IRISH SEA NUTRIENTS SURVEY

Dr I ZINGER GIZE
EQ & PC
JULY 1991

TABLE OF CONTENT

IRISH SEA NUTRIENTS SURVEY

LIST OF TABLES AND FIGURES

IRISH SEA NUTRIENT SURVEY

1.0 INTRODUCTION

Within a Northern Seas Action Programme (NORSAP) initiative, more information on nutrient levels in the Irish Sea has been acquired, *via* intensive survey work at the beginning of 1991. The objective of the project has been to coordinate and establish a database for nutrient trends in the Irish Sea, with the help of existing monitoring programmes.

Within its terms of references, UK organisations have been responsible for surveying the North West Coast of England and Wales. The NRA - North West region contribution is illustrated in Figure 1. In the present report, further data was also acquired by NRA - Wales region and MAFF in order to better understand and interpret results.

2.0 RESULTS

Sampling was achieved within a two week period, which under winter conditions is acceptable as biological activity is at a minimum. Also as required, all dissolved nutrient concentrations have been recorded in µmol/l: for SiO_2 in the form of Si, NO_3 and NH_3 in form of N, and PO_4 in terms of P.

Discussions on the relationship between SiO_2-Si, NO_3-N, NH_3-N, PO_4-P and salinity will be presented in the current document, with emphasis on sampling sites which display unexpected nutrient levels. Raw data is listed in Appendix 1, while basic statistical information such as mean, minimum and maximum concentrations have also been compiled in Appendix 2.

2.1 ESTUARY DATA

Four major estuaries in the North West of England have been surveyed, namely: the Solway Firth, the Ribble, the Mersey and the Dee. To explore linear regressions between nutrients and salinity, equations with their respective probabilities have been computed, with the linear trends illustrated in Figures 2 to 5. The equations, with respective statistics, have been tabulated in Appendix 3. Appendix 4 provides for each estuary all nutrient equation residuals plotted against station numbers, which helped identify possible localised water quality phenomena. An overview of all results follows, with some detailed descriptions of each estuary.

2.1.1 Estuary Comparisons

Table 1 summarises the equation slope differences between estuaries, and Table 2 shows the extrapolated inland levels at zero salinity. In general, it appears that the Solway is the least polluted estuary, as its nutrient levels are lower than the other estuaries.

The Mersey tends to display greater slopes and higher 'inland concentrations' with NH_3 reaching an hypothetical 445 μmol/l NH_3-N. The Mersey and the Ribble have ten times more PO_4 than the two other estuaries, and the NH_3 reaches 306 μmol/l NH_3-N in the Dee.

2.1.2 Individual estuaries

In order to help understand the nutrient inputs to the Irish Sea, a brief description of each estuary data have been summarised in this section.

2.1.2a Solway

The data used to examine the Solway incorporated some of the N-S coastal stations readings, i.e. sites 75-88, due to the presence and influence of the Marchon effluent discharge located along the coast, between stations 65 and 70. Using this set of data, equations were computed to determine the nutrients - salinity relationships. Note that because of erroneous findings no data from station 80 are given, and that nutrient data is missing for stations 86 to 89 and S6.

With the exception of PO_4, the linear regressions demonstrated that all equations were significant at the 0.01 level, i.e. correlation exists at a 99.99% confidence interval, with a high percentage of data fitting the equations. Results also demonstrate the decrease in nutrient concentrations with increasing salinity, i.e. 'salting-out' effect.

In the case of PO_4, the equation is significant at the 0.05 level, but with only 32.4% data fitting. The noticeable positive slope in the equation (Figure 5) can be explained by the coastal effluent at Marchon, known to discharge annually 18 615 tonnes of phosphate (Greenpeace, 1990).

Station S5, located at the mouths of the Waver and the Wampool rivers, displays lower than expected levels of Si, NO_3 and NH_3. This phenomenon, coupled with a close examination of the raw data, provides evidence that nutrients originate from further upstream, possibly caused by sewage, and that the merging of these rivers results in a net dilution.

Principal component analysis (PCA), which combines nutrient and salinity measurements for each station, shows that the dominant nutrient factor 'influencing' the Solway is NO_3, followed by PO_4. Furthermore, the high N:P ratios at stations S1 to S3 indicate that the Solway could be prone to algal blooms in the upstream section of the estuary.

2.1.2b Ribble

High levels between 6.5 and 16.5 µmol/l PO_4-P were seen to the concentrated inland, between stations R14 and R19. These levels result possibly from the presence of the Clifton March sewage work in that stretch of the estuary.

Similarly, the high NH_3 residual values recorded in stations R11 to R15, illustrated in Figure 6, indicate anthropological inputs explained by the presence of various sewage works in the area. The predominant sources are possibly the Wigan and Skelmersdale sewage works which discharges into the Douglas River, a tributary to the Ribble.

It can be observed that the latter tributary contributes to the Ribble water quality, as the Si:P ratio, indicative of fresh water inputs, increases up to 42 at station R12.

Results indicate that all linear regressions are significant at the 0.01 level. However, in the case of PO_4 only 45.0% data fit the equation. The principal component analysis also indicates that salinity, followed by PO_4, help in 'differentiating' stations.

2.1.2c Mersey

Due to water circulation patterns, it has proven difficult to establish where the Mersey estuary ends and the Irish Sea begins. As a result, the data set used to compute the nutrients <u>versus</u> salinity equations comprise sampling points from the Mersey survey, together with all three coastal runs. The station numbers were then renamed, and referred in Appendix 1.

Various industrial effluents are present along the Mersey estuary and are possibly responsible for some of the unusual levels of nutrients recorded, e.g. as seen in the residual Si plot in Figure 7. Stations M18-M15 were found to contain very high NH_3 concentrations, ranging up to 357.1 µmol/l NH_3-N, with high levels also of NO_3, Si and PO_4. Low levels of Si and PO_4, together with high NH_3 concentrations are found between stations M15 and M11. It worth noting that the river Weaver joins the Mersey near station M12 and may contribute to dilution. Station M1 shows a higher than expected PO_4 concentration.

All computed equations were found to be significant at the 0.01 level, and all showed a negative correlation between nutrients and salinity. The parameters which vary the most within the Mersey appear to be salinity and Si, and to a lesser degree NO_3, as well illustrated in the 'upstream' stretch of the estuary, i.e. from stations M10 to M19.

2.1.2d Dee

A constant level equal to 0.2 µmol/l NH_3-N was recorded throughout the estuary, with about 42 % missing values. These two facts give reason to suspect erroneous measurements, and therefore no further comments will be given for this parameter.

Stations D16 to D23 demonstrate high Si and NO_3 concentrations, possibly derived from the presence of nearby sewage work discharges. However, station D19 shows lower concentrations which could indicate a difference in water quality around that particular part of the estuary. Also, lower than expected PO_4 levels were recorded between stations D10 and D20, perhaps indicative of a PO_4-P sink along that section of the estuary. The high N:P ratios indicate that this upstream section of the estuary, i.e. D14 to D24, may be susceptible to algal bloom production.

The equations for Si, NO_3 and PO_4 were found to be significant at the 0.01 levels, but only accounted for 56% of PO_4 data. All three equations showed a negative correlation between nutrients and salinity.

The parameters which vary the most within the Mersey, identified by PCA, were salinity, followed by PO_4. The residual PO_4 (derived from the equation) versus station plot (Figure 8) illustrates the scattered behaviour of this nutrient within the estuary.

2.2 SEA DATA

Three sea, as opposed to estuarine, surveys were carried out during the NORSAP exercise: N-S and W-E coastal runs, and an Irish Sea transect running from the Isle of Man to the mouth of the Mersey. As before, Appendix 1 contains all raw data while Appendices 2 and 3 reveal, respectively, basic data statistics and linear regression equations (nutrients versus salinity) for each coastal run.

2.2.1 Coastal runs

Nutrient level averages within the Irish Sea and W-E coastal runs are similar, whereas the N-S Coast nutrient concentrations tend to be higher, perhaps due to the difference in salinity. The mean salinity within the N-S traverse is more dilute, 31.51 o/oo *versus* 33.7 and 34.14 o/oo for W-E coast and Irish Sea transect, indicating a potentially greater capacity for traditional solutes.

2.2.1a West-East Coast

Sludge dumping activities along the W-E coastal run (around stations SB19 and SB20) are currently under operation. In parallel, high levels of PO_4 are encountered between stations SB16 and SB20, reaching 2.3 μmol/l PO_4-P. Nutrient levels at station SB21 indicate that a different type of water quality was probably encountered, as all concentrations were lower than normally expected, e.g. site SB20 has 10.6 μmol/l NO_3-N, while site SB21 shows 6.8 μmol/l NO_3-N.

Only the Si *versus* salinity equation was significant at the 0.01 level, and the greatest variability in nutrients was observed in PO_4, followed by NO_3. On the basis of the Si:P ratios, fresh water input was greater at SB22 and SB23.

2.2.1b North-South Coast

Following the coast from the north towards the south, samples were taken at one mile interval. It can be observed that some sampling sites display higher than expected NH_3 levels, reaching up to 66 μmol/l NH_3-N, i.e. namely stations 61, 53, 48, 39, and 15. For station 41 the Si concentration is 23.9 μmol/l SiO_2-Si.

Between stations 55 and 59, high concentrations ranging from 2.0 to 4.6 µmol/l PO_4-P were recorded, and remained elevated all the way to station 75. The northern presence of the Marchon industrial outlet, already mentioned in section 2.1.2a, coupled with the nearby British Nuclear Fuel discharge, provide some explanations for the PO_4 levels measured along that coastal stretch.

The levels of NO_3 between stations 26 and 30 ranged from 26.5 to 39.8 NO_3-N µmol/l and could be possibly due to a strong influence by Morecambe Bay water quality, and also by the Fleetwood sewage discharge locally. The NO_3 residual plot in Figure 9 provides further evidence to this effect.

