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REPORT

MARINE BASLINE FIELD MEASUREMENTS, SURVEY AND LABORATORY ANALYSIS

To: TETRA TECH INTERNATIONAL DEVELOPMENT B.V., UK BRANCH

Agreement: 785-E4441-MA Marine Science Station (BFM) 07102021 C

PROJECT DESCRIPTION

Seawater and sediment quality analysis, as well as bottom habitat survey and currents for selected locations at different depths, as a part of the National Desalination and Conveyance and ESIA Study.

SUMMARY

The present report describes the current status of marine environmental conditions at the study area at the south of Gulf of Aqaba. This study aimed to determine the water physical and chemical properties in the selected sites, at the south part of the Gulf of Aqaba, 12 water samples were collected from different sites and depth; 5 m depth (SSA1, 29°22'16.80"N, 34°57'51.55"E), 25 m depth (SSA2, 29°22'19.09"N, 34°57'48.05"E) and 50 m depth (SSA3, 29°22'19.38"N, 34°57'43.88"E). The samples were analyzed for temperature, salinity, transparency, pH, dissolve oxygen, total suspended solids (TSS), inorganic nutrients, chlorophyll a, hydrocarbon, zooplankton biomass, siltation potential, and bio-fouling potential. Moreover, four representative sediment surface samples were collected from two different depth; 10 m bottom (ISH1, 29°22'17.46"N, 34°57'50.94"E) and 20 m depth (ISH2, 29°22'18.97"N, 34°57'48.62"E) . The physio-chemical characteristics were investigated in these sediments including: particle size analysis (PSA), total organic carbon (TOC), color, and odor. Furthermore, the interstitial living assemblages were also investigated at surface bottom sediments at 10 and 20 m depth. On the other hand, seawater currents speed and direction were also investigated within two deferent water column; 25 m (SWC1, 29°22'19.09"N, 34°57'48.05"E), and 50 m (SWC2, 29°22'19.38"N, 34°57'43.88"E). A benthic habitat survey and fish community structure were carried out in two deferent depth, 10 m bottom (BHS1, 29°22'17.46"N, 34°57'50.94"E) and 20 m bottom (BHS2, 29°22'18.97"N, 34°57'48.62"E).

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TABLE OF ACRONYMS

Abbreviation	Meaning
SWC	Seawater current
ISM	In situ seawater measurements
SSA	Seawater sampling and analysis
BHS	Bottom Habitat Survey
ISH	Interstitial Habitat
PSA	Particle size analysis
TOM	Total organic matter
IL	Ignition loss
PSU	Practical Salinity Unit
DO	Dissolved Oxygen
TSS	Total Suspended Solids
SDI	Silt density index
MFI	Modified fouling index
HC	Hard coral
SC	Soft coral
SP	Sponge
RC	Rock
RB	Rubble
SD	Sand
SI	Silt
OT	Other
RKC	Recently killed coral
RA	Relative abundance

Avg	Average
Std Dev	Standard deviation
SE	Standard error

INTRODUCTION

The present report describes the environmental physio-chemical properties of seawater and bottom sediment and biological quality at selected locations within different depths, as a part of the National Desalination and Conveyance and ESIA Study. The report has been prepared by the Marine Science Station of the University of Jordan and Yarmouk University on request of TETRA TECH INTERNATIONAL DEVELOPMENT B.V., UK BRANCH. It represents the current status of marine environmental conditions at the study area at the south of Gulf of Aqaba. In the following sections we present and describe the different parameters that are planned to be carried out within the framework of the signed agreement between MSS and TETRA TECH INTERNATIONAL DEVELOPMENT B.V., UK BRANCH. The main components of the report are seawater currents and chemical properties, chlorophyll a (phytoplankton)and zooplankton, bottom habitat survey, and interstitial habitat.

PART ONE: METHODOLOGY

Study site and sampling

Samples for physio-chemical properties of seawater and bottom sediment and biological quality were described in table below (see Fig. 1 for location):

Table 1: Sampling sites location and acronyms

Item General	No.	Location	Indicative Coordinates (Degrees, Minutes, Seconds)	Item Specific / Quantity
Currents by ADCP	SWC1	At 25 m depth	29°22'19.09"N, 34°57'48.05"E	Two 24 hour deployment
	SWC2	At 50 m depth	29°22'19.38"N, 34°57'43.88"E	
In situ seawater measurements	ISM	At 50 m depth	29°22'19.38"N, 34°57'43.88"E	CTD down to 50m, Transparency, Dissolved Oxygen and pH just below surface at a water depth of 50m

Seawater sampling and analysis	SSA1	Surface at 5 m	29°22'16.80"N, 34°57'51.55"E	Ammonia, Nitrate, Nitrite, Phosphate, Particulate Matter, Chlorophyll *a*, Plankton Biomass, Siltation Potential, Biofouling Potential, Total Hydrocarbons,
	SSA2	Surface and bottom at 25m depth	29°22'19.09"N, 34°57'48.05"E	
	SSA3	Surface at 50m depth	29°22'19.38"N, 34°57'43.88"E	
Bottom Habitat Survey	BHS1	At 10 m bottom	29°22'17.46"N, 34°57'50.94"E	Visual census: Standard Reef Check at two site
	BHS2	At 20m bottom	29°22'18.97"N, 34°57'48.62"E	
Interstitial Habitat	ISH1	At 10m bottom	29°22'17.46"N, 34°57'50.94"E	Color, Odor, Interstitial Living Assemblages, Grain Size, Calcium carbonate and Organic carbon Concentrations
	ISH2	At 20 m bottom	29°22'18.97"N, 34°57'48.62"E	

Figure 1: Sampling sites

PART TWO: ANALYTICAL PROCEDURES

Seawater Currents

Water currents were measured using an Acoustic Doppler Current Profiler (ADCP 1200 kHz or 600 kHz).

Seawater Measurements

Inorganic nutrients ammonium, nitrate, nitrite, phosphate and silicate were analyzed spectrophotometrically according to Grasshoff (1999). Chlorophyll a in water samples were measured fluorometrically using the method of Elizabith and Gary (1992) using acetone (95%) as the extraction agent. White-Secchi disk was used to measure transparency of the water. pH was measured in-situ using portable pH meter. Temperature, salinity, oxygen was recorded using a selfrecording Conductivity, Temperature and Pressure Recorder (SBE 19pluseV2 SEACAT PROFILER).

Zooplankton biomass

A simple plankton net (200 µm mesh; ARI, USA) was towed vertically from a boat at a speed of 1-2 sec/meter along the water column in each selected site. Zooplankton samples were kept on ice for about 2 hours until delivered to the Marine Science Station laboratories. Samples were filtered on pre-dried and pre-weight GF/C filters for 24-48 hrs at 60 °C, and re-weighed. Biomass (mg. dry wt. m-3) was calculated as follows:

Biomass (mg.l-1) = [zooplankton dry weight (gm) /volume of water filtrate (m3)] × 1000, Where the volume of water filtrate = velocity (m. sec-1) × area of net (m2) × time of collection (sec).

Siltation and Bio-fouling Potential

Siltation and Bio-fouling Potential was measured according to Abushaban et al, 2020, and Abushaban et al, 2021.

Bottom Habitat Survey

Standard Reef Check Methodology; Tropical Program, Red Sea will be followed. https://www.reefcheck.org/tropical-program/tropical-monitoring-instruction/

Interstitial Living Assemblage

Bottom sediments were collected from seabed at the different selected locations. In laboratory, weight of sediment was measured to nearest gram and was preserved in 80% alcohol and Rose Bengal for further study and identification. Encountered taxons were identified to lowest possible taxon level. Counts of major categories were made using binocular Olympus microscope and hand counter in a sample of 100 g dry weight of sediment.

Sediment physio-chemical properties

The following parameters were analyzed in these samples and include particle size analysis (PSA) analyses using a set of calibrated analytical sieves (US standard sieves), total organic matter (TOM) by determined the ignition loss (IL) value for sediment (combustion at 500°C). The total organic carbon (TOC) was measured by titration with ferrous ammonium sulphate solution (Gaudette et al., 1974).

PART THREE: RESULTS

I. Seawater Currents

Average daily current speed profile along the 25m water column depth is varying slightly between 3-4 cm/s from the surface down to 22m depth with direction rotating from 80 to almost 0 degrees. Current speed suddenly increases at the end of the water column at 25 m to reach 10 cm/s at the bottom, while its direction flips occasionally to 240 degrees at 22m depth to reach 300 degrees then back to 100 degrees at the bottom.

While along the 50m water column, the behavior of the average daily seawater currents speed shows approximate gradual increase from 2cm/s to 4cm/s with changing direction clockwise starting from the surface down to 45 m depth. At the bottom of the 50m water column abrupt increase of current speed and flipping of currents occurs.

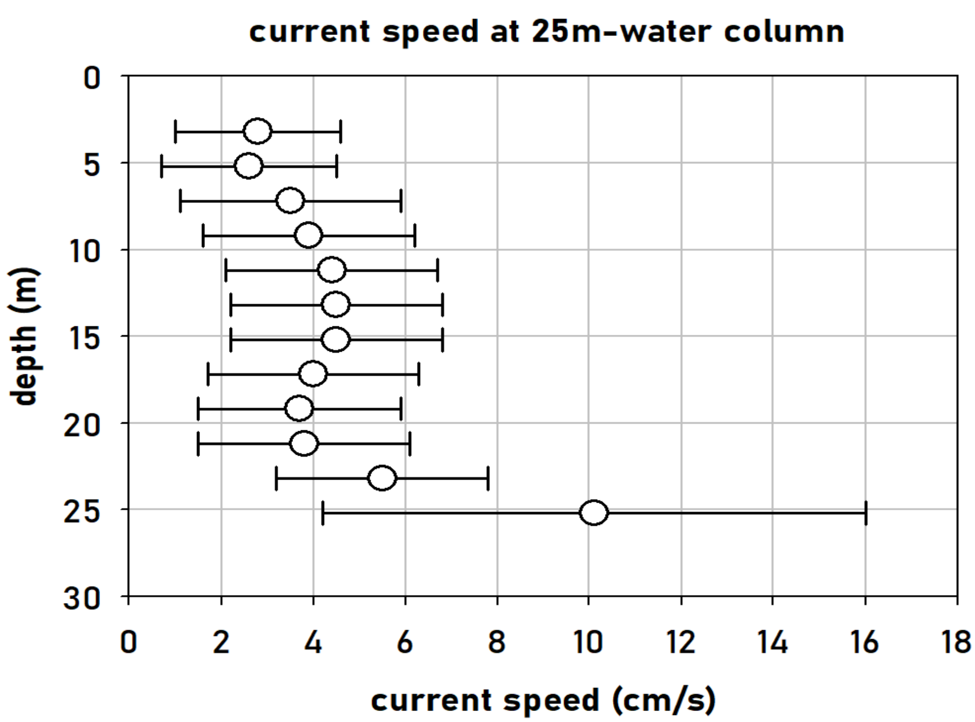

Figure 2: Average seawater current speed at SWC1, 25 m depth.

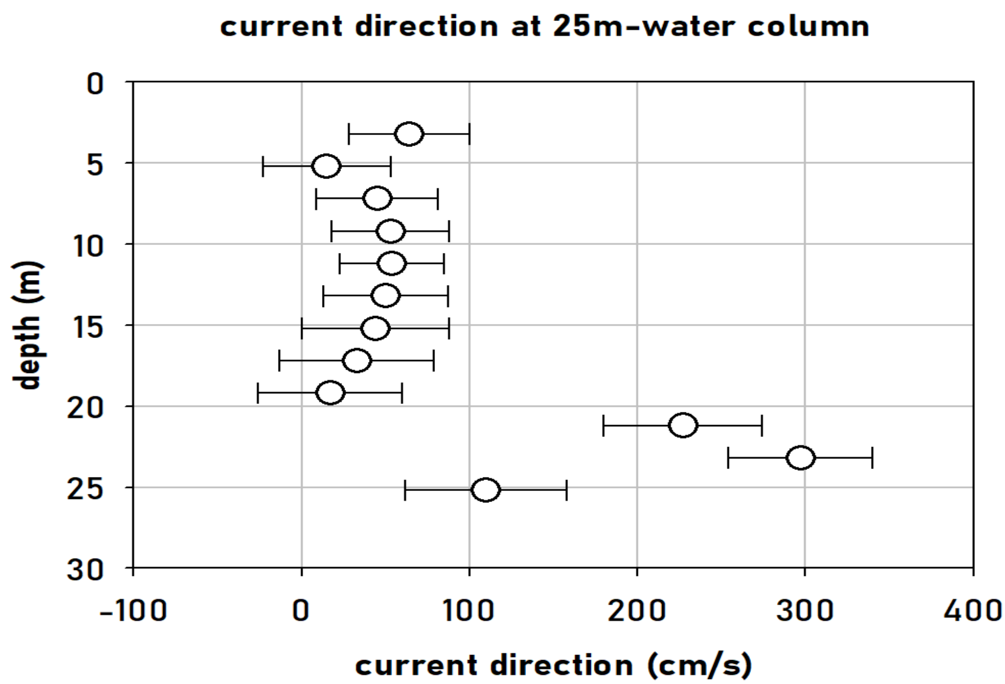

Figure 3: Average seawater current directions at SWC1, 25 m depth.

