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TREND-SURFACE AND COMPONENT ANALYSIS OF NUMBERS OF INVERTEBRATES FROM THE MORECAMBE BAY MAIN SURVEY

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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 of the pilot survey have also been described (Jeffers, 1970a). The results of trend-surface and principal component analyses of a smaller range of physical and chemical variables determined in the more extensive main survey of the sands and muds of the Morecambe Bay have also been described (Jeffers, 1970b).

This paper summarises the results of trend-surface and principal component analyses of the numbers of seven species of invertebrates, and the correlations between the components of the numbers of invertebrates and the components of the physical and chemical variables of the main survey. The methods of analysis used in the interpretation of the invertebrate data were exactly the same as those used for the pilot survey and the physical and chemical variables of the main 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 particle size and chemical elements as part of the feasibility study for the Morecambe Bay Barrage.

The numbers of 22 species or species groups of invertebrates were determined for each of the samples. Only seven of these species have been included in the current analysis, the other species being too sparsely distributed for analysis to be worthwhile. The seven species included were as follows:-

1. Macoma balthica
2. Tellina tenuis
3. Hydrobia ulvae
4. Corophium volutator
5. Nereis diversicolor
6. Arenicola marina
7. Nephthys hombergii

3. TREND-SURFACE ANALYSIS

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

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	0.1006***	0.0218	0.3771***	0.1224	0.4995
2	0.0001	0.0037	0.0050	0.0038	0.0088
3	0.0094	0.0342*	0.0561**	0.0436	0.0997
4	0.0176	0.0164	0.0467**	0.0340	0.0807
5	0.0481***	0.0559***	0.2956***	0.1040	0.3996
6	0.0619***	0.0271*	0.1183***	0.0890	0.2073
7	0.0122	0.0398**	0.0845***	0.0520	0.1365

The cubic trend-surfaces were significant for all of the variables except for Tellina tenuis (2), for which none of the regressions were significant. For Macoma balthica (1) and Nereis diversicolor (5) the trend-surfaces accounted for nearly 50 per cent and nearly 40 per cent respectively of the total variability in numbers. The percentages of variability accounted for by the surfaces for the other invertebrates were considerably lower, ranging from 20.7 for Arenicola marina (6) to only 8.1 for Corophium volutator (4).

The coefficients defining the predictive equations are given in Table 2, and the trend-surfaces determined by the coefficients are given in Figures 1-6.

4. PRINCIPAL COMPONENT ANALYSIS

The basic data for the 329 samples used for the determination of numbers of invertebrates are summarised in Table 3.

Table 3. Summary of basic data

Variable	Minimum	Mean	Maximum	S.D.
1	0	2325	56325	5966
2	0	49.2	9800	544
3	0	374.2	8525	1014
4	0	540.5	8700	1180
5	0	63.3	750	116
6	0	16.7	222	26
7	0	4.94	100	17

Table 2. Coefficients defining computed trend-surfaces

Coefficient	Variable 1	3	4	5	6	7
X	-3301370	10368.0	89183.9	-62712.0	5404.50	-1364.37
Y	-607872	-21072.0	-19248.0	-11078.0	359.000	128.906
X^2	275520	7283.50	294.000	4919.50	-295.062	48.9531
Y^2	-110816	6368.00	10847.9	-2290.75	331.687	-120.644
XY	658560	-9844.00	-25160.0	12792.0	-1237.25	334.515
X^3	-5029.00	-138.644	-159.554	-76.4610	-1.29162	7.58589
Y^3	11530.0	-542.375	-863.375	233.343	-28.7929	8.27393
X^2Y	-32763.9	-929.500	195.250	-608.562	47.8398	-20.6538
XY^2	-29216.0	1190.25	1655.00	-579.625	60.5312	-11.8652
Constant	5809620	19385.7	-93094.7	110445	-8277.01	1639.39

The coefficients of the correlations between the original variables are given in Table 4. The numbers of Macoma balthica (1) were significantly positively correlated with those of Hydrobia ulvae (3), Nereis diversicolor (5), Arenicola marina (6), and negatively correlated with those of Nephthys hombergii (7). The numbers of Hydrobia ulvae (3), Corophium volutator (4), and Nereis diversicolor (5) were all significantly intercorrelated, and the numbers of Corophium volutator (4) negatively correlated with those of Nephthys hombergii (7).

