Merlewood Research and Development Paper

Number 17

TREND-SURFACE AND COMPONENT ANALYSIS OF CHEMICAL AND PHYSICAL VARIABLES OF THE MORECAMBE BAY MAIN SURVEY

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R. & D. 70/17

1. INTRODUCTION

The results of trend-surface analyses and of principal component analyses of the physical and chemical variables measured in a pilot survey of Morecambe Bay have been described in earlier papers (Jeffers 1969a, 1969b). Similar analyses of the numbers of six species of invertebrates and the correlations between principal components of the numbers of invertebrates and of the physical and chemical variables have also been described (Jeffers 1970). This paper summarises the results of trend-surface and principal component analyses of the physical and chemical variables determined in the main survey of the sands and muds of the Morecambe Bay. This survey was carried out a year later than the pilot survey and was more extensive in both the numbers of samples taken, and in the distribution of the samples. The results, therefore, might be expected to be more stable and more readily interpreted, although differences between the results of the two surveys might also be due to real differences in the physical and chemical properties in the two years.

The methods of analysis used in the interpretation of the physical and chemical variables from the main survey were exactly the same as those used for the pilot survey, and will not be described in detail in this paper.

2. VARIABLES ASSESSED

The main survey was undertaken during the months of August and September 1968, the samples being taken in conjunction with a survey of invertebrates as part of the feasibility study for the Morecambe Bay Barrage. Ten 10cm cores were taken at each sampling point, the sampled material being bulked immediately, and one quarter of the bulked sample being retained for chemical and physical analysis. Eight variables were assessed on each of 274 samples, the variables being as follows:-

1. Percentage of particles > 250 microns
2. Percentage of particles 125-250 microns
3. Percentage of particles 62.5-125 microns
4. Percentage of particles < 62.5 microns
5. Percentage loss on ignition at 550°C.
6. Percentage calcium
7. Percentage phosphorus
8. Percentage nitrogen

The choice of these variables was guided by the principal component analysis of the data from the pilot survey, and the consequent reduction in the number of physical and chemical variables analysed, therefore, represents one immediate benefit from the earlier analyses.

3. TREND-SURFACE ANALYSIS

The proportions of the variability accounted for by the linear, quadratic, and cubic terms of the regressions of the chemical and physical variables on the grid co-ordinates of the sampling points are given in Table 1.

The cubic trend-surfaces were significant for three of the variables, the percentage loss on ignition, the percentage of particles between 125-250 microns, and the percentage of particles between 62.5-125 microns. All the other variables showed significant quadratic surfaces. Except for the percentage of particles between 62.5-125 microns, however, for which the trend-surface accounted for nearly 80 per cent of the variability, the percentage of the total variability accounted for by the trend-surfaces were low. At best, they accounted for 30 percent of the variability, at worst, only about 12 per cent.

Table 1 Proportions of variability accounted for by the linear, quadratic, and cubic terms of the regression on grid co-ordinates

	Proportion of variability			Cumulative proportions	
Variable	Linear	Quadratic	Cubic	Quadratic	Cubic
1	0.0707**	0.1326**	0.1051**	0.2033	0.3084
2	0.1638**	0.0620**	-	0.2258	-
3	0.1310**	0.0086**	-	0.1396	-
4	0.1256**	0.1565**	-	0.2821	-
5	0.0781**	0.0561**	-	0.1342	-
6	0.0107**	0.1213**	0.1006**	0.1320	0.2326
7	0.2340**	0.0425**	0.5151**	0.2765	0.7916
8	0.0838**	0.0456**	-	0.1294	-

The coefficients defining the predictive equations are given in Tables 2 and 3, for quadratic and cubic surfaces, respectively.

Table 2 Coefficients defining quadratic trend-surfaces

Variable	Coefficient					
	Constant	X	Y	X^2	Y^2	XY
2	-169.448	-66.2168	114.751	-4.23191	-13.3019	13.3759
3	-93.5307	-12.3574	41.3271	-1.22068	-4.35384	5.19263
4	204.057	128.261	-140.223	2.98999	17.7906	-22.7913
5	0.225963	1.93890	-1.08947	0.124899	0.20374	-0.38840
8	-0.04388	0.02989	-0.00684	0.001702	0.00270	-0.00628

Table 3 Coefficients defining cubic trend-surfaces

Coefficient	Variable 1	Variable 6	Variable 7
X	650.250	20.5390	-0.471191
Y	1430.50	125.211	-0.576660
X^2	183.312	22.9951	-0.017960
Y^2	-90.1719	-8.99512	0.033234
XY	-374.875	-29.7871	0.154480
X^3	-8.71094	-1.07318	-0.001044
Y^3	-2.07031	-0.12024	0.001213
X^2Y	-12.4082	-1.55941	0.005058
XY^2	32.8906	2.91223	-0.013969
Constant	-4421.80	-335.651	2.10611

The trend-surfaces determined by the coefficients are given in Figures 1-8. These surfaces show fairly marked differences in the trends for the several variables, but those for percentage nitrogen, the percentage of particles between 125 and 250 microns, and percentage loss on ignition are fairly similar in general shape.