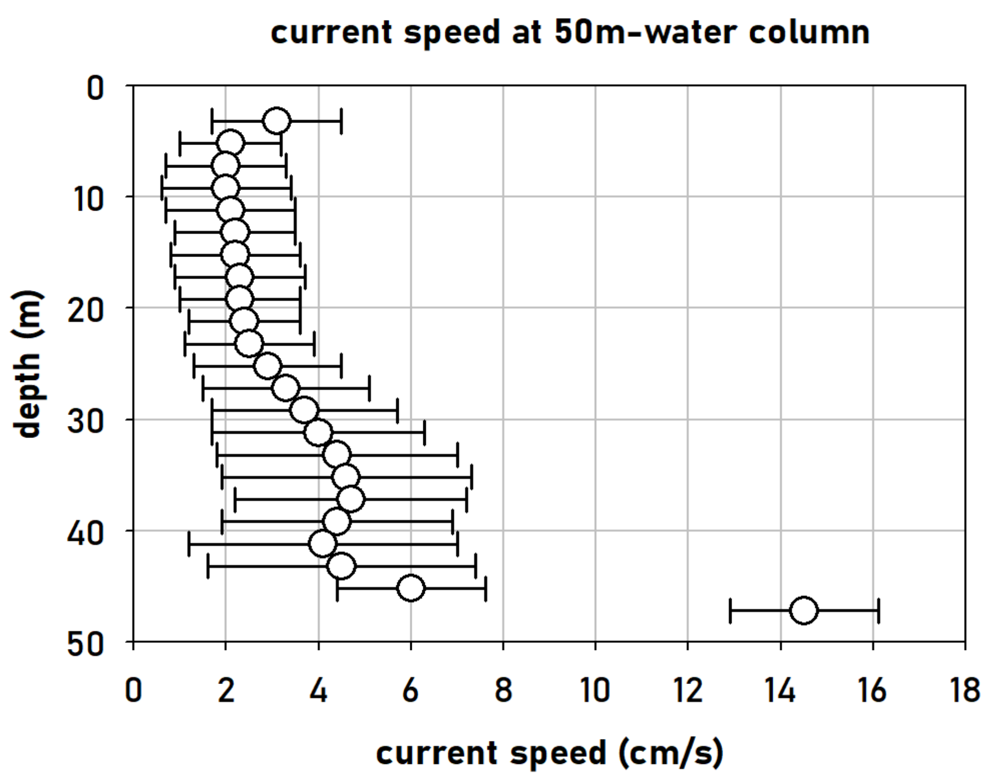

Figure 4: Average seawater current speed at SWC2, 50 m depth.

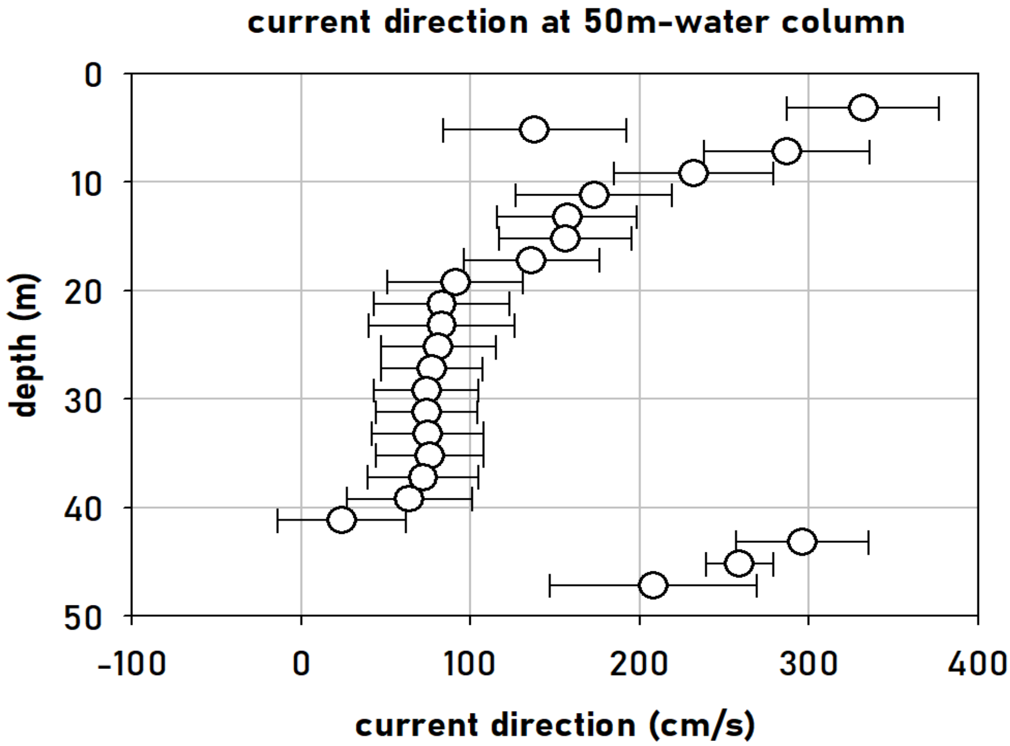

Figure 5: Average seawater current directions at SWC2, 50m depth.

II. IN SITU SEAWATER MEASUREMENTS

- **Seawater temperature and salinity**

The maximum value of seawater temperature 25.20 °C was recorded in surface at site (SSA2), which was higher of about 0.22 °C than the average value at 25 m depth in the same site (Fig. 6). In contrast, the minimum value of seawater temperature of 24.75 °C was recorded in 50 m depth at site (SSA3), which was lower of about 0.23 °C than the average value within 25 m depth at SSA2 site.

The maximum value of seawater salinity 40.58 PSU was recorded in the surface all sites (SSA2 and SSA3), which was higher of about 0.03 and 0.08 PSU than the average value at the surface of SSA2 and SSA3 site respectively (Fig. 7).

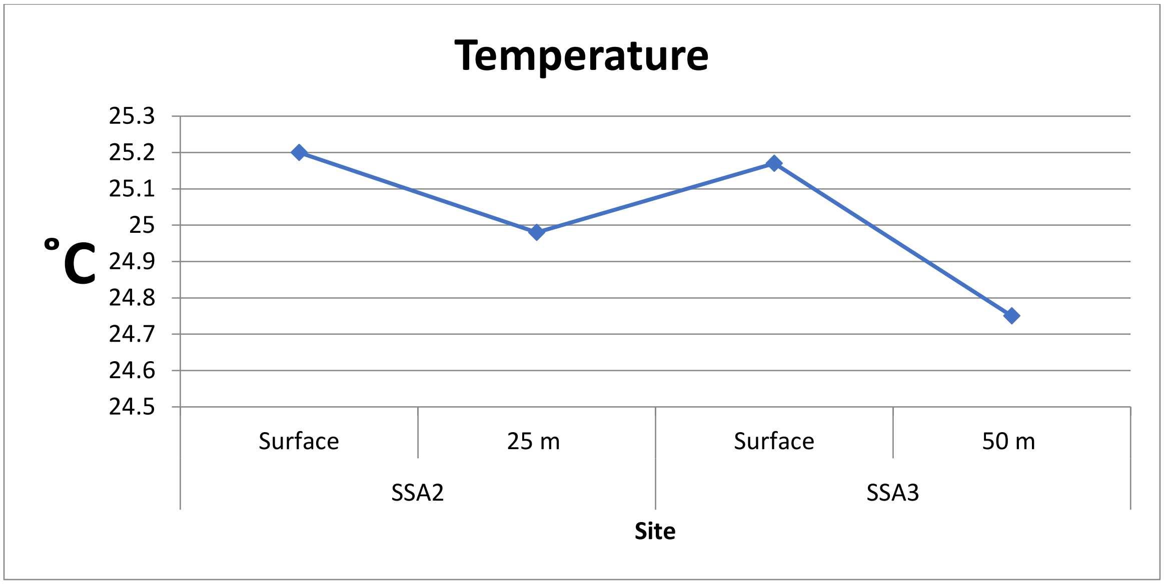

Figure 6: Average seawater temperature (°C) measurements at different depth.

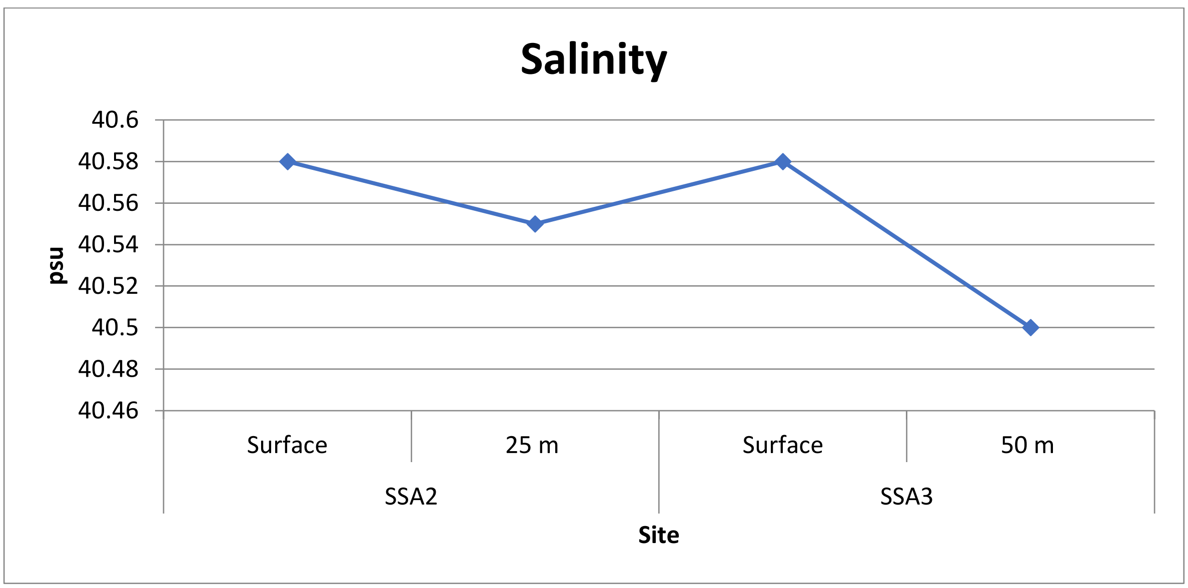

Figure 7: Average seawater salinity (psu) measurements at different depth.

III. SEAWATER SAMPLING AND ANALYSIS

- **Inorganic nitrogen nutrients**

There is no clear difference was noted between ammonium concentrations in surface and bottom water at SSA1. Whereas, some difference were reported at SSA2 and SSA3 within 25 m and 50 m deep, respectively, compared to the surface at the same sites (Fig. 8). However, the concentrations were generally acceptable compared with other sites in the Gulf and with the Jordanian and International standards. As for nitrate and nitrite, there are no major differences between concentrations in the selected sites (Fig. 9 and Fig. 10).

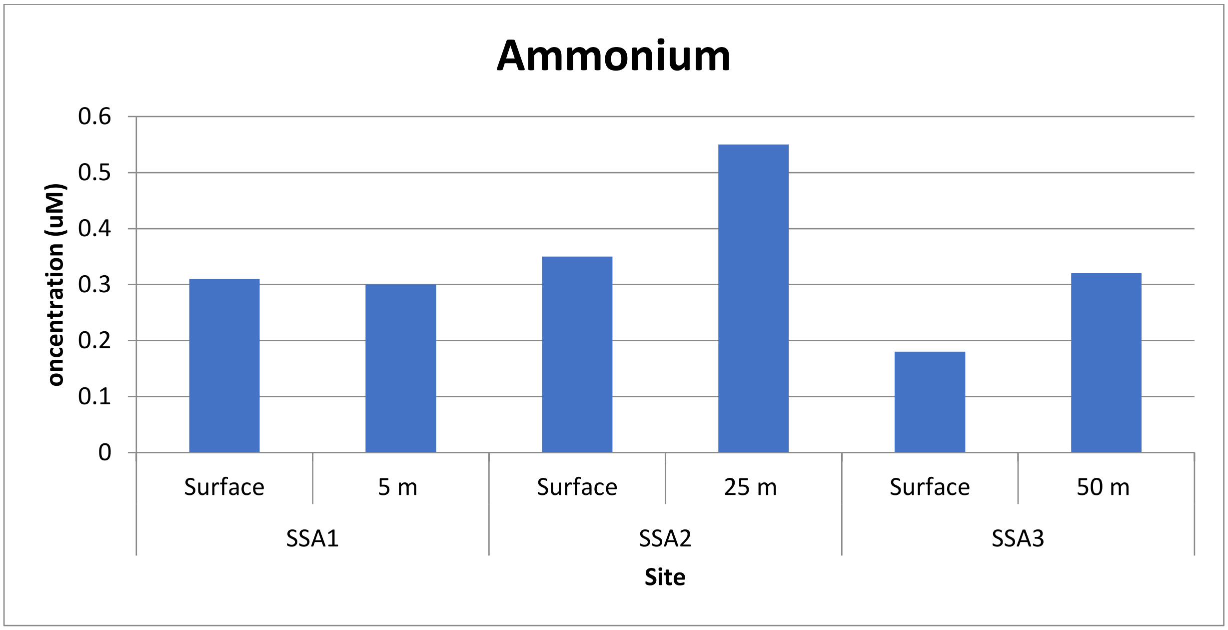

Figure 8: Average ammonium concentrations (uM) at selected sites.

