

3. Seabed characteristics

The physical characteristics of the seabed were assessed from two replicate samples taken at each station. The 2010 replicate sediment properties are summarised in Table 3.1. PSA histograms and cumulative curves are given in appendix 3.

Table 3.1 Physical Properties Chirag Benthic survey 2010

Station Number	Rep	Mean diameter μm	Carbonate %	Organic %	Silt-Clay %	Silt %	Clay %	Wentworth scale	Sorting index
1	1	737	70	1.34	9	4	5	Coarse sand	Very poor
	2	1208	73	1.78	9	5	3	Very coarse sand	Very poor
2	1	684	65	2.00	13	7	6	Coarse sand	Extremely poor
	2	639	53	2.88	21	15	6	Coarse sand	Extremely poor
7	1	833	58	2.41	17	9	8	Coarse sand	Extremely poor
	2	20	25	4.13	81	48	33	Medium silt	Extremely poor
8	1	2054	75	1.94	5	4	1	Granule	Poor
	2	1415	74	2.39	7	3	4	Very coarse sand	Very poor
9	1	836	62	2.29	12	6	6	Coarse sand	Extremely poor
	2	1101	71	1.97	12	6	6	Very coarse sand	Very poor
15	1	884	66	2.39	12	7	6	Coarse sand	Extremely poor
	2	2386	62	3.25	6	4	2	Granule	Poor
16	1	2721	78	2.42	5	4	1	Granule	Poor
	2	1242	69	2.69	7	3	4	Very coarse sand	Very poor
25	1	919	65	2.32	15	7	7	Coarse sand	Extremely poor
	2	2485	68	2.93	6	3	3	Granule	Poor
33	1	1467	61	2.97	12	8	4	Very coarse sand	Extremely poor
	2	957	65	2.43	14	8	7	Coarse sand	Extremely poor
34	1	72	27	2.87	46	27	18	Very fine sand	Extremely poor
	2	158	34	2.40	34	23	11	Fine sand	Extremely poor
35	1	1525	74	1.94	10	7	3	Very coarse sand	Very poor
	2	1018	64	2.90	13	6	7	Very coarse sand	Extremely poor
36	1	263	50	2.48	39	33	5	Medium sand	Extremely poor
	2	94	38	3.95	47	24	23	Very fine sand	Extremely poor
37	1	777	67	1.95	9	5	3	Coarse sand	Very poor
	2	705	47	4.21	15	11	4	Coarse sand	Extremely poor
38	1	70	44	2.09	58	33	25	Very fine sand	Extremely poor
	2	34	40	2.92	62	6	56	Coarse silt	Extremely poor
39	1	482	68	2.01	11	6	5	Medium sand	Very poor
	2	898	69	2.46	15	7	8	Coarse sand	Extremely poor
40	1	565	57	2.84	22	15	7	Coarse sand	Extremely poor
	2	836	74	1.27	7	3	4	Coarse sand	Very poor
41	1	1979	60	3.47	8	5	4	Very coarse sand	Very poor
	2	1046	63	2.68	10	5	5	Very coarse sand	Very poor
42	1	37	29	3.54	67	38	29	Coarse silt	Extremely poor
	2	61	36	5.00	61	32	28	Coarse silt	Extremely poor
43	1	19	30	4.50	77	38	39	Medium silt	Extremely poor
	2	14	25	4.32	84	41	43	Fine silt	Very poor
44	1	70	37	3.05	57	33	24	Very fine sand	Extremely poor
	2	8	19	3.43	93	43	50	Fine silt	Poor