4. PRINCIPAL COMPONENT ANALYSIS

The basic data for the 274 sampling points are summarised in Table 4.

Table 4 Summary of basic data

Variable	Minimum	Mean	Maximum	S.D.
1	0.100	1.207	43.0	4.479
2	0.050	20.31	94.0	23.27
3	0.100	53.67	97.0	21.36
4	0.500	24.74	88.0	20.77
5	44.00	1.504	37.2	0.555
6	1.500	2.401	9.00	0.704
7	0.016	0.028	0.048	0.0056
8	0.001	0.013	0.054	0.0093

The coefficients of the correlations between the original variables are given in Table 5.

The percentages of the particles greater than 250 microns and between 125 and 250 microns were significantly positively correlated, and negatively correlated with the percentages of particles between 62.5 and 125 microns and less than 62.5 microns. The percentages of particles between 62.5 and 125 microns and below 62.5 microns were also significantly negatively correlated.

The four chemical variables were all significantly and positively intercorrelated. Loss on ignition was positively correlated with the percentages of particles between 62.5 and 125 microns and below 62.5 microns and negatively correlated with the percentage of particles between 125 and 250 microns. The percentage calcium was positively correlated with the percentages of particles greater than 250 microns and less than 62.5 microns, and negatively correlated with the percentage of particles between 125 and 250 microns. The phosphorus content was negatively correlated with the percentages of particles above 125 microns and positively correlated with the percentages of particles below 125 microns. The nitrogen content was negatively correlated with the percentage of particles between 125 and 250 microns and positively correlated with the percentage of particles below 62.5 microns.

Table 6 Principal Component Analysis

	Component.-			
	1	2	3	4
Percentage variability	39.0	23.4	15.7	10.3
Variable	Weighting given to original variables			
1	0.05	1.00	0.49	0.17
2	-0.90	0.40	-0.23	-1.00
3	0.25	-0.72	1.00	0.24
4	0.74	0.07	-0.87	0.84
5	1.00	0.01	-0.03	-0.64
6	0.61	0.79	0.53	0.24
7	0.80	-0.27	0.04	-0.86
8	0.97	0.17	-0.16	-0.42

The principal component analysis of the correlation matrix is summarised in Table 6. The first four components together accounted for 88.4 per cent of the total variability measured by the eight original variables. The first component accounting for 39.0 per cent of the variability is a contrast of the loss on ignition, and percentages of phosphorus and nitrogen with the percentage of particles between 125 and 250 microns, and probably represents a measure of the general "fertility" of the sands and muds. The second component, accounting for a further 23.4 per cent, is an index of the percentage of the largest particles, i.e. greater than 250 microns, and the calcium content, and is a measure of the amount of broken shells. The third component, 15.7 per cent, is a contrast of the percentage of particles between 62.5 and 125 microns with the percentage of particles below 62.5 microns, and is a measure of the deposition of seaborne silt. The fourth component, 10.3 per cent, is a contrast of the percentage of particles between 125 and 250 microns and the phosphorus content with the percentage of particles below 62.5 microns, and may represent a measure of river-borne deposits.

The trend-surfaces for the four components are plotted in Figures 9-12. The trend-surface for the first component shows strong affinities to those of Figures 2, 5, and 8, as might be expected. Similarly, the surface for the second component is clearly related to the plotted surfaces for the largest sized particles and the calcium content. The third component shows a rather complex surface, related to those of the individual variables, but obviously representing an index of those variables. The extracted components, therefore, appear to be relatively successful in summarising the complex inter-relationships between the chemical and physical variables and their general trends over the area of the Bay.

DISCUSSION

The analysis of the main survey, based on a reduced number of variables from the original list of variables tested in the pilot survey both confirms and augments the results from the pilot survey. The selection of the variables for the main survey was partly guided by the component analysis of the pilot survey, and the correlations between the variables are broadly similar to those obtained from the pilot survey.

Bearing in mind the very much larger sample used in the main survey, and the better distribution of the sample points, the trend-surfaces for the individual variables are reasonably consistent between the two surveys. The proportions of the total variability accounted for by the trend-surfaces are also fairly consistent between the two surveys, although the achievement of 70 per cent of the variability of the percentage of phosphorus by the cubic regression of the main survey, in contrast to only 51 per cent for the pilot survey, is a fairly striking improvement. Generally speaking, however, the main survey provided more complex trend-surfaces than the pilot survey, and the linear trends given by the more limited information available for the pilot survey were replaced by more easily interpretable surfaces.

The component analysis of the variables in the main survey again suggests that a limited number of dimensions are sufficient to account for the major variability in the chemical and physical properties of the sands and muds of the Bay. In this case, four components were sufficient to account for 88 per cent of the total variability, and the resulting components are readily interpretable in terms of identifiable types of variation. The trend-surfaces of the components also effectively summarise the main types of trends obtained for the original variables. Having achieved this degree of summarisation, it will be interesting to compare the numbers of invertebrates counted in the samples of the main survey with these components, as in the examination of