The regression equations for Si and PO_4 are significant at the 0.01 level, while for NO_3 at the 0.05 level. However, in all three cases, only low data percentages are explained, i.e. 19.8% Si, 18.7% PO_4, and 6.1% NO_3. These low percentages indicate that other parameters (e.g. local industries) disturb the nutrient distribution in the N-S coastal waters. The greatest variability in additional parameters was salinity, followed by NH_3.

2.2.1c Irish Sea

Sampling was carried out every two miles from the Isle of Man towards the Mersey estuary. As a result it is not unreasonable to consider that different water masses were encountered. Indeed, for stations I23 and I27, differences in nutrient levels compared to neighbouring stations could be explained by such water quality differences.

Lower than expected levels of Si were observed between stations I26 and I31, while high PO_4 were recorded generally between stations I17 and I26. High N:P ratios were recorded for stations I1 to I15.

While the computed equations were significant for Si, NO_3, and PO_4 at the 0.01 level, only part of the data could be explained by the expected relationship, i.e. 45.7% of the Si data, 42.0% of the NO_3 data, and 38.0% of the PO_4 data. Other factors (such as front currents) clearly influence the nutrient distributions within the Irish Sea.

3.0 DISCUSSION

Four Irish Sea studies have been used to compare the present findings with past winter nutrient levels, see Table 3. In Jones & Folkard (1971), SiO_2, NO_3 and PO_4 concentrations were recorded during February, with reported salinities ranging between 29 to 34.2 o/oo. In addition, ratios of N:P, N:Si, and Si:P were computed and contours drawn to illustrate the distribution of water masses in the Irish Sea. The current nutrient findings are found to be within similar concentration ranges as the Jones and Folkard (1971) results.

A second more recent study (ICES, 1988) provides further references to nutrient concentrations in winter conditions, but with salinities ranging only between 32 and 34.1 o/oo. In this instance however, the ICES report clearly shows lower nutrient concentrations throughout, perhaps due to differences in analytical techniques.

Hunt and Foster (1977) have concentrated their efforts on the Liverpool Bay waters, looking at dissolved silicate distribution. While Table 3 does show the overall differences between their findings and the 1991 results, Figure 10 illustrates better the changes over the 14 years. It is interesting to note that silicate concentrations seem to have decreased with time.

In the Irish Sea Study Group Report (1990), nitrogen (N) and phosphorus (P) annual loads into the Irish Sea have been summarised, and can be found in Table 4. The findings indicate that the Mersey contributes approximating 29% N and 16% P of the total estimated nutrient inputs into the Irish sea, while the Ribble contributes to 9% N and 4% P. The main sources of nitrogen inputs appears to be industrial for both the Mersey and the Ribble, both at 38%. For phosphorus sources, domestic practices were responsible for 49% input in the Mersey, and 16% of riverine activities in the Ribble. No references were given for the Solway and the Dee estuaries. While no direct measurements of nutrient loads were attempted in the current study, the data appears to be in agreement with the above comments as so far as the linear regression equations for NO_3-N only (not PO_4-P) demonstrate that the Mersey is generally 'more polluted' than the Ribble.

4.0 CONCLUSIONS

Within a Northern Seas Action Programme (NORSAP) initiative, more information on nutrient levels in the Irish Sea has been acquired under winter conditions, when biological activity is hoped to be at a minimum. Figure 1 illustrate best the area investigated by the NRA - North West region.

The current data provided a snap shot of the variation of key nutrients within the operating area under study. Maximum nutrient concentrations were reached in the Mersey as 164.0 μmol/l SiO_2-Si and 357.1 μmol/l NH_3-N, and in the

Ribble as 315.8 µmol/l NO_3-N and 16.3 µmol/l PO_4-P. These high levels were a consequence of localised agricultural and industrial activities, e.g. known silicate effluent at the top of the Mersey estuary, station M19.

Apart from these pollution point sources, the calculation of linear regressions (decreasing nutrient concentrations with increasing salinity) helped describe conservative nutrient behaviour in estuarine conditions. Lower than expected nutrient levels could be explained by riverine dilution, absorption factor (sink), 'salting-out' effect or water current differentiation.

Future investigations should include nutrient levels under summer conditions, and other parameters such as temperature, and more importantly pH. This latter factor influences nutrient chemical speciation and dictates their solubility properties, consequently determining wether the system is at an equilibrium or not, i.e saturation level.

5.0 SELECTED REFERENCES

Greenpeace: 1990. Clean Irish Sea. A Greenpeace response to the Irish Sea Study Group Report: Waste inputs and Pollution. Eds. P. Johnston & M. Simmonds, Amsterdam, 48 pages.

Hunt D.T.E., P. Foster: 1977. Studies of the mixing of coastal waters in Liverpool Bay using dissolved silicate as a tracer. Water Research 11: 465-470.

ICES (International Council for the Exploration of the Sea): 1988. The status of current knowledge on anthropogenic influences in the Irish Sea. Eds. R.R. Dickson & R.G.V. Boelens, Copenhagen, 88 pages.

Irish Study Group: 1990. The Irish Sea: an environmental review. Part two - Waste inputs and Pollution. Liverpool University Press, 165 pages.

Jones P.G.W., Folkard A.R.: 1971. Hydrographic observations in the Eastern Irish Sea with particular reference to the distribution of nutrient salts. J. Mar. Biol. Assoc. UK 51: 159-182.

Table 1: Slope differences between surveyed estuaries

Si	Solway < Ribble < Dee < Mersey	
NO_3	Solway < Ribble < Mersey < Dee	
NH_3	Solway < Ribble < Mersey	no Dee
PO_4	Dee < Mersey < Ribble	Solway (+) slope

Table 2: Estimated inland nutrient inputs, derived for the linear regressions

Si	Solway < Ribble < Dee < Mersey 67.4 113 179 183 µmol/l
NO_3	Solway < Ribble < Mersey < Dee 182 256 277 306 µmol/l
NH_3	Solway < Ribble < Mersey no Dee 12.3 83.9 445 µmol/l
PO_4	Solway < Dee < Mersey < Ribble 0.52 1.82 8.43 12.9 µmol/l

Table 3: Comparison of nutrient levels by several authors.

a. Overall

	1971 Study**	Current Study		ICES Report
	Range	Mean	Range	Range
SiO_2-Si	6 - 25	5.1	0.2 - 23.9	0.05 - 0.29
NO_3-N	6 - 35	11.2	2.3 - 50.0	0.36 - 0.50*
PO_4-P	0.6 - 2.0	1.2	0.10 - 4.60	0.03 - 0.04
N:P	5 - 25	18.1	2.6 - 194.0	
N:Si	1.1 - 1.6	3.2	0.6 - 27.8	
Si:P	6 - 15	8.0	1.0 - 89.0	

All units in µmol/l
** Jones and Folkard authors

* up to 2.86

b. SiO_2-Si

	Irish Sea	Solway	Mersey
ICES Report	0.05 - 0.29	0.50	0.89
Current Study	0.2 - 23.9	19.65	35.82

All units in µmol/l

	Irish Sea	W-E Coast	N-S Coast
Hunt & Foster	12.5 - 12.9	7.7 - 10.7	10.7 - 19.6
Current Study*	0.2 - 23.9	0.7 - 5.4	0.2 - 12.8

* data points restricted to Hunt & Foster study area
All units in µmol/l

.../...

Table 3: Cont'd

c. NO_3-N

	Irish Sea	Mersey
ICES Report	0.36 - 0.50*	2.07 - 2.57
Current Study	2.3 - 50.0	76.69

* up to 2.86 µmol/l
All units in µmol/l

d. PO_4-P

	Irish Sea	Mersey
ICES Report	0.03 - 0.04	0.07
Current Study	0.10 - 4.60	2.61

All units in µmol/l

Table 4: Estimated annual nitrogen and phosphorus loads into the Irish Sea (extract: Waste Inputs and Pollution, Irish Sea Study Group 1990).

a. **NITROGEN**

	D	I	R	TOTAL*
Total*	10.7	2.6	76.4	89.7
Mersey Ribble	4 - 37% 1 - 9%	1 - 38% 1 - 38%	21 - 27% 6 - 8%	26 - 29% 8 - 9%

Units in 1000 tons/year
* Total nutrient input into the Irish Sea
D = Domestic
I = Industry
R = River

b. **PHOSPHORUS**

	D	I	R	TOTAL*
Total*	1.9	16.3	6.1	24.3
Mersey Ribble	1 - 53% 0 - 0%	0 - 0% 0 - 0%	3 - 49% 1 - 16%	4 - 16% 1 - 4%

Units in 1000 tons/year
* Total nutrient input into the Irish Sea
D = Domestic
I = Industry
R = River