Table 3.1 (Continued) Physical Properties Chirag Benthic survey 2010

Station Number	Rep	Mean diameter μm	Carbonate %	Organic %	Silt-Clay %	Silt %	Clay %	Wentworth scale	Sorting index
45	1	54	39	3.59	63	33	30	Coarse silt	Extremely poor
	2	104	37	3.70	52	28	24	Very fine sand	Extremely poor
46	1	674	61	3.65	18	13	5	Coarse sand	Extremely poor
	2	1227	55	3.38	14	8	6	Very coarse sand	Extremely poor
47	1	1136	74	1.89	11	5	6	Very coarse sand	Very poor
	2	1529	73	2.62	9	7	3	Very coarse sand	Very poor
48	1	1329	78	1.83	8	3	5	Very coarse sand	Very poor
	2	1060	72	2.15	11	5	6	Very coarse sand	Extremely poor
49	1	56	39	4.41	58	31	26	Coarse silt	Extremely poor
	2	1326	69	2.02	16	13	3	Very coarse sand	Extremely poor
50	1	22	27	3.44	77	44	33	Medium silt	Extremely poor
	2	146	41	3.11	39	24	15	Fine sand	Extremely poor
51	1	833	59	3.06	18	17	1	Coarse sand	Extremely poor
	2	124	45	3.14	43	26	16	Very fine sand	Extremely poor
52	1	428	64	1.86	16	8	8	Medium sand	Extremely poor
	2	15	27	3.97	81	43	38	Fine silt	Very poor
53	1	221	44	6.34	38	28	10	Fine sand	Extremely poor
	2	18	47	2.41	79	43	36	Medium silt	Very poor
54	1	87	42	2.83	53	33	20	Very fine sand	Extremely poor
	2	139	46	2.73	43	18	25	Fine sand	Extremely poor
55	1	1079	63	1.68	12	6	5	Very coarse sand	Very poor
	2	825	67	2.47	12	8	3	Coarse sand	Very poor
56	1	46	23	3.56	67	39	28	Coarse silt	Extremely poor
	2	19	24	2.65	79	50	29	Medium silt	Very poor
57	1	13	21	4.80	88	44	44	Fine silt	Very poor
	2	617	56	3.20	19	9	10	Coarse sand	Extremely poor
Minimum		8	19	1.27	5	3	1		
Maximum		2721	78	6.34	93	50	56		
Median		679	58	2.78	17	9	7		
Mean		704	53	2.90	32	18	14		
Std Deviation		675	17	0.94	27	15	14		
% CV		96	33	33	84	82	97		

Initial examination of the replicate data indicates variation in sediment structure within and between stations. Classification ranged from fine silt to granule, with the majority of samples being classified as containing coarse to very coarse sand and granule. The sediments throughout the survey area were poorly to extremely poorly sorted, indicating that they contained substantial proportions of a wide range of particle sizes.

The greatest within station variation was observed at stations 57, 52, 7, 49, 53, 50, 44 and 51. This is illustrated on the cumulative PSA % curves in appendix 3b.

Replicate mean diameter ranged from $8\mu\text{m}$ at station 44R2 to $2,721\mu\text{m}$ at station 16R1. The median and mean values were 679 and $704\mu\text{m}$ respectively and the variation coefficient was high at 96%.

Silt and clay content ranged from 5% at station 8R1 & 16R1 to 93% at station 44R2. The respective median and mean values were 17 and 32% and the %CV was high at 84.

Carbonate content ranged from 19% at station 44R2 to 78% at station 48R1 with a median and mean of 58 and 53% and a CV of 33%. A similar %CV was observed for organic content which ranged from 1.27% at station 40R2 to a maximum of 6.34 at station 53R1 with median and mean values of 2.78 and 2.9 respectively.

3.1. Relationship between Sediment Characteristics

The relationship between sediment characteristics was tested by a Pearson's *r* correlation analysis of replicate results. The correlation coefficients are given in table 3.2.

High correlation coefficients have been indicated between mean diameter and carbonate content, which will likely be due to coarser grained sediment being made up of a high proportion of broken down shell material.

Organic content is shown to be related to the silt and clay content and will likely be the result of the higher adsorption capacity of finer grained silt and clay sediments.