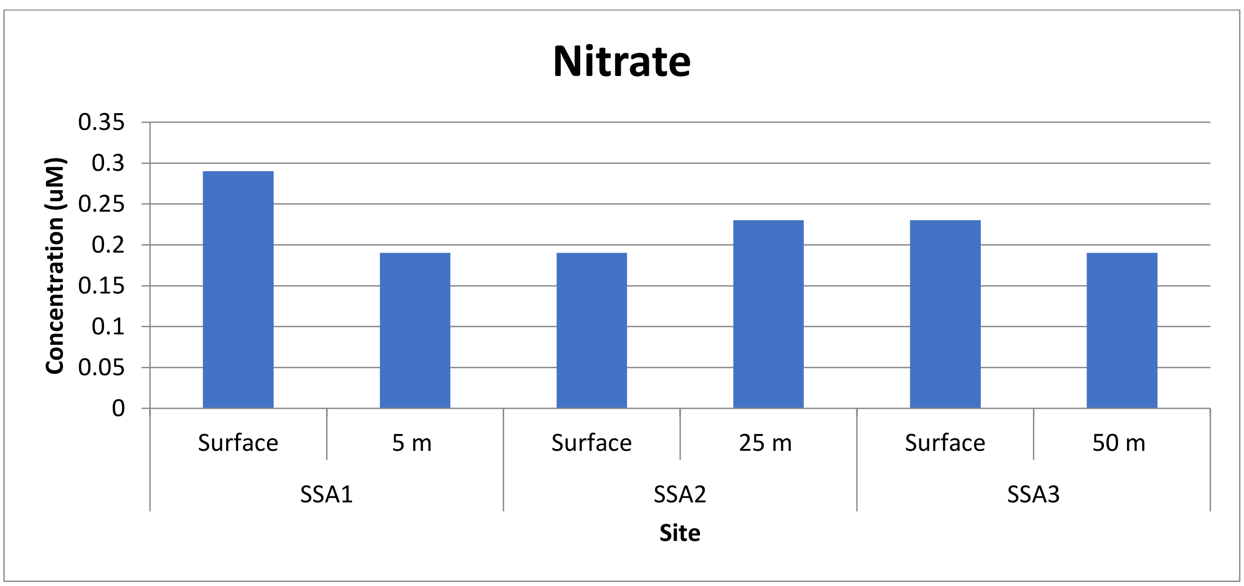

Figure 9: Average nitrate concentrations (uM) at selected sites.

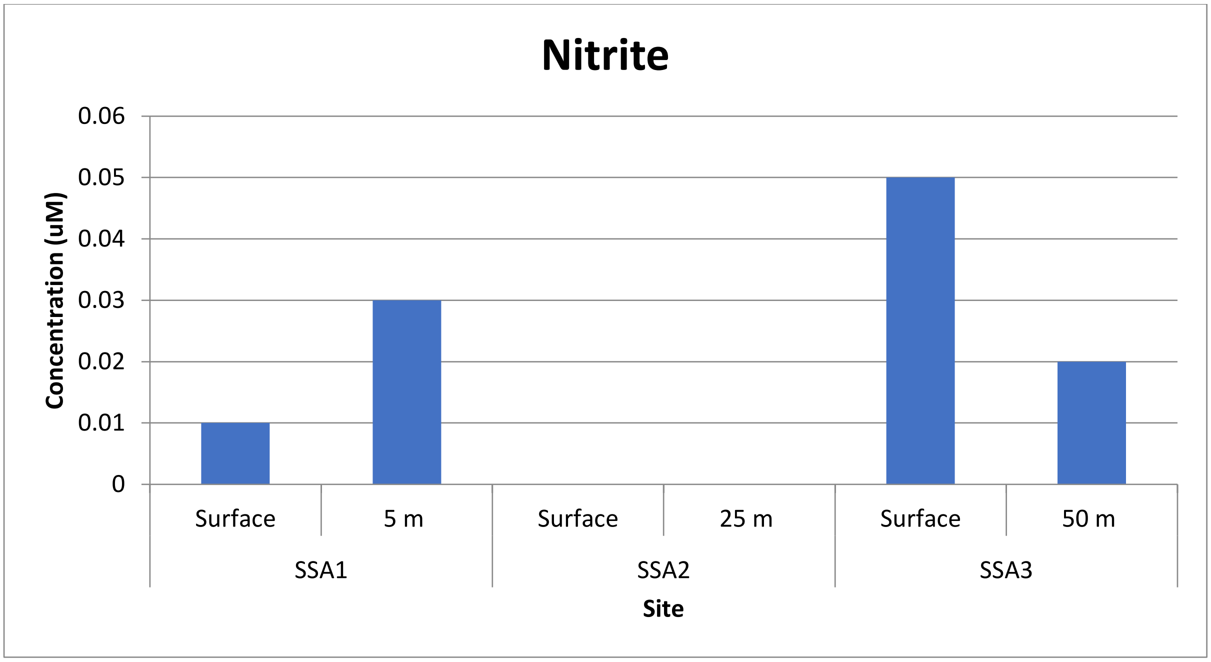

Figure 10: Average nitrite concentrations (uM) at selected sites

- **Phosphate**

Typical of the oligotrophic waters, phosphate concentrations were fluctuated around 0.065 µM (Fig. 11). Records of phosphate at the selected sites and reference sites in the Gulf of Aqaba showed always low values (less than 0.10 µM).

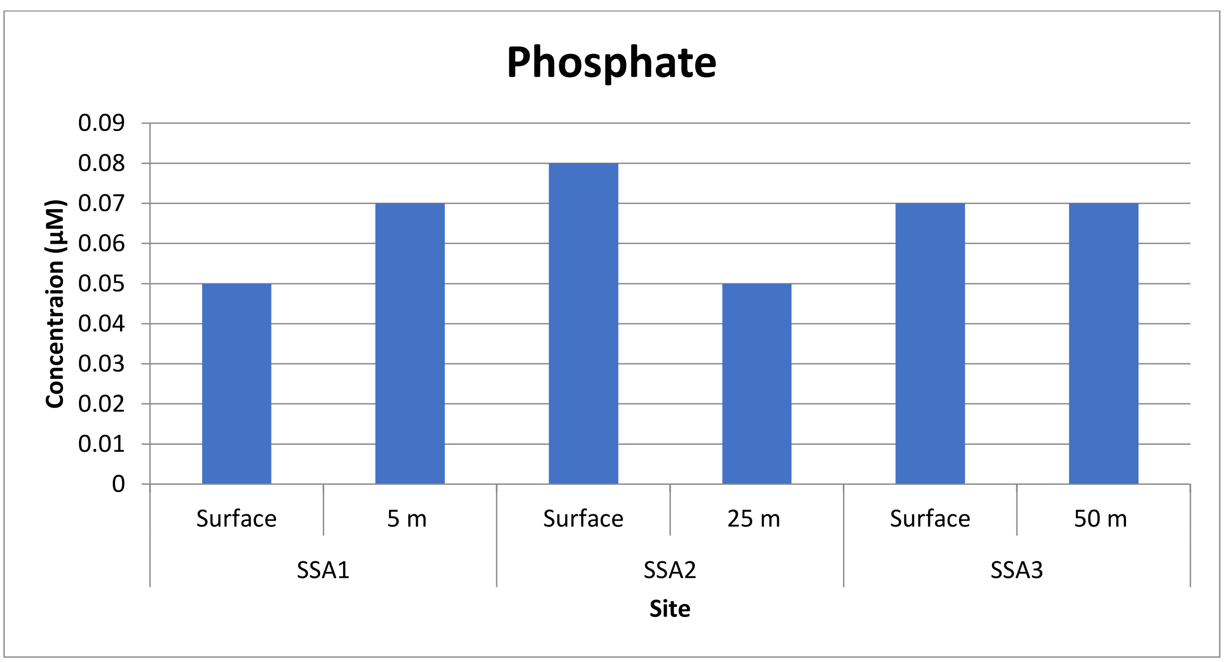

Figure 11: Phosphate concentrations (uM) at selected sites.

- **Silicate**

Silicate concentrations (Fig. 12) showed a shift from 1.31 µM to 1.65 µM. There are no major differences between concentrations in the selected sites and the reference sites in the Gulf of Aqaba waters.

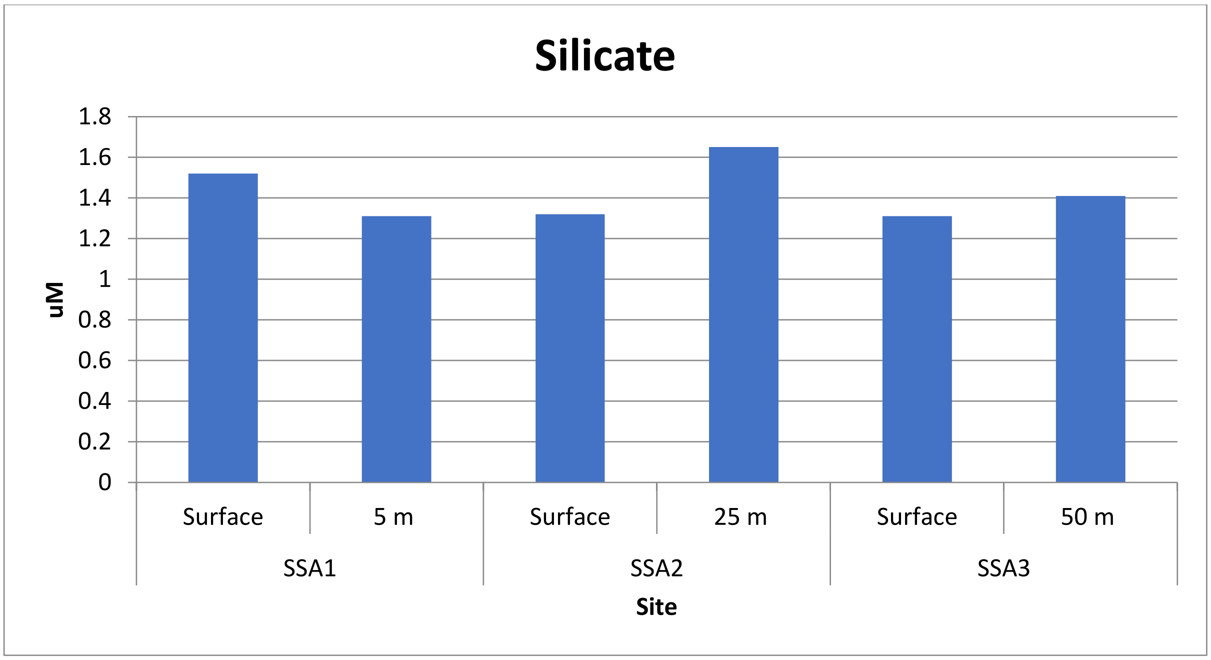

Figure 12: Silicate concentration (uM) at selected sites.

- **Chlorophyll a**

Records of chlorophyll a were ranged from 0.17 µg/l in to 0.22 µg/l in with no major difference between the selected sites and the reference site at the Gulf of Aqba waters (Fig. 13). Chlorophyll a values which considered as the main indication of eutrophication were below 1 µg/l; the limiting concentration for Eutrophication in oilgotrophic water as reported by several researchers.

