CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter discussed the results of the analysis for data obtained from the DOE and the UMMReC Project. Discussion was based on literature reviews and two water quality standards i.e. the Interim Marine Water Quality Standards for Malaysia (IMWQS) and the Marine Water Quality Criteria for the ASEAN Region (AMWQC). At the end of the chapter, result for the geodatabase setup also been highlighted.

4.2 Geospatial data

The processes of creating geospatial data for this study were described in Chapter 3. As in most GIS study, the results are the maps as shown at the end of the explanation/method of creating it. Using some of GIS techniques such as digitizing, georeferencing, dissolve, labeling and mapping, output raster in .png format was created for the locations of survey and sampling, the DOE water quality monitoring stations, and the UMMReC Project study sites. The spatial data was later being used in the point distance analysis to select the points/stations that were relevant to the study.

4.3 Selected Data for Analysis

Since there are too many of DOE water quality monitoring stations (WQMS), a selection has to be made for WQMS that were relevant to the study area. The water quality data from the selected DOE WQMS was used later in the statistical analysis. Using the point distance analysis and the overlay technique in GIS, 15 locations of survey from the UMMReC Project and nine (9) DOE WQMS have been recognized as relevant to the study area (i.e. Sungai Johor).

The points/stations was group into five (5) sites i.e. Site 1 – Site 5 (Table 4.1). Site 1 and Site 2 were indicates outside seagrass area, else Site 3, Site 4 and Site 5 indicates inside seagrass area where the field observation and transect samples were collected.

Table 4.1: Selected UMMReC Project Study Sites and DOE WQMS

Sites	**UMMRec Project Locations of Survey**	**DOE WQMS**	**Seagrass Area**
Site 1 **(S1)**	Stulang Laut	Pantai Stulang Laut	NA*
Site 2 **(S2)**	Pasir Gudang (ferry jetty) Kg. Pasir Putih	Pel. Pasir Gudang Sg. Kim-Kim Kg. Pasir Putih	NA*
Site 3 **(S3)**	Tg. Kopok Perigi Acheh (guard post)	Kg. Tanjung Kopok	Tg. Kopok
Site 4 **(S4)**	Tanjung Buai Tanjung Surat (right hand) Tg. Surat Tg. Perumput 1 Tg. Perumput 2 Kuala Sg. Lebam	Tanjung Buai Kuala Sungai Johor	NA* Kuala Sg. Lebam Tanjung Surat
Site 5 **(S5)**	Kg. Pasir Gogok Kuala Sg. Santi 1 Kuala Sg. Santi 2 Sg. Santi	Pasir Gogok Tanjung Sepang	Pasir Gogok Kuala Sg. Santi

(Note: NA* - not available)

4.4 Seagrass Diversity

Species diversity is the number of different species in a particular area. Seagrass diversity in the study area was relatively small compared to the total number of 11 seagrass species reported found in Johor (see Table 2.1, page 15). Table 4.2 shows the three (3) seagrass species found in the studied transect. Pasir Gogok (S5) has the highest seagrass diversity with three (3) species, followed by Tanjung Kopok (S3), two (2) species and Tanjung Surat (S4), one (1) species. With only one (1) species found in Tanjung Surat, this findings almost agree to some extent with Lee Long et al. (1993) that estuary/inlet seagrass meadows often have high shoot densities but low species diversity.

Pasir Gogok is an extensive mudflat, with *Halophila ovalis* dominant nearshore and *Enhalus acoroides* nearer the sea. *Halophila spinulosa was* also observed at the area. Tanjung Kopok which had sandy, muddy and rocky substratum, with mangroves in the background was dominated by *Halophila ovalis* and *Halophila spinulosa*, though not as dense as Pasir Gogok. Only *Halophila ovalis* was observed at Tanjung Surat, where mudflat (1 to 1.5m deep mud) and mangroves were present.

Table 4.2: Seagrass Diversity in Transect Studies

No.	Taxa	Tanjung Kopok	Tanjung Surat	Pasir Gogok
	Family Hydrocharitaceae			
1.	*Enhalus acoroides* (L.f.Royle)			x
2.	*Halophila ovalis* (R. Brown) Hooker f.	x	x	x
3.	*Halophila spinulosa* (R. Brown) Ascherson	x		x
	No. of species:	2	1	3

4.5 Seagrass Abundance

In terms of cover for Tanjung Kopok (S3), seagrass cover per quadrat ranged from <6.25 to 100%. Highest cover was from *Halophila ovalis*. At Tanjung Surat (S4), seagrass cover ranged from <6.25 to 100%, *Halophila ovalis* dominant. At Pasir Gogok (S5), seagrass cover ranged from being absent to 100%, with *Halophila ovalis* dominant. Cover of seagrass examined in the study area is shown in Table 4.3. The total combined area of seagrass meadows in the Sungai Johor area was 6.15 km^2 (see Figure 3.4, page 41).

Dry weight (DW) biomass for seagrass in the studied transects is shown in Table 4.4. In Tanjung Kopok, biomass of *Halophila ovalis* ranged from 19.32 to 62.36 $gDW.m^{-2}$, increasing towards the sea. At Tanjung Surat, biomass of *Halophila ovalis* ranged from 10.12 to 22.36 $gDW.m^{-2}$, decreasing towards the sea. At Pasir Gogok, biomass of *Halophila ovalis* ranged from 7.08 to 43.08 $gDW.m^{-2}$, decreasing towards the sea. Biomass for *Enhalus acoroides* was 40 $gDW.m^{-2}$. The biomass (total of *Halophila*, *Enhalus*) for Pasir Gogok ranged from 7.08 to 63.84 $gDW.m^{-2}$ with an average of 29.65 ± 19.04 $gDW.m^{-2}$. The average value of dry weight biomass shows that Tanjung Kopok (40.84 ± 30.43 $gDW.m^{-2}$) has the highest biological productivity, followed by Pasir Gogok (29.65 ± 19.04 $gDW.m^{-2}$) and Tanjung Surat (16.34 ± 4.66 $gDW.m^{-2}$).

Table 4.3: Cover of Seagrass in Transect Studies

Location	Transect	Quadrat	*E. acoroides*	*H. ovalis*	*H. spinulosa*
Tanjung Kopok (substrate: mud) N 01° 25´ 44.4" E 103° 54´ 36"	1	Q1	0	5	0
N 01° 25´ 8.4" E 103° 59´ 24"	1	Q2	0	0	0
N 01° 25´ 37.2" E 103° 59´ 13.2"	1	Q3	0	5	0
N 01° 25´ 40.8" E 103° 59´ 20.4"		Q4	0	5	1
Tanjung Surat	1	Q0L	0	0	0
(subsrate: mud)	1	Q0R	0	0	0
	1	Q1L	0	0	0
Quad distance: 20m	1	Q1R	0	0	0
	1	Q2L	0	1	0
	1	Q2R	0	4	0
N 01° 28´ 52.2"	1	Q3L	0	0	0
E 104° 03´ 00.3"	1	Q3R	0	0	0
	1	Q4L	0	4	0
	1	Q4R	0	4	0
	1	Q5L	0	0	0
	1	Q5R	0	0	0
	1	Q6L	0	2	0
	1	Q6R	0	5	0
	1	Q7L	0	0	0
	1	Q7R	0	0	0
	1	Q8L	0	0	0
	1	Q8R	0	0	0
	1	Q9L	0	4	0
	1	Q9R	0	5	0
	2	Q0L	0	0	0
	2	Q0R	0	0	0
N 01° 28´ 51.8"	2	Q1L	0	0	0
E 104° 03´ 11.2"	2	Q1R	0	0	0
	2	Q3L	0	0	0
	2	Q3R	0	0	0
Pasir Gogok	1	Q0L	1	1	0
(substrate: mud)	1	Q0R	0	4	0
	1	Q1L	0	5	0
N 01° 24´ 18.3"	1	Q1R	0	5	0
E 104° 06´ 10.3"	1	Q2L	0	0	0
	1	Q2R	0	5	0
Quad distance: 20m	1	Q3L	0	5	0
	1	Q3R	0	5	1
	1	Q4L	0	5	1
	1	Q4R	0	5	0
	1	Q5L	0	4	0
	1	Q5R	0	4	0

KEY	Class:	5	4	3	2	1	0
	% Cover:	50-100	25-50	12.5-25	6.25-12.5	< 6.25	0

Table 4.4: Biomass ($gDW.m^{-2}$) of Seagrass in Transect Studies

Location	Transect	Quadrat	*H. ovalis*	*E. acoroides*	Average
Tanjung Kopok (Site 3)	1	Q1	19.32		19.32
	1	Q3	62.36		62.36
			40.84 ± 30.43		40.84 ± 30.43
Tanjung Surat (Site 4)	1	Q1	17.4		17.4
	1	Q3R	18.2		18.2
	1	Q7R	22.36		22.36
	1	Q10R	10.12		10.12
	1	Q10L	13.64		13.64
			16.34 ± 4.66		16.34 ± 4.66
Pasir Gogok (Site 5)	1	1A	23.84	40	63.84
	1	1B	32.48		32.48
	1	1C	43.08		43.08
	1	1D	26.08		26.08
	2	2A	17.12		17.12
	2	2B	17.88		17.88
	2	2C	7.08		7.08
			23.94 ± 11.63	40 ± 0.01	29.65 ± 19.04

Seagrass data (in terms of diversity, cover and biomass) from Table 4.2, Table 4.3 and Table 4.4 was put into a map format in Figure 4.1. The map gives a better visualization and interpretation of the seagrass data in the study area.

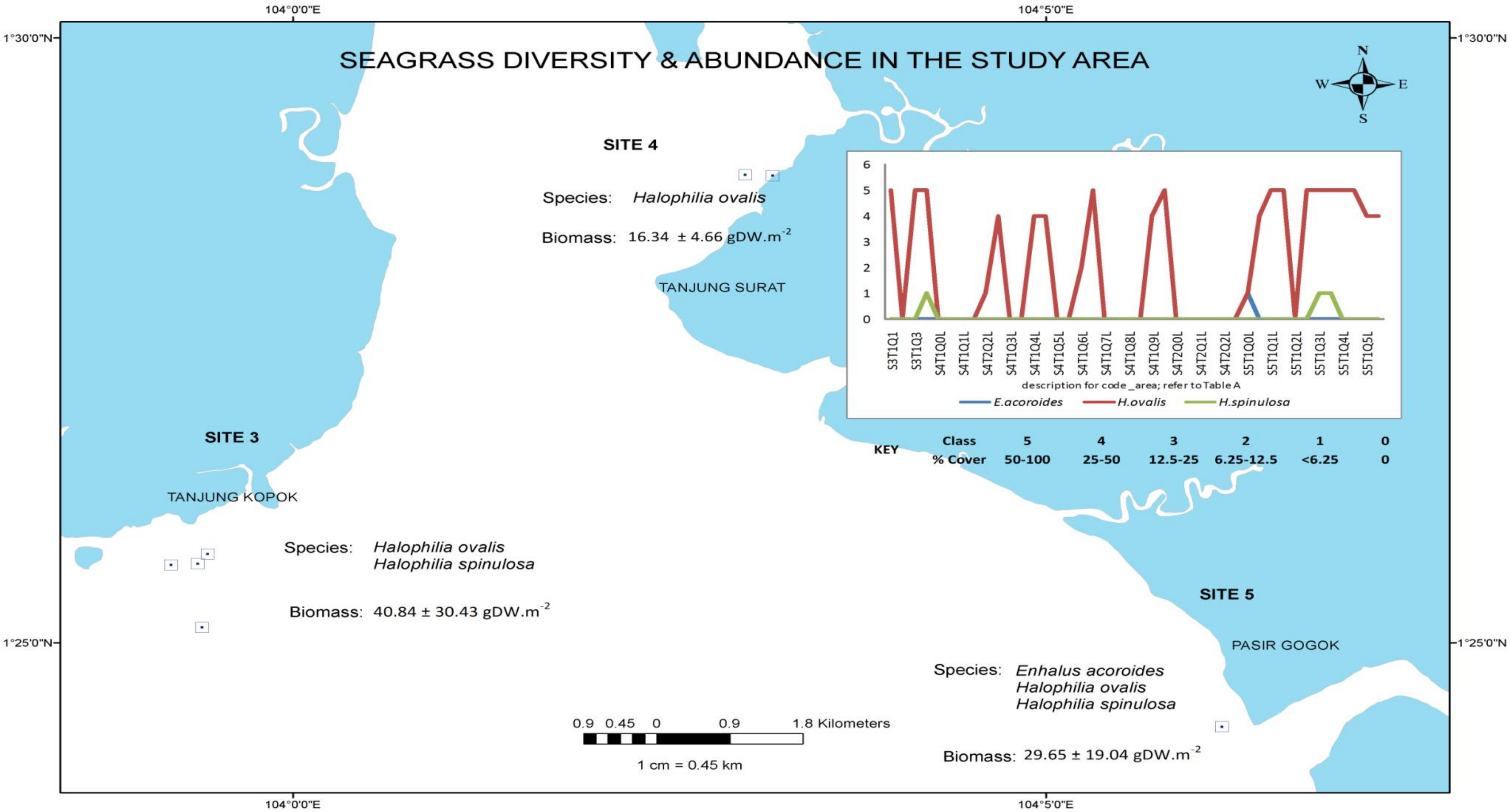


Figure 4.1: Seagrass Diversity and Abundance in the Study Area

4.6 Statistical Analysis

Statistical analysis has been performed to the water quality data from both sources, the DOE (DOE data) and the UMMReC Project (field work – FW data), and the dry weight biomass of the seagrass. Descriptive statistic was chosen to determine the differences and similarities between the sites for physical, nutrient, biological and heavy metal parameters from the DOE. The results for physical parameters are shown in Table 4.5 and Figure 4.2; and for nutrient, biological and heavy metal parameters in Table 4.6 and Figure 4.4. These results also were map in Figure 4.3 and Figure 4.5 for better visualization of linkages to the sites of study.

