0.63 0.46	20.90 52.16 30.90	0.97 2.34 1.70	0.02 0.06 0.04	0.50 2.41 0.94	2.03 7.68 4.18	0.50 1.58 1.05	17.9 52.4 35.1	0.6 3.4 1.3	10.2 69.1 35.8
4	0.38 1.69 0.65	0.01 0.22 0.08	0.19 0.73 0.42	0.58 1.97 1.16	0.14 0.62 0.44	12.15 38.74 26.31	0.51 3.46 2.04	0.00 0.09 0.04	0.59 5.30 1.23	0.52 16.04 4.73	0.68 1.47 1.06	7.5 332.2 62.9	0.4 2.3 1.2	11.7 249.0 51.7
5	0.38 1.85 0.67	0.01 0.18 0.06	0.17 0.69 0.34	0.68 2.12 1.07	0.13 0.60 0.39	14.84 37.21 23.22	0.54 3.95 1.91	0.01 0.10 0.04	0.78 2.56 1.16	0.55 13.29 4.08	0.58 1.83 1.16	6.5 151.2 46.2	0.4 2.0 1.1	16.0 74.6 41.2
6	0.37 0.68 0.48	0.01 0.13 0.05	0.12 0.41 0.27	0.50 1.22 0.80	0.26 0.47 0.39	14.84 49.45 30.10	0.31 1.60 1.07	0.01 0.08 0.04	0.43 1.80 0.90	1.86 7.48 4.39	0.65 1.97 1.11	10.0 57.4 29.5	0.3 1.5 0.9	9.1 91.1 46.4
7	0.36 0.99 0.67	0.01 0.15 0.08	0.17 0.69 0.40	0.60 1.80 1.15	0.28 0.54 0.41	12.20 49.42 27.86	0.53 3.29 1.82	0.02 0.05 0.03	0.41 1.79 0.95	1.03 8.68 3.78	0.65 1.67 1.03	15.0 106.0 47.2	0.4 1.9 1.3	16.6 76.1 40.4
8	0.43 1.26 0.73	0.02 0.24 0.10	0.20 2.65 0.79	0.68 3.45 1.62	0.24 0.84 0.49	15.28 43.09 30.32	0.77 7.88 3.13	0.03 0.68 0.16	0.76 2.18 1.45	2.28 31.28 9.21	0.59 1.70 1.22	1.7 91.4 33.4	0.5 2.0 1.4	1.3 55.0 23.9
9	0.33 0.90 0.55	0.02 0.16 0.06	0.12 0.54 0.33	0.67 1.23 0.94	0.21 0.61 0.41	16.99 47.18 34.43	0.56 2.00 1.18	0.03 0.53 0.12	0.43 3.10 1.55	0.85 24.65 7.78	0.69 2.14 1.14	1.3 46.5 19.7	0.4 1.5 1.0	3.0 59.0 21.0
10	0.54 1.54 0.79	0.04 0.16 0.09	0.34 0.71 0.51	1.01 2.23 1.38	0.31 0.54 0.44	14.21 72.16 31.35	0.59 4.51 2.35	0.02 0.55 0.13	1.04 3.65 2.05	0.93 36.82 8.28	0.63 2.62 1.24	2.2 95.5 26.0	0.4 3.5 1.4	2.0 138.9 25.9
11	0.36 2.38 0.80	0.02 0.17 0.08	0.29 0.76 0.41	0.86 2.70 1.30	0.12 0.60 0.41	14.14 60.51 30.04	0.56 2.90 1.88	0.01 0.17 0.06	0.48 7.34 3.20	0.26 16.33 4.64	0.55 2.25 1.15	5.8 215.8 47.1	0.5 4.5 1.5	5.8 74.9 30.5
12	0.48 2.43 0.86	0.01 0.20 0.09	0.18 0.84 0.46	0.91 2.73 1.40	0.11 0.69 0.41	21.09 50.13 31.89	0.40 2.64 1.85	0.01 0.10 0.05	0.48 2.71 1.38	0.44 12.50 4.69	0.57 1.74 1.03	10.5 227.5 49.2	0.8 3.5 1.5	8.9 74.9 29.7
13	0.48 2.52 0.89	0.02 0.18 0.07	0.19 0.63 0.42	0.84 2.80 1.38	0.10 0.53 0.39	14.44 40.79 27.48	1.06 3.62 2.03	0.03 0.12 0.06	0.77 3.23 1.34	0.83 13.97 5.19	0.64 2.73 1.18	8.6 104.4 40.5	0.3 3.7 1.5	9.3 50.7 26.9
14	0.51 2.01 0.81	0.06 0.19 0.10	0.47 0.81 0.62	1.16 2.88 1.53	0.30 0.59 0.49	18.66 53.56 32.17	1.46 3.28 2.38	0.01 0.08 0.04	0.55 2.24 1.31	0.79 12.21 3.23	0.67 2.00 1.20	17.4 130.6 55.4	0.7 2.6 1.4	16.6 105.8 42.1
15	0.45 1.39 0.76	0.04 0.30 0.11	0.26 0.76 0.52	0.92 2.22 1.39	0.33 0.60 0.46	25.58 50.12 33.11	0.94 2.61 1.85	0.02 0.10 0.05	0.45 3.05 1.19	1.78 12.26 4.88	0.61 2.25 1.31	10.4 68.7 34.2	0.5 1.7 1.2	14.3 77.4 32.5
Max.	0.54 2.76 0.89	0.06 0.30 0.11	0.47 2.65 0.79	1.41 3.76 2.40	0.21 0.77 0.47	25.58 72.16 34.43	1.04 7.24 2.70	0.03 0.68 0.16	5.30 5.30 5.30	0.60 25.71 7.28	0.69 2.73 1.31	3.7 88.3 27.3	0.8 2.8 1.6	1.8 104.4 23.8
Min.	0.31 0.68 0.48	0.01 0.13 0.05	0.12 0.41 0.27	0.47 1.20 0.79	0.26 0.60 0.44	12.15 37.21 23.22	0.62 2.53 1.77	0.00 0.05 0.03	1.44 1.44 1.44	0.66 4.48 2.97	0.44 1.47 1.02	22.7 252.1 58.6	0.4 1.6 1.1	17.2 238.3 60.0
Rang Average	0.42 2.76 0.71	0.01 0.30 0.08	0.12 2.65 0.47	0.86 1.93 1.36	0.26 0.66 0.45	12.15 72.16 29.86	0.76 3.66 2.10	0.00 0.68 0.07	1.44 5.30 3.01	1.05 16.29 5.11	0.44 2.73 1.15	5.7 97.3 30.58	0.6 2.2 1.31	7.1 93.8 27.13