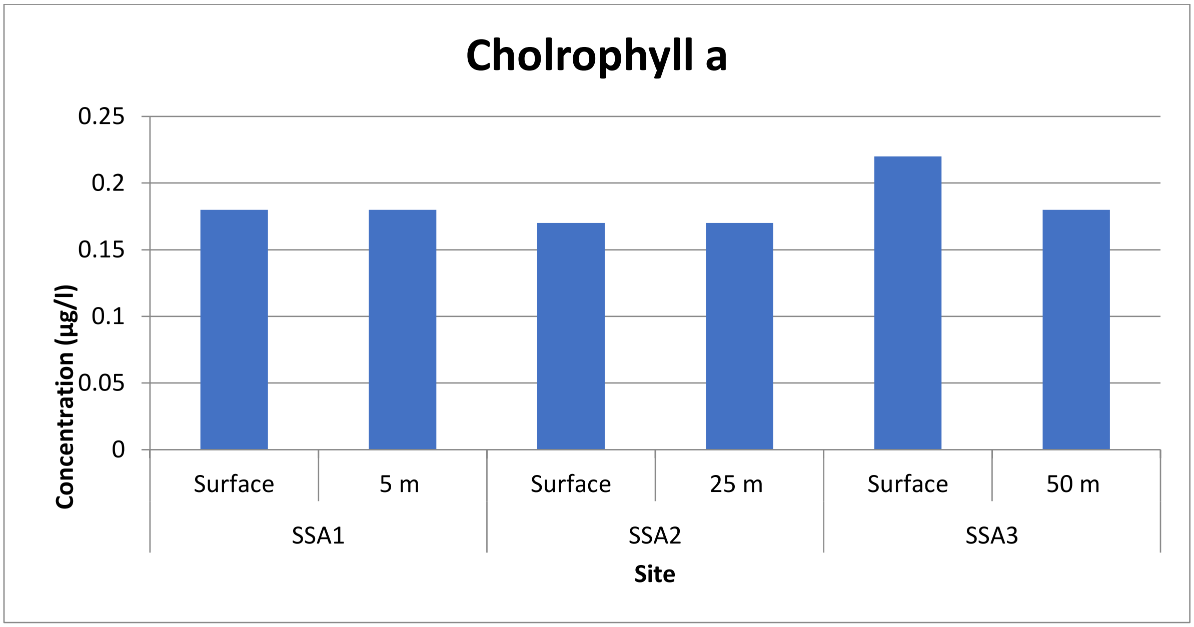

Figure 13: Average Cholrophyll a concentrations (µg/l) at selected sites.

- **pH**

Records of pH, in all selected sites, were fluctuated around 8.2 (Fig. 14) showing no difference between the surface and bottom at each site and between selected sites. The very minor variations the pH can be attributed to the oligotrophic properties of the water of the Gulf which are always saturated with calcium carbonate acts as a buffer and resists any change in the pH.

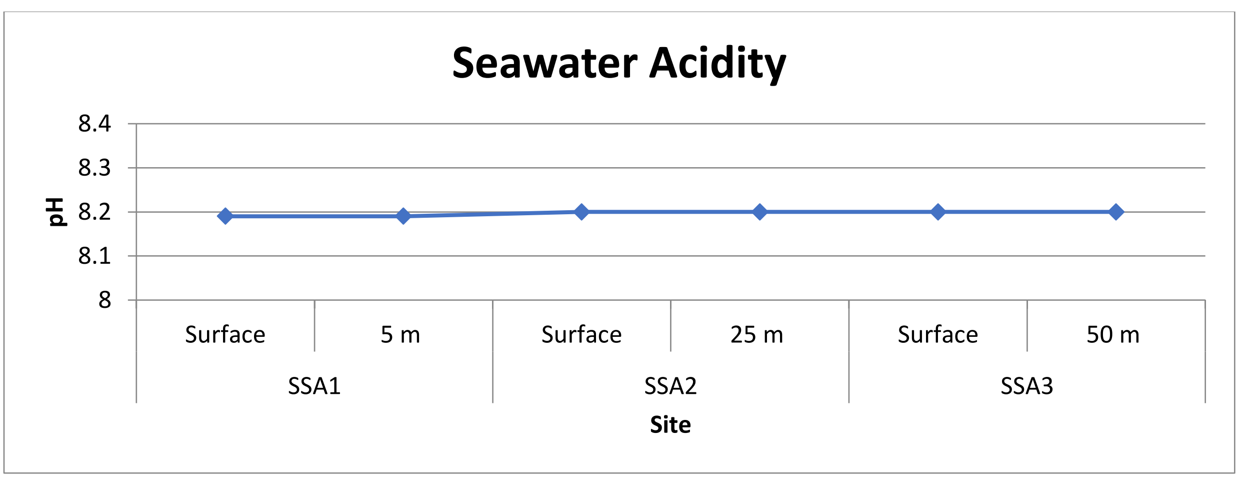

Figure 14: Average seawater acidity measurements at selected sites.

- **Dissolved Oxygen**

The dissolved oxygen concentration at all sites showed a regular pattern inversely proportional to that of temperature with a range of 6.53 to 6.6 mgl-1 (Fig. 15), indicating the effect of temperature. The solubility of oxygen in seawater usually increases as temperature decreases.

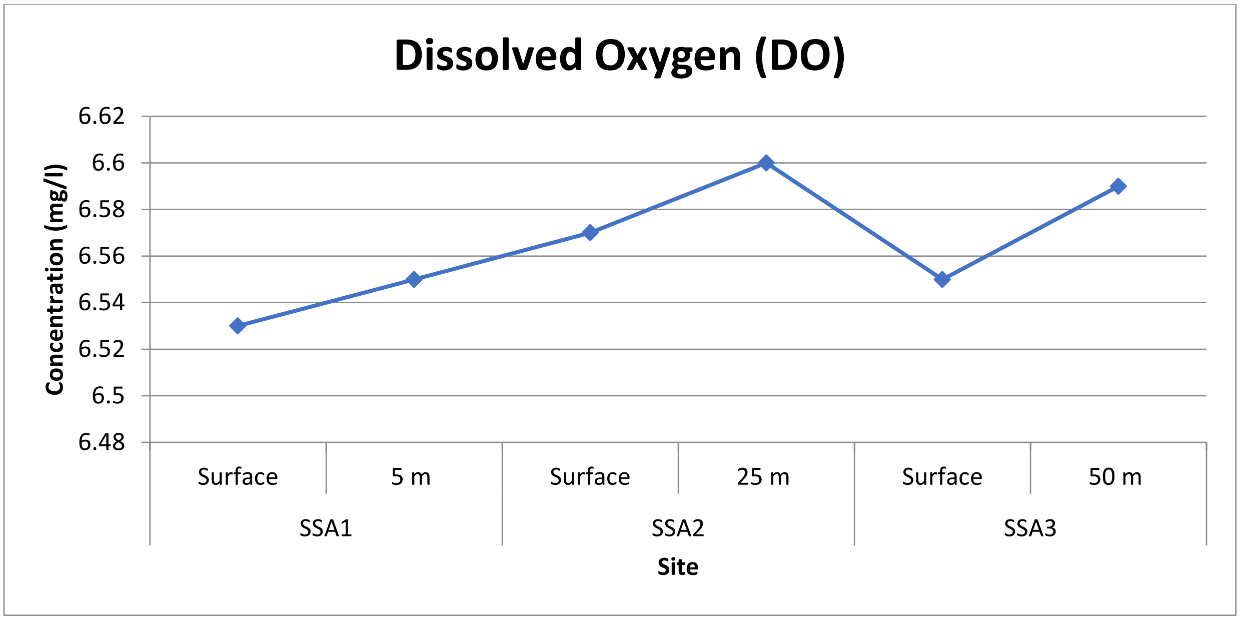

Figure 15: Average dissolved oxygen concentrations (mg/l) at selected sites.

- **Total Suspended Solids (TSS)**

TSS records at the selected sites (Fig. 16) ranged from 2.6 mg/l to 8.6 mg/l. There were no differences between surface and bottom at all sites.

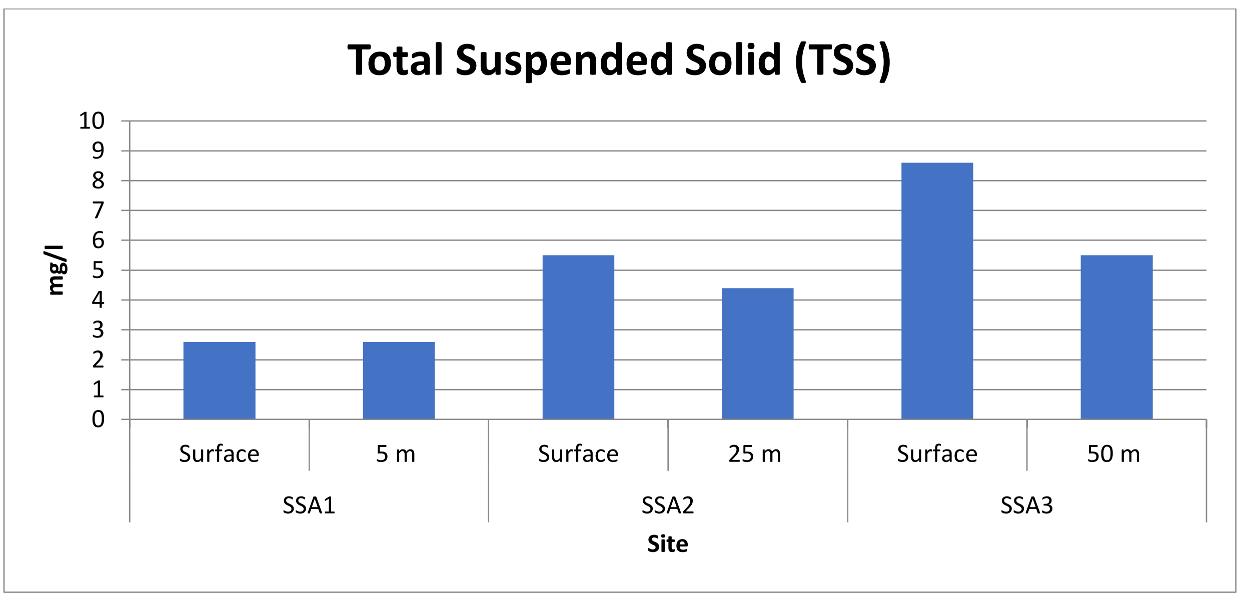

Figure 16: Average total suspended solid concentration (mg/l) at selected sites.

- **Total Hydrocarbons**

Hydrocarbon concentrations were always even 0.001 mg/l for all sites. These low concentrations indicate that there is no oil pollution at all sites (Fig. 17).

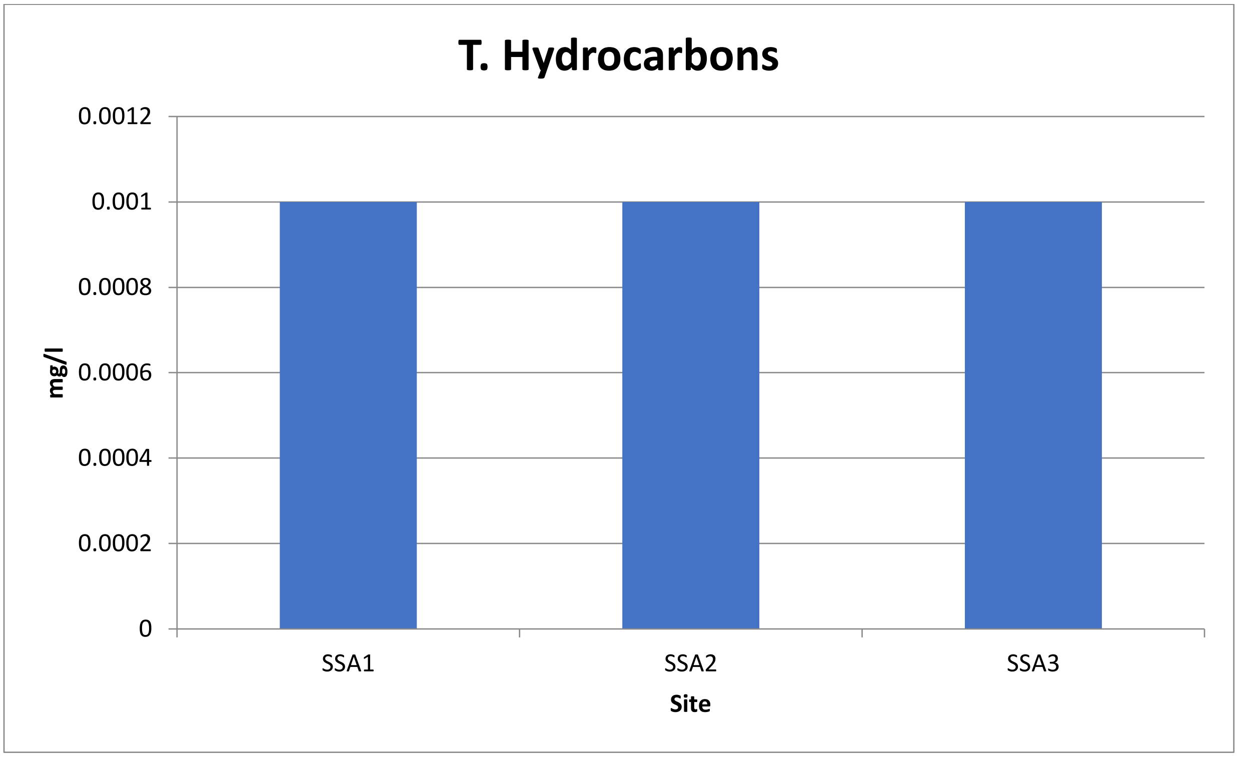

Figure 17: Average total hydrocarbons measurements (mg/l) at selected sites.