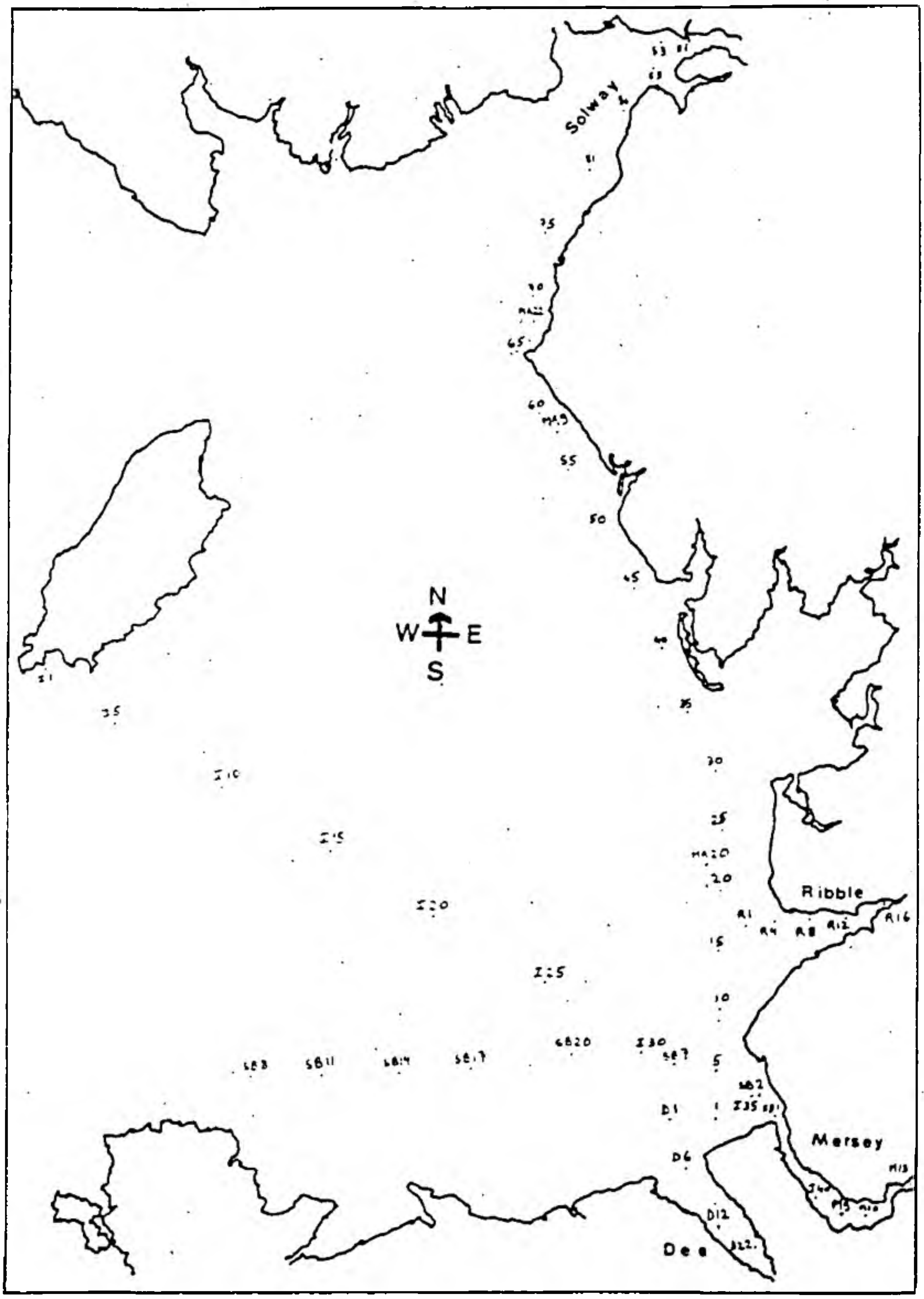
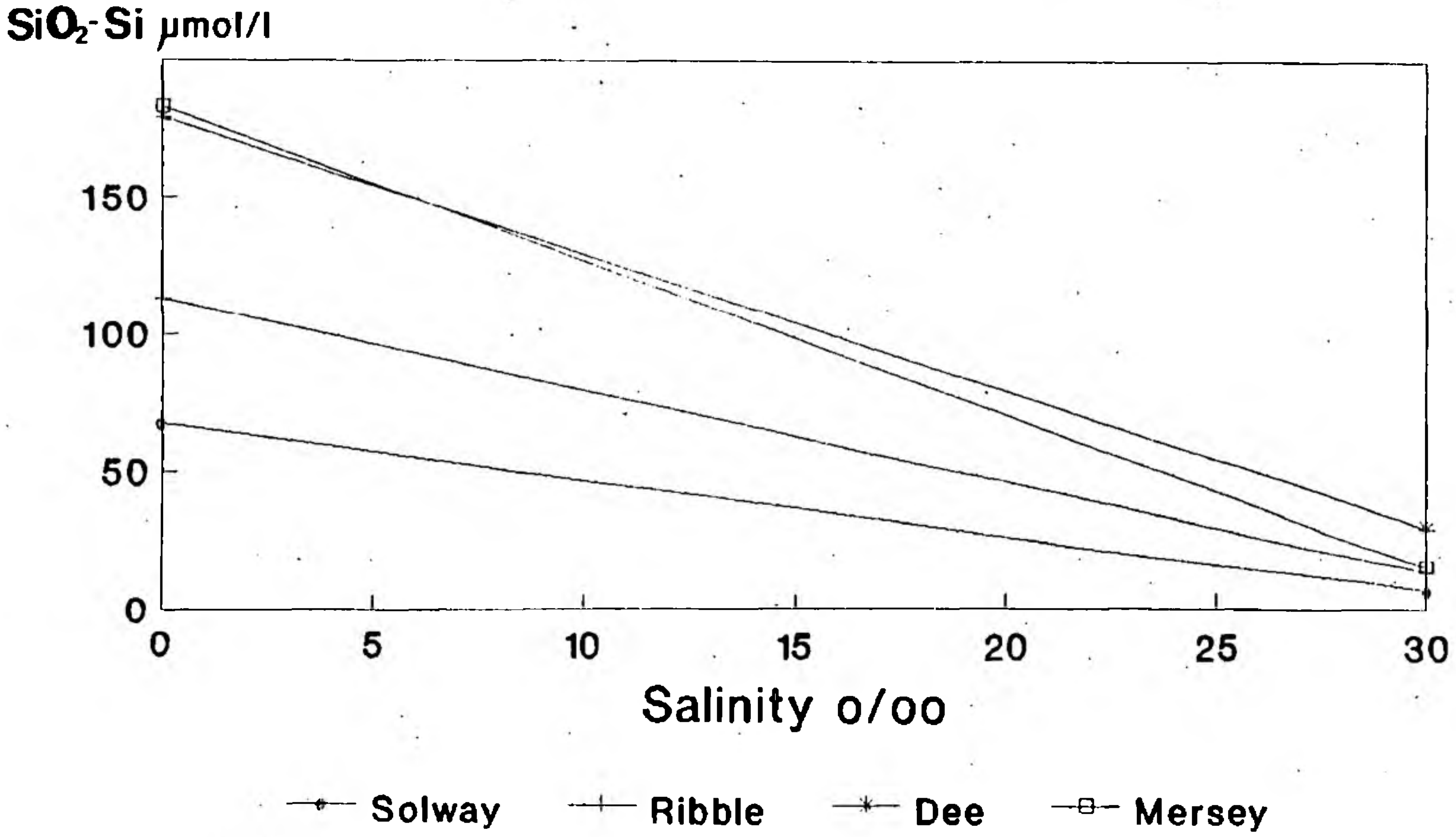


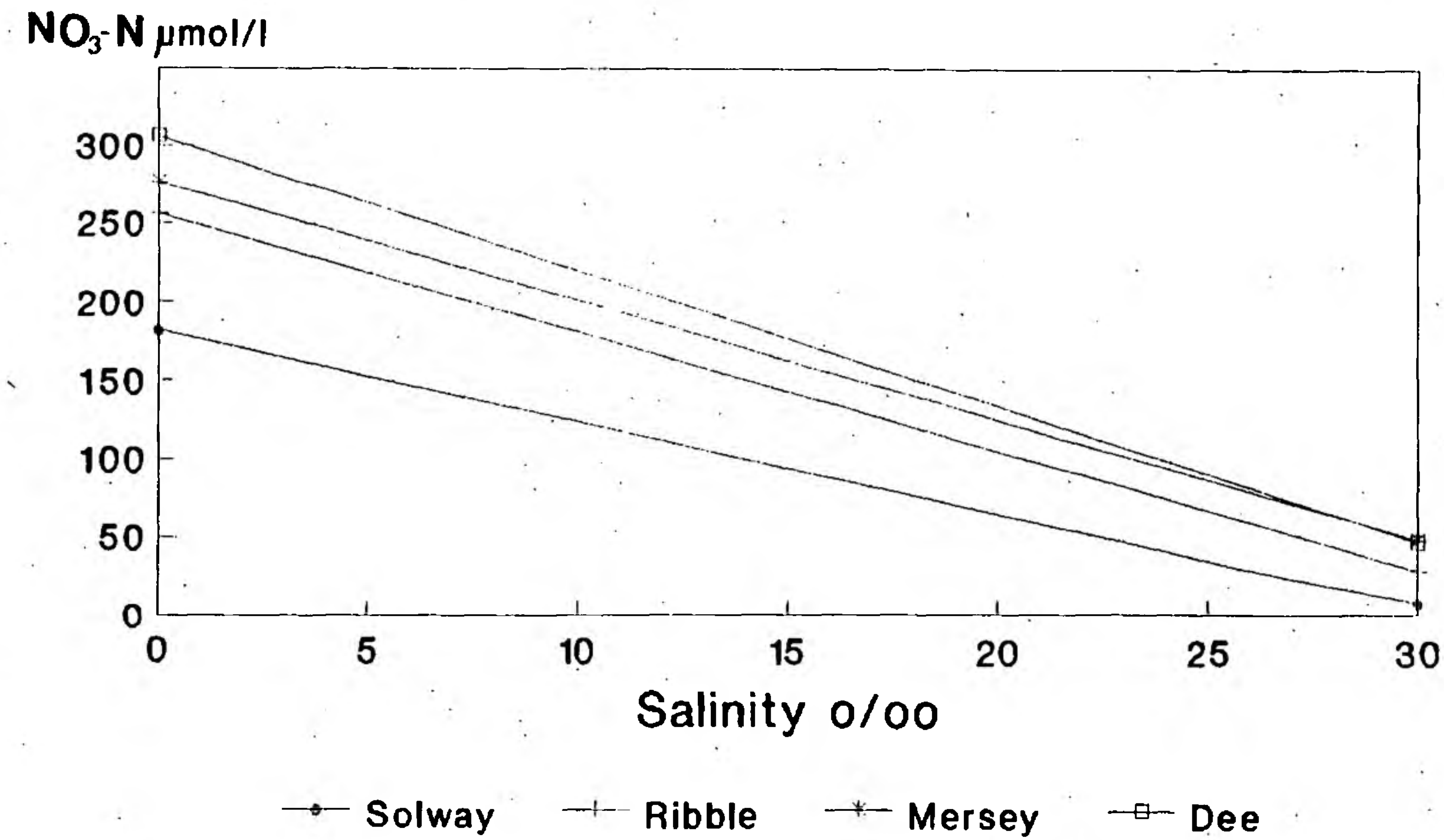
Figure 1: Position of some sampling sites in the Irish Sea survey. [S = Solway, R = Ribble, M = Mersey, D = Dee, MA = MAFF samples, I = Irish Sea transect, SB = W-E coastal run, plain numbers = N-S coastal run]