Table 4. Coefficients of correlations between basic variables

1						
-0.028	2					
0.358**	0.032	3				
0.051	0.054	0.313**	4			
0.569**	0.009	0.302**	0.162**	5		
0.174**	-0.003	0.081	-0.095	0.084	6	
-0.170**	-0.000	-0.099	-0.118*	-0.092	-0.011	7

Coefficients greater than 0.108 significant at 0.05 level of significance

Coefficients greater than 0.141 significant at 0.01 level of significance.

Table 5. Principal component analysis

	Component 1	2	3	4	5
Percentage variability	28.3	17.1	14.3	13.6	12.2
Variable	Weighting given to individual components				
1	1.00	-0.48	-0.01	0.13	-0.43
2	0.04	0.40	1.00	-0.20	-0.41
3	0.89	0.32	0.04	0.11	0.59
4	0.51	1.00	-0.05	0.13	0.71
5	0.99	-0.22	-0.01	0.19	-0.59
6	0.29	-0.86	0.25	-0.54	1.00
7	-0.32	-0.44	0.34	1.00	0.47

The principal component analysis of the correlation matrix is summarised in Table 5. The first five components together accounted for 85.5 per cent of the total variability measured by the seven original variables. The first component, accounting for 28.3 per cent of the variability, is an index of the numbers of Macoma balthica, Hydrobia ulvae, and Nereis diversicolor. The second component, accounting for a further 17.1 per cent of the variability, is a contrast of the numbers of Corophium volutator with those of Arenicola marina. The remaining components, accounting for 14.3, 13.6, and 12.2 per cent respectively, are measures of the numbers of Tellina tenuis, Nephthys hombergii, and Arenicola marina respectively.

The trend surfaces for components 1, 2, 4, and 5 are plotted in Figures 7-10, there being no significant trends for the third component. Cubic trend surfaces accounted for between 6.8 per cent and 43.1 per cent of the variability in the four components.

5. CORRELATIONS BETWEEN INVERTEBRATE AND PHYSICAL AND CHEMICAL COMPONENTS

The correlations between the computed values of the invertebrate and physical and chemical components for 272 samples where both sets of components were available are summarised in Table 6 and Figure 11.

Table 6. Coefficients of correlations between invertebrate and physical/chemical components

Invertebrate component	Physical and chemical component:- 1	2	3	4
1	0.408***	-0.029	0.039	-0.031
2	-0.047	-0.164**	-0.097	0.153*
3	-0.078	-0.007	0.120*	-0.000
4	-0.029	-0.187**	0.062	-0.101
5	-0.004	0.042	0.095	0.156**

The first invertebrate component, an index of the numbers of Macoma balthica, Hydrobia ulvae, and Nereis diversicolor, was positively correlated with the first of the particle size and chemical components, an index of general fertility. The contrast between the numbers of Corophium volutator and Arenicola marina was negatively correlated with the second physical and chemical component, and positively correlated with the fourth component, i.e. with the deposit of river-borne material. The number of Tellina tenuis was positively correlated with the third physical and chemical component; the number of Nephthys hombergii was negatively correlated with the second component, and the number of Arenicola marina was positively correlated with the fourth component.

6. DISCUSSION

As in the analysis of the physical and chemical data, the analysis of the invertebrate data from the main survey both confirms and augments the results of the analysis of the invertebrate data from the pilot survey. There are some inconsistencies in the trend-surfaces for the two sets of data which are not entirely accounted for by the differences in the distributions and sizes of the samples, but the trend-surfaces for the main survey accounted for considerably greater proportions of the total variability than the trend-surfaces for the corresponding species in the pilot survey. For both surveys, there were no significant regressions of the numbers of Tellina tenuis on linear, quadratic, or cubic components of the grid co-ordinates.

There were marked similarities in the results of the principal component analyses for the two surveys. Macoma balthica and Hydrobia ulvae are strongly weighted in the first components of both surveys, but Nereis diversicolor replaced Corophium volutator in the first component of the main survey. The contrast between Corophium volutator and Arenicola marina formed the second component of the main survey.

The correlations between the invertebrate components and the physical and chemical components of the main survey were less complex for the main survey than for the pilot survey. The component measuring general fertility was correlated with the numbers of Macoma volutator, Hydrobia ulvae, and Nereis diversicolor, a similar, though slightly more complex, relationship having been observed in the pilot survey. The component giving greatest weight to the percentage of calcium and large particle sizes was negatively correlated with the contrast of Corophium volutator and Arenicola marina and with Nephthys hombergii, and a similar relationship between the numbers of Arenicola marina and the percentage of calcium was observed in the pilot survey. The associations of Tellina tenuis with sea-borne silt, and of Corophium volutator and Arenicola marina with river-borne deposits recorded in the main survey were not observed in the pilot survey.