Inferential statistic (correlation and regression) to determine the inequality and relationships between parameters have been performed for these variables:

(i) water quality data from the UMMReC Project and the DOE. Results are shown in Table 4.7 and Figure 4.6; and

(ii) dry weight biomass (as dependent variable) and water quality data from DOE (as independent variables). Results are shown in Table 4.8 and Figure 4.7 (biomass versus physical parameters) and Table 4.9 and Figure 4.8 (biomass versus selected nutrient, biological and metal parameters).

4.6.1 Physical Parameters

Table 4.5 shows the central tendency values for the physical parameters. Temperature and pH show no obvious difference between sites but there are some differences for salinity, conductivity, dissolved oxygen (DO) and total suspended solid (TSS). The results for selected parameters were explained graphically in Figure 4.2 and Figure 4.3.

Average (mean) water temperature ranged from 30.26 ^{o}C to 30.81 ^{o}C which is the typical temperature of tropical waters, while pH ranged from 7.53 to 7.67 at all sites. Mean value for salinity ranged from 23.68 ppt to 27.94 ppt in S1 and S2, and show greater value ranged from 28.45 ppt to 31.21 ppt in S3, S4 and S5. Conductivity shows the same trend with salinity where S1 and S2 have mean values ranged from 41.72 $mScm^{-1}$ to 46.40 $mScm^{-1}$, while values for S3, S4 and S5 were greater, ranged from 46.49 $mScm^{-1}$ to 49.58 $mScm^{-1}$. S3 has the highest reading (49.58 $mScm^{-1}$) for conductivity. Dissolved oxygen for all sites ranged from 6.15 mg/l (S5, seagrass area) to 7.22 mg/l (S2, no seagrass); a little contradict to the fact that higher dissolved oxygen levels may be indicative of the high biomass of seagrass and primary productivity present.

Total suspended solid (TSS) give the most significant different readings between sites, ranged from 41.00 mg/l (S3) to 141.50 mg/l (S5). TSS in the seagrass area (S3, S4 and S5) ranged from 41.00 mg/l to 109.00 mg/l, very much lower from the readings in S1 and S2, ranged from 121.75 mg/l to 141.50 mg/l. According to Malaysian Environmental Quality Report 2005 (DOE, 2006), TSS remained as one of the main contaminant of the coastal water of all State where Johor has exceeded the Interim

Marine Water Quality Standards (IMWQS) by 80.13 percent. Only S3 has TSS value lower than the IMWQS standard.

Table 4.5: Descriptive statistic results of for six (6) physical parameters.

SITE	Parameter	Temp. (°c)	Salinity (ppt)	Condtvt (mS/cm)	DO (mg/l)	pH	TSS (mg/l)
1	Min.	30.22	22.38	39.55	5.91	7.23	41.00
	Max.	31.52	25.90	45.84	7.61	8.00	310.00
	Range	1.30	3.52	6.30	1.70	0.77	269.00
	Mean	30.81	23.68	41.72	6.78	7.67	121.75
	Std Dev.	0.54	1.53	2.84	0.69	0.34	126.19
	Sample size	4	4	4	4	4	4
2	Min.	29.98	25.47	28.74	6.07	7.00	39.00
	Max.	31.78	30.68	52.64	7.86	7.97	559.00
	Range	1.80	5.21	23.90	1.79	0.97	520.00
	Mean	30.68	27.94	46.40	7.22	7.63	141.50
	Std Dev.	0.64	1.62	6.77	0.60	0.35	184.40
	Sample size	10	10	10	10	10	10
3	Min.	29.57	27.05	47.17	6.39	7.22	39.00
	Max.	30.94	31.01	51.99	7.26	7.92	43.00
	Range	1.37	3.96	4.81	0.87	0.70	4.00
	Mean	30.26	29.03	49.58	6.83	7.57	41.00
	Std Dev.	0.97	2.80	3.40	0.62	0.49	2.83
	Sample size	2	2	2	2	2	2
4	Min.	29.18	24.76	39.07	5.73	6.88	48.00
	Max.	32.77	30.70	52.76	7.77	7.95	455.00
	Range	3.59	5.94	13.69	2.04	1.07	407.00
	Mean	30.73	28.45	46.49	6.61	7.62	109.00
	Std Dev.	1.03	2.42	4.44	0.67	0.33	140.31
	Sample size	8	8	8	8	8	8
5	Min.	28.87	28.42	44.22	5.93	5.41	54.00
	Max.	32.51	32.91	50.58	6.44	8.09	150.00
	Range	3.64	4.49	6.36	0.51	2.68	96.00
	Mean	30.35	31.21	48.26	6.15	7.53	88.63
	Std Dev.	1.30	1.82	2.63	0.18	0.87	32.12
	Sample size	8	8	8	8	8	8
IMWQS		NA	NA	NA	NA	NA	50
AMWQC		Increase not more than 2^{o}C above the maximum ambient temperature	NA	NA	4	NA	Permissible 10% maximum increase over seasonal average concentration

(Note: NA - not available)

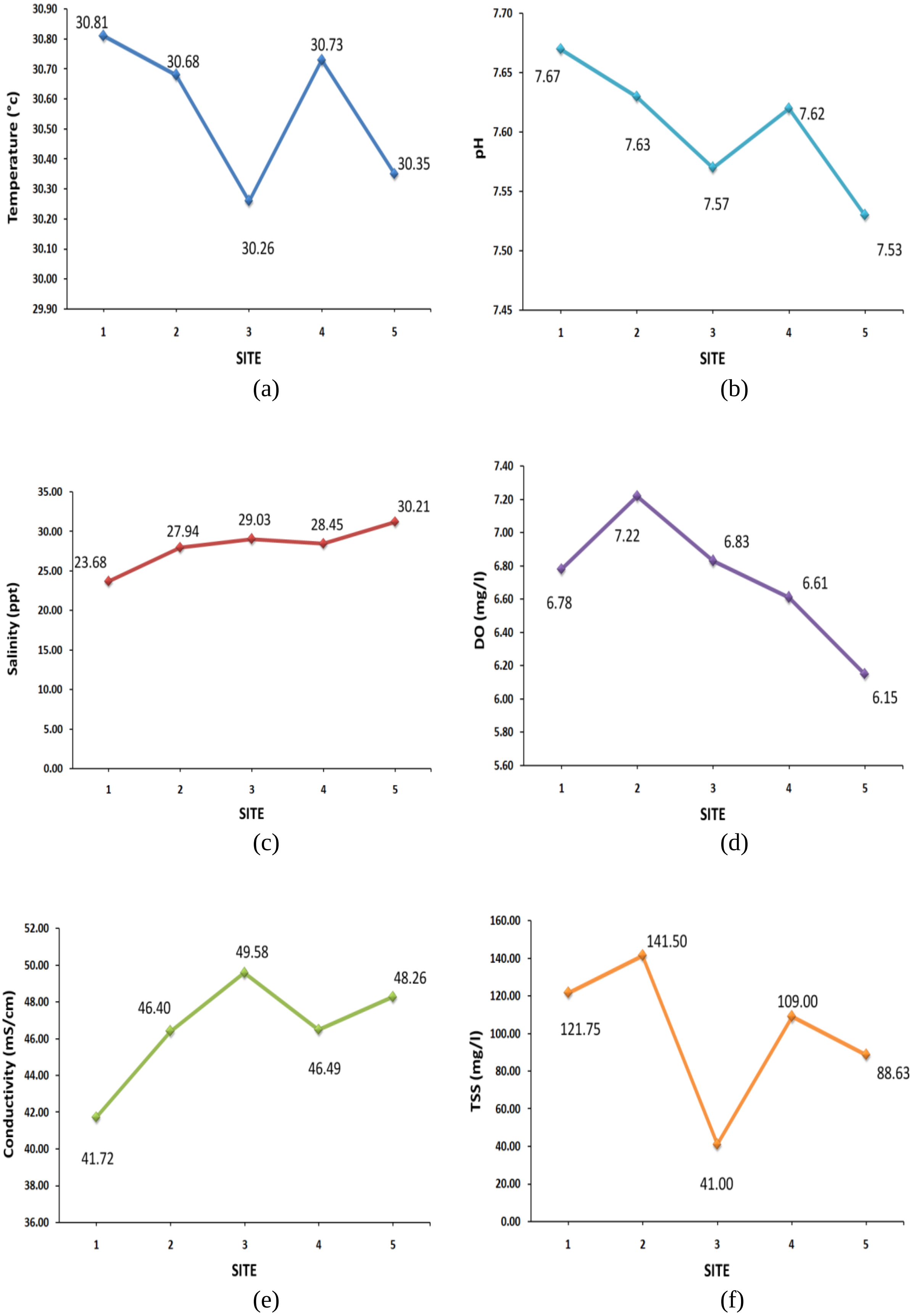


Figure 4.2: Graph for selected physical parameter in S1 to S5

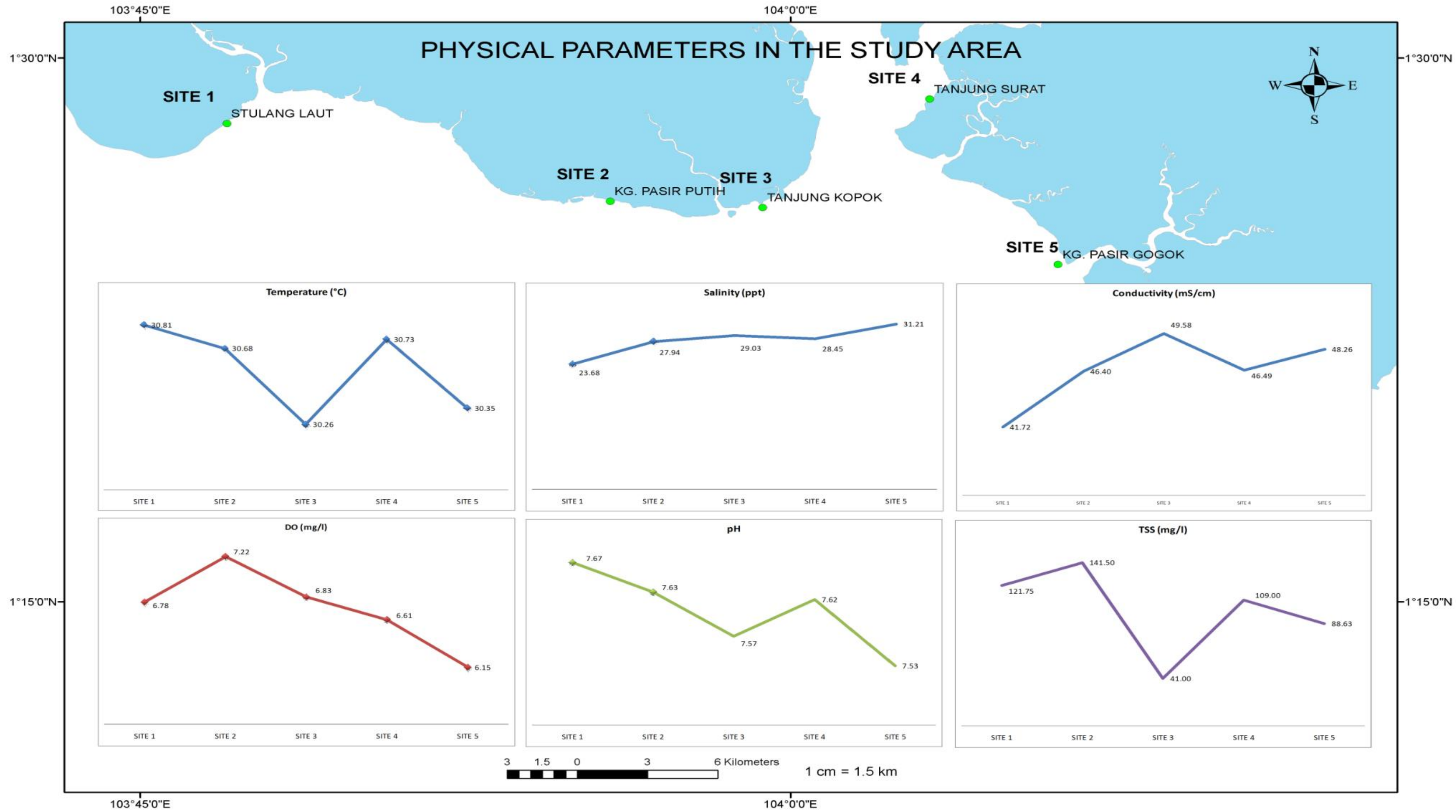


Figure 4.3: Selected physical parameters in the study area

4.6.2 Nutrient, Biological and Metal Parameters

Measures for central tendency (the descriptive statistic) on selected nutrient, biological and metal parameters were shown in Table 4.6. The results were explained graphically in Figure 4.4 and Figure 4.5. Nutrient was represented by ammonia (NH_3-N), nitrate (NO_3-N) and total nitrogen (TN), *Escherichia coli* (*E. coli*) for biological parameters, and Cuprum (Cu) and Ferum (Fe) represents the heavy metal.