Figure 2: Si Distribution
Estuary Data



Winter 1991

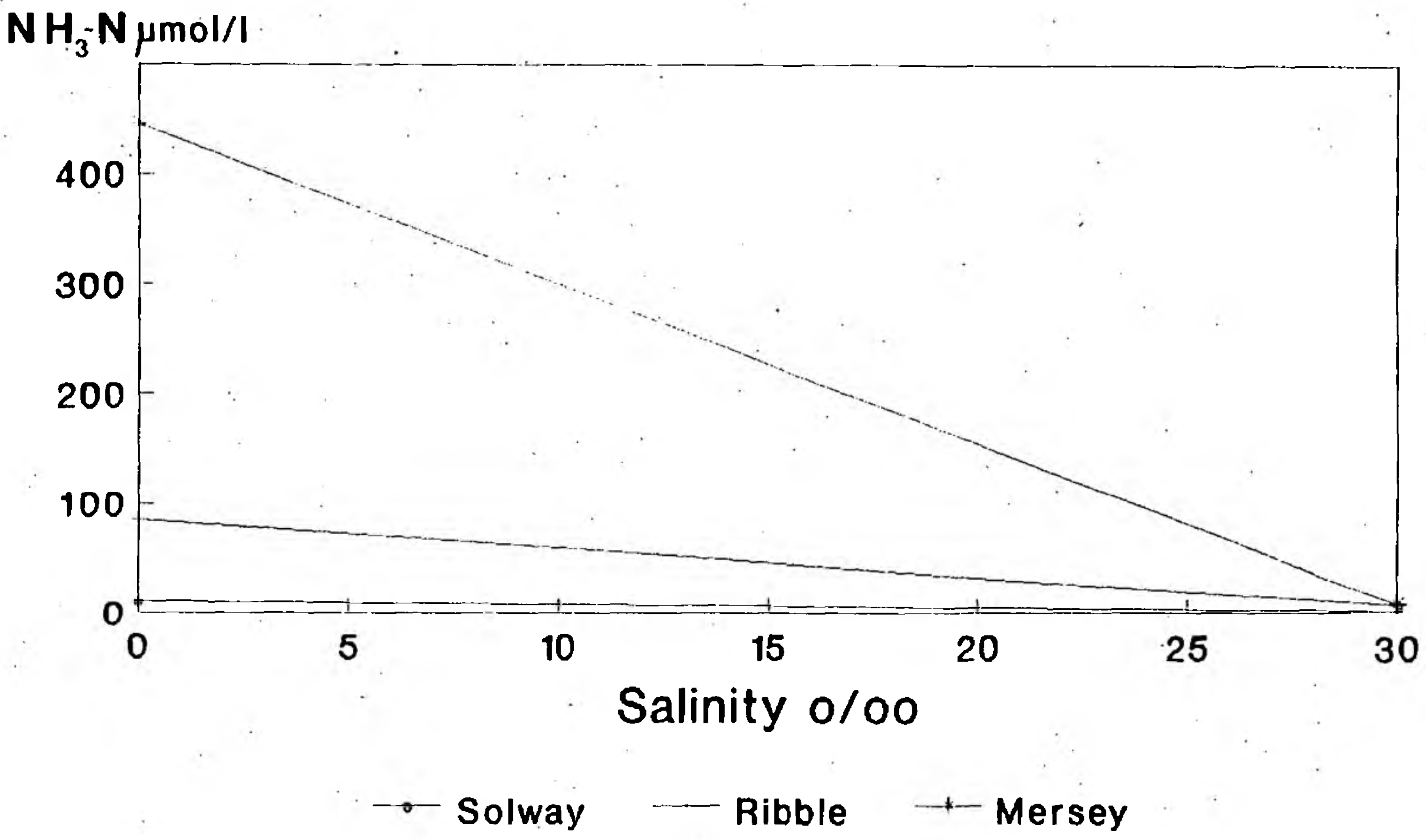
Figure 3: NO_3 Distribution
Estuary Data



