9. Discussion

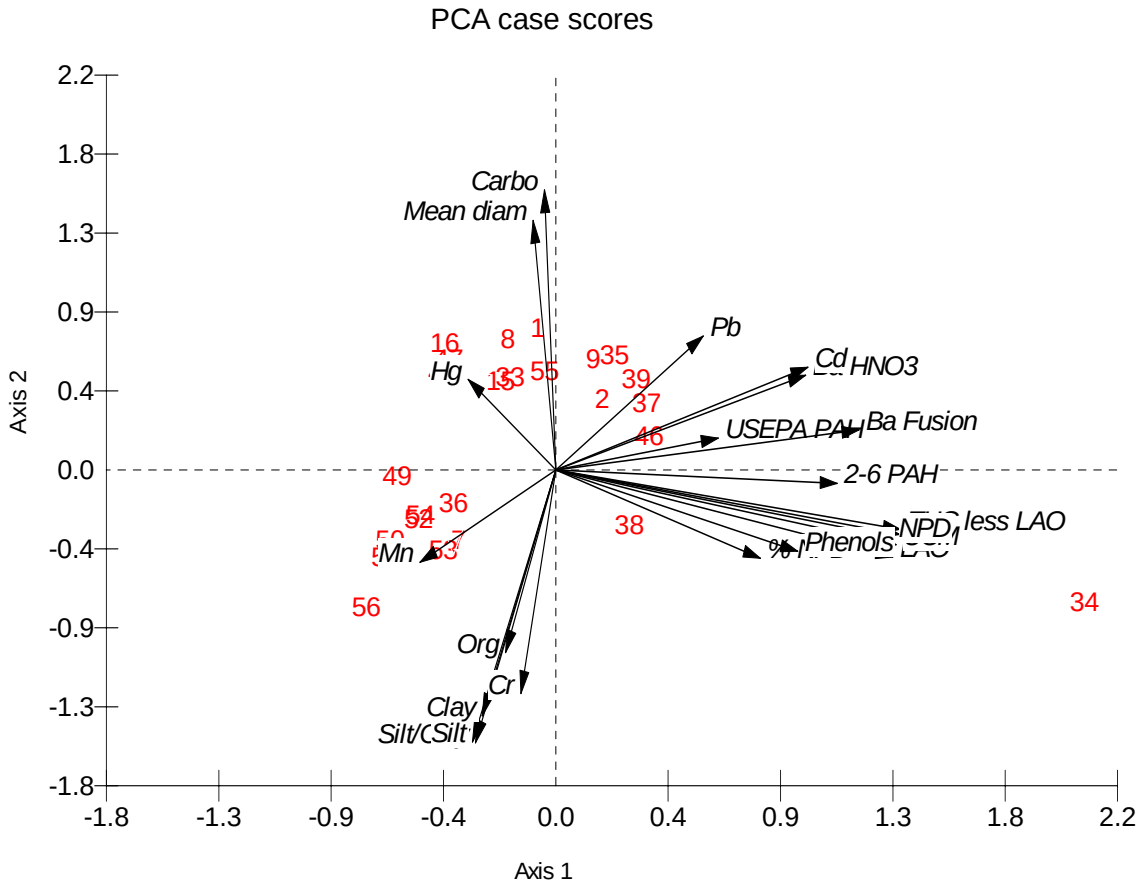
From the preceding sections, it is clear that the Chirag survey stations vary with regard to their physical, chemical and biological characteristics. The interrelationships between the different aspects of the seabed investigated during the survey will be addressed in the following section.

9.1. Physiochemical Environment

The associations between physiochemical parameters were tested by a Pearson's r correlation analysis of replicate data. The results matrix is given in appendix 8.

Moderate positive correlations were indicated for Ba Fusion with THC (0.68) and LAO (0.61). Chromium was moderately positively correlated with sediment silt-clay (0.70) and inversely correlated to mean particle size (-0.66). Weak positive correlations of ~0.50 were given for mean particle size with Hg and Mn.