There were some differences between sites for all selected nutrient, biological and heavy metal parameters, however the differences for Ammonia (NH_3-N), Nitrate (NO_3-N) and Cuprum were small. Ammonia ranged from 0.04 mg/l (S3) to 0.11 mg/l (S2 and S5), exceeded the AMWQC standard at all sites except for S3. Nitrate shows a very little different between sites, ranged from 0.04 mg/l (S3) to 0.09 mg/l (S5), and exceeded the AMWQC standard at all sites except for S2 and S3.

Total nitrogen (TN) varies from 0.35 mg/l (S2) to 0.67 mg/l (S5). TN values in the seagrass areas were obviously higher from the area without seagrass, while there were no different at all between the seagrass sites. This finding may indicate that seagrass survived better in the area with sufficient nutrients. *E. coli* present ranged from 2.30 MPN/100ml (S3) to 7533.33 MPN/100ml (S1). Both sites without the seagrass have exceeded the IMWQS and AMWQC standard (100 MPN/100ml) up to thousand percent, while seagrass area especially S3 and S5 can be considered as clean from biological contamination even though S4 has exceed the standards by 82.63 MPN/100ml. Malaysian Environmental Quality Report 2005 (DOE, 2006) also named *E. coli* as one of the main contaminant of the coastal water of all State where Johor has exceeded the Interim Marine Water Quality Standards (IMWQS) by 46.81 percent.

Table 4.6: Descriptive statistic results for nutrient, biological and metal parameters

SITE	Parameter	NH_3-N (mg/l)	NO_3-N (mg/l)	TN (mg/l)	*E. coli* (MPN/100ml)	Cu (mg/l)	Fe (mg/l)
1	Min.	0.04	0.07	0.30	3100.00	0.06	0.10
	Max.	0.13	0.10	0.65	16000.00	0.17	0.50
	Range	0.09	0.03	0.35	12900.00	0.11	0.40
	Mean	0.09	0.08	0.45	7533.33	0.13	0.30
	Std Dev.	0.06	0.02	0.18	7335.08	0.05	0.28
	Sample size	4	4	4	4	4	4
2	Min.	0.04	0.04	0.07	2.30	0.04	0.09
	Max.	0.18	0.06	1.32	4600.00	0.18	0.20
	Range	0.14	0.02	1.25	4597.70	0.14	0.11
	Mean	0.11	0.05	0.35	1457.79	0.13	0.13
	Std dev.	0.06	0.01	0.43	1690.84	0.06	0.06
	Sample size	10	10	10	10	10	10
3	Min.	0.04	0.04	0.55	2.30	0.05	0.09
	Max.	0.04	0.04	0.78	2.30	0.06	0.09
	Range	0.00	0.00	0.23	0.00	0.01	0.00
	Mean	0.04	0.04	0.66	2.30	0.06	0.09
	Std Dev.	0.00	0.00	0.16	0.00	0.01	0.00
	Sample size	2	2	2	2	2	2
4	Min.	0.04	0.04	0.04	0.23	0.03	0.09
	Max.	0.28	0.26	2.48	840.00	0.21	0.60
	Range	0.24	0.22	2.44	839.77	0.18	0.51
	Mean	0.10	0.07	0.61	182.63	0.09	0.20
	Std Dev.	0.08	0.08	0.84	313.13	0.08	0.18
	Sample size	8	8	8	8	8	8
5	Min.	0.04	0.04	0.04	0.33	0.03	0.09
	Max.	0.31	0.31	1.93	160.00	0.10	0.60
	Range	0.27	0.27	1.89	159.67	0.07	0.51
	Mean	0.11	0.09	0.67	26.67	0.06	0.31
	Std Dev.	0.09	0.09	0.7	54.44	0.03	0.20
	Sample size	8	8	8	8	8	8
IMWQS		NA	NA	NA	100	0.1	NA
AMWQC		0.07	0.06	NA	100	0.008	NA

(Note: NA - not available)

Cuprum ranged from 0.06 mg/l (S3 and S5) to 0.13 mg/l (S1 and S2). Even though the value seems so small, all sites have exceeded the AMWQC standard (ten times higher), and only S3 and S5 were satisfactory according to IMWQS standard. Heavy metals pollution was comparatively low (DOE, 2006) in Malaysian waters, where Cuprum exceeded the IMWQS by 20.7 percent for all State and Johor exceeded the standard by 25.66 percent. There were some variations of Ferum at all sites, ranged from 0.09 mg/l to 0.36 mg/l. This finding cannot be compared to the IMWQS or AMWQC since there is neither standard nor criteria for Ferum.

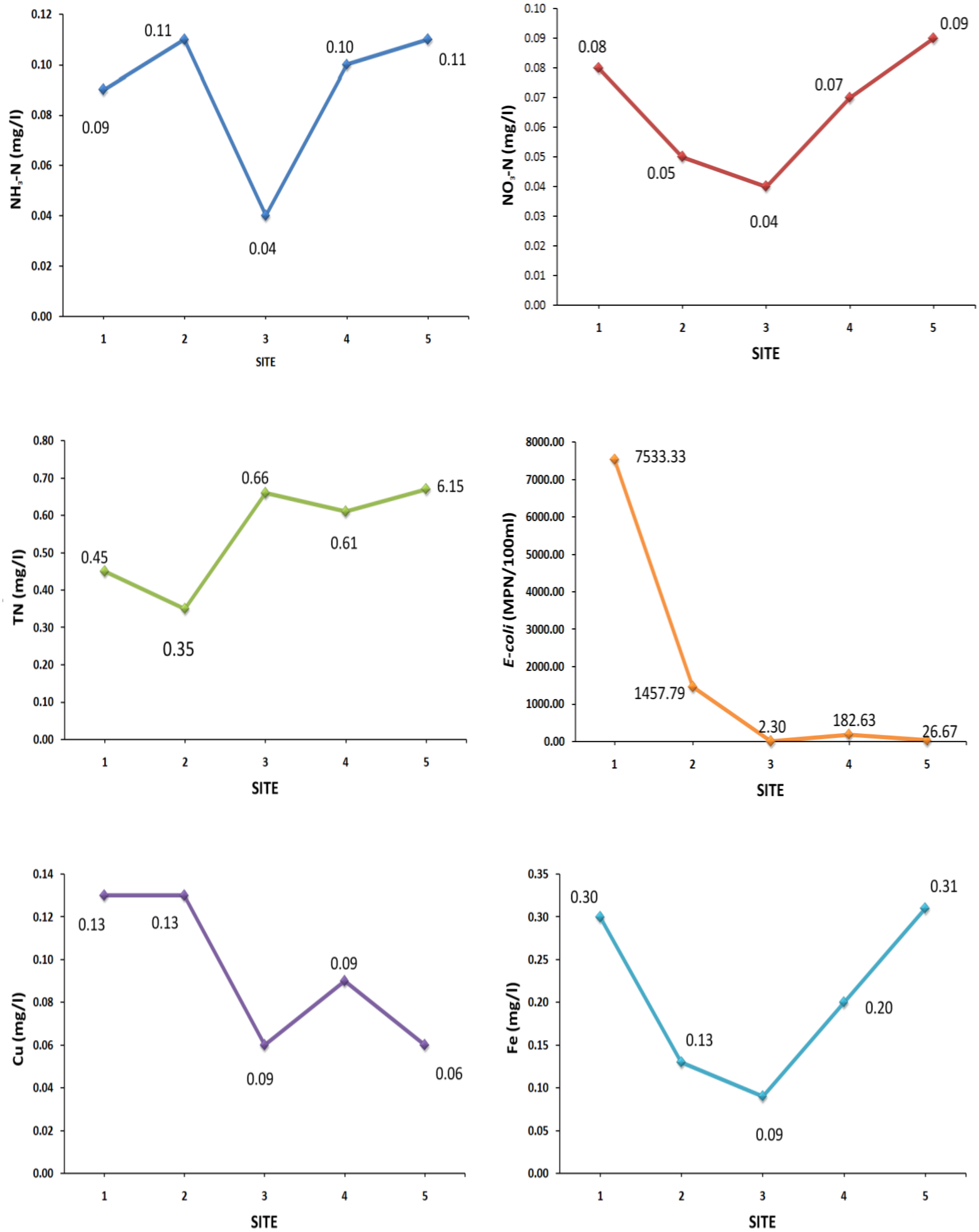


Figure 4.4: Graph for selected nutrient, biological and metal parameters

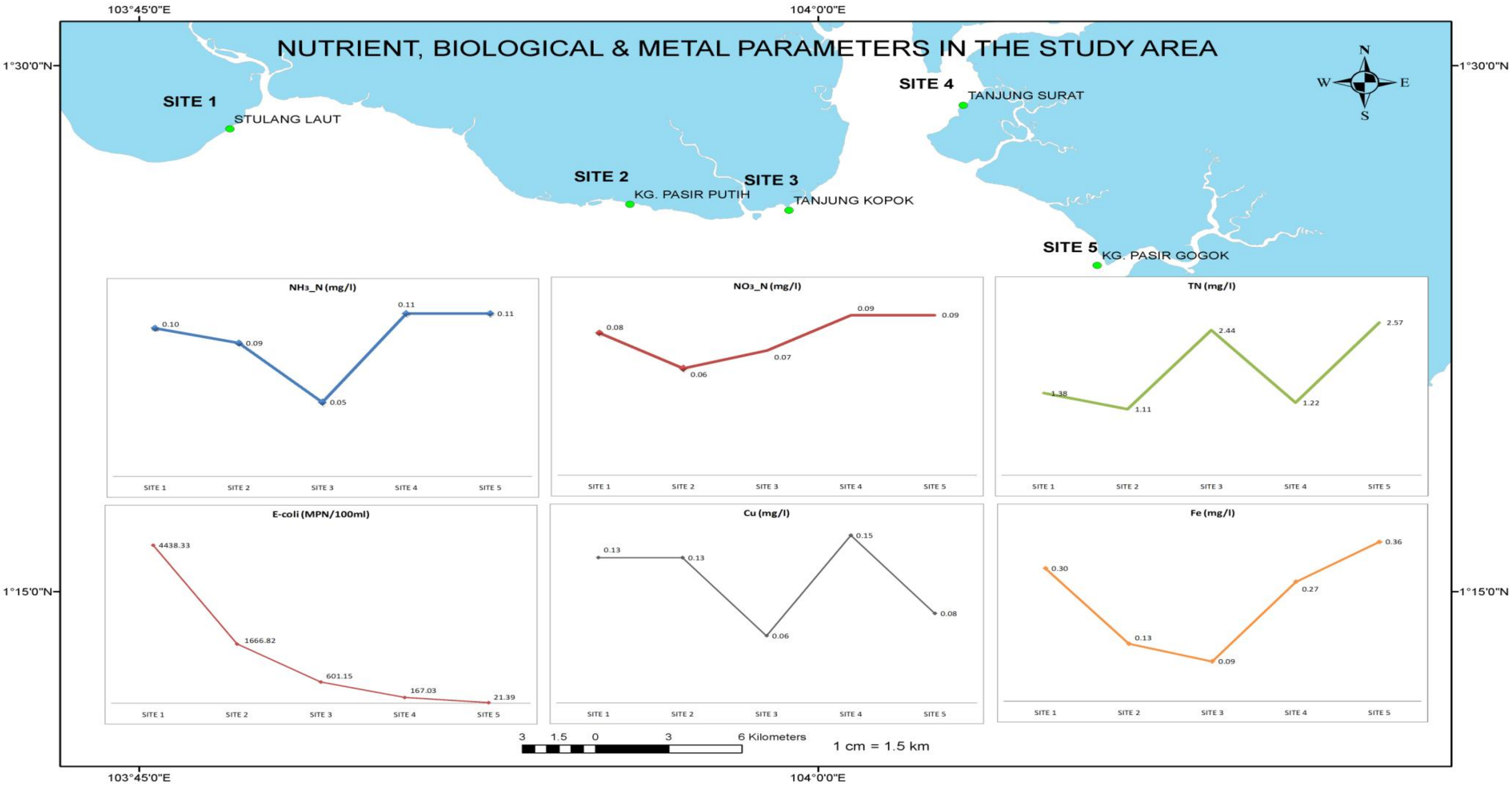


Figure 4.5: Selected nutrient, biological and metal parameters in the study area

4.6.3 Correlation and Regression between the UMMReC Project and the DOE Water Quality Data

Results for correlation and regression analysis on UMMReC Project (field work - FW) and the DOE water quality data are shown in Table 4.7. The regression lines were plotted and shown in Figure 4.6. Since the UMMReC Project did not carry out field work sampling for water quality data at S1 and S2, only S3, S4 and S5 were analyzed in this section. Comparison and correlation between secchi depth and light from UMMReC Project (FW) and total suspended solid (TSS) from the DOE also been done. The three (3) parameters were very much relevant to the condition of light in the study area, so the analysis was done on whatever available data from both sources to get the best description.