Table 3.2 Pearson's *r* Correlation Coefficients of Replicate Sediment Characteristics; Chirag Benthic survey 2010

	<i>Mean diameter</i>	<i>Carbonate</i>	<i>Organic</i>	<i>Silt/Clay</i>	<i>Silt</i>	<i>Clay</i>
Mean diameter	1					
Carbonate	0.79	1.00				
Organic	-0.41	-0.67	1.00			
Silt/Clay	-0.78	-0.93	0.58	1.00		
Silt	-0.76	-0.91	0.58	0.95	1.00	
Clay	-0.72	-0.85	0.52	0.95	0.80	1.00

3.2. Spatial Distribution of Sediment Characteristics

The spatial distribution of Mean Particle size μm , % Silt & Clay, % Carbonate and % Organic Matter content are illustrated in the contour diagrams in figure 3.2. These have been created using the mean values for the parameter at each station which are given in table 3.3. Due to the difference between replicate values at a number of stations the confidence limit of the mean values at these stations will be higher.

Table 3.3 Station Average Physical Properties Chirag Benthic survey 2010

Station	Mean diameter μm	Carbonate %	Organic %	Silt-Clay %	Silt %	Clay %
1	973	71	1.6	9	5	4
2	661	59	2.4	17	11	6
7	427	41	3.3	49	28	20
8	1735	74	2.2	6	3	3
9	968	67	2.1	12	6	6
15	1635	64	2.8	9	5	4
16	1981	74	2.6	6	4	2
25	1702	67	2.6	10	5	5
33	1212	63	2.7	13	8	5
34	115	30	2.6	40	25	14

Table 3.3 Continued Station Average Physical Properties Chirag Benthic survey 2010

Station	Mean diameter μm	Carbonate %	Organic %	Silt-Clay %	Silt %	Clay %
35	1271	69	2.4	11	6	5
36	178	44	3.2	43	29	14
37	741	57	3.1	12	8	4
38	52	42	2.5	60	20	40
39	690	68	2.2	13	6	7
40	701	65	2.1	14	9	5
41	1513	62	3.1	9	5	4
42	49	33	4.3	64	35	29
43	17	27	4.4	81	40	41
44	39	28	3.2	75	38	37
45	79	38	3.6	57	31	27
46	951	58	3.5	16	10	5
47	1332	74	2.3	10	6	4
48	1194	75	2.0	10	4	5
49	691	54	3.2	37	22	15
50	84	34	3.3	58	34	24
51	479	52	3.1	30	22	9
52	222	46	2.9	49	26	23
53	119	46	4.4	59	36	23
54	113	44	2.8	48	26	22
55	952	65	2.1	12	7	4
56	33	24	3.1	73	44	28
57	315	38	4.0	54	27	27

Examination of the contour plots in figure 3.1 indicates a relatively patchy distribution of all individual characteristics. As observed on previous surveys a triangular area within stations 55 (1200m NE), 8 (500m S) and 16 (1500m SE) generally has a higher mean particle size and lower silt-clay content. Stations to the west of this area, in general, have a higher silt and clay content. However, contiguous stations 37 and 9 directly to the WNW and W, station 1 and 2 directly to the north and station 48, 800m SW of the platform, exhibit opposite characteristics, with coarse grained sediments with a low silt and clay content.