- **Zooplankton biomass**

The measurements of biomass zooplankton is important to evaluate the distribution of the zooplankton biomass abundance through water column; this will give indication indirectly to relative status of eutrophication at the different selected sites. The results of the zooplankton biomass in the water column (25 m to surface) for sampling stations (SSA2 and SSA3) , does not show any remakable differences (Fig. 18). However, slightly lower biomass was found in the water column (50 mto 25m) at site SSA3 with mean concentration of 0.22 mg/l .

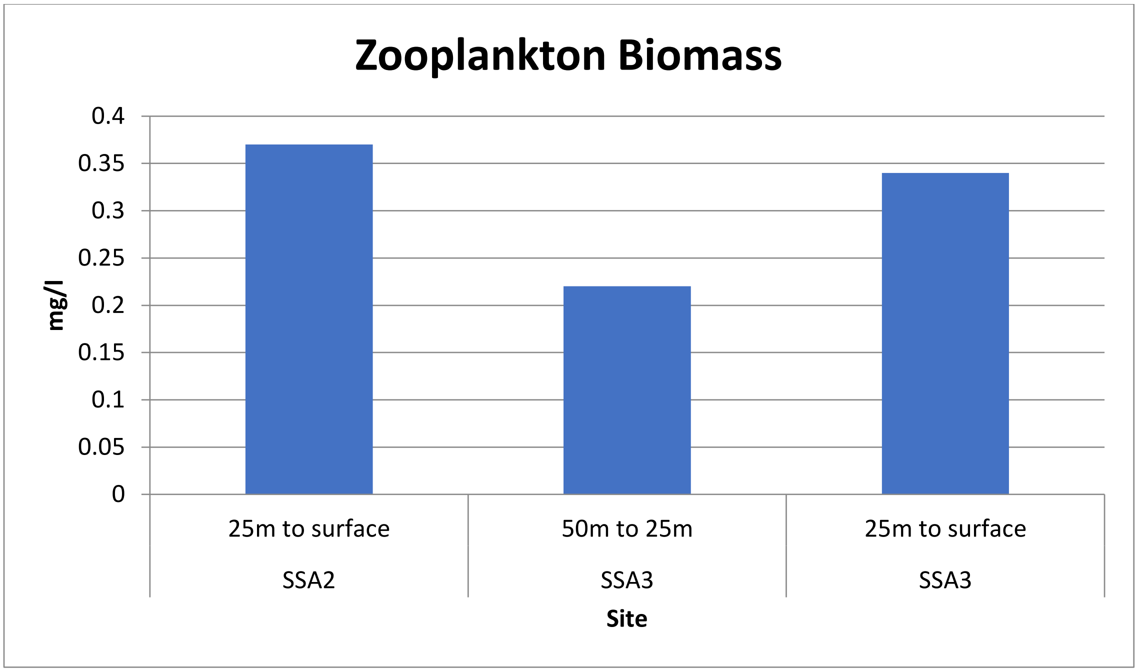

Figure 18: Average zooplankton biomass (mg/l) at selected sites.

- **Siltation and Bio-fouling Potential**

Table 2: Particulate fouling potential at selected sites.

Site	Depth	SDI5	SDI10	SDI15	MFI-0.45
SSA1	Surface	7.4954	5.06518	3.86204	2.6596
SSA2	Surface	6.61439	4.62363	3.58635	1.92514
SSA3	Surface	6.45572	4.54106	3.53384	1.98551
Site	**Depth**	**SDI5**	**SDI10**	**SDI15**	**MFI-0.45**
SSA2	25 m	11.9412	7.01437	5.01273	8.002
SSA3	50 m	7.78879	5.2071	3.94922	2.93127

SDI= silt density index, MFI= modified fouling index

Table 3: Bio-fouling potential at selected sites.

Site	Depth	[ATP] ng-ATP/L
SSA1	Surface	142989703.9
SSA2	Surface	144957774.5
SSA3	Surface	147241627.4
SSA2	25 m	112989075.1
SSA3	50 m	52862028.68

IV. Bottom Habitat Survey

- **Benthic Habitat at 10m Bottom (BHS1)**

Study of the benthic habitat in the BHS1 (Transct A and Trabsect B, 10 m depth) have shown that the bottom habitat in this area is mainly sand with a cover percentage that exceeds 49% and 43%, respectively (Fig.19 and Fig. 22). However, the mean percent of living cover was about 36 % (Transect A, Fig. 20) and 49 % (Transect B, Fig. 23).

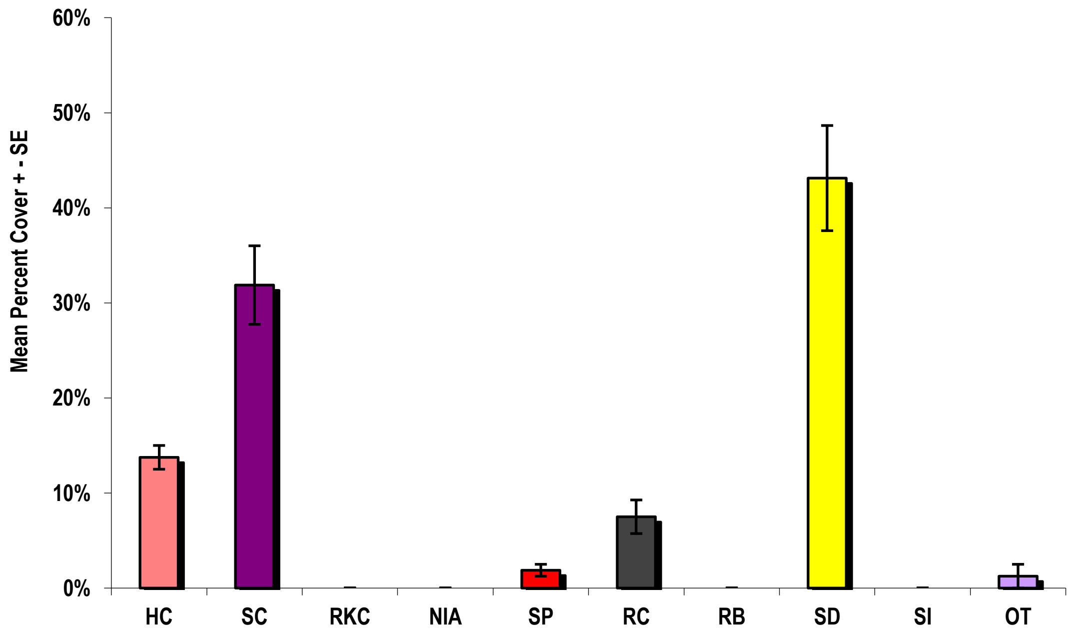

Figure 19: Mean percent cover for transect A at BHS1, 10 m depth.

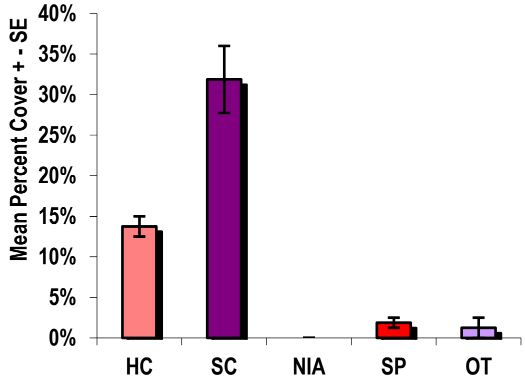

Figure 20: mean percent living cover at BHS1, transect A

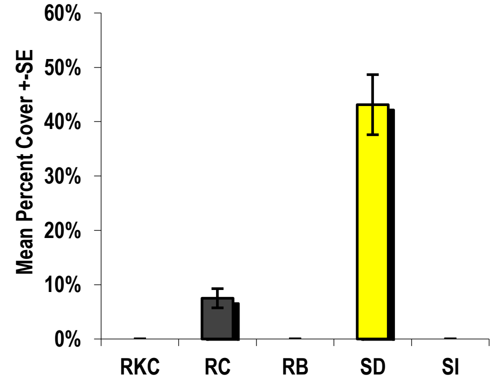

Figure 21: mean percent non-living cover at BHS1, transect A.

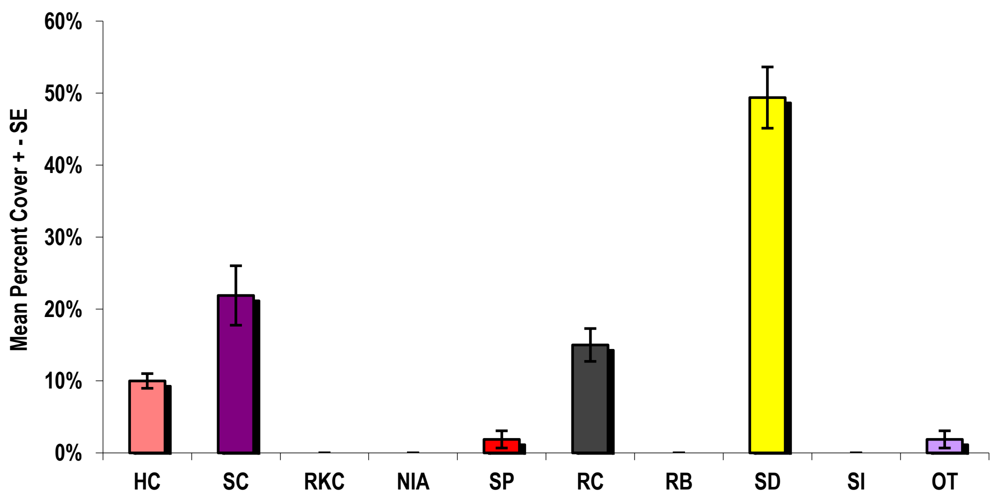

Figure 22: Mean percent cover for transect B at BHS1, 10 m depth

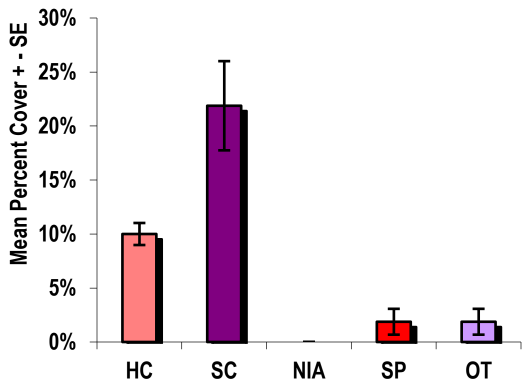

Figure 23:mean percent living cover at BHS1, transect B.

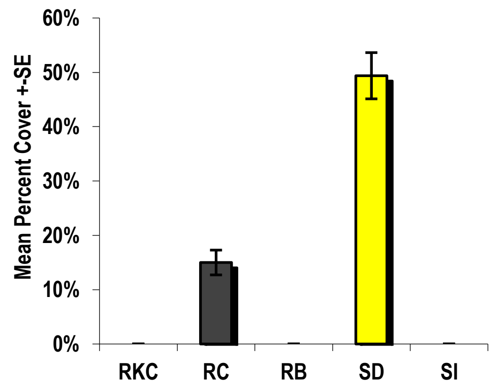

Figure 24:mean percent non-living cover at BHS1, transect B.

- **Benthic Habitat at 20m Bottom (BHS2)**

Study of the benthic habitat in the BHS2 (20 m depth) have shown that the bottom habitat in this area is mainly hard coral and rock with an even cover percentage of about 34% (transect A and B, respectively) (Fig. 25 and Fig. Fig. 28). However, the mean percent of living cover was about 63 % (Transect A, Fig. 26) and 55 % (Transect B, Fig. 29).