Winter 1991

Figure 4: NH_3 Distribution

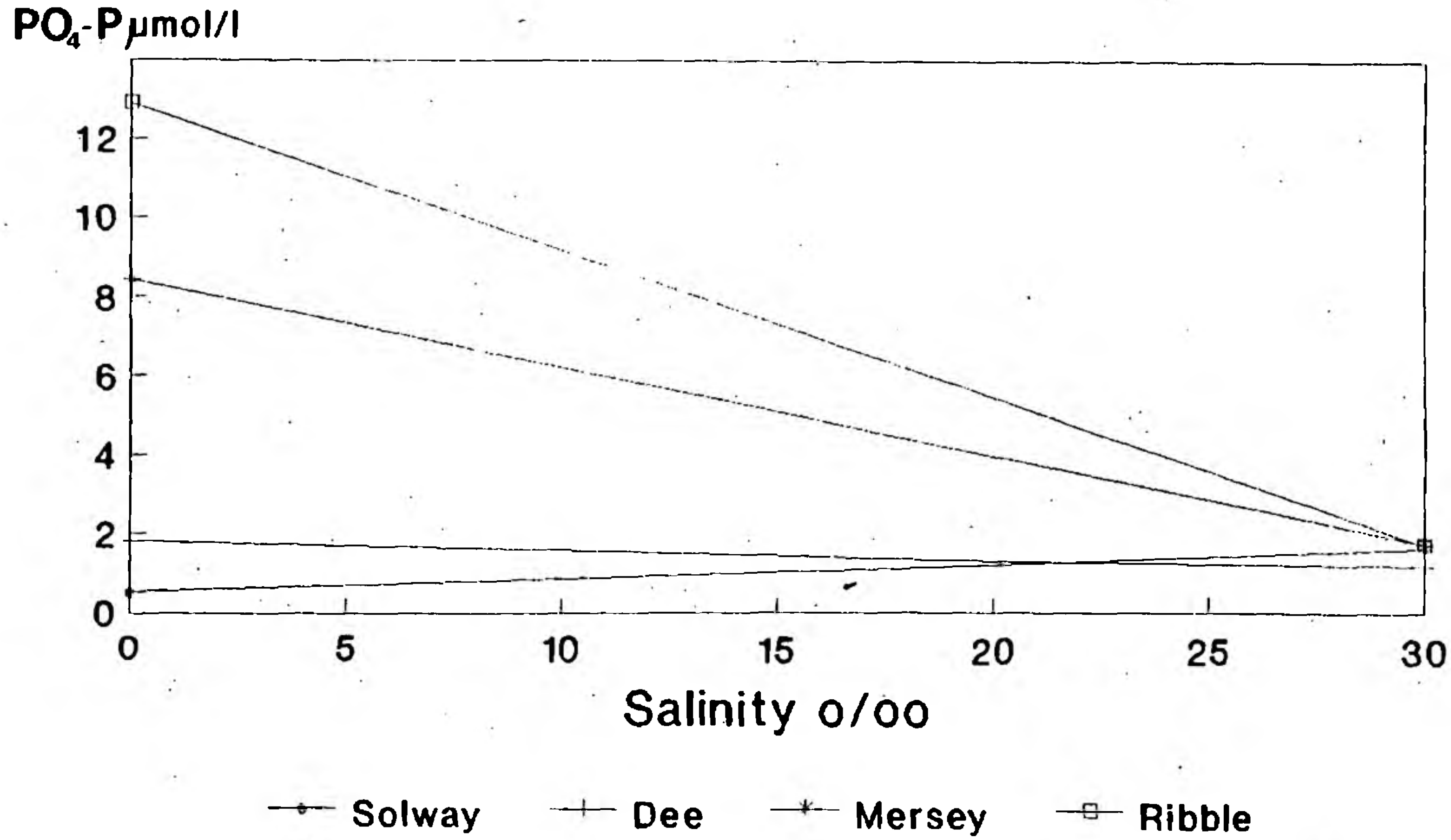
Estuary Data



Winter 1991

Figure 5: PO_4 Distribution

Estuary Data



Winter 1991

Figure 6a: Bar chart

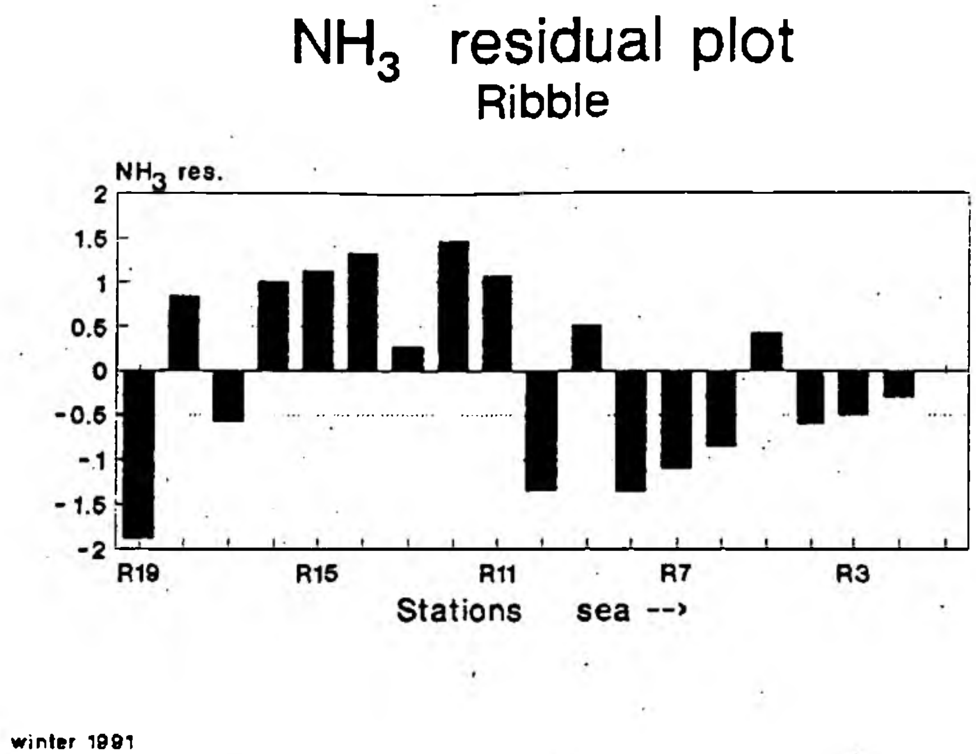


Figure 6b: Graph

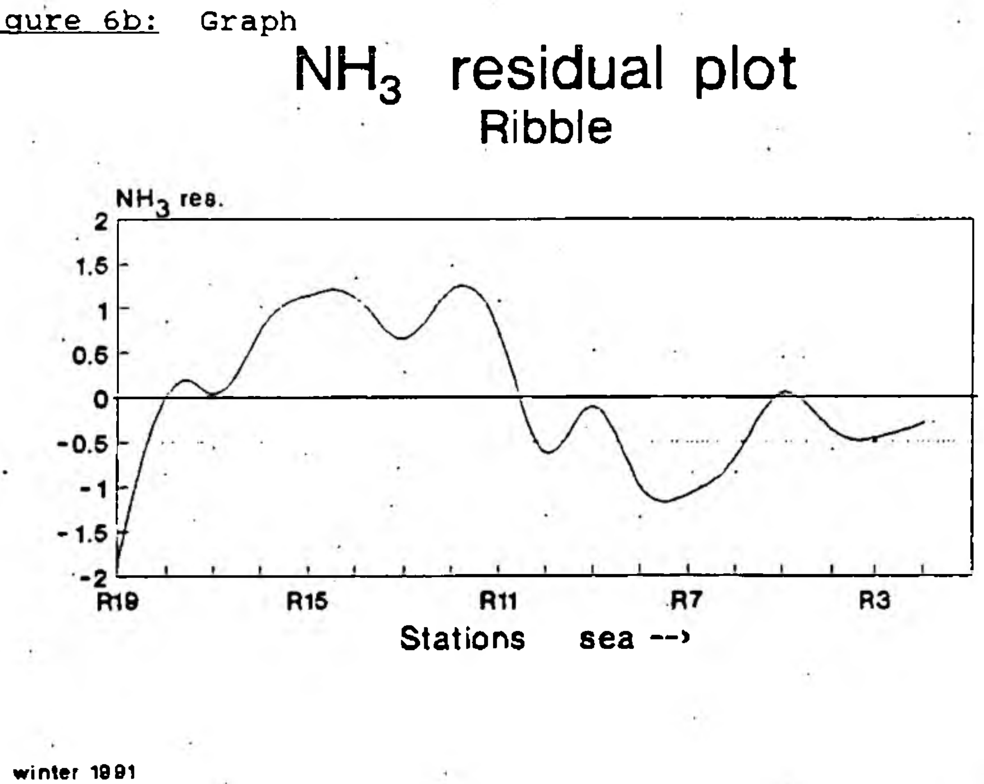


Figure 7a: Bar chart