A Principal Component analysis was carried out on the average physiochemical data using MVSPv3. This analysis produces an ordination plot with vectors representing the association between variables and the ordination of stations being related to the dominance of each of the measured variables at that location. Vectors which are pointing in the same direction are positively correlated, vectors in the opposite direction will be negatively correlated and those at right angles will have no correlation. The ordination plot is given in figure 9.1 and the case scores for axis 1 and 2 are given in appendix 9.



Vector scaling: 4.10

Figure 9.1 PCA Ordination

The PCA ordination indicates that the stations where LAO was detected also had the greatest concentration of Ba and hydrocarbons.

It was observed in chapter 5 that a relationship was present between concentrations of Ba and Cd. This relationship was strongest where Cd and Ba fusion concentrations were below 0.50 and 20,000µg.g^{-1} respectively. The relationship became less apparent as concentrations exceeded these levels and may be due to the presence of additional barite from drilling discharges.

Figure 9.2 below gives the distribution plots for LAO, Ba fusion, THC (Less LAO) and Cd. This indicates the footprint of LAO detection and the area where respective Ba and Cd concentrations exceeding 0.50 and 20,000µg.g^{-1} were recorded.

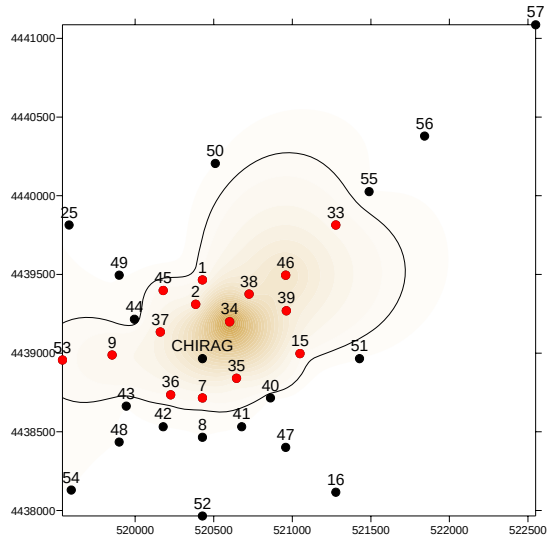
As LAO can only be present from discharged/spilled drilling mud or contaminated drill cuttings, and as barite is a major component of drilling mud, the similarities in the distribution plots suggest that the higher Ba concentrations recorded within the LAO footprint are likely the result of drilling discharges, which may also have resulted in an elevated Cd concentration within this area.

The distribution plot for THC (less LAO) gives the contours for 30 and 50µg.g^{-1}, this gradient is similar to the LAO footprint.

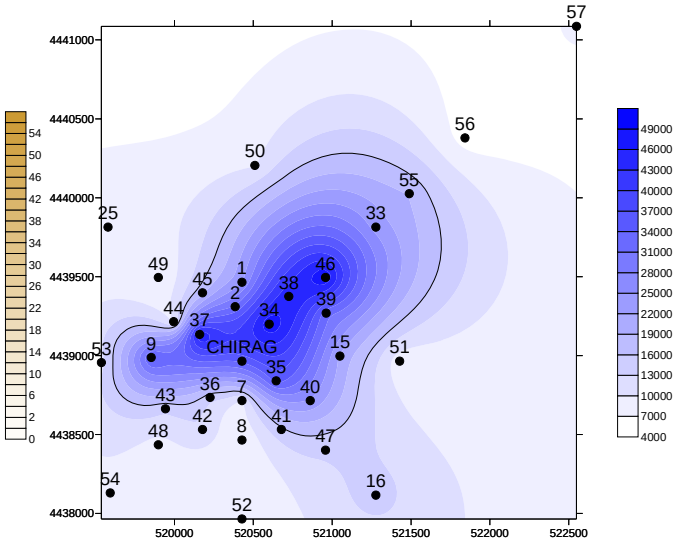
LAO analysis commenced in 2004. The contamination footprint identified in 2004 was similar on subsequent surveys. High hydrocarbon concentrations were also observed within this area in 2004.