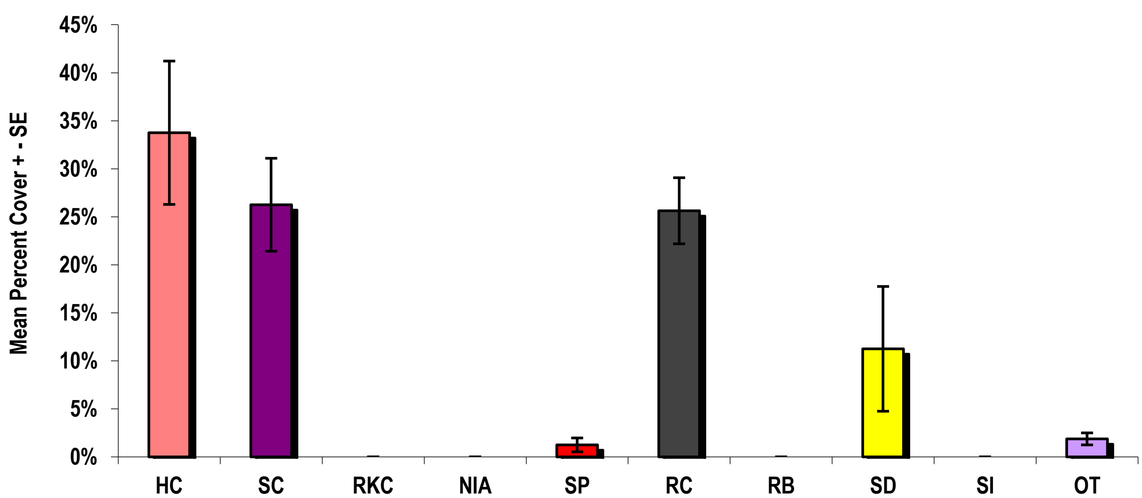

Figure 25: Mean percent cover for transect A at BHS2, 20 m depth

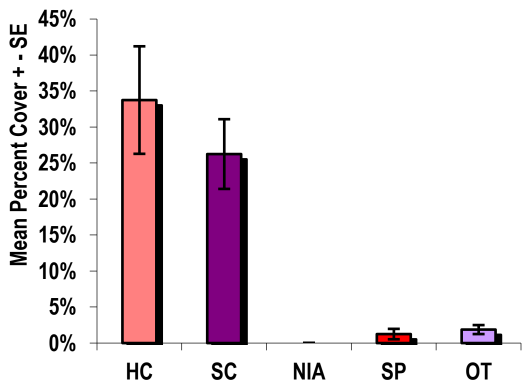

Figure 26:mean percent living cover at BHS2, transect A.

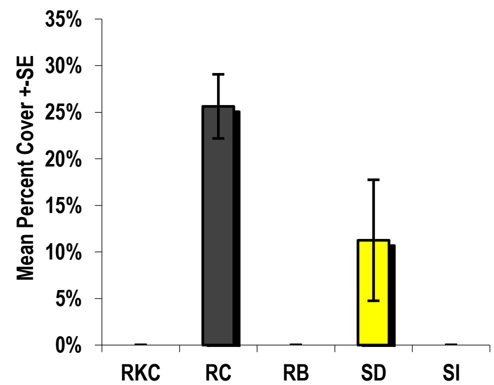

Figure 27::mean percent living cover at BHS2, transect A.

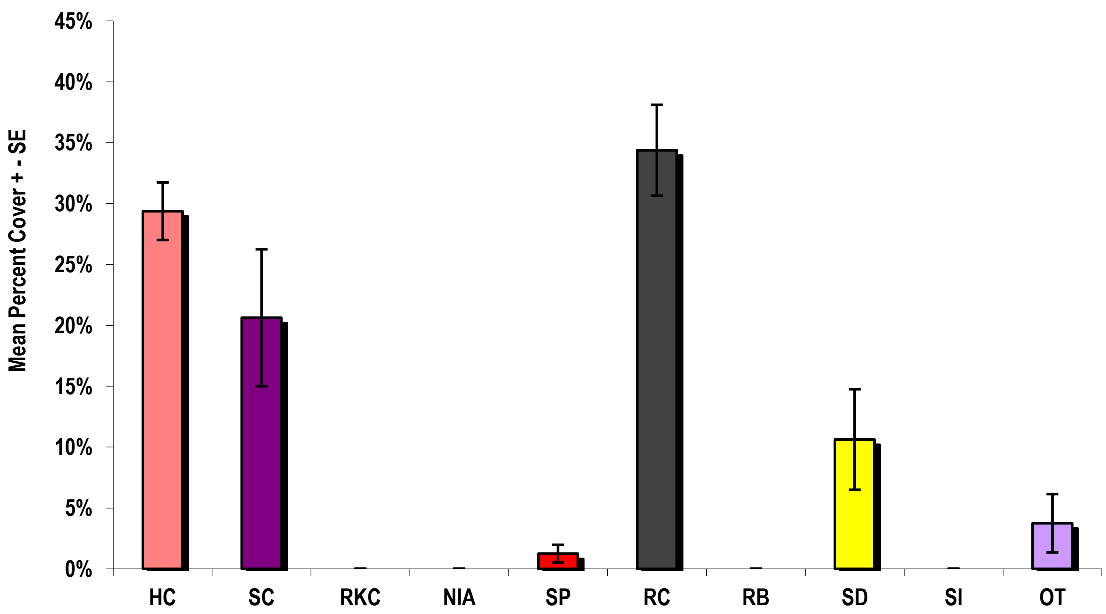

Figure 28:Mean percent cover for transect B at BHS2, 20 m depth

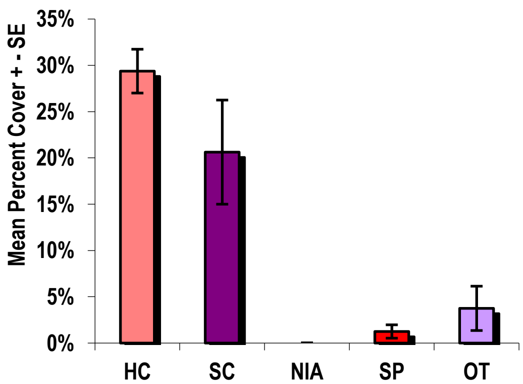

Figure 29:mean percent living cover at BHS2, transect B.

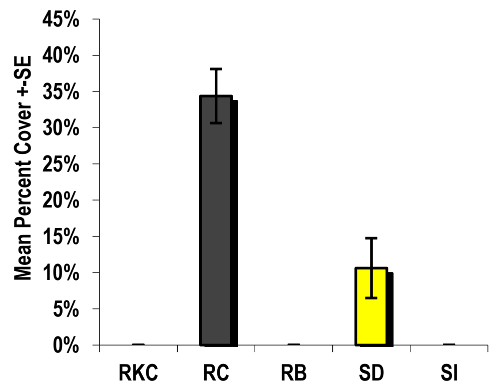

Figure 30:mean percent living cover at BHS2, transect B.

- **Fish community structure**

A total of 47637 fish individuals were counted in the present survey at selected sites; BHS1 (10 m bottom) and BHS2 (20 m bottom), representing 47 shallow-water species at each site belonging to 14 fish families. In term of relative abundance per families at site BHS1, the results revealed that the family Serranidae constitute (RA=45.83%) of the total fish population. Followed by Caesionidae (RA=22.48%), Labridae and Pomacanthidae (RA=16.72%, RA=7.36%, respectively). These 4 fish family represent (RA=92.39%) of the total fish population at BHS1. Whereas, at site BHS2, the family Caesionidae constitute (RA=38.08%) of the total fish population. Followed by Serranidae (RA=28.34%), Pomacanthidae (RA=14.35%), and Labridae (RA=13.87%). These 4 fish family represent (RA=94.64%) of the total fish population at BHS1 (Table 4).

Table 4: Fish family relative abundance per (75 m2) at 10 m depth (BHS1), and 20 m depth (BHS2).

Family	10m depth Relative Abundance %	20 m depth Relative Abundance %
Holocentridae	4.08	2.89
Serranidae	45.83	28.34
Pseudochromidae	0.31	0.27
Caesionidae	22.48	38.08
Mullidae	0.43	0.29
Lethrinidae	0.15	0.08
Chaetodontidae	0.25	0.20

Pempheridae	0.75	0.41
Pomacanthidae	7.36	14.35
Labridae	16.72	13.87
Scaridae	0.23	0.17
Acanthuridae	0.52	0.51
Siganidae	0.66	0.41
Tetraodontidae	0.24	0.15

V. INTERSTITIAL HABITAT

- **Interstitial Living Assemblage**

Present investigation demonstrated that the encountered taxon groups are generally four. Namely, bivalves, snails, polychaets and foraminifera. The four taxa of meiofauna were recorded in the selected sites (BHS1; 10 m depth and BHS2; 20 m depth). Abundance of Foraminifera illustrated change of increase at 20 m compared with values observed at 10 m depth. Moreover, Bivalves showed slightly increased in sediment samples at 20 m depth. On the other hand, abundance of Polychaeta and Snails illustrated slight change of decrease at 20 m with values observed at 10 m depth (Fig,31).

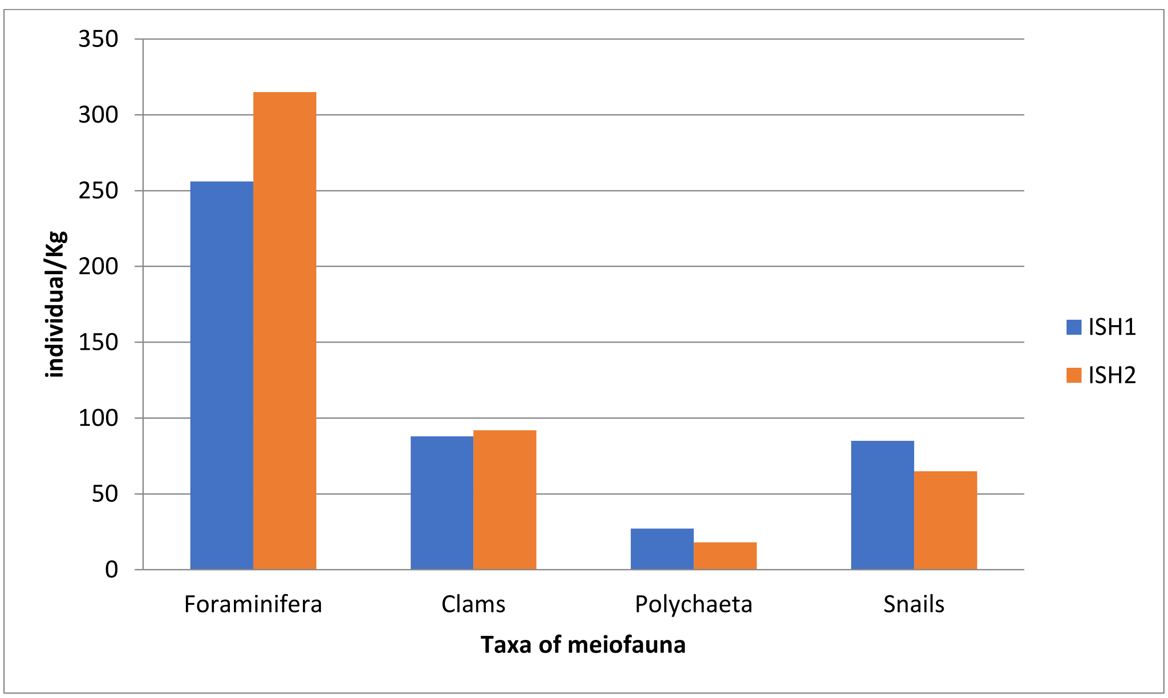

Figure 31: Interstitial living assemblages at 10 depth (ISH1), and 20 m depth (ISH2).

- **Sediment physical properties (particle size analysis, PSA)**

All sediments from the selected sites (BHS1 and BHS2) had almost similar textural composition. The most dominant fractions were the sand (250-500µm) which comprises more than 32% of all sizes. The mud fraction (<63µm) in the two sites sediments (average 1.11 %) which is lower than that from offshore shallow station (4.07 %).