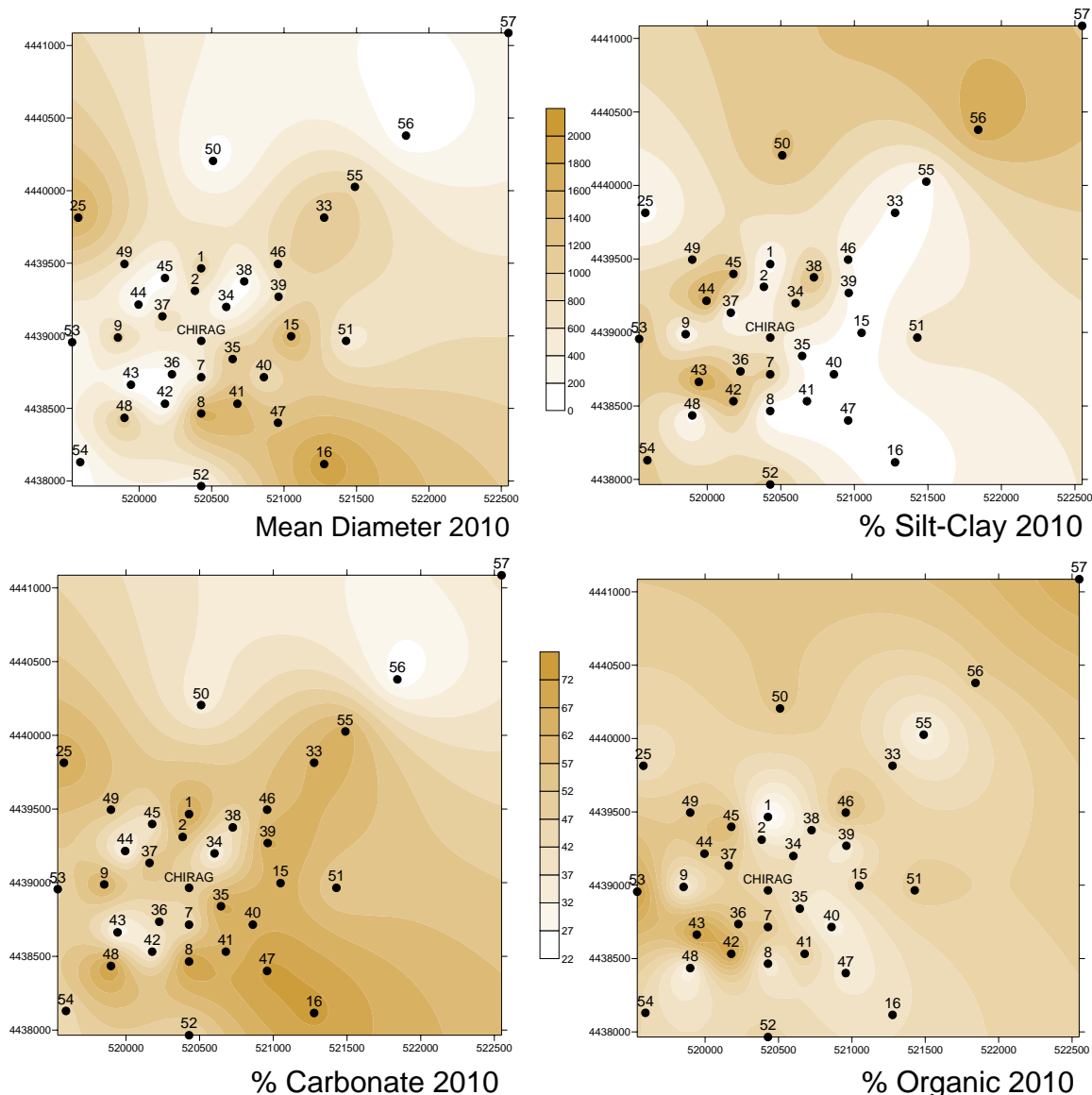


Figure 3.2 Spatial Distribution of mean sediment Characteristics; Chirag Benthic Survey 2010

3.3. Comparison to Previous Survey Data

To allow a comparison with previous data the mean value at each station has been used. As previously indicated, there are differences between replicate values at a number of the 2010 stations which will increase the confidence limit of the mean values. It should be noted that within station variation was also prevalent on previous surveys and appears to be a feature of this area.

Table 3.4 gives the time series data for stations that have been sampled on consecutive surveys. The characteristics at the majority of stations have remained relatively similar on each survey. However, variation has been observed between years at a number of stations.

Between 2008 and 2010 sediments have become finer with a higher silt-clay content at station 38, whereas the opposite was observed at station 46 with coarser sediments being present in 2010.

A general trend of reducing mean particle size and increasing silt-clay content has been observed from 2004 at station 54. The inverse has been observed at station 36 with average particle size increasing and silt-clay content reducing on consecutive surveys from 2004.

A finer average sediment structure was observed at stations 2 and 49 in 2008, with the average results from 2010, 2006 and 2004 being relatively similar. The average results have fluctuated consecutively from 2004 at station 7. Poor replicate agreement has been observed at these three stations which will account for the variation between years.