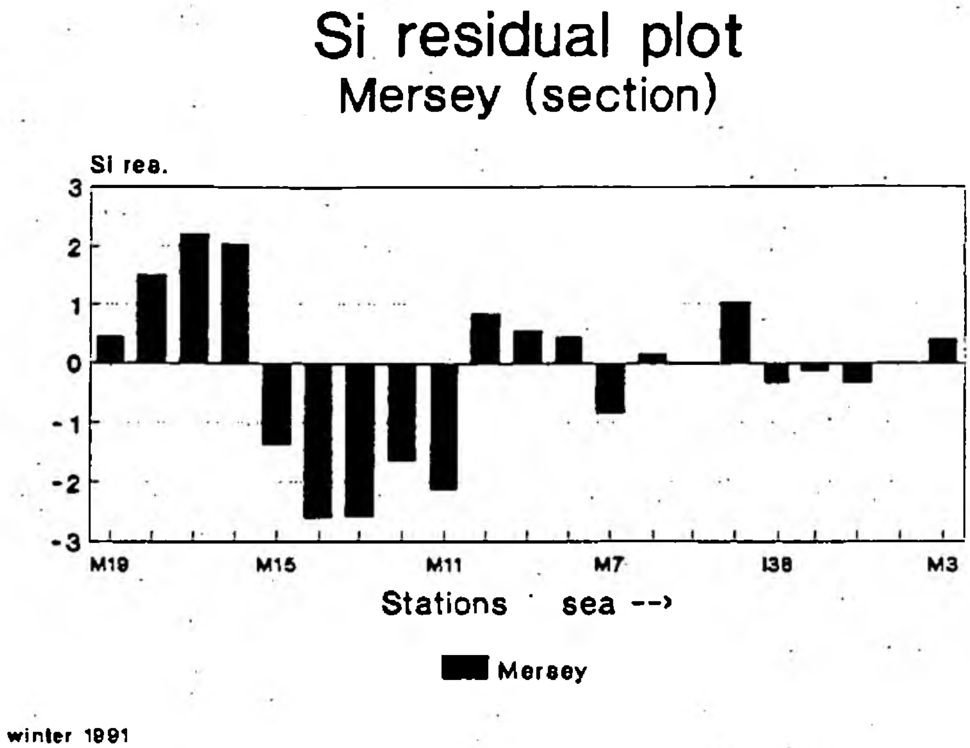


Figure 7b: Graph

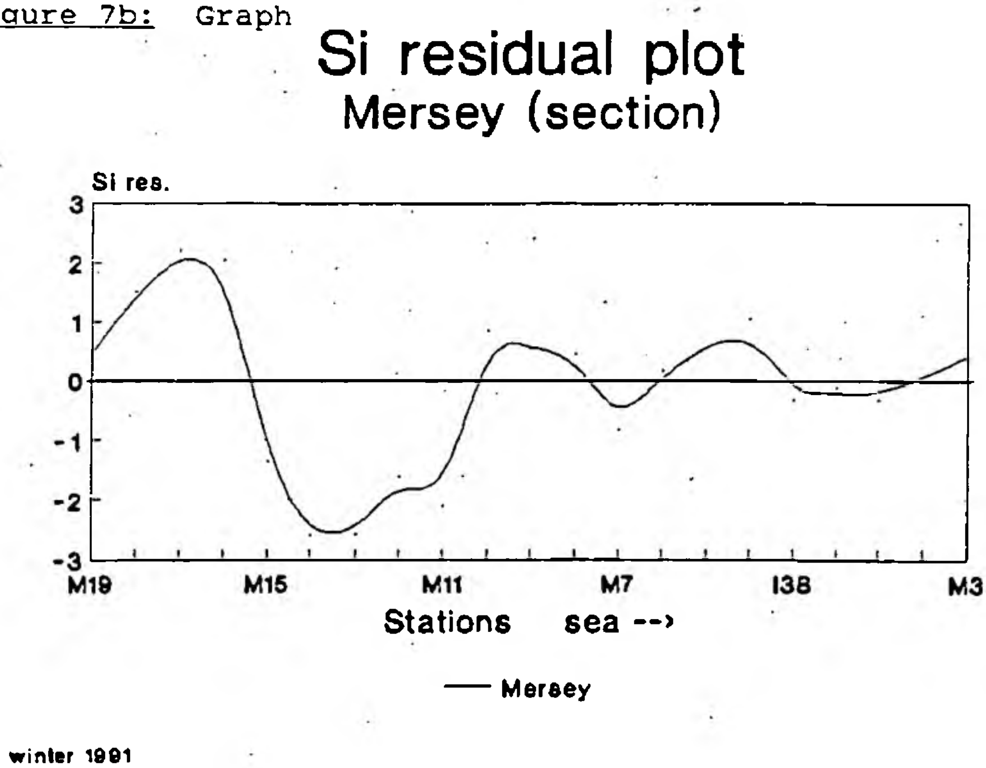


Figure 8a: Bar chart

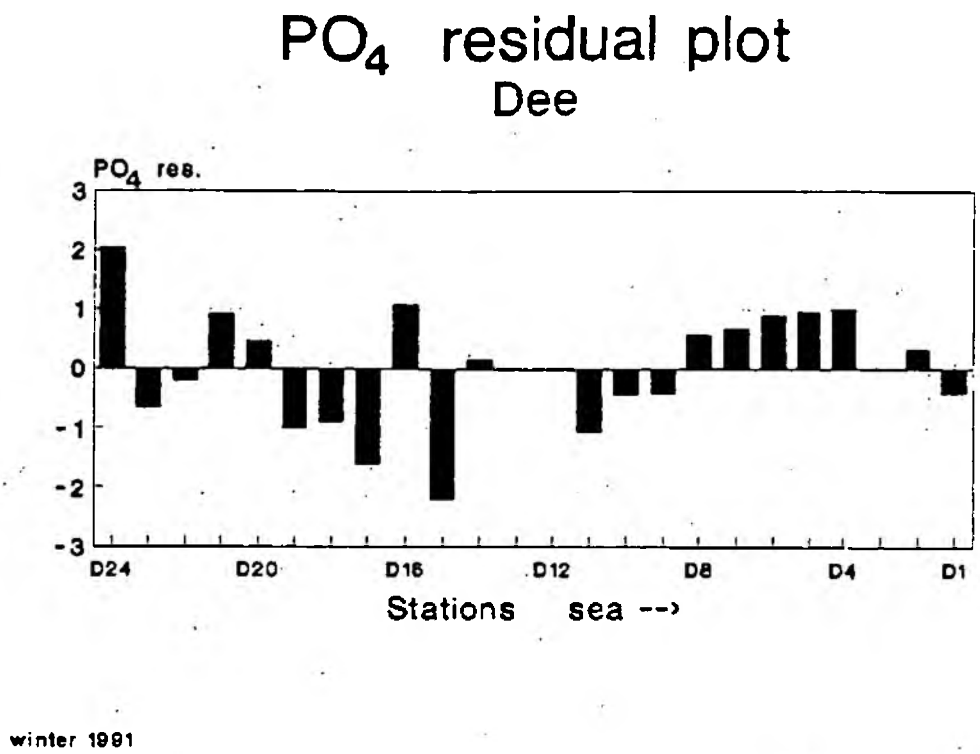


Figure 8b: Graph

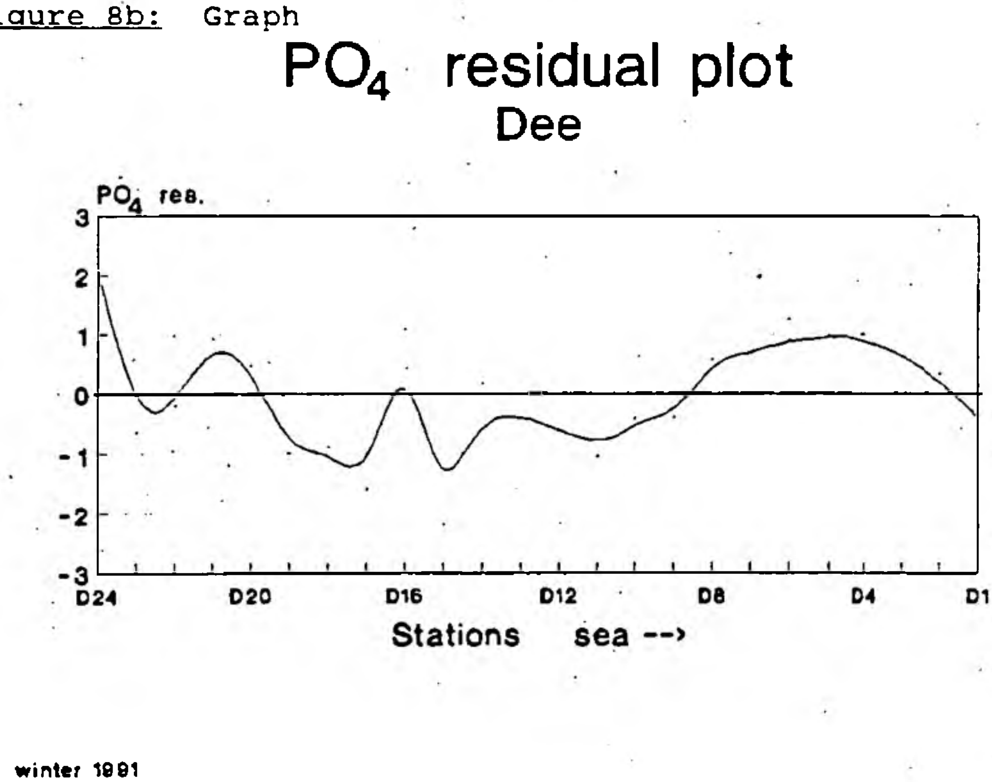


Figure 9a: Bar chart

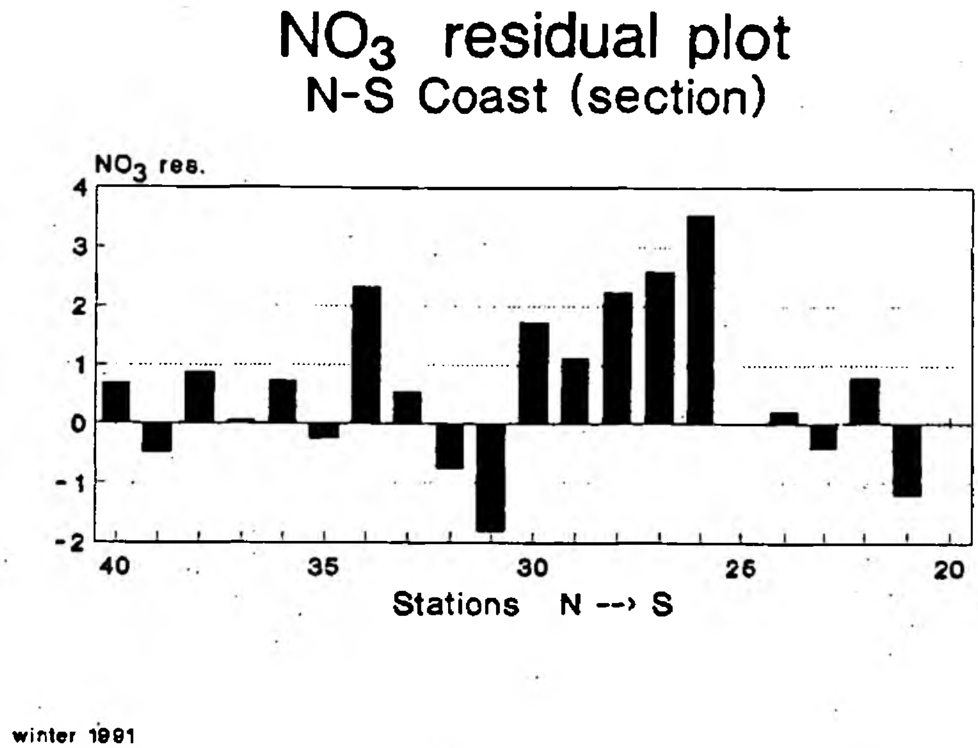
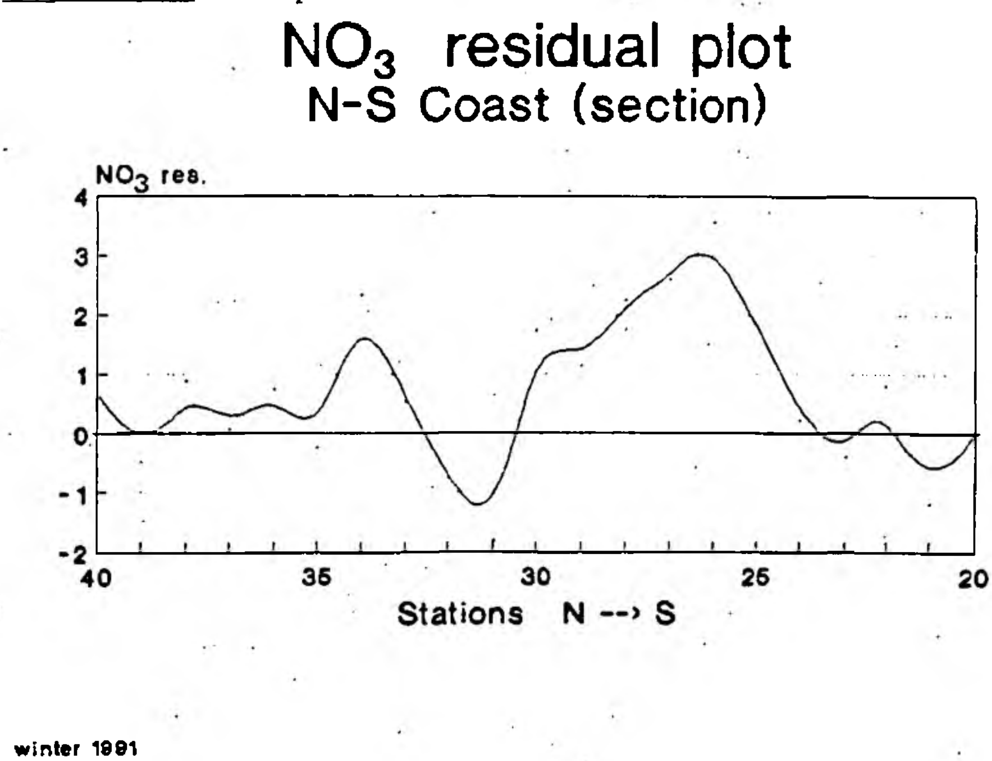