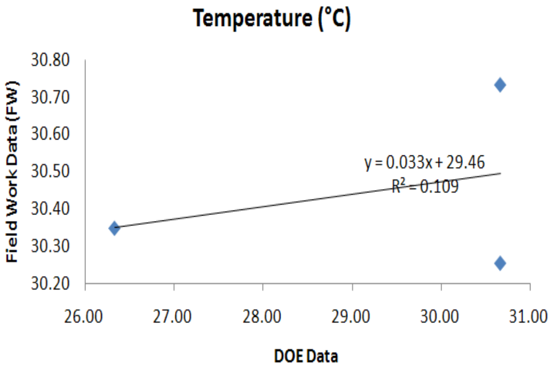
Table 4.7: Correlation and Regression between UMMReC Project (FW) and DOE Water Quality Data

Site	Temp (^{o} C)		Salinity (ppt)		Conductivity (mS/cm)		DO (mg/l)		pH	
	FW	**DOE**	**FW**	**DOE**	**FW**	**DOE**	**FW**	**DOE**	**FW**	**DOE**
S3	30.67	30.26	33.00	29.03	41.00	49.58	5.47	6.83	7.50	7.57
S4	30.67	30.73	26.00	28.45	41.00	46.49	6.57	6.61	7.50	7.62
S5	26.33	30.35	33.00	31.21	42.47	48.26	3.47	6.15	6.66	7.53
COR	0.33115		0.66351		0.08435		0.78104		0.84100	
R^2	0.10900		0.44000		0.00700		0.61000		0.70700	

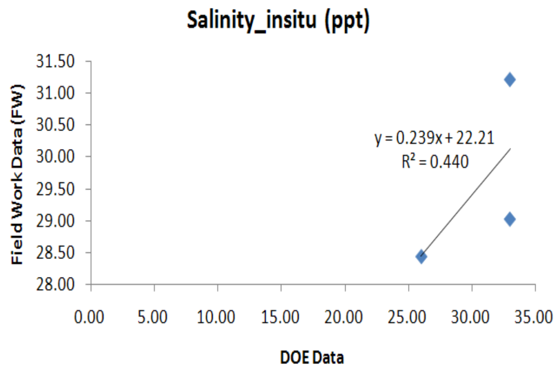
Table 4.7: continued

Site	Secchi depth (cm)	Light (klx)	TSS (mg/l)
	FW	**FW**	**DOE**
S3	26.00	37.00	41.00
S4	33.00	18.00	109.00
S5	16.67	20.00	88.63
COR	0.21241	-0.98001	
R^2	0.04500	0.96000	

Form Table 4.7, water quality from both samples (UMMReC and DOE) show a considerable positive correlation for salinity (r=0.66) and dissolve oxygen (r=0.78), with pH (r = 0.84) show the strongest positive correlation of all. A weak correlation for water temperature (r = 0.33), conductivity (r = 0.084) and secchi depth/TSS (r = 0.21) were observed. Light which has been correlated with TSS shows a strong negative correlation (r = -0.96).



(a)



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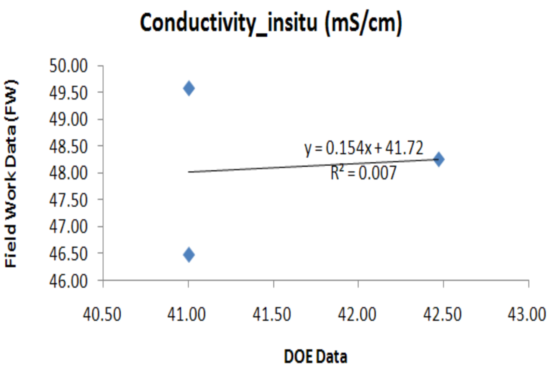

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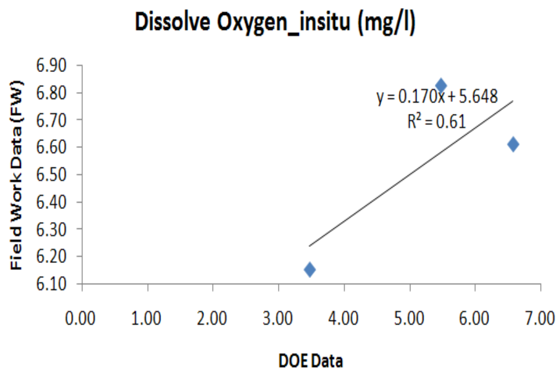
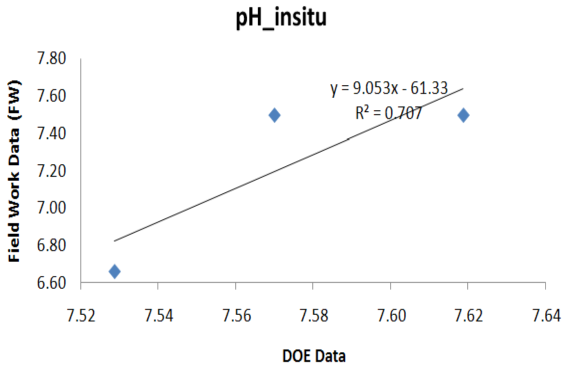
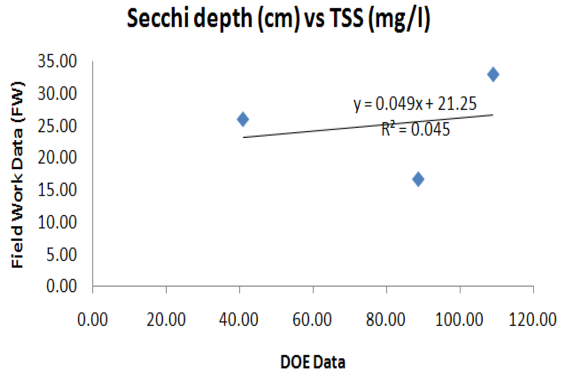


(d)

Figure 4.6: Regression Line for UMMReC Project (FW) versus DOE Water Quality Data



(e)



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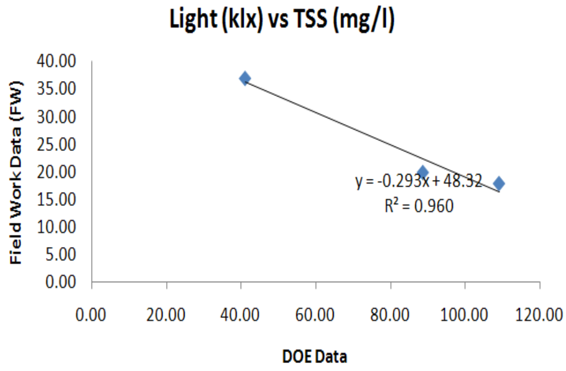


(g)

Figure 4.6: continued

Results from the regression graph and the R^2 value ($0 \leq R^2 \leq 1$) denotes the strength of the linear association between *x* (DOE data) and *y* (UMMReC Project data). R^2 represents the percent of the data that is the closest to the line of best fit. High R^2 value for four (4) parameters discussed above shows the regression lines represents the data very well for dissolve oxygen (R^2 = 0.61), pH (R^2 = 0.71) and light (R^2 = 0.96); contrary to salinity that has R^2 value of 0.44 (less than 0.50). While the correlation results show a weak correlation for the other three (3) parameters, the R^2 value shows that the regression lines do not represents the data for the parameters very well. The low R^2 value for water temperature (R^2 = 0.109), conductivity (R^2 = 0.007) and secchi depth/TSS (R^2 = 0.045) may cause from lack of data collection throughout the year 2005.

4.6.4 Correlation and Regression between Dry Weight Biomass (DW) and Physical Parameters

Results for correlation and regression analysis between Dry Weight Biomass (DW) from the UMMReC Project and physical parameters from the DOE are shown in Table 4.8. The regression lines were plotted and shown in Figure 4.7.

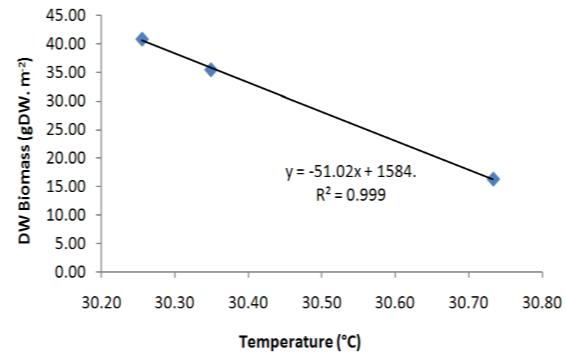
Table 4.8: Correlation and Regression between Dry Weight Biomass and Physical Parameters

Site	Temp (^{o} C)	Salinity (ppt)	Conductivity (mS/cm)	DO (mg/l)	pH	TSS (mg/l)
S3	30.26	29.03	49.58	6.83	7.57	41.00
S4	30.73	28.45	46.49	6.61	7.62	109.00
S5	30.35	31.21	48.26	6.15	7.53	88.63
COR	-0.99973	0.49338	0.97375	0.00287	-0.77438	-0.85697
R^2	0.99900	0.24300	0.94820	0.00001	0.59900	0.73400

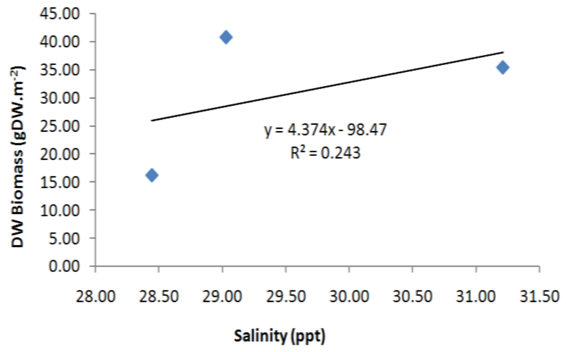
Table 4.8: continued

Site	Secchi depth (cm)	Light (klx)	DW (gDW,m-^{2})
S3	26.00	37.00	40.84
S4	33.00	18.00	16.24
S5	16.67	20.00	35.46
COR	-0.68563	0.73730	
R^2	0.47000	0.54400	

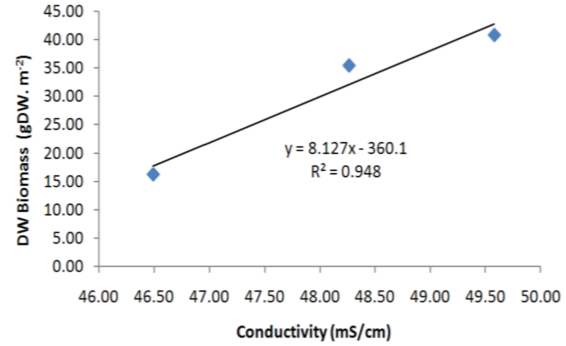
Table 4.8 shows there were strong positive correlation with biomass for conductivity (r = 0.97) and light (r = 0.74); while a strong inverse proportionality (negative correlation) with dry weight biomass were observed for water temperature (r = -0.99), pH (r = -0.77), TSS (r = -0.86) and secchi depth (r = -0.68). While salinity has a weak correlation with biomass (r = 0.49), dissolved oxygen shows no apparent correlation (r = 0.003) with it at all.