7. REFERENCES

J. N. R. Jeffers, 1969a. Trend-surface analysis of chemical and physical variables from a pilot survey of Morecambe Bay. Merlewood Research and Development Paper No. 14.

J. N. R. Jeffers, 1969b. Principal component analysis of physical and chemical data from a pilot survey of Morecambe Bay. Merlewood Research and Development Paper No. 15.

J. N. R. Jeffers, 1970a. Trend-surface and principal component analysis of invertebrate data from a pilot survey of Morecambe Bay. Merlewood Research and Development Paper No. 16.

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VARIABLE 1
MACOMA BALTHICA

FIGURE 1

STEP SIZE = 2000

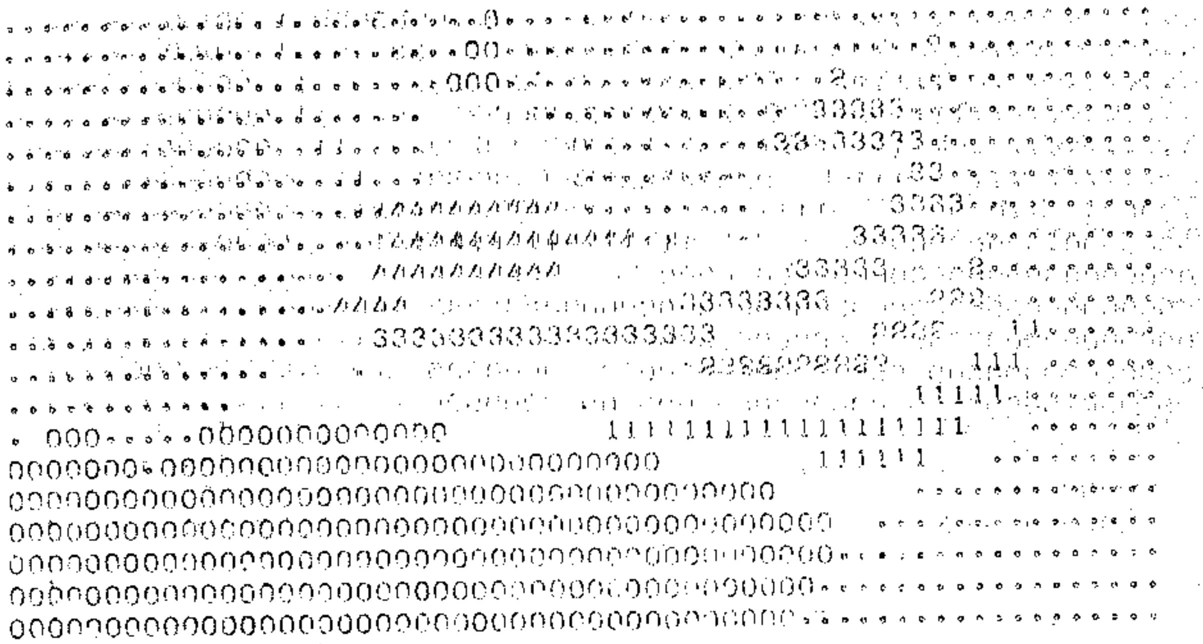
VARIABLE 2
HYDROBIA ULVAE

FIGURE 2

STEP SIZE = 100

VARIABLE 4
COROPHIUM VOLUTATOR

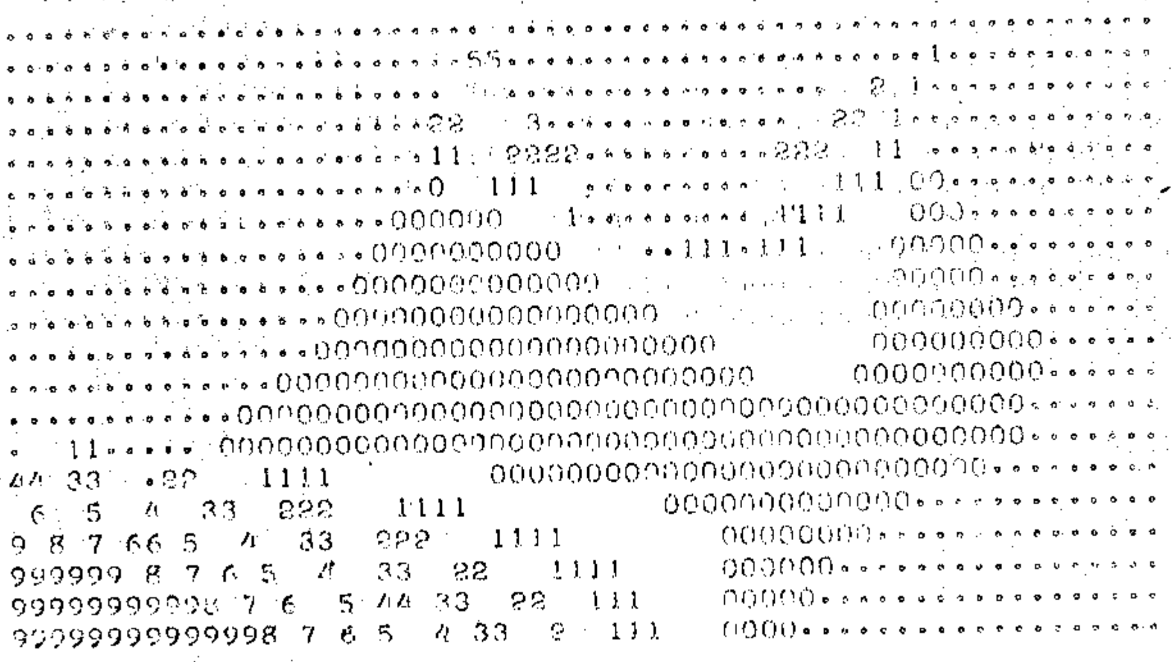
FIGURE 3



STEP SIZE = 100

VARIABLE 5
NEREIS DIVERSICOLOR

FIGURE 4



STEP SIZE = 60

VARIABLE 6
ARENICOLA MARINA

FIGURE 5

STEP SIZE = 8

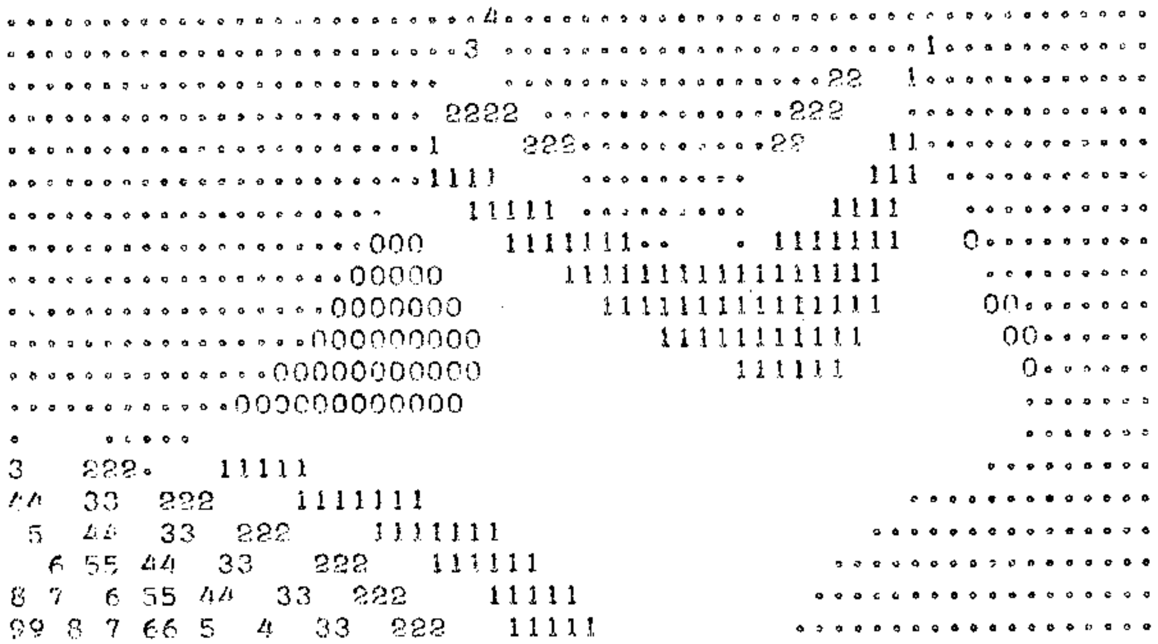
VARIABLE 7
NEPHTHYS HOMBERGII

FIGURE 6

STEP SIZE = 5

FIRST COMPONENT

FIGURE 7



STEP SIZE = 1.0

SECOND COMPONENT

FIGURE 8

STEP SIZE = 1.0

FOURTH COMPONENT

FIGURE 9

STEP SIZE = 1.0

FIFTH COMPONENT

FIGURE 10

STEP SIZE = 1.0

Figure 11. Relationships between invertebrate and physical and chemical components