Figure 9b: Graph



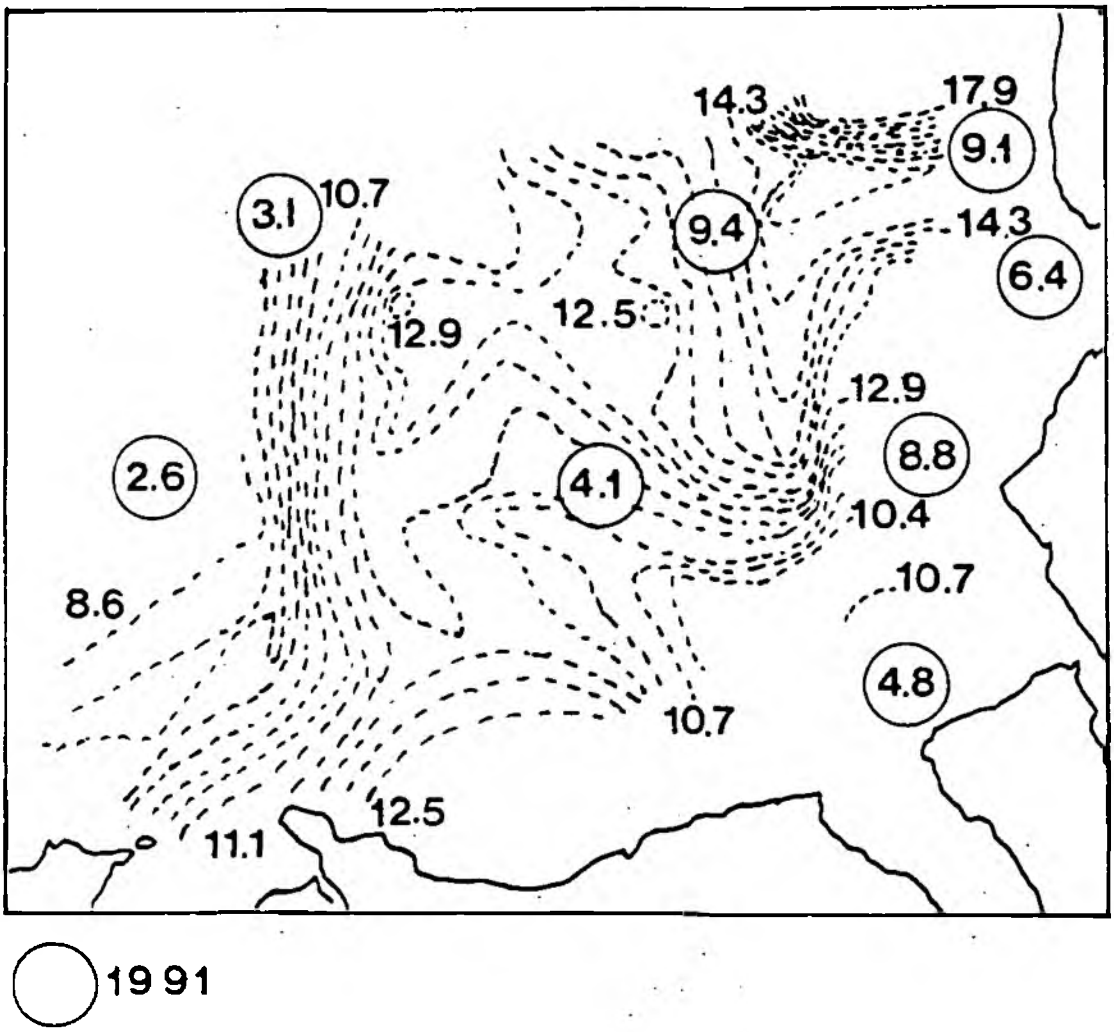


Figure 10: Silicate distribution comparison between 1975 (Hunt and Foster, 1977) and 1991, in μmol/l

APPENDIX 1

RAW DATA

KEY:

ToN	Total oxidised Nitrogen (μmol/l)
Si	SiO_2-Si (μmol/l)
NO2	NO_2-N (μmol/l)
NO3	NO_3-N (μmol/l)
NH3	NH_3-N (μmol/l)
PO4	PO_4-P (μmol/l)
Salin.	Salinity in o/oo
*	missing data points
☐	circled numbers indicate erroneous data points to be ignored

Solway

station	date	Si	ToN	NO2	NO3	NH3	PO4	Salin.
S3	910116	49.6	115.7	0.3	115.4	7.9	1.2	13.082
S2	910116	41.8	105.7	0.4	105.3	6.9	1.2	14.023
S1	910116	42.9	113.2	0.4	112.8	8.1	1.2	14.878
S5	910116	6.2	32.9	0.4	32.5	4.4	1.3	18.355
S6	910116	*	*	*	*	*	*	19.297
86	910116	*	*	*	*	*	*	19.430
88	910116	*	*	*	*	*	*	20.092
S4	910116	24.6	60.7	0.3	60.4	5.1	1.4	20.701
87	910116	*	*	*	*	*	*	21.857
85	910116	33.7	49.1	0.2	48.9	*	1.2	23.990
84	910116	12.4	*	0.2	*	3.1	1.1	24.954
79	910115	6.9	24.4	0.3	24.1	3.6	1.4	25.773
83	910116	2.7	11.0	0.1	10.9	2.1	1.9	27.723
82	910116	13.0	20.7	0.3	20.4	2.0	2.0	28.080
81	910116	11.7	25.4	0.3	25.1	2.3	1.6	28.308
78	910115	11.7	19.6	0.3	19.3	2.1	2.2	28.428
77	910115	7.4	20.7	*	*	1.6	1.3	28.508
76	910115	18.6	20.8	0.1	20.7	1.4	1.4	29.099
75	910115	11.6	13.4	0.4	13.0	3.0	2.4	29.709

Ribble

station	date	Si	ToN	NO2	NO3	NH3	PO4	Salin.
R1	910130	4.8	34.9	1.9	33.0	9.6	1.5	*
R19	910130	105.8	284.2	4.3	279.9	72.1	16.3	1.126
R18	910130	111.1	320.9	5.1	315.8	79.0	1.0	3.736
R17	910130	58.2	99.1	2.1	9.7	52.9	14.1	11.157
R16	910130	61.1	130.0	5.0	125.0	43.6	11.7	18.656
R15	910130	27.0	64.9	1.8	63.1	35.1	6.5	22.371
R13	910130	41.8	50.1	4.3	45.8	25.4	1.9	24.197
R14	910130	42.9	81.5	1.7	79.8	31.0	6.5	24.493
R12	910130	33.9	81.2	1.9	79.3	26.1	0.8	26.788
R11	910130	28.9	54.7	1.5	53.2	21.2	1.5	27.811
R9	910130	22.3	53.4	*	*	15.6	1.1	28.688
R10	910130	11.7	34.7	3.1	31.6	3.9	1.1	28.914
R8	910130	14.5	50.9	3.4	47.5	3.8	1.1	28.931
R7	910130	15.8	50.4	3.4	47.0	4.9	1.1	29.099
R6	910130	16.5	43.1	3.6	39.5	3.9	2.4	30.106
R5	910130	6.6	27.2	2.1	25.1	11.5	2.3	30.135
R4	910130	6.4	25.8	1.8	24.0	3.9	1.1	30.735
R3	910130	4.7	43.4	1.9	41.5	3.9	1.7	30.940
R2	910130	11.0	45.6	1.3	44.3	4.6	2.0	31.166

Solway

station	N:P	N:Si	Si:P
S3	96.1667	2.32661	41.3333
S2	87.7500	2.51914	34.8333
S1	94.0000	2.62937	35.7500
S5	25.0000	5.24194	4.7692
S6	*	*	*
86	*	*	*
88	*	*	*
S4	43.1429	2.45528	17.5714
87	*	*	*
85	40.7500	1.45104	28.0833
84	*	*	11.2727
79	17.2143	3.49275	4.9286
83	5.7368	4.03704	1.4211
82	10.2000	1.56923	6.5000
81	15.6875	2.14530	7.3125
78	8.7727	1.64957	5.3182
77	*	*	5.6923
76	14.7857	1.11290	13.2857
75	5.4167	1.12069	4.8333

Ribble

station	N:P	N:Si	Si:P
R1	22.000	6.87500	3.200
R19	17.172	2.64556	6.491
R18	315.800	2.84248	111.100
R17	0.688	0.16667	4.128
R16	10.684	2.04583	5.222
R15	9.708	2.33704	4.154
R13	24.105	1.09569	22.000
R14	12.277	1.86014	6.600
R12	99.125	2.33923	42.375
R11	35.467	1.84083	19.267
R9	*	*	20.273
R10	28.727	2.70085	10.636
R8	43.182	3.27586	13.182
R7	42.727	2.97468	14.364
R6	16.458	2.39394	6.875
R5	10.913	3.80303	2.870
R4	21.818	3.75000	5.818
R3	24.412	8.82979	2.765
R2	22.150	4.02727	5.500

Mersey

	station	date	Si	ToN	NO2	NO3	NH3	PO4	Salin.
14.0	M6	910131	35.7	60.5	3.6	56.9	20.9	2.6	*
16.5	M4	910131	10.2	29.6	2.5	27.1	8.6	2.6	*
18.6	SB29	910121	39.3	134.6	10.4	124.2	29.3	4.4	*
18.2	SB28	910121	39.3	91.4	3.4	88.0	6.8	2.9	*
20.0	SB27	910121	36.6	50.1	2.4	47.7	17.1	4.2	*
1.0	M19	910131	164.0	99.8	4.2	95.6	357.1	9.6	4.251
2.0	M18	910131	144.7	249.9	8.9	241.0	321.4	5.5	10.050
3.0	M17	910131	137.6	245.4	8.6	236.8	300.0	5.3	12.920
4.0	M16	910131	124.9	250.6	12.4	238.2	302.1	*	14.893
6.0	M14	910131	57.0	118.9	4.6	114.3	300.4	4.9	16.671
5.0	M15	910131	67.6	152.5	8.1	144.4	315.0	3.0	17.563
7.0	M13	910131	39.4	93.6	3.7	89.9	93.2	2.6	19.805
8.0	M12	910131	47.0	125.7	2.1	123.6	55.3	2.1	20.630
9.0	M11	910131	35.1	110.4	3.1	107.3	57.9	4.1	21.619
10.0	M10	910131	69.0	162.1	9.7	152.4	35.9	4.9	22.293
11.0	M9	910131	54.3	161.3	8.4	152.9	57.1	3.4	24.289
13.5	I40	910123	47.4	200.0	7.8	192.2	60.9	2.1	24.648
18.4	SB1	910121	46.4	114.6	11.3	103.3	28.6	3.0	25.218
12.0	M8	910131	44.6	124.0	7.1	116.9	26.6	3.1	25.808
14.5	I39	910123	46.1	105.9	4.2	101.7	27.4	3.1	26.891
13.0	M7	910131	21.0	43.2	2.1	41.1	21.3	2.6	27.062
15.0	I38	910123	24.5	91.3	4.1	87.2	19.6	1.3	27.582
20.6	SB2	910121	32.0	69.6	4.9	64.7	10.7	2.2	27.763
16.0	I37	910123	19.6	78.2	2.5	75.7	25.3	2.8	28.482
18.0	I36	910123	*	76.7	2.5	74.2	57.6	1.4	28.565
20.3	I35	910123	11.3	45.8	1.8	44.0	7.8	2.4	29.933
22.0	SB4	910121	8.9	38.1	0.9	37.2	18.6	1.5	29.986
21.3	SB3	910121	11.2	39.1	0.9	38.2	5.6	1.6	30.051
23.0	SB26	910121	8.0	5.4	1.6	3.8	9.1	1.7	30.092
21.6	I34	910123	16.0	37.6	1.4	36.2	4.0	0.1	30.107
15.5	M5	910131	12.1	26.1	1.2	24.9	4.1	1.6	30.300
23.5	SB5	910121	13.6	41.3	1.7	39.6	0.5	2.3	30.739
26.0	SB6	910121	10.3	34.4	0.8	33.6	4.7	1.8	30.743
19.0	M2	910131	11.7	22.1	1.6	20.5	*	1.1	30.934
25.0	SB25	910121	6.5	28.4	0.7	27.7	2.4	1.3	30.996
21.0	M1	910131	15.1	31.5	1.9	29.6	1.9	3.1	31.263
17.0	M3	910131	13.4	31.3	1.9	29.4	2.9	2.0	31.278
24.4	4	910115	10.8	37.3	0.2	37.0	3.9	1.7	31.734
24.3	3	910115	8.2	29.8	0.3	29.5	3.2	1.8	31.780
27.0	SB24	910121	9.2	24.6	0.4	24.2	1.8	1.3	31.978
24.5	5	910115	7.8	19.4	0.1	19.2	2.1	1.6	32.129
24.6	6	910115	3.0	27.5	0.1	27.4	1.2	0.1	32.539
24.1	1	910115	4.8	15.6	0.1	15.5	0.6	1.3	32.829
27.5	SB7	910121	4.6	16.8	0.1	16.7	0.1	1.3	32.921
24.2	2	910115	6.2	19.5	0.1	19.4	1.7	1.5	32.955