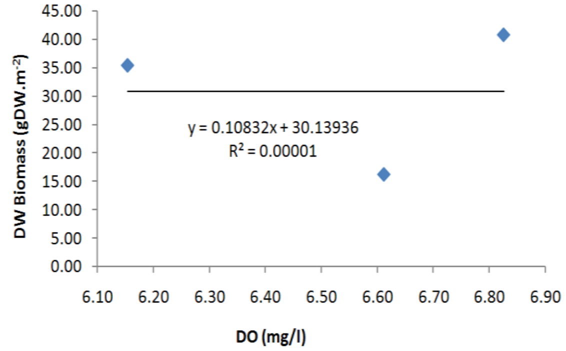
(a)



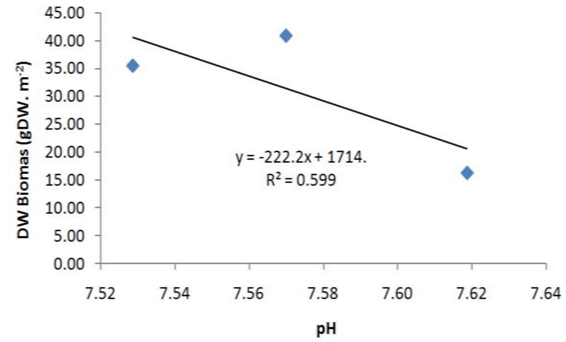
(b)



(c)



(d)



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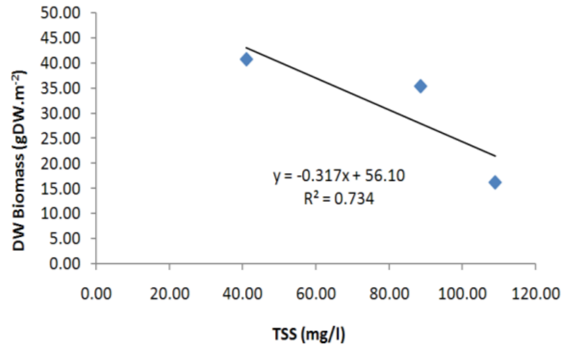

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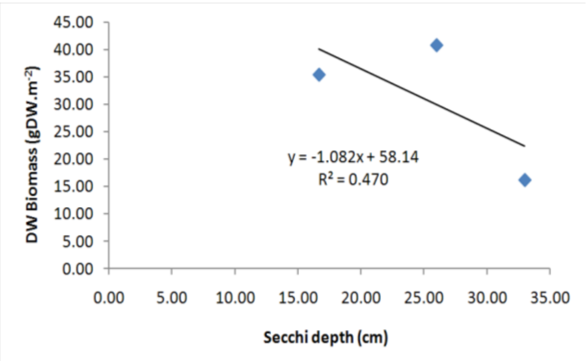

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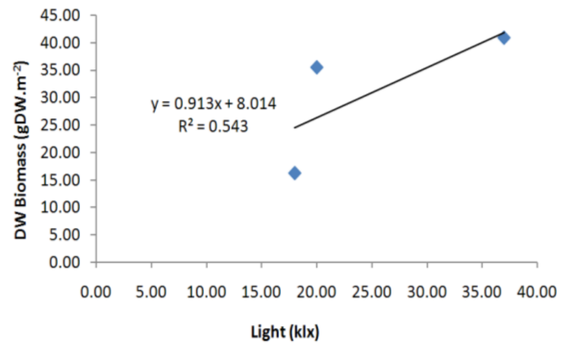


(h)

Figure 4.7: Regression Line for Dry Weight Biomass versus Physical Parameters

Results from the regression graph with high R^2 value for all parameters that have strong correlation (positive or negative) with the biomass shows the regression lines represents the data very well, except for secchi depth with the R^2 value of 0.47. As with the correlation results, the strength of the linear association between *x* (water quality) and *y* (biomass) also very weak for salinity and dissolved oxygen, both with R^2 value of 0.24 and 0.00001 respectively.

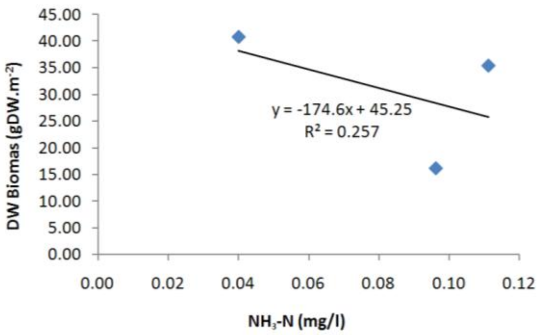
4.6.5 Correlation and Regression between Dry Weight Biomass (DW) and Selected Nutrient, Biological and Heavy Metal Parameters

Results for correlation and regression analysis between Dry Weight Biomass (DW) from the UMMReC Project and selected nutrient, biological and metal parameters from the DOE are shown in Table 4.9. The regression lines were plotted and shown in Figure 4.8.

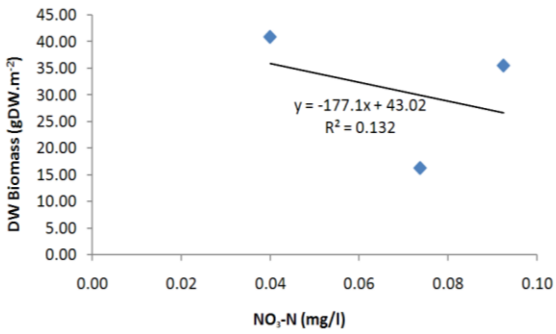
Table 4.9: Correlation and Regression between Dry Weight Biomass and Selected Nutrient, Biological and Metal Parameters

Site	NH3_N (mg/l)	NO3_N (mg/l)	TN (mg/l)	E-coli (MPN/100ml)	Cu (mg/l)	Fe (mg/l)	DW (gDW, m-²)
S3	0.04	0.04	0.66	2.30	0.06	0.09	40.84
S4	0.10	0.07	0.61	182.63	0.09	0.20	16.24
S5	0.11	0.09	0.67	26.67	0.06	0.31	35.46
COR	-0.50735	-0.36443	0.93938	-0.99642	-0.98143	-0.17953	
R^2	0.25700	0.13200	0.88200	0.99200	0.96300	0.03200	

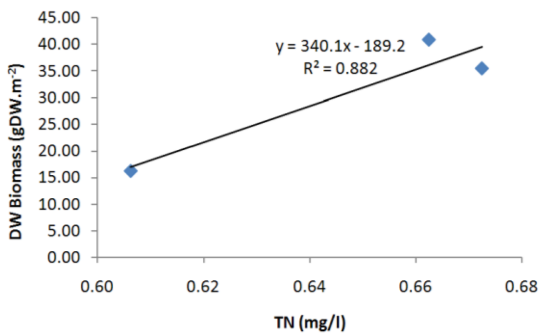
Table 4.9 shows there are strong positive correlation with biomass for total nitrogen (r = 0.94) while a strong inverse proportionality (negative correlation) with dry weight biomass were observed for *E. coli* (r = -0.99) and Cuprum (r = -0.98). Weak negative correlations with biomass were observed for Ammonia (r = -0.51), Nitrate (r = -0.36) and Ferum (r = -0.18).



(a)



(b)



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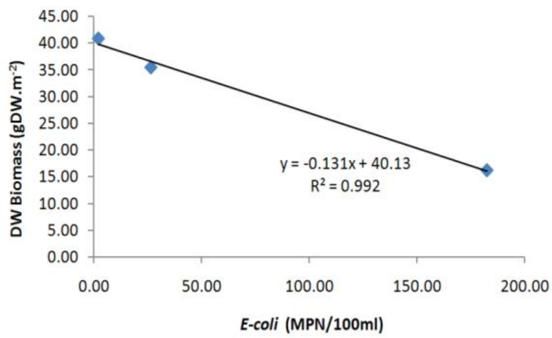

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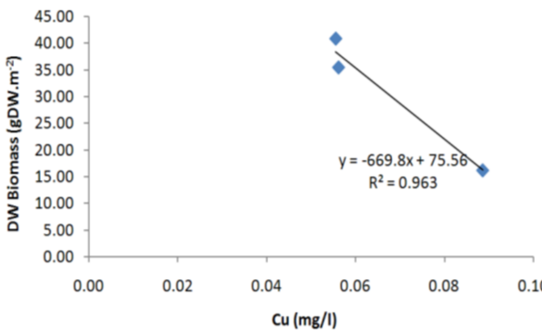

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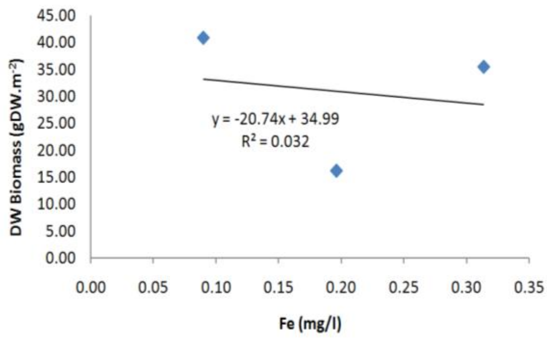


(f)

Figure 4.8: Regression Line for Dry Weight Biomass versus Selected Nutrient, Biological and Metal parameters

Results from the regression graph with high R^2 value for all parameters that have strong correlation (positive or negative) with the biomass shows the regression lines represents the data very well. As with the correlation results, the strength of the linear association between *x* (water quality) and *y* (biomass) also very weak for Ammonia ($R^2 = 0.26$), Nitrate ($R^2 = 0.13$) and Ferum ($R^2 = 0.03$).

4.7 Discussion on Seagrass and Water Quality

Five (5) sites (S1, S2, S3, S4 and S5) have been selected for the analysis of their water quality data. As mention before, the water quality parameters chosen for this study should represent those likely to have the greatest influence on seagrass growth and distribution. However, not all of water quality data supplied by the DOE can accommodate this requirement since not all can be analyzed statistically.

Apart from that, UMMReC Project also provided some physical parameters data. The correlation and regression analysis between these data and DOE water quality data shows a weak correlation for temperature, and between secchi depth and TSS; give an impression that these two (2) parameters are not suitable to be analyzed further. However, the parameters gave some interesting results in the analysis with the dry weight biomass (later will be referred as DW biomass) of the seagrass.

From the results of correlation and regression analysis between seagrass DW biomass and water quality data, a few parameters have been excluded from the discussion because of no apparent correlation. The parameters are dissolved oxygen (DO), nitrate nitrogen (NO_3-N) and Ferum (Fe).

Results of the central tendency measurement (descriptive statistic) was used to discussed the similarities and differences of all sites with S1 and S2 represent the area without seagrass (as a control for the study), and S3, S4 and S5 were representing the seagrass area. The results of the analysis suggest there were some characteristic that can differentiate the sites.

The determination of seagrass distribution by any single factor is highly unlikely (Livingston *et al.* 1998). Bach et al. (1998) suggest that multiple environmental factor axes affect the distribution of seagrass species simultaneously, and the resultant distributions may not agree with those predicted by a single factor axis. Abide the suggestion; results from the analysis will be discussed simultaneously, where appropriate.

4.7.1 Seagrass Distribution

Seagrass species was not really diverse in the study area with only three (3) species were found i.e. *Halophila ovalis*, *Halophila spinulosa* and *Enhalus acoroides*. These three (3) species represent the extreme range of seagrass sizes of South East Asia, from the smallest *Halophila* species to *Enhalus acoroides*, the largest seagrass species. *Halophila ovalis* was the most dominant species, occur at all sites and cover up to 100% in most of transect studied.

Since *Halophila ovalis* were dominant in all study sites, some information about the species are appropriate to be mentioned here. Den Hartog (1970) and Kirkman (1985) describe *Halophila ovalis* as a small, fragile plant that is easily detached by wave action, but it also roots easily from fragments, and is often the first seagrass to settle on newly available substrata. *Halophila ovalis* is capable of surviving in very turbid and/or polluted waters, and is also markedly eurybiontic (Den Hartog, 1970). In different parts of the world it occurs over a wide range of salinities, temperatures and light levels, and is found on substrata from soft mud to coarse coral rubble. This ecological tolerance may explain its dominance in the study area. The relatively sheltered conditions in the estuary have also enabled it to form unusually dense stands.

The biomass, productivity and biometry of *Halophila ovalis* were strongly influenced by salinity, temperature and light supply (Hillman et al., 1995). However, since this plant was little affected by the salinity range experienced (15-35‰), light was considered the more important factor controlling growth, since the waters of the estuary are generally turbid, and subject to sudden increases in turbidity.

The presence of *Halophila spinulosa* at S3 and S5, and *Enhalus acoroides* that only presence at S5 indicates some environmental factor that suited both species exists in the area.

4.7.2 Biomass

Biomass means the cumulation of living matter, the total living biological material in a given area. Biomass is measured by weight or by dry weight, per area. In this study, DW biomass for S3 and S4 came from *Halophila ovalis* per se, while for S5 the contribution also came from *Enhalus acoroides*. UMMReC Report mention an interesting findings that at S4 and S5, *Halophila ovalis*'s biomass decreased towards the sea, contrary to S3 (Tanjung Kopok) where the biomass of this species increased towards the sea. Tanjung Kopok also has the highest value for biomass in the study area.

Hillman et al. (1995) studied the biomass, distribution and primary production of *Halophila ovalis* in relation to environmental factors, and found out that uniform stands of *Halophila ovalis* reached a biomass of up to 120 gDW.m^{-2} in late summer/early autumn, and maximum productivities of up to 40 gDW.m^{-2} day^{-1} in summer.

Enhalus acoroides was found in only one of the transect studied in S5 with <6.25 percent cover, but its DW biomass of 40 ± 0.01 gDW.m^{-2} was almost the same as average DW biomass at S3 (40.84 ± 30.43 gDW.m^{-2}), the highest average of dry weight biomass of all sites. It's reflected the difference in structure between *Enhalus acoroides* and *Halophila ovalis* and supports the findings by Duarte and Chiscano (1999) that differences in biomass among seagrass populations were largely the result of species specific differences in biomass development, with a tendency for large-sized seagrass species to develop high below-ground biomass.

4.7.3 Temperature and pH

Water temperature controls the rate of seagrasses growth and health. All species have an optimum temperature for photosynthesis and growth, and tropical species of seagrasses generally increase their photosynthesis at elevated temperature (Perez and Romero, 1992; Ralph, 1998). Above the optimum, plants experience thermal stress that can be detrimental and result in plant mortality. The efficiency of photosynthesis activities decrease when temperature increases above the normal upper limit of 35^{o}C, because high temperatures bring about increased respiration and photosynthetic enzyme breakdown (Ralph, 1998). The results of the analysis seem to agree with this where significant negative correlation between biomass and temperature was observed in the study area.