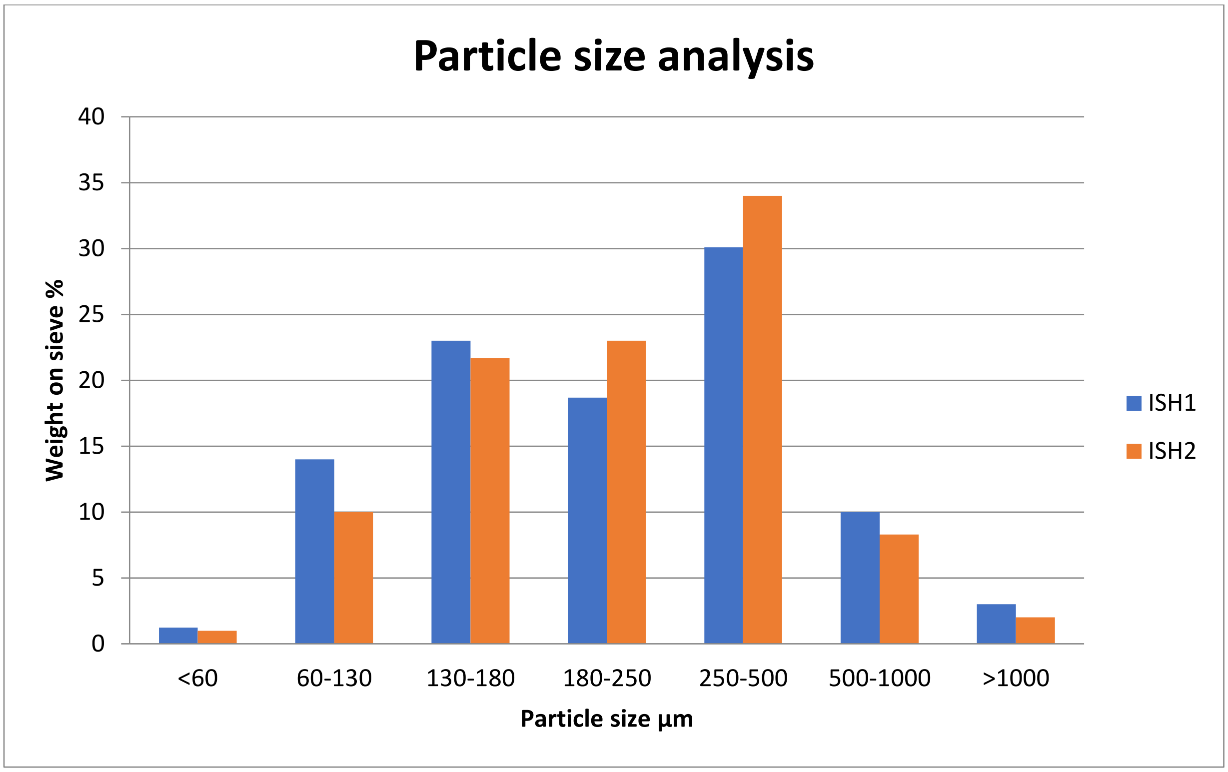

Figure 32: Bottom sediments particle size analysis (PSA) at 10 m depth (ISH1), and 20 m depth (ISH2).

- **Seawater Currents**

Table 5: Average seawater current speed and direction at 25 m water column.

Depth	Avg. Speed (cm/s)	Std Dev Speed (cm/s)	Avg. Direction (°)	Std Dev Direction (°)
3.19	2.8	1.8	64	36
5.19	2.6	1.9	15	38
7.19	3.5	2.4	45	36
9.19	3.9	2.3	53	35
11.19	4.4	2.3	54	31
13.19	4.5	2.3	50	37
15.19	4.5	2.3	44	44
17.19	4.0	2.3	33	46
19.19	3.7	2.2	17	43
21.19	3.8	2.3	227	47
23.19	5.5	2.3	297	43
25.19	10.1	5.9	110	48

Table 6: Average seawater current speed and direction at 50 m water column.

Depth	Avg. Speed (cm/s)	Std Dev Speed (cm/s)	Avg. Direction (°)	Std DevDirection (°)
3.19	3.1	1.4	332	45
5.19	2.1	1.1	138	54
7.19	2.0	1.3	287	49
9.19	2.0	1.4	232	47
11.19	2.1	1.4	173	46
13.19	2.2	1.3	157	41
15.19	2.2	1.4	156	39
17.19	2.3	1.4	136	40
19.19	2.3	1.3	91	40
21.19	2.4	1.2	83	40
23.19	2.5	1.4	83	43
25.19	2.9	1.6	81	34
27.19	3.3	1.8	77	30
29.19	3.7	2.0	74	31
31.19	4.0	2.3	74	30
33.19	4.4	2.6	75	33
35.19	4.6	2.7	76	32
37.19	4.7	2.5	72	33
39.19	4.4	2.5	64	37
41.19	4.1	2.9	24	38

43.19	4.5	2.9	296	39
45.19	6.0	1.6	259	20
47.19	14.5	1.6	208	61

- **IN SITU SEAWATER MEASUREMENTS**

Table 7: Average Seawater temperature and salinity at selected sites.

Parameters	**SSA1**		**SSA2**		**SSA3**	
/Depth (m)	Surface	5	Surface	25	Surface	50
Temperature (SST), °C	**	**	25.20	24.98	25.17	24.75
Salinity, psu	**	**	40.58	40.55	40.58	40.50
Transparency (Tr), m	**	**	**	**	28	**

For CTD Profile See Annex 1, 2

Table 8: Seawater sampling and analysis at selected sites.

Parameters	**SSA1**		**SSA2**		**SSA3**	
/Depth (m)	Surface	5	Surface	25	Surface	50
Ammonium (NH_4^+),uM	0.31	0.30	0.35	0.55	0.18	0.32
Nitrate (NO_3^-), uM	0.29	0.19	0.19	0.23	0.23	0.19
Nitrite (NO_2^-), uM	0.01	0.03	0.00	0.00	0.05	0.02
Phosphate (PO_4^{3-}), uM	0.05	0.07	0.08	0.05	0.07	0.07
Silicate (SiO_2), uM	1.52	1.31	1.32	1.65	1.31	1.41
Cholrophyll*a* (Chl*a*), µg/l	0.18	0.18	0.17	0.17	0.22	0.18
T. Hydrocarbons (HC), mg/l	0.001	N.D.	0.001	N.D.	0.001	N.D.
Total Suspended Solid (TSS), mg/l	2.60	2.60	5.50	4.40	8.60	5.50
Seawater Acidity, pH	8.19	8.19	8.20	8.20	8.20	8.20
Dissolved Oxygen (DO), mg/l	6.53	6.55	6.57	6.60	6.55	6.59

- **Zooplankton biomass**

Table 9: Average zooplankton biomass in water column at selected sites.

Site	Depth (m)	Biomass (mg/l)
SSA2	25m to surface	0.37
SSA3	50m to 25m	0.22
SSA3	25m to surface	0.34

- **Bottom Habitat Survey**

Table 10: Benthic Habitat at 10m Bottom (BHS1), transect A.

Transect (A)	Mean % Cover	SE
Hard Coral	10%	0.01
Soft Coral	22%	0.04
Sponge	2%	0.01
Rock	15%	0.02
Sand	49%	0.04
Other	2%	0.01

Table 11: Benthic Habitat at 10m Bottom (BHS1), transect B.

Transect (B)	Mean % Cover	SE
Hard Coral	14%	0.01
Soft Coral	32%	0.04
Sponge	2%	0.006
Rock	8%	0.017
Sand	43%	0.055
Other	1%	0.012

Table 12: Benthic Habitat at 20m Bottom (BHS2), transect A.

Transect (A)	Mean % Cover	SE
Hard Coral	34%	0.07

Soft Coral	26%	0.05
Sponge	1%	0.01
Rock	26%	0.03
Sand	11%	0.06
Other	2%	0.01

Table 13: Benthic Habitat at 20m Bottom (BHS2), transect B.

Transect (B)	Mean % Cover	SE
Hard Coral	29	0.02
Soft Coral	21	0.06
Sponge	1	0.01
Rock	34	0.04
Sand	11	0.04
Other	4	0.02

- **Fish community structure**

Table 14:Average fish abundance per (75 m2) at 10 m depth (BHS1), and 20 m depth (BHS2).

Family	Species (scientific name)	10m Average abundance	20m Average abundance
Holocentridae	*Sargocentrondiadema*	74	62
Serranidae	*Epinephelus fasciatus*	5	3
	Variola louti	3	2
	Pseudanthiassquamipinnis	2500	1833
Pseudochromidae	*Pseudochromisfridmani*	8	12
	Pseudochromis olivaceous	5	3
	Pseudochromisspringeri	4	3
Caesionidae	*Caesio sp.*	410	823
Mullidae	*Parupeneusforsskali*	11	9
	Parupeneusmacronemus	5	4
Lethrinidae	*Lethrinusborbonicus*	3	2
Chaetodontidae	*Chaetodon auriga*	1	1
	Chaetodon austriacus	5	6
	Chaetodon fasciatus	3	4
	Chaetodon melannotus	2	2
	Chaetodon paucifasciatus	16	11
	Chaetodon trifascialis	1	2
Pempheridae	*Heniochusdiphreatus*	25	15

	Heniochus intermedius	3	3
Pomacanthidae	*Apolymichthysxanthotis*	3	2
	Centropygemultispinis	11	11
	Pomacanthus imperator	1	1
	Pygoplitesdiacanthus	1	1
	Amphiprionbicinctus	35	31
	Chromisdimidiate	77	113
	Dascyllusaruanus	32	12
	Chromisviridis	73	0
	Dascyllusmarginatus	97	80
	Dascyllustrimaculatus	97	48
	Neopomacentrusmiryae	800	2733
	Pomacentrustrichourus	387	381
Labridae	*Gomphosus caeruleus klunzingeri*	3	3
	Labriodesdimidiatus	1	3
	Larabicusquadrilineatus	10	7
	Thalassomaklunzingeri	70	43
	Cheilinus mentalis	13	15
	Cheilinustrilobatus	5	7
	Paracheilinusoctotaenia	2333	2317
	Anampsestwistii	4	5
Scaridae	*Chlorurus sordidus*	4	4
	Scarus gibbus	5	4
Acanthuridae	*Acanthurusnigrofuscus*	17	17
	Ctenochaetusstriatus	8	13
	Zebrasomaxanthurum	3	3
Siganidae	*Siganusluridus*	15	6
	Siganusrivulatus	9	12
Tetraodontidae	*Canthigaster coronate*	3	3
	Ostracioncubicus	6	4

Table 15:Relative fish abundance per (75 m2) at 10 m depth (BHS1), and 20 m depth (BHS2).

Family	Species (scientific name)	10m Relative Abundance %	20m Relative Abundance %
Holocentridae	*Sargocentrondiadema*	1.03	0.72
Serranidae	*Epinephelus fasciatus*	0.07	0.03
	Variola louti	0.04	0.03
	Pseudanthiassquamipinnis	34.71	21.13
Pseudochromidae	*Pseudochromisfridmani*	0.12	0.13
	Pseudochromis olivaceous	0.06	0.03
	Pseudochromisspringeri	0.06	0.04

Caesionidae	*Caesio sp.*	5.69	9.49
Mullidae	*Parupeneusforsskali*	0.15	0.1
	Parupeneusmacronemus	0.06	0.05
Lethrinidae	*Lethrinusborbonicus*	0.04	0.02
Chaetodontidae	*Chaetodon auriga*	0.02	0.02
	Chaetodon austriacus	0.06	0.07
	Chaetodon fasciatus	0.05	0.04
	Chaetodon melannotus	0.03	0.02
	Chaetodon paucifasciatus	0.22	0.13
	Chaetodon trifascialis	0.01	0.02
Pempheridae	*Heniochusdiphreatus*	0.34	0.17
	Heniochus intermedius	0.04	0.03
Pomacanthidae	*Apolymichthysxanthotis*	0.05	0.02
	Centropygemultispinis	0.15	0.13
	Pomacanthus imperator	0.01	0.01
	Pygoplitesdiacanthus	0.01	0.01
	Amphiprionbicinctus	0.48	0.35
	Chromis dimidiate	1.06	1.31
	Dascyllusaruanus	0.44	0.14
	Chromisviridis	1.02	0
	Dascyllusmarginatus	1.34	0.92
	Dascyllustrimaculatus	1.34	0.55
	Neopomacentrusmiryae	11.11	31.51
	Pomacentrustrichourus	5.37	4.39
Labridae	*Gomphosus caeruleus klunzingeri*	0.04	0.03
	Labriodesdimidiatus	0.02	0.03
	Larabicusquadrilineatus	0.14	0.08
	Thalassomaklunzingeri	0.98	0.5
	Cheilinus mentalis	0.18	0.17
	Cheilinustrilobatus	0.06	0.08
	Paracheilinusoctotaenia	32.39	26.71
	Anampsestwistii	0.06	0.06
Scaridae	*Chlorurus sordidus*	0.05	0.04
	Scarus gibbus	0.06	0.04
Acanthuridae	*Acanthurusnigrofuscus*	0.24	0.19
	Ctenochaetusstriatus	0.12	0.15
	Zebrasomaxanthurum	0.04	0.03
Siganidae	*Siganusluridus*	0.21	0.07
	Siganus rivulatus	0.12	0.13
Tetraodontidae	*Canthigaster coronate*	0.04	0.03
	Ostracioncubicus	0.08	0.04

- **Interstitial habitat**

Table 16: Interstitial living assemblage at 10 m bottom (ISH1)

Taxon	Number/Kg of sediments	Std Dev
Foraminifera	256	14
Clams	88	11
Polychaeta	27	4
Snails	85	11

Table 17: Interstitial living assemblage at20 m bottom (ISH2)

Taxon	Number/Kg of sediments	Std Dev
Foraminifera	315	7
Clams	92	6
Polychaeta	18	1
Snails	65	10

Table 18: Sediment physio-chemical properties at selected sites.

Parameters	BHS1	BHS2
Color	Black to Gray	Black to Gray
Odor	N.D.	N.D.
Organic Carbon (g/Kg)	1.2	0.93
Calcium Carbonate (% $CaCO_3$)	11	5.5

N.D.= Not Detectable

Table 19: Sediments grain size analysis at 10 m bottom (ISH1).