Table 9.2 gives the 2004 to 2010 LAO, THC (less LAO), Ba and Cd summary statistics at stations where LAO was initially detected in 2004. Although the LAO detection and hydrocarbon footprints generally remain the same, the time series data indicates that LAO and hydrocarbon concentrations have reduced within this area on all consecutive surveys from 2006, with the 2010 hydrocarbon concentrations being, in general, low throughout.

Despite the reduction of LAO and THC, the concentrations of Ba fusion and Cd have remained relatively constant between 2006 and 2010.



LAO 2010



Ba Fusion 2010

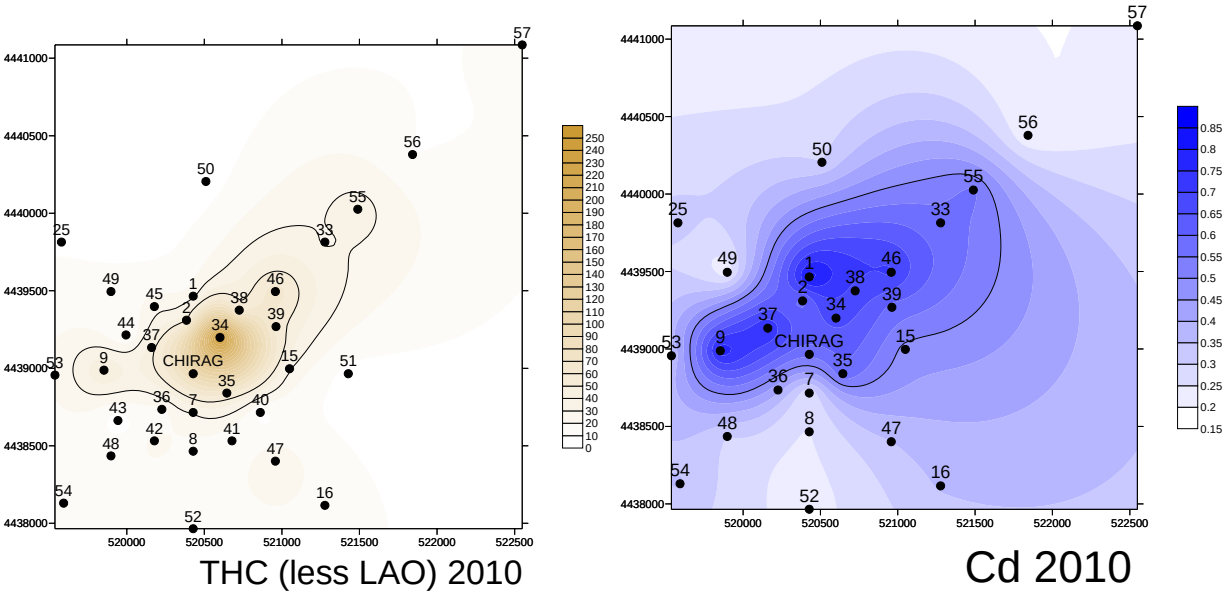


Figure 9.2 LAO, Total Ba & THC (Less LAO) 2010

Table 9.1 Total Ba, Cd, LAO & THC (Less LAO) Summary Statistics 2004 - 2010

	Ba fusion µg.g^{-1}				Cd µg.g^{-1}			
	2004	**2006**	**2008**	**2010**	**2004**	**2006**	**2008**	**2010**
Min	5,865	8,660	6555	9,661	0.17	0.06	0.37	0.23
Max	114,000	64,650	58550	48,809	0.40	0.78	0.76	0.83
Med	22,125	22,375	16750	27,962	0.22	0.52	0.66	0.58
Mean	33,097	25,824	20178	29,512	0.23	0.49	0.63	0.56