Temperature also controls the range of pH and dissolved carbon dioxide (CO_2) concentrations in the water column; factors critical in plant survival in the marine environment. Seagrass require inorganic carbon for growth, and the two (2) different pathways in carbon uptake were species specific. Some species (e.g. *Halophila ovalis, Cymodocea rotundata, Syringodium isoetifolium* and *Thalassia*) use bicarbonate

(HCO_3^-), whereas others (e.g. *Enhalus acoroides, Halodule, Cymodocea serrulata)* use enzymes to make CO_2 available as inorganic carbon source (McKenzie and Yoshida, 2009). Between pH 6 and 9 the proportion of inorganic carbon that is present in seawater as free dissolved CO_2 rapidly declines, and is virtually zero at pH 9 when all inorganic carbon is in the form of bicarbonate or carbonate (Hemminga and Duarte, 2000). All of seagrass areas in this study have pH range between 7.53 and 7.62, indicates a balance of bicarbonate and carbon dioxide in the seawater.

Negative correlation between biomass and pH, as the result of the analysis also agree with the above literature findings. The persistent photosynthetic activity (even though the biomass value was low) in S4 which recorded the highest pH level, could be taken as evidence for the capability of *Halophila ovalis* to utilized bicarbonate better than other species. Beer et al. (2006) investigated some ecophysiological adaptation strategies of *Halophila ovalis* with respect to this plant's ability to grow in the upper intertidal in either monospecific pools (but not together with other intertidal species) or emergent and exposed to high temperatures and irradiances during several hours every day. They suggested that *Halophila ovalis* cannot grow in intertidal pools together with the other major intertidal species because the latter raise the pH above its pH compensation point, thus restricting its utilization of inorganic carbon. This may be one of the factors to explain the *H. ovalis* exclusive reside in S4.

On the other hand, the existent of *Enhalus acoroides* in S5 which recorded the lowest pH level (more acidic than other areas) could be an indication that the availability of CO_2 was more than HCO_3^- in the area. However, in view of the lack of significant differences in average water temperature and pH between sites, it is very hard to discuss the role of these two (2) parameters in the observed trend.

4.7.4 Salinity and Conductivity

Salinity is a constant factor in the open sea, although it can fluctuate in more closed environments (lagoons, bays, estuaries, etc.) due to natural freshwater inputs or human activities. Although most seagrasses can tolerate short-term salinity fluctuations, salinity variations will significantly affect some of the biochemical processes involved in photosynthesis and growth, determining the biomass, distribution, and productivity of these species (Hillman et al., 1995). Typically, seagrasses grow best in salinities of 35 parts per thousand (www.seagrasswatch.org). Mean salinity for S1 and S2 which were much lower than the seagrass areas (S3, S4 and S5), explained one of the reasons for the absence of seagrass in the areas.

Seagrass can tolerate a range of salinities even though some species are less tolerant that others. Salinity tolerance may be a factor promoting different species distributions along salinity gradients, e.g. going up estuaries (McKenzie and Yoshida, 2009). Even though salinities at all study sites were lower than 35 ppt, but there exist a positive correlation between salinity and biomass of the seagrasses. The correlation was not strong ($r = 0.49$) with low R^2 value (0.24), but it can be used to describe the pattern.

The significant difference in mean salinity for the three (3) seagrass areas consistent with the seagrass diversity, but did not match up with the biomass of the seagrass in the area. Located at the upper stream, Tanjung Surat (S4) has the lowest mean salinity (28.45 ppt) and has the lowest seagrass diversity (only *Halophila ovalis* was found) and the lowest DW biomass; could agreed with Hillman et al. (1995) who concluded that the extent *of Halophila ovalis* upstream could be corresponded to the changeover point from the salinity regime of the estuarine basin to that of the upper estuary. Tanjung Kopok (S3), which is located nearer to the sea recorded a higher mean salinity (29.03 ppt) while Pasir Gogok (S5) which located at more nearly to the sea (please refer the map in Figure 3.1, page 31) has the highest mean salinity (31.21 ppt). A little contradict when S3 demonstrates the greatest value in DW biomass compared to S5 which has the highest number of seagrass species (with the present of *Enhalus acoroides*), but fails to agree with previous study. However, salinity was not the only factor in determining productivity and biomass of seagrasses, when light was considered the more important factor controlling growth (Hillman et al., 1995).

Conductivity and salinity are related to the concentration of total dissolved (as opposed to suspended) solids (TDS) in water. Salinity is a measure of the amount of salt dissolved in water. TDS is approximately equal to salinity. Since the conductivity recorded for all study sites showed exactly the same pattern with salinity, result and discussion for salinity were also applied for conductivity.

4.7.5 Light

It is recognized that the quantity of light required by seagrasses is high in comparison to other marine and terrestrial flora (Dennison et al., 1993; Duarte, 1991) because of their extensive belowground roots and rhizomes (Fourqurean et al., 2003). Estimates of light requirements of seagrasses differ between species (e.g., 4.4 and to 29% of surface light) and within a species (e.g. 5 to 20% of surface light) (Dennison et al., 1993) while an average requirement of seagrasses as a group of plants has been calculated to be 11% of surface light (Duarte, 1991).

There are three (3) parameters in this study which can be used to exhibit the condition of light/water clarity in the seagrass area i.e. total suspended solid (TSS), secchi depth and light. TSS data from the DOE significantly isolated S1 and S2 from the seagrass area (S3, S4 and S5), where the values for both sites were very much higher. This finding obviously agrees with many literatures (Shepherd et al., 1989; Giessen et al., 1990; Abal and Dennison, 1996) that conclude TSS was higher in the unvegetated area than in the seagrass colonized site. Moreover, Stulang Laut (S1) and Pasir Gudang (S2) are well known as a place with busy water activities, port and shipping. Between the seagrass areas, TSS and light gave a consistent variation while secchi depth readings deviated a bit. With reference to the correlation of secchi depth and TSS before which was very weak (r = 0.21), secchi depth readings might not be suitable to discussed. However, results/data for all the three (3) parameters illustrated that S4 was the most turbid site, and S3 has the lowest TSS value with the most intense light.

The above findings also support the results for correlation analysis between DW biomass and TSS/secchi depth/light. DW biomass shows a negative correlation with TSS and secchi depth and has a positive correlation with light intensity. S3 which has the best water clarity exhibit the highest DW biomass, whereas S4 which has the most turbid water exhibit the lowest DW biomass and species diversity. Once again the present of *Enhalus acoroides* with two (2) other species in S5 attracted attention where a same condition was noticed in Banten Bay, West Java by Kiswara et al. (2005). *E. acoroides* is able to cope with low light conditions (secchi depth was as times as low as ca. 50cm), and where the water column is more transparent, *Enhalus* is also found, but in communities with other seagrass species. As for *Halophila ovalis*, the species in Malaysia exhibit morphological variability particularly in the leaves in response to the different environmental factors in the various habitats (Annaletchumy et al., 2005). Annaletchumy et al. (2005) found that at deeper depths, turbid water and muddy substrate, leaves of *H. ovalis* are elongated in shape and with longer petiole length.

With these variants and other tolerances, the present of *H. ovalis* in all of the seagrass-vegetated sites in the study area can be understood and not an issue anymore.

4.7.6 Nutrient

The typically clear, warm, and low-nutrient waters of tropical seas, together with the predominantly carbonate nature of the sediments where tropical seagrasses grow, led to consider seagrass growth to be nutrient-limited in these environments (Short, 1987). In most cases, nitrogen and phosphorus are nutrients that are the limiting factors for plant growth; however excessive nutrient loads will lead to eutrophication which is not good for macrophytes including seagrasses.

Data for ammonia and nitrate not vary much between sites. Ammonia and nitrate exceed the AMWQC standard at all sites except for S3; and S2 and S3 respectively. Total nitrogen (TN) were more important when it shows a significant different between the seagrass areas (which has a higher value) and the areas without seagrass. TN value between seagrass areas were consistent with the species diversity in the area, where S5 which has the highest TN value exhibit the highest number of species, thus S4 which has the lowest TN value exhibit only one species in the area. The existent of *Enhalus acoroides* in S5 might be because it is more prone than other tropical seagrasses to nutrient limitation (Terrados et al., 1999). However, the extent of nutrient limitation of *E. acoroides* showed high variability both in space and time which cannot be directly linked with differences in light or nutrient availability among the study sites (Terrados et al., 1999).

While DW biomass have a weak negative correlation with ammonia (r = - 0.51) and nitrate (r = -0.36), it display an astonishing strong positive correlation with TN (r = 0.94). The positive correlation between biomass and TN is consistent with a study by

Short (1987) that nutrients are one of the environmental factors controlling the primary productivity of seagrass meadows.

4.7.7 Heavy Metal

The role of anthropogenic pollutants in the decline of seagrass distribution and biomass is poorly understood (Short and Wyllie-Echeverria, 1996). As the major anthropogenic contaminants of estuaries, heavy metals should be of considerable concern to coastal resource managers. Mechanisms of accumulation and the contribution of seagrasses to heavy metal cycling have been documented by many studies, but less is known about the physiological effects of heavy metal accumulation (Macinnis-Ng and Ralph, 2002).

The only heavy metal that gives significant result was Cuprum (Cu). Cuprum exceeded the AMWQC in all sites, while according to IMWQS (which set the standard at higher value) Cu in all seagrass sites was still acceptable. Even though the impact of heavy metal on seagrass is not much comprehend, but the higher and 'untolerable' value exhibit in the area without seagrass indicates that it is abysmal for the survival of seagrass. Cuprum gives a strong negative correlation with DW biomass ($r = -0.98$) as expected, because one of the impact of heavy metals is on the photosynthetic apparatus of seagrasses. Ralph and Burchett (1998) demonstrated that the stress response was dependant on the particular heavy metal. Photosynthesis was most affected by Cu and Zn and least affected by Cd and Pb. While metals can disrupt the function of the photosynthetic apparatus, permanent damage may not necessarily occur.

4.8 Results for Geodatabase

Final geodatabase that has been build for this study is as Figure 4.9. All data that have been import into database (SEAGRASS.mdb) can be extracted if user needs it by exporting it into table, vector or raster data. Example of table data is the Field_biomass_ table.

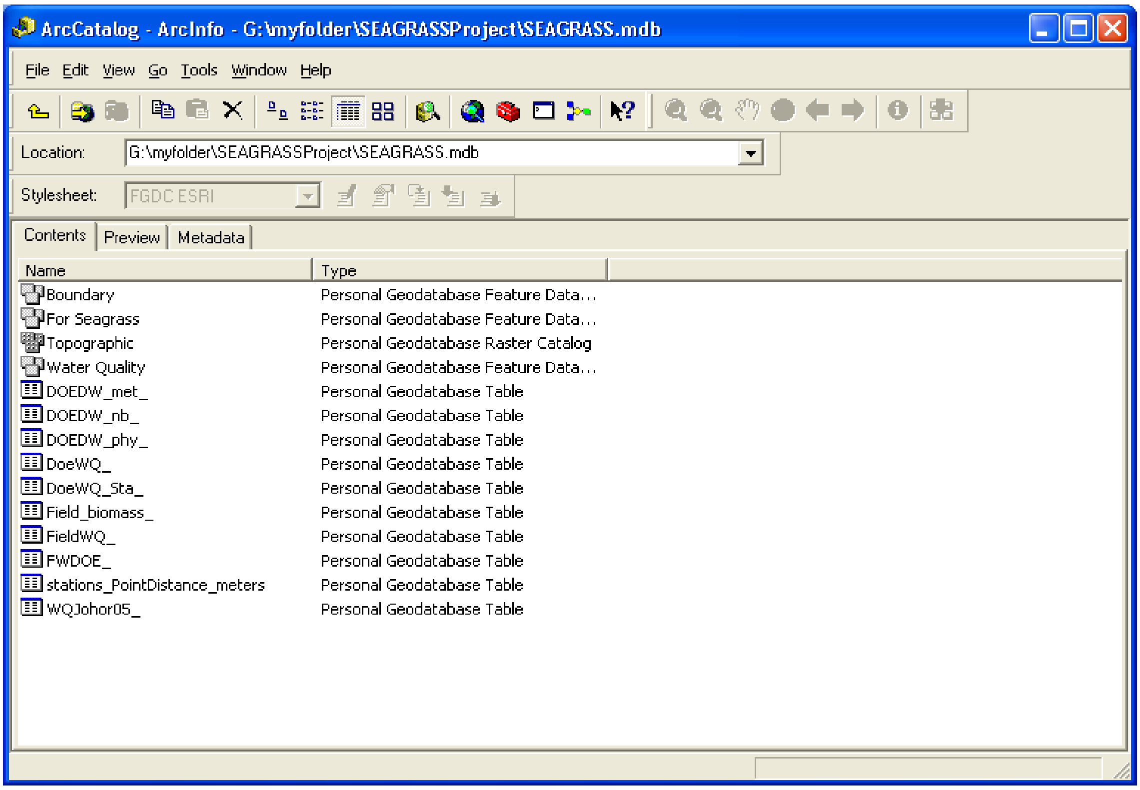


Figure 4.9: Seagrass database at SEAGRASS.mdb

Database users commonly manage geodatabase using ArcCatalog, where one can view and edit the content of the geodatabase. Within ArcCatalog interface, by clicking the desired table, users enable to export it to selected format in .dbf or .xml. Figure 4.10 shows the table data was exported into .dbf format.