Sample details	diam. (mm)	Q	wt. on sieve (g)	% wt. on sieve	Cumulative %
Sieve analysis	0.00	10.00	1.22	1.22	1.22
100g sample	0.06	3.99	14	14.00	15.22
10m depth-bottom	0.13	3.00	23	23.00	38.22
(ISH1)	0.18	2.47	18.68	18.68	56.90
	0.25	2.00	30.1	30.10	87.00
	0.50	1.00	10	10.00	97.00

	1.00	0.00	3	3.00	100.00

Table 20: Sediments grain size analysis at 20 m bottom (ISH2)

Sample details	diam. (mm)	Q	wt. on sieve (g)	% wt. on sieve	Cumulative %
Sieve analysis	0.00	10.00	1	1.00	1.00
100g sample	0.06	3.99	10	10.00	11.00
20m depth-bottom	0.13	3.00	21.7	21.70	32.70
(ISH2)	0.18	2.47	23	23.00	55.70
	0.25	2.00	34	34.00	89.70
	0.50	1.00	8.3	8.30	98.00
	1.00	0.00	2	2.00	100.00

PART THREE: REFERENCES

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ANNEX 1: SEAWATER COLUMN PROFILE DEPTH (25M), TEMPRATURE AND SALINITY.

Location	**29°22'19.09"N, 34°57'48.05"E**	
Depth(m)	Temp©	Sal(psu)
0.276	25.1528	40.5672

0.38	25.1689	40.5251
0.594	25.1689	40.5565
1.225	25.1803	40.5495
1.711	25.1892	40.5131
1.95	25.1766	40.5356
2.562	25.1792	40.5472
2.849	25.1627	40.5646
3.492	25.1667	40.552
4.013	25.1572	40.5482
4.4	25.1483	40.5497
5.047	25.1512	40.5382
5.668	25.1483	40.5384
6.135	25.1371	40.5441
6.359	25.1262	40.5623
7.144	25.1386	40.5587
7.163	25.1366	40.5608
8.036	25.1441	40.5677
8.56	25.1307	40.5649
8.787	25.1026	40.5638
8.992	25.0748	40.5602
9.705	25.0529	40.5481
9.875	25.0374	40.5545
10.474	25.0303	40.5468
11.057	25.0226	40.5482
11.656	25.0173	40.5441
12.129	25.0121	40.5456
12.495	25.0101	40.5453
12.883	25.0055	40.5493
13.709	24.9908	40.5438
14.567	24.9775	40.5455
14.804	24.9727	40.548
14.914	24.9712	40.5489
15.789	24.9777	40.543
17.023	24.9777	40.5467
16.998	24.9759	40.5477
17.143	24.9727	40.5565
17.096	24.9751	40.5559
17.622	24.9747	40.5545
19.019	24.9777	40.5513
19.294	24.9712	40.5514
19.366	24.9804	40.5526
19.322	24.9795	40.5514
20.791	24.9798	40.5507

22.144	24.9804	40.5505
22.128	24.9714	40.5515
22.267	24.9814	40.5516
22.466	24.9813	40.5518
24.112	24.9813	40.5511
24.91	24.9794	40.5504
24.96	24.9753	40.5503
25.083	24.9797	40.5514
25.758	24.9671	40.5475
26.127	24.9213	40.543
25.361	24.9295	40.5506
24.585	24.9337	40.5484
23.813	24.9411	40.5472
23.163	24.9446	40.5485
22.4	24.9553	40.5506
21.571	24.9585	40.5516
21.082	24.9628	40.5502
20.249	24.9965	40.5487
19.502	24.97	40.5459
19.196	24.9743	40.5462
18.531	24.9762	40.5495
17.862	24.9822	40.5495
17.386	24.9828	40.5492
16.61	24.9838	40.5485
15.636	24.9847	40.554
14.794	24.9837	40.5387
14.608	24.9833	40.5388
13.798	24.9839	40.5388
13.227	24.9864	40.5436
12.628	24.9872	40.5496
11.653	25.0002	40.5536
11.117	25.0124	40.5503
10.625	25.0166	40.5508
9.862	25.0294	40.5671
9.502	25.0496	40.5585
8.891	25.0564	40.5625
8.235	25.0662	40.5685
7.73	25.0858	40.5776
7.021	25.1084	40.5857
6.431	25.1393	40.5902
5.857	25.1561	40.5793
4.974	25.1617	40.5862
4.595	25.1735	40.5866

4.025	25.1851	40.5889
3.208	25.1905	40.5788
3.047	25.1891	40.5831
2.293	25.1884	40.5829
1.442	25.19	40.5857
1.212	25.1999	40.5551
0.584	25.2039	40.5804
0.228	25.2039	40.5846
0.07	25.2055	40.5854

ANNEX 2: SEAWATER COLUMN PROFILE DEPTH (50M), TEMPRATURE AND SALINITY.

Location	**29°22'19.38"N, 34°57'43.88"E**	
Depth(m)	Temp. ©	Sal(PSU)
0.572	25.3092	40.524
0.85	25.3257	40.8804
0.897	25.3526	40.8761
0.979	25.3146	40.963
0.941	25.2559	40.9421
1.065	25.2772	40.984
0.989	25.3808	40.7762
0.998	25.3536	40.8685
1.084	25.2913	41.0397
1.039	25.2786	40.8298
1.061	25.3277	40.8417
1.109	25.3687	40.8295
1.052	25.2854	40.9577
1.036	25.2636	40.8338
1.099	25.3492	40.8185
1.055	25.4577	40.6976
1.058	25.4239	40.7835
1.109	25.4821	40.9545
1.058	25.6993	40.9317
1.541	25.5037	40.517
2.484	25.2097	40.6559
3.014	25.1812	40.6987
3.131	25.2478	40.7091
3.191	25.2734	40.7456
3.143	25.342	40.9112
3.149	25.4643	40.5009

3.257	25.2238	40.5543
3.468	25.186	40.5852
3.56	25.1832	40.5873
3.506	25.1856	40.5872
3.525	25.1875	40.5877
3.496	25.1906	40.5875
3.534	25.193	40.5868
3.704	25.1835	40.564
4.219	25.1617	40.5801
4.184	25.1622	40.5808
4.215	25.162	40.578
4.181	25.162	40.5823
4.269	25.1689	40.5808
4.502	25.1658	40.5808
4.569	25.1707	40.5808
4.6	25.1716	40.5816
4.622	25.1741	40.5826
4.622	25.1755	40.5759
4.673	25.1677	40.5817
4.663	25.1729	40.5813
5.455	25.1686	40.5658
6.991	25.1419	40.5672
7.051	25.1371	40.5556
7.117	25.0983	40.5448
7.372	25.0752	40.5589
7.625	25.0713	40.5603
8.183	25.0697	40.5599
8.441	25.0685	40.5602
8.609	25.0681	40.5587
9.019	25.0658	40.5602
9.041	25.0662	40.5602
8.94	25.0667	40.5595
9.022	25.0657	40.5598
9.577	25.0655	40.5561
10.643	25.0556	40.5537
10.873	25.0505	40.5521
10.655	25.0447	40.5566
10.822	25.0455	40.553
11.1	25.0433	40.553
11.847	25.0334	40.5472
11.85	25.0292	40.5504
11.876	25.026	40.5515
12.185	25.0276	40.5461

13.276	25.0141	40.5429
13.109	25.011	40.5487
13.304	25.0057	40.5423
14.332	25.0001	40.5425
14.49	24.9989	40.5457
14.663	24.9985	40.544
14.496	24.9986	40.5447
14.72	24.9995	40.546
15.881	24.9986	40.54
16.899	24.9877	40.5367
16.874	24.9859	40.5455
17.019	24.9927	40.5449
16.972	24.9951	40.5435
17.498	24.9947	40.5403
18.895	24.9877	40.5374
19.17	24.9812	40.5412
19.078	24.9836	40.5416
19.242	24.9824	40.5404
19.198	24.983	40.5397
20.667	24.9803	40.5381
22.02	24.9794	40.5405
22.004	24.9804	40.5406
22.143	24.9804	40.5379
22.046	24.9776	40.5408
22.342	24.9803	40.5401
23.988	24.9803	40.5394
24.786	24.9784	40.5393
24.836	24.9797	40.5404
24.959	24.9783	40.536
24.843	24.973	40.5365
25.634	24.9695	40.5361
27.185	24.9611	40.521
27.501	24.9404	40.5304
27.63	24.9363	40.5267
27.766	24.9299	40.5289
27.687	24.9287	40.5281
28.481	24.9269	40.5268
30.216	24.9244	40.5211
31.029	24.9066	40.5194
31.055	24.9018	40.5212
31.089	24.8988	40.5222
31.427	24.8977	40.5219
31.253	24.8988	40.5225

31.332	24.896	40.5189
31.288	24.8936	40.5227
31.379	24.8945	40.5211
31.994	24.891	40.5191
31.931	24.8908	40.5225
32.035	24.8866	40.5164
32.723	24.8816	40.5193
33.246	24.8781	40.5178
33.984	24.8719	40.5157
34.514	24.8677	40.517
34.58	24.8672	40.5185
35.296	24.8686	40.5186
35.617	24.8707	40.5176
35.687	24.8697	40.5171
35.87	24.8692	40.5165
37.043	24.8679	40.5167
37.566	24.867	40.5167
37.642	24.8673	40.5172
37.844	24.8672	40.5173
38.556	24.8666	40.515
39.773	24.8623	40.5135
40.108	24.8584	40.5138
40.42	24.8535	40.5138
40.628	24.8532	40.5152
40.754	24.8542	40.5143
41.949	24.8517	40.5125
43.579	24.847	40.5081
44.175	24.8374	40.5095
44.355	24.8294	40.4986
44.932	24.7931	40.4788
46.367	24.7538	40.4929
46.663	24.7501	40.4992
46.758	24.7501	40.4965
47.092	24.7486	40.4961
47.884	24.7478	40.4974
47.918	24.749	40.497
47.921	24.7494	40.4969
47.918	24.7496	40.4969
47.918	24.7501	40.4965
47.915	24.7507	40.4965
47.918	24.7506	40.4966
47.918	24.7501	40.4969
47.921	24.7497	40.4967

47.918	24.7489	40.4969
47.918	24.7498	40.4973
47.918	24.7505	40.4959
47.918	24.7496	40.4964
47.88	24.7491	40.498
47.669	24.7518	40.4966
46.922	24.7518	40.4972
46.083	24.752	40.4971
45.304	24.7529	40.4981
44.415	24.7552	40.5019
43.538	24.7675	40.5138
42.712	24.7945	40.5268
41.795	24.8304	40.5233
41.082	24.8466	40.5148
40.136	24.8521	40.5165
39.395	24.8575	40.5174
38.603	24.862	40.5166
37.865	24.8633	40.5159
36.948	24.8648	40.5197
36.182	24.8713	40.5203
35.488	24.8743	40.5194
34.655	24.8773	40.5208
33.782	24.8801	40.5189
32.959	24.8825	40.5245
32.149	24.8913	40.5233
31.411	24.8893	40.516
30.708	24.8825	40.5174
29.932	24.8815	40.5231
29.207	24.8866	40.5203
28.522	24.8868	40.5225
27.772	24.9002	40.535
27.173	24.9185	40.5305
26.28	24.9273	40.5323
25.514	24.9385	40.5396
24.738	24.9507	40.5374
23.966	24.9561	40.5362
23.316	24.9586	40.5375
22.553	24.963	40.5396
21.724	24.9685	40.5406
21.235	24.9728	40.5392
20.402	24.9745	40.5377
19.655	24.973	40.5349
19.349	24.9693	40.5352

18.684	24.9682	40.5385
18.015	24.9702	40.5385
17.539	24.9708	40.5382
16.763	24.9708	40.5375
16.145	24.973	40.541
15.789	24.9777	40.543
15.057	24.9858	40.547
14.468	24.9928	40.5454
13.957	24.9961	40.5445
13.197	24.9989	40.5426
12.796	25.0014	40.5442
12.412	25.0003	40.545
11.648	25.0025	40.5486
11.402	25.0111	40.5508
10.929	25.0193	40.5541
10.157	25.0333	40.5588
9.709	25.049	40.5603
9.233	25.0555	40.5564
8.533	25.059	40.5571
7.918	25.0648	40.5646
7.41	25.082	40.5697
6.846	25.1002	40.57
6.199	25.1069	40.5661
5.682	25.1227	40.5803
5.026	25.141	40.5752
4.392	25.1432	40.565
3.916	25.1515	40.583
3.288	25.1654	40.5723
2.806	25.1731	40.5782
2.431	25.1759	40.5781
1.639	25.1765	40.563
0.904	25.1749	40.5455
0.387	25.1749	40.5762
0.201	25.1762	40.5792
0.169	25.1774	40.5789