Table 4. Correlation Coefficient between physicochemical parameters and nutrient salt in Red Sea Region during 1998-2008.

	S‰	*pH*	*DO*	*Chll-a*	*TSM*	*Tr*	*NH4-N*	*NO2-N*	*NO3-N*	*TN*	*PO4-P*	*TP*	*SiO4-Si*	*CB*	*PEC*	*FSB*
S‰	1															
pH	0.05	1.00														
DO	-0.40	-0.04	1.00													
Chll-*a*	0.30	-0.29	-0.11	1.00												
TSM	0.56	-0.13	-0.03	0.19	1.00											
Tr	-0.12	0.42	-0.02	-0.08	-0.17	1.00										
NH4-N	0.36	0.32	-0.24	-0.01	-0.01	0.15	1.00									
NO2-N	0.44	-0.30	-0.20	0.52	0.73	-0.26	-0.09	1.00								
NO3-N	0.32	-0.25	-0.18	0.43	0.27	-0.19	0.06	0.54	1.00							
TN	0.32	0.30	-0.40	-0.06	-0.16	0.27	0.55	-0.28	0.02	1.00						
PO4-P	-0.16	0.17	0.08	-0.06	-0.17	0.03	0.00	-0.19	0.00	0.11	1.00					
TP	0.32	-0.18	-0.09	0.18	0.14	-0.02	0.07	0.10	0.19	-0.06	-0.08	1.00				
SiO4-Si	0.33	0.33	-0.04	-0.13	0.45	-0.01	0.02	0.23	0.06	-0.17	0.03	-0.03	1.00			
CB	-0.17	-0.16	0.09	-0.03	-0.08	0.05	-0.07	-0.10	-0.07	-0.09	0.04	-0.06	-0.03	1.00		
PEC	-0.14	-0.21	0.02	-0.01	-0.09	-0.09	-0.06	-0.07	-0.04	-0.08	-0.02	-0.05	-0.02	0.84	1.00	
FSB	-0.12	-0.04	0.11	-0.02	-0.03	0.17	-0.05	-0.08	-0.07	-0.09	0.10	-0.03	-0.01	0.78	0.34	1

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