	LAO µg.g^{-1}				THC (Less LAO) µg.g^{-1}			
	2004	**2006**	**2008**	**2010**	**2004**	**2006**	**2008**	**2010**
Min	4	1	0	0	36	17	0	4
Max	939	2,336	187	55	1,898	3,430	531	308
Med	28	13	7	4	92	50	44	43
Mean	109	191	17	8	260	317	65	58

9.2. Relationship Between Environmental and Macrobenthic Characteristics

Abundance and species richness were generally higher for all taxonomic groups on the periphery of the survey area which reduced towards the platform. To test the association between physicochemical parameters and the macrobenthic community characteristics, a correlation analysis was carried out on the 1m^2 species abundance data and the DCA case scores with the average physicochemical data and the case scores from the PCA. The results matrix is given in appendix 10.

A moderate positive correlation is given between annelid abundance and mean particle size, and between the CA first axis and hydrocarbon parameters.

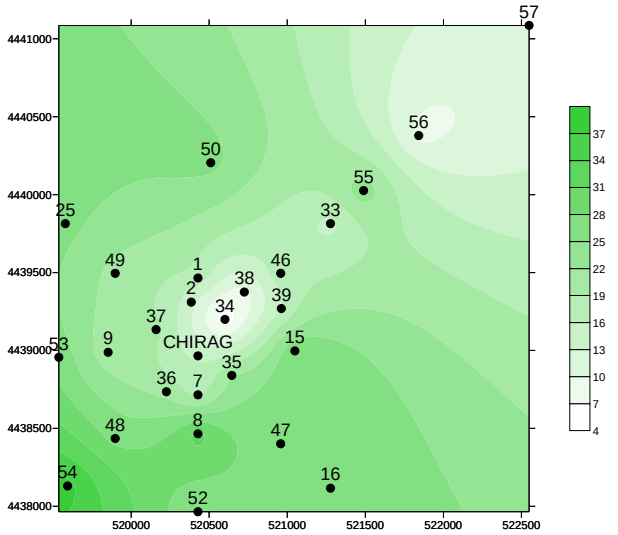
Although weak, the abundance and taxonomic richness data is, in general, positively correlated to mean particle size and the 2nd axis of the PCA analysis (which relates to increasing particle

size), and inversely correlated to silt-clay content, hydrocarbon parameters and the concentrations of Ba and Cd.

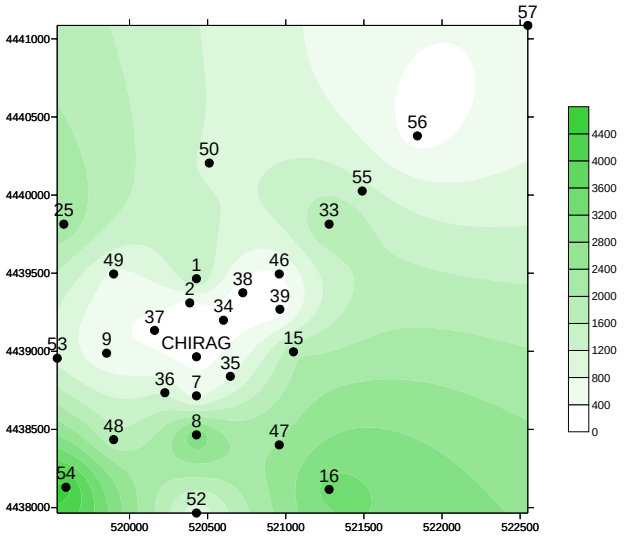
Figure 9.3 below gives the distribution plots for mean particle size, total abundance and taxonomic richness. These plots indicate that in general, abundance and richness appear to be lower at stations where the sediment structure was finer. However, it should be noted that the sediment structure at stations 37, 9 and 2 was coarse grained with a low silt-clay content.

The area where abundance and richness were low closely corresponds to the LOA and Ba footprint identified above in figure 9.2. This pattern was also identified in previous Chirag surveys.