Table 3.4 Station Average Sediment Characteristics, Chirag Benthic Survey 2010 with Comparative Data for Re-sampled Stations

Station	Year	Mean diameter μm	Carbonate %	Organic %	Silt-Clay %	Wentworth Scale Of Station Average Particle Size
1	2010	973	71	1.6	9	Coarse sand
	2008	878	68	2.1	14	Coarse sand
	2006	850	65	2.8	12	Coarse sand
	2004	1726	73	2.9	8	Very coarse sand
	2001	552	65	1.6	19	Coarse sand
	1998	732	70	2.0	20	Coarse sand
2	2010	661	59	2.4	17	Coarse sand
	2008	232	50	3.2	45	Fine sand
	2006	915	57	3.0	13	Coarse sand
	2004	785	60	3.5	20	Coarse sand
	2002	418	50	2.2	25	Medium sand
7	2010	427	41	3.3	49	Medium sand
	2008	12	24	3.7	90	Fine silt
	2006	503	63	2.5	10	Coarse sand
	2004	21	52	4.8	77	Medium silt
8	2010	1735	74	2.2	6	Very coarse sand
	2008	1353	68	2.2	10	Very coarse sand
	2006	731	59	2.8	14	Coarse sand
	2004	791	65	4.2	13	Coarse sand
	1998	908	72	1.4	6	Coarse sand
9	2010	968	67	2.1	12	Coarse sand
	2008	948	68	1.6	14	Coarse sand
	2006	199	51	3.0	34	Fine sand
	2004	94	34	6.0	45	Very fine sand
	2000	229	62	1.5	29	Fine sand
	1998	113	44	3.2	43	Very fine sand
15	2010	1635	64	2.8	9	Very coarse sand
	2008	609	66	1.8	14	Coarse sand
	2006	842	69	2.8	11	Coarse sand
	2004	1256	72	3.2	10	Very coarse sand
	2000	385	68	1.6	23	Medium sand
	1998	285	65	1.8	24	Medium sand
33	2010	1212	63	2.7	13	Very coarse sand
	2008	1317	63	2.8	9	Very coarse sand
	2006	1299	68	2.2	11	Very coarse sand
	2004	864	73	2.1	13	Coarse sand
	2000	283	53	2.7	26	Medium sand

Table 3.4 Continued Station Average Sediment Characteristics, Chirag Benthic Survey 2010 with Comparative Data for Re-sampled Stations

Station	Year	Mean diameter μm	Carbonate %	Organic %	Silt-Clay %	Wentworth Scale Of Station Average Particle Size
34	2010	115	30	2.6	40	Very fine sand
	2008	144	37	3.0	39	Fine sand
	2006	441	54	3.9	40	Medium sand
	2004	102	42	4.4	52	Very fine sand
35	2010	1271	69	2.4	11	Very coarse sand
	2008	1264	70	1.7	11	Very coarse sand
	2006	1022	65	2.5	17	Very coarse sand
	2004	1152	79	2.4	9	Very coarse sand
36	2010	178	44	3.2	43	Fine sand
	2008	99	42	2.5	53	Very fine sand
	2006	17	30	4.3	79	Medium silt
	2004	114	52	4.2	47	Very fine sand
37	2010	741	57	3.1	12	Coarse sand
	2008	667	59	2.7	11	Coarse sand
	2006	323	30	6.0	33	Medium sand
	2004	472	38	6.1	31	Medium sand
38	2010	52	42	2.5	60	Coarse silt
	2008	419	56	2.3	28	Medium sand
	2006	688	62	2.7	19	Coarse sand
39	2010	690	68	2.2	13	Coarse sand
	2008	680	69	1.6	13	Coarse sand
	2006	49	35	5.8	66	Coarse silt
46	2010	951	58	3.5	16	Coarse sand
	2008	320	51	2.9	30	Medium sand
	2006	440	66	2.7	31	Medium sand
	2004	52	40	3.1	64	Coarse silt
47	2010	1332	74	2.3	10	Very coarse sand
	2008	1193	77	2.5	11	Very coarse sand
	2006	1157	74	2.5	11	Very coarse sand
	2004	1526	76	3.6	10	Very coarse sand
48	2010	1194	75	2.0	10	Very coarse sand
	2008	1783	79	1.7	9	Very coarse sand
	2006	2009	81	1.4	8	Granule
	2004	890	67	2.8	15	Coarse sand
49	2010	691	54	3.2	37	Coarse sand
	2008	68	39	3.2	60	Very fine sand
	2006	393	62	2.2	23	Medium sand
	2004	357	49	3.5	40	Medium sand
54	2010	113	44	2.8	48	Very fine sand
	2008	246	50	2.1	33	Fine sand
	2006	1640	45	5.1	12	Very coarse sand
	2004	610	70	2.6	17	Coarse sand