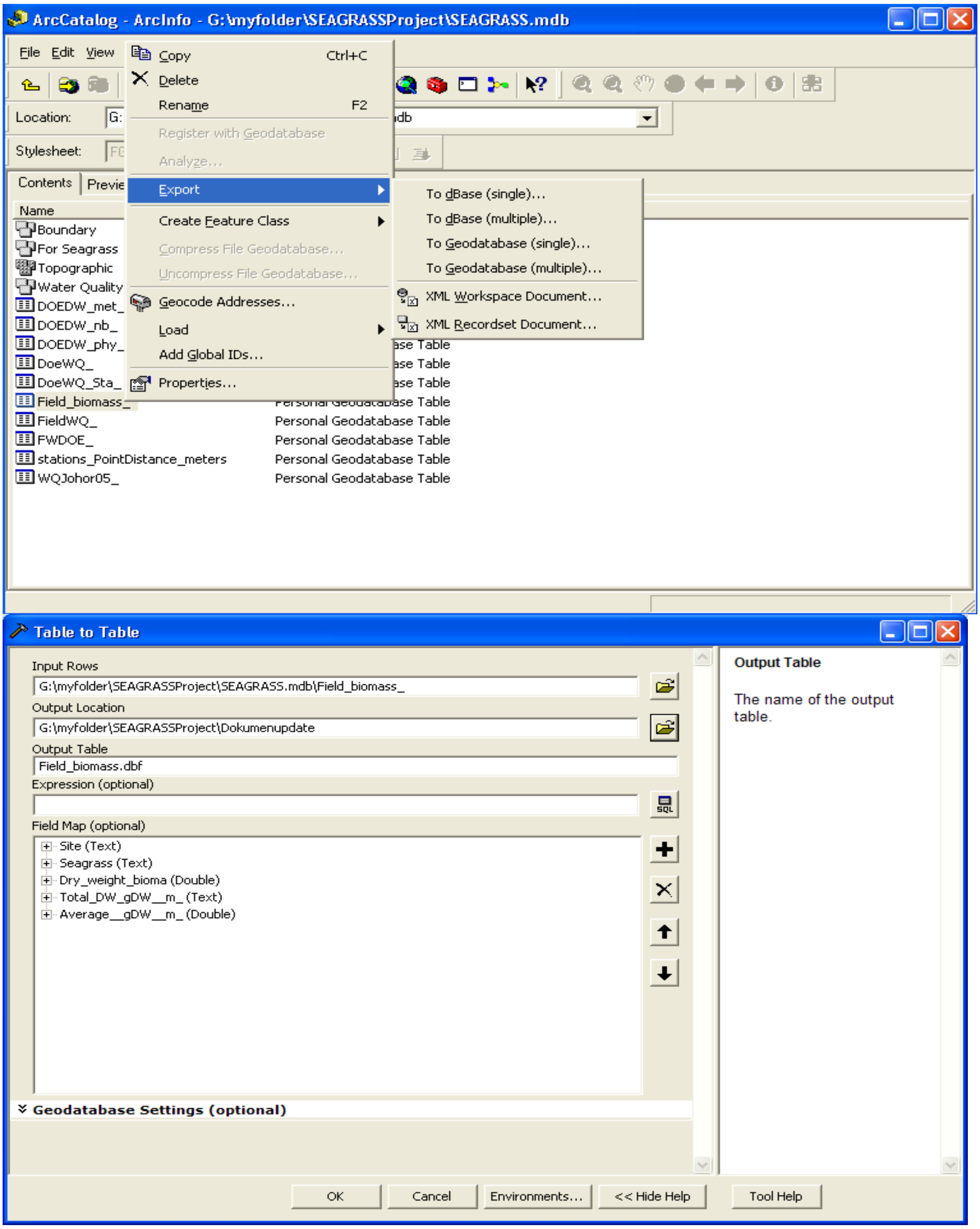


Figure 4.10: To export Table Data into .dbf format

Export output for Field_biomass is as Figure 4.11 (a), 4.11 (b), 4.11 (c), 4.11 (d) and 4.11 (e). Dbf format can be view using ArcCatalog or Microsoft Excel.

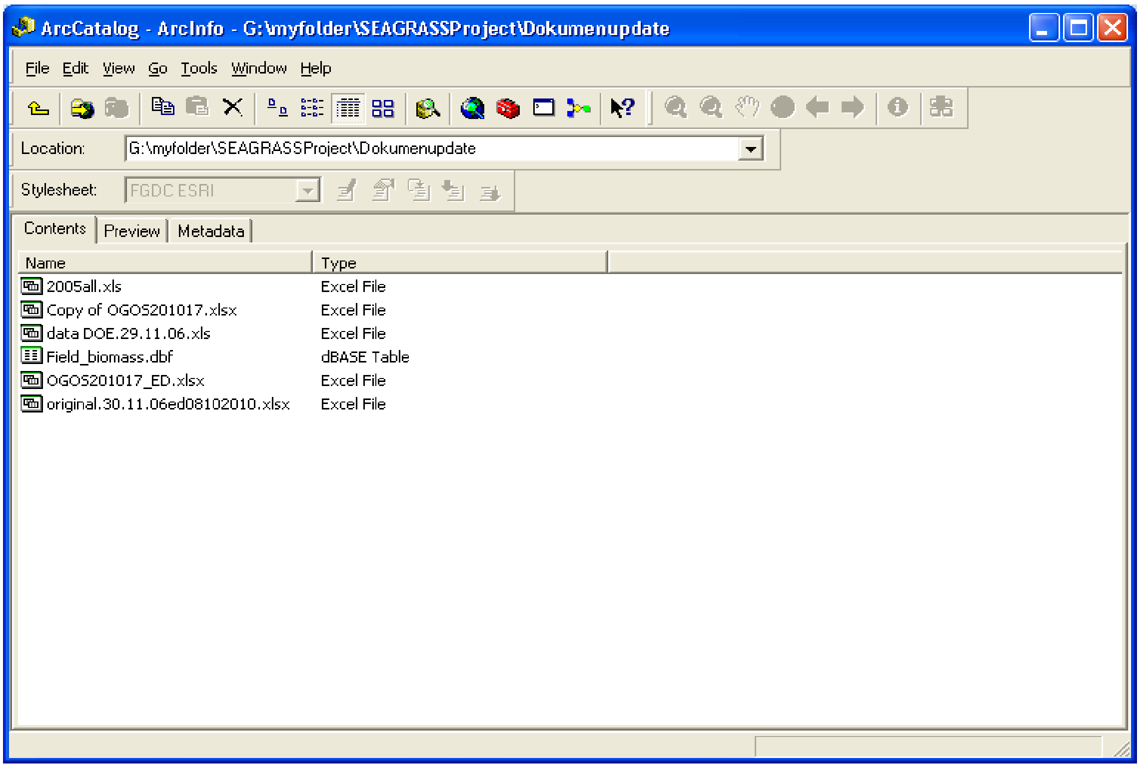


Figure 4.11 (a): Export Output: Field_biomass in .dbf format.