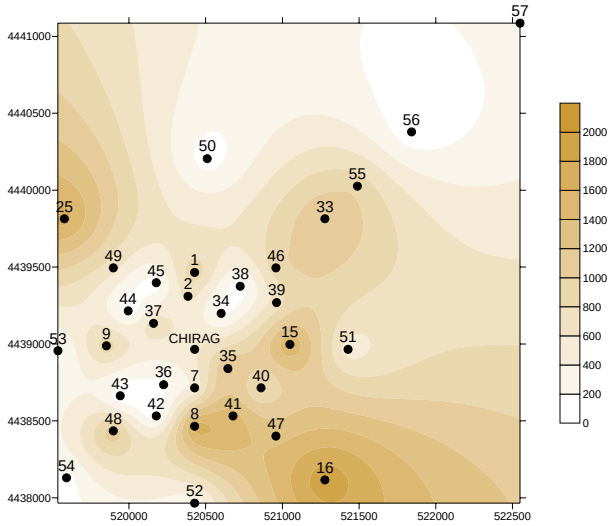
As stations with low abundance and taxonomic richness were found to vary with regard to sediment structure, it is more likely that the community structure in this area is being influenced by operational activities rather than the natural physical environment.



Taxonomic Richness 2010



Abundance 2010



Mean Diameter 2010

Figure 9.3 Abundance, Taxonomic Richness, & Mean particle Size Distribution Plots

The physicochemical time series data shows a general reduction in hydrocarbon concentrations at the Chirag location from 2004, including stations within the LAO contamination footprint. In general the sediment structure and metal concentrations have remained relatively constant.

Toxicity tests were carried out on sediment samples on the 2004, 2006 and 2010 surveys. Mortality rates were highest in 2004 and reduced in 2006 with no mortality being recorded in 2010.

Despite the reduction in hydrocarbon concentrations and the reduction in toxicity of the measured samples, the community present reduced in abundance and richness on consecutive years up to and including 2008. The NMDS ordination (figure 6.7) also denotes that the overall community present at the Chirag survey location has changed on each consecutive survey up to 2008.

Both of these trends came to an end in 2010. Annelid and amphipod abundance and taxonomic richness increased at the majority of stations, including those within the LAO and Ba footprint where the least taxonomically rich and/or abundant communities were observed, and the NMDS ordination indicated strong similarities between the 2008 and 2010 communities. It should be noted that amphipods remain almost absent at station 34, where the highest hydrocarbon and LAO concentrations have been continually recorded.

No distinct change in the physicochemical characteristics has been observed between 2008 and 2010 that can be attributed to the reversal of these trends.

9.3. Conclusion

As was the case on previous surveys the sediment characteristics and metal concentrations around Chirag were found to be highly variable within and between stations, with generally little change being observed from 2008.

Despite the detection footprint remaining unchanged from previous years, LAO concentrations continue to reduce. THC and PAH concentrations were generally low, with the highest concentrations being recorded at stations directly to the northeast of the platform.

The 2010 macrobenthic community was numerically dominated by polychaetes and amphipods. Abundance and species richness were highest at stations on the periphery of the survey area and decreased towards the platform.

The LAO and Ba footprint, indicating the extent of contamination from platform drilling discharges was found to extend 1250m NE, 500m N, 750m E, 1000m W and 250m S of the Chirag platform position. Stations within this area were found to have a low abundance and taxonomic richness, with the sparsest communities being present at stations directly to the northeast of the platform.

Despite a continual reduction in hydrocarbon concentrations from 2006, a general reduction in abundance and taxonomic richness has been observed at the Chirag survey area from 2000 to 2008. This negative trend has reversed in 2010, with a survey wide increase in annelid abundance and amphipod abundance and taxonomic richness being observed. No distinct change in the physicochemical characteristics has been observed between 2008 and 2010 that can be attributed to the abrupt reversal of these trends.

No additional physicochemical impacts from operational activities have been observed between 2008 and 2010 and in general contamination levels continue to reduce.

9.4. Recommendations

To retain the level of detail observed in the 2010 survey, it is advised that future surveys around the Chirag platform follow a similar design to provide good coverage in all directions around the platform location.