Table 3.4 Continued Station Average Sediment Characteristics, Chirag Benthic Survey 2010 with Comparative Data for Re-sampled Stations

Station	Year	Mean diameter μm	Carbonate %	Organic %	Silt-Clay %	Wentworth Scale Of Station Average Particle Size
55	2010	952	65	2.1	12	Coarse sand
	2008	956	54	3.0	40	Coarse sand
	2006	551	56	2.9	11	Coarse sand
56	2010	33	24	3.1	73	Coarse silt
	2008	17	25	3.7	83	Medium silt
	2006	11	23	3.4	91	Fine silt
57	2010	315	38	4.0	54	Medium sand
	2008	83	33	3.8	56	Very fine sand
	2006	308	48	2.5	19	Medium sand

Summary statistics describing sediment characteristics from all surveys carried out around Chirag are given in table 3.5. Direct comparison of these summary statistics is complicated by the fact that, for operational reasons, different sets of stations were analysed in each of the surveys.

Overall the results are very similar. The only difference between 2008 and 2010 is the higher maximum mean diameter of 2721 μm , which exceeds the maximum recorded on all previous surveys.

Table 3.5 Summary Statistics of Replicate Sediment Physical Properties, Chirag Surveys 1998 to 2010

	Year	Mean diameter μm	Carbonate %	Organic %	Silt/Clay %	Silt %	Clay %
Min	2010	8	19	1.3	5	3	1
	2008	8	21	1.1	7	3	4
	2006	11	23	1.4	8	3	4
	2004	21	21	2.0	6	3	1
	2000	8	20	1.5	12	8	3
	1998	18	16	1.4	6	3	3
Max	2010	2721	78	6.3	93	50	56
	2008	1929	87	4.7	97	54	48
	2006	2009	81	6.0	91	57	46
	2004	1921	80	6.4	78	46	35
	2000	1589	68	6.7	95	43	53
	1998	1602	77	10.4	79	63	38

Table 3.5 (Continued) Summary Statistics of Replicate Sediment Physical Properties, Chirag Surveys 1998 to 2010

	Year	Mean diameter µm	Carbonate %	Organic %	Silt/Clay %	Silt %	Clay %
Median	2010	679	58	2.8	17	9	7
	2008	573	59	2.4	17	9	9
	2006	551	59	2.8	17	8	7
	2004	683	67	3.4	16	9	6
	2000	318	53	2.9	35	23	12
	1998	337	57	3.1	30	19	9
Mean	2010	704	53	2.9	32	18	14
	2008	609	54	2.6	33	17	16
	2006	685	55	3.2	27	15	12
	2004	676	60	3.7	28	18	10
	2000	363	50	3.2	40	23	17
	1998	403	52	3.3	34	21	13
CV (%)	2010	96	33	33	84	82	97
	2008	92	33	36	84	88	82
	2006	77	28	38	89	96	96
	2004	88	28	36	81	83	90
	2000	97	28	45	57	46	82
	1998	90	33	55	61	69	69

3.4. Summary

The sediment characteristics around Chirag varied within and between stations. This appears to be characteristic of this location, with large variations in sediment type on a scale of metres (*ie* within stations) to hundreds of metres (between stations) being observed in all six surveys carried out at this location.

Overall the distribution of sediment characteristics in 2010 was relatively patchy, with a generally similar pattern of distribution to that observed in 2008.

Examination of the average time series data indicates finer and coarser sediment characteristics at stations 38 and 46 respectively in 2010, and a general trend of reducing mean particle size and increasing silt-clay content from 2004 at station 54 with the inverse being observed at station 36.