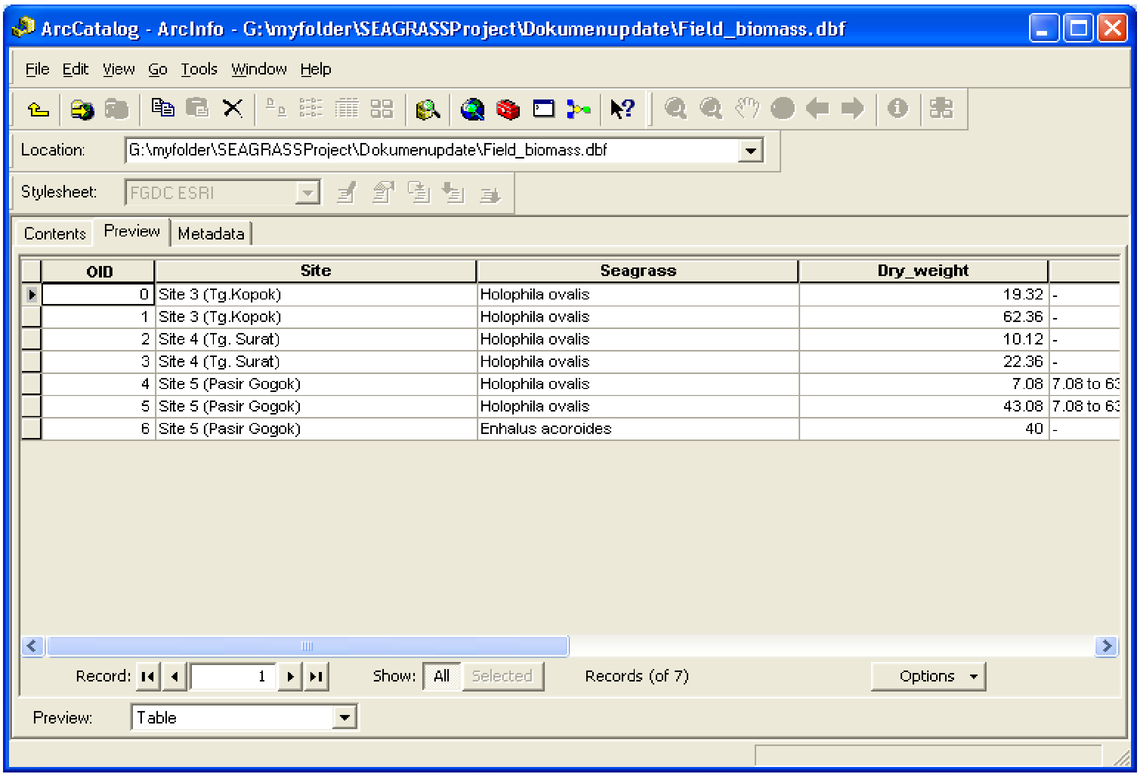


Figure 4.11 (b): Export Output: Field_biomass data preview in ArcCatalog

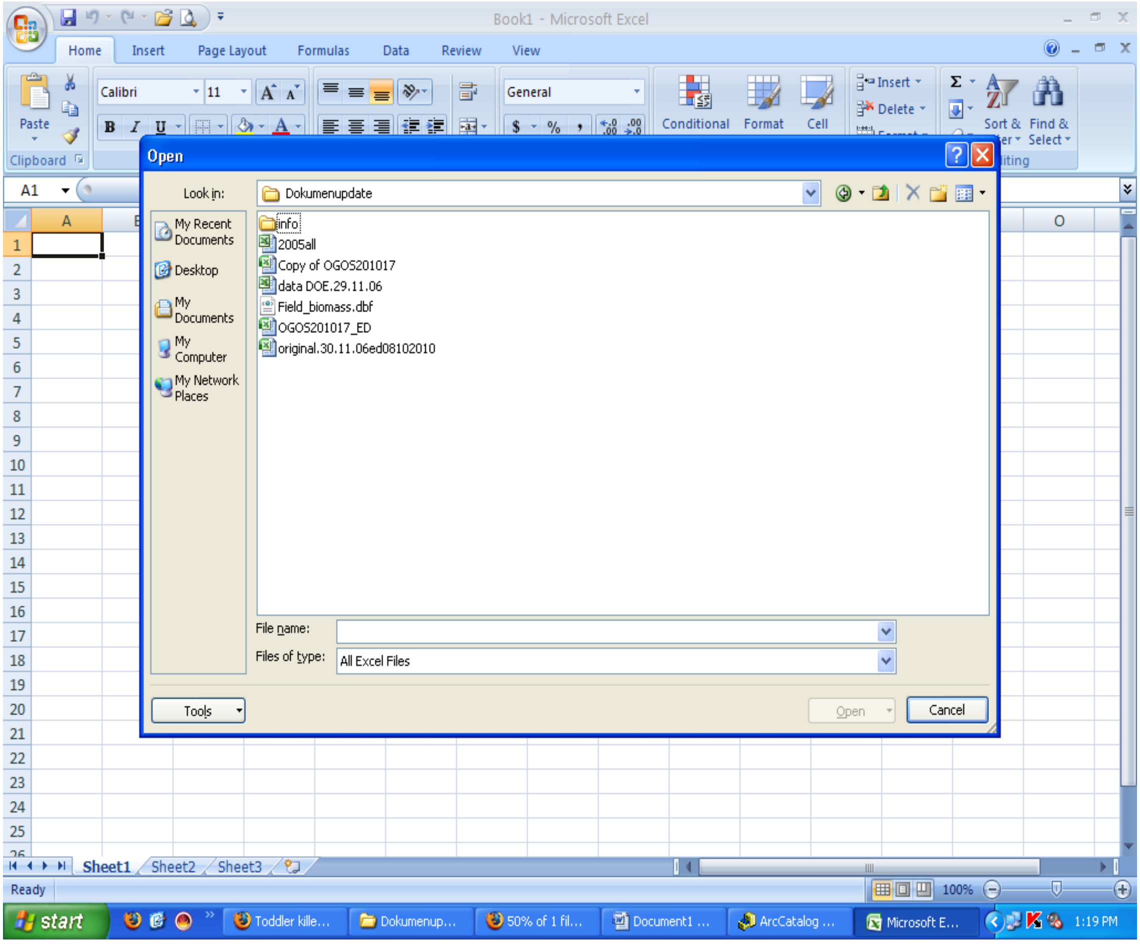


Figure 4.11 (c): To Open Field_biomass database through Excel

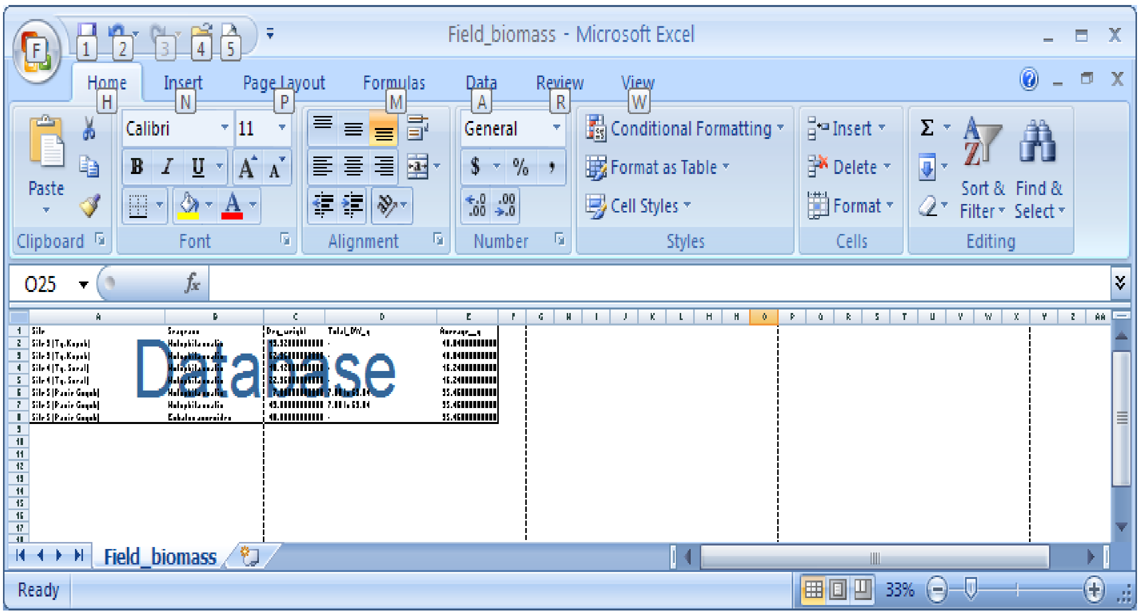
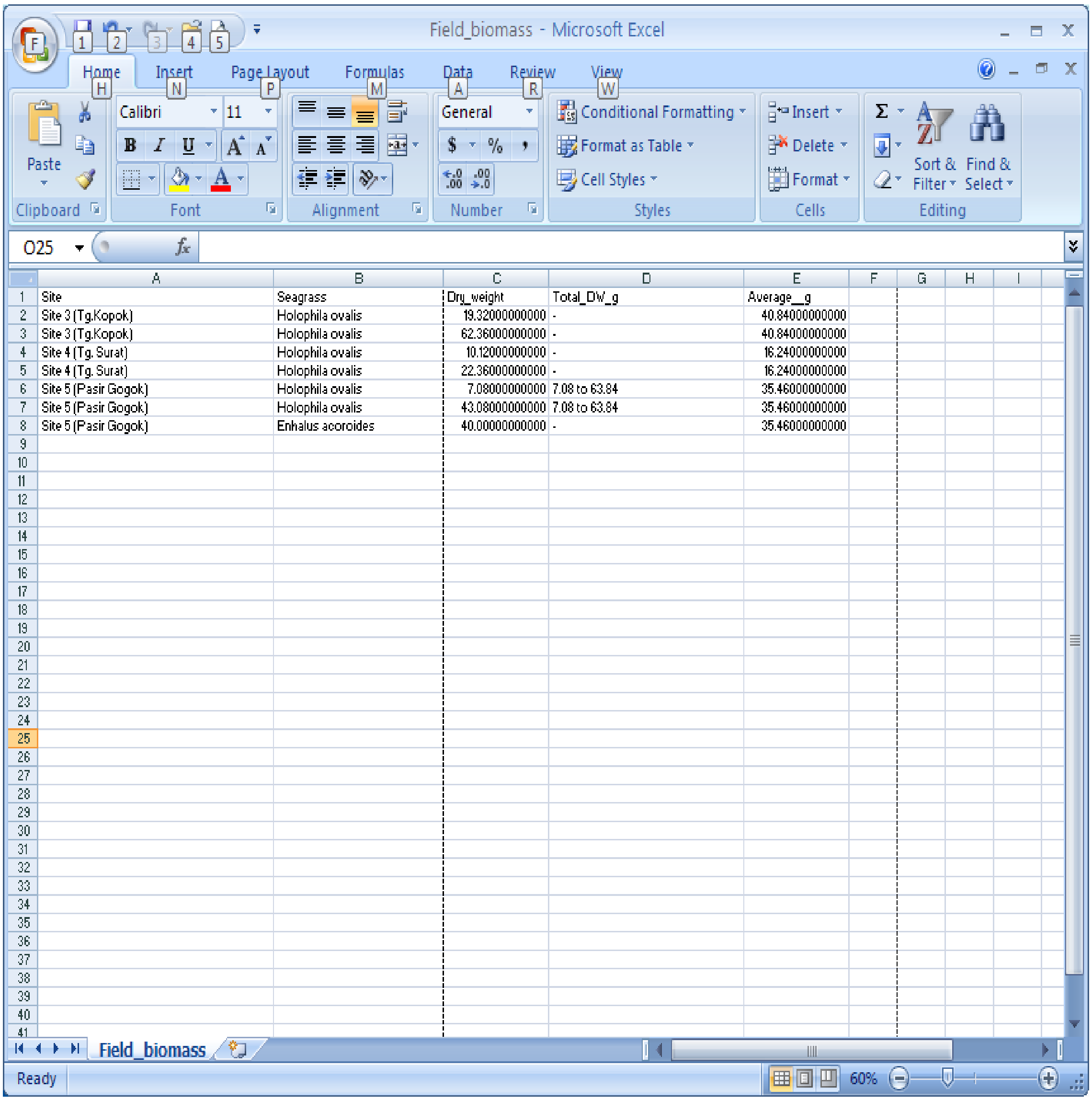


Figure 4.11 (d): Field_biomass Output database through Excel



Site	Seagrass	Dry_weight	Total_DW_g	Average__g
Site 3 (Tg.Kopok)	Holophila ovalis	19.32000000000	-	40.84000000000
Site 3 (Tg.Kopok)	Holophila ovalis	62.36000000000	-	40.84000000000
Site 4 (Tg. Surat)	Holophila ovalis	10.12000000000	-	16.24000000000
Site 4 (Tg. Surat)	Holophila ovalis	22.36000000000	-	16.24000000000
Site 5 (Pasir Gogok)	Holophila ovalis	7.08000000000	7.08 to 63.84	35.46000000000
Site 5 (Pasir Gogok)	Holophila ovalis	43.08000000000	7.08 to 63.84	35.46000000000
Site 5 (Pasir Gogok)	Enhalus acoroides	40.00000000000	-	35.46000000000

Figure 4.11 (e): Preview of Field_biomass Output database through Excel

All data was export using the same ways as above. By using the database, users can retrieved data anytime they need it and in desired format. The format provided by ArcGis is a common format that been used around the world.

4.9 Discussion on the Usage of GIS in Coastal Management

One of the most persistent and pervasive buzzwords in the field of GIS is "integration". Integration, in a GIS context, is the synthesis of spatial and non-spatial information, within the framework of coherent data model, and a definition of the linkages between different data sets. GIS makes it possible to integrate different kinds of geographic information, such as digital maps, aerial photographs, satellite images and global positioning system data (GPS), along with associated tabular database information (e.g., 'attributes' or characteristics about geographic features).

With GIS, all of this information can be incorporated into a single system and execute common database operations. GIS allows statistical analysis or spatial queries to be performed on the data of, to explore 'what-if' scenarios, and to create predictive models. This involves the bringing together of diverse information from the variety of sources, requiring effective matching of similar entities and demanding information consistency across the data sets. By performing operations across sets of information in tandem, a far richer set of questions can be answered and a far broader range of problems can be solved than in the systems that handle just attribute or spatial data alone.

These specialties will allow planners and decision makers to examine and analyze geographic information at different levels of detail or from different perspectives. Then, it enables us to customize the display of the maps and analysis for presentation to particular audiences.

4.9.1 Utilizing the Geographic Database

The GIS has two (2) distinct utilization capabilities, the first pertaining to querying and obtaining information and the second pertaining to integrated analytical modeling (Burrough and McDonnell, 1998). However, both of these capabilities depend upon the core of the GIS database that has been organized. Many a GIS utilization has been limited because of improper database organization. The importance of the GIS database stems from the fact that the data elements of the database are closely interrelated and thus need to be structured for easy intergration and retrieval. In a GIS domain, these considerations are more pertinent because of the varied types and nature of data that need to be organized and stored.

The geographic database (GDB) or geodatabase is the native data structure for ArcGIS and is the primary data format used for editing and data management. It’s embedded in GIS to facilitate storage and retrieval of data collections. Exploiting the GDB satisfies the needs of several complementary end uses, which themselves have implications for the reality model and therefore the nature of the GDB. The utilization procedures are tightly linked to the tasks to be accomplished using the GIS. They can be organized into three categories i.e. spatial inventory, spatial analysis and spatial management as shown in Figure 4.12 (Caloz and Collet, 1997).

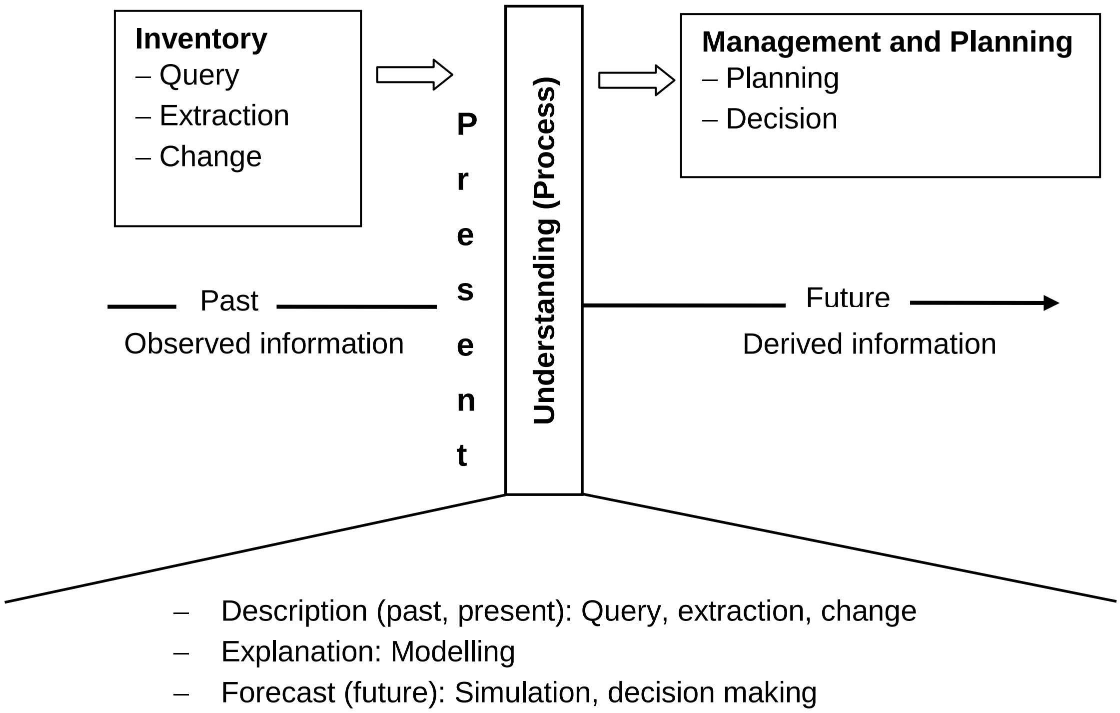


Figure 4.12: Contexts for exploiting the geodatabase in a GIS

One can see that in terms of software, GIS in object structure most effectively accomplishes the tasks of spatial inventory. For spatial analysis, two (2) levels can be identified i.e. describing the spatial distribution of the phenomena's characteristics and modelling their interactions (spatial processes). Finally for spatial management, GIS provide a favourable environment for designing development scenarios for the future as the functions of the data on the past and present reality were understood earlier.

GIS forms an important tool for the management of critical habitats such as seagrass beds, mangroves, coral reefs and wetland. Most of these habitats have become very vulnerable to intense human activities resulting in the loss of unique ecosystems. In response to the loss of seagrass-dominated ecosystems worldwide, a proper management of these systems has become a priority and GIS would be the most useful tool for it. Development of task oriented GIS enables identifying and prioritizing areas and resources at risk on which management actions need to be taken. It also serves as baseline information for monitoring and/or protection. Spatial analysis in GIS will be able to make well-informed policy recommendations on issues such as landuse, upland and coastal activities, delineation of core zones for preservation, etc. The responsible government agencies should take the responsibility of capacity building and create an integrated coastal and marine area management which includes critical habitat information system as part of GIS, to be used by the stake holders in making related decisions.