Dee

station	date	Si	ToN	NO2	NO3	NH3	PO4	Salin.
D13	910116	35.1	68.4	0.9	67.5	0.2	1.3	*
D12	910116	35.3	46.9	0.5	46.4	0.2	1.2	*
D3	910116	12.3	16.1	0.1	16.0	0.2	1.2	*
D24	910116	126.8	251.4	1.7	249.7	*	1.9	8.215
D23	910116	116.1	214.6	1.5	213.1	*	1.5	12.271
D19	910116	102.4	117.1	1.4	115.7	*	1.4	15.062
D22	910116	110.0	210.4	1.3	209.1	*	1.5	15.092
D21	910116	100.8	168.6	1.2	167.4	*	1.6	17.518
D16	910116	89.4	68.2	1.2	67.0	*	1.6	18.568
D20	910116	82.5	147.9	1.0	146.9	*	1.5	19.536
D18	910116	76.4	152.1	1.2	150.9	*	1.3	20.469
D17	910116	89.4	156.1	1.0	155.1	*	1.2	20.779
D15	910116	*	71.4	0.9	70.5	0.2	1.0	26.920
D14	910116	*	117.9	0.9	117.0	*	1.3	27.706
D10	910116	36.3	57.1	0.4	56.7	0.2	1.2	28.776
D9	910116	34.6	53.6	0.4	53.2	0.2	1.2	28.995
D11	910116	32.5	49.4	0.5	48.9	0.2	1.1	29.641
D8	910116	28.3	46.3	0.3	46.0	0.2	1.3	30.385
D7	910116	24.0	38.8	0.3	38.5	0.2	1.3	31.148
D6	910116	16.6	23.7	0.1	23.6	0.2	1.3	32.530
D5	910116	15.5	20.9	0.1	20.8	0.2	1.3	32.833
D4	910116	12.9	18.6	0.1	18.5	0.2	1.3	33.160
D2	910116	10.8	12.7	0.1	12.6	0.2	1.2	33.821
D1	910116	9.2	8.9	0.1	8.8	0.2	1.1	34.058

Mersey

	station	N:P	N:Si	Si:P
14.0	M6	21.885	1.59384	13.731
16.5	M4	10.423	2.65686	3.923
18.6	SB29	28.227	3.16031	8.932
18.2	SB26	30.345	2.23919	13.552
20.0	SB27	11.357	1.30328	8.714
1.0	M19	9.958	0.58293	17.083
2.0	M18	43.818	1.66551	26.309
3.0	M17	44.679	1.72093	25.962
4.0	M16	*	1.90713	*
6.0	M14	23.327	2.00526	11.633
5.0	M15	48.133	2.13609	22.533
7.0	M13	34.577	2.28173	15.154
8.0	M12	58.857	2.62979	22.381
9.0	M11	26.171	3.05698	8.561
10.0	M10	31.102	2.20870	14.082
11.0	M9	44.971	2.81584	15.971
13.5	I40	91.524	4.05485	22.571
18.4	SB1	34.433	2.22629	15.467
12.0	M8	37.710	2.62108	14.387
14.5	I39	32.806	2.20607	14.871
13.0	M7	15.808	1.95714	8.077
15.0	I38	67.077	3.55916	18.846
20.6	SB2	29.409	2.02187	14.545
16.0	I37	27.036	3.86224	7.000
18.0	I36	52.000	*	*
20.3	I35	18.333	3.89361	4.708
22.0	SB4	24.800	4.17978	5.933
21.3	SB3	23.875	3.41071	7.000
23.0	SB26	2.235	0.47500	4.706
21.6	I34	362.000	2.26250	160.000
15.5	M5	15.562	2.05785	7.562
23.5	SB5	17.217	2.91176	5.913
26.0	SB6	18.667	3.26214	5.722
19.0	M2	18.636	1.75214	10.636
25.0	SB25	21.308	4.26154	5.000
21.0	M1	9.548	1.96026	4.871
17.0	M3	14.700	2.19403	6.700
24.4	4	21.765	3.42593	6.353
24.3	3	16.389	3.59756	4.556
27.0	SB24	18.615	2.63043	7.077
24.5	5	12.000	2.46154	4.875
24.6	6	274.000	9.13333	30.000
24.1	1	11.923	3.22917	3.692
27.5	SB7	12.846	3.63043	3.538
24.2	2	12.933	3.12903	4.133

Dee

station	N:P	N:Si	Si:P
D13	51.923	1.92308	27.0000
D12	38.667	1.31445	29.4167
D3	13.333	1.30081	10.2500
D24	131.421	1.96924	66.7368
D23	142.067	1.83549	77.4000
D19	82.643	1.12988	73.1429
D22	139.400	1.90091	73.3333
D21	104.625	1.66071	63.0000
D16	41.875	0.74944	55.8750
D20	97.933	1.78061	55.0000
D18	116.077	1.97513	58.7692
D17	129.250	1.73490	74.5000
D15	70.500	*	*
D14	90.000	*	*
D10	47.250	1.56198	30.2500
D9	44.333	1.53757	28.8333
D11	44.455	1.50462	29.5455
D8	35.385	1.62544	21.7692
D7	29.615	1.60417	18.4615
D6	18.154	1.42169	12.7692
D5	16.000	1.34194	11.9231
D4	14.231	1.43411	9.9231
D2	10.500	1.16667	9.0000
D1	8.000	0.95652	8.3636

Irish Sea

station	date	Si	ToN	NO2	NO3	NH3	PO4	Salin.
MA17	*	9.1	15.3	*	*	*	1.8	32.560
I31	910123	5.7	11.9	0.4	11.5	0.1	1.1	32.761
MA14	*	7.8	13.0	*	*	*	1.6	33.130
I30	910123	3.4	8.6	0.1	8.5	0.1	1.0	33.577
I29	910123	3.5	11.1	0.1	11.0	0.1	1.4	33.578
I28	910123	2.6	8.9	0.1	8.8	0.1	1.3	33.602
I27	910123	8.2	14.4	0.1	14.3	0.1	0.1	33.658
I25	910123	4.7	9.1	0.1	9.0	0.1	1.1	33.726
I24	910123	4.9	9.1	0.1	9.0	0.1	1.7	33.731
I26	910123	2.2	7.6	0.1	7.5	1.6	1.8	33.741
I23	910123	8.9	19.5	0.1	19.4	1.9	0.1	33.764
I22	910123	3.7	7.7	0.1	7.6	0.1	1.5	33.981
I17	910123	3.4	6.1	0.1	6.0	0.1	1.4	34.124
I21	910123	3.3	6.8	0.1	6.7	0.1	1.4	34.140
I18	910123	3.4	6.0	0.1	5.9	0.1	1.3	34.141
I20	910123	3.1	6.5	0.1	6.4	0.1	1.0	34.173
I16	910123	3.0	6.4	0.1	6.3	0.1	1.0	34.184
I19	910123	2.9	6.3	0.1	6.2	0.1	0.9	34.200
I15	910123	*	5.0	0.1	4.9	0.1	0.1	34.252
I12	910123	*	5.0	*	*	0.1	0.1	34.568
I11	910123	2.1	4.9	0.1	4.8	0.1	0.1	34.588
I6	910123	2.0	5.7	0.1	5.6	0.1	0.5	34.605
I7	910123	2.1	6.1	0.1	6.0	0.1	0.7	34.609
I8	910123	1.9	5.6	0.1	5.5	0.1	0.6	34.614
I10	910123	2.9	5.9	0.1	5.8	0.1	0.1	34.636
I9	910123	3.1	5.6	0.1	5.5	0.1	0.1	34.644
I1	910123	2.6	2.4	0.1	2.3	0.1	0.1	34.674
I5	910123	*	4.9	0.1	4.8	*	0.1	34.678
I13	910123	1.8	4.9	0.1	4.8	0.1	0.2	34.706
I4	910123	3.8	6.6	0.1	6.5	0.1	0.3	34.720
I3	910123	4.8	4.3	0.1	4.2	*	0.1	34.721
I2	910123	2.5	5.4	0.1	5.3	0.1	0.2	34.726
I14	910123	2.3	7.8	0.1	7.7	0.1	1.2	34.970

W-E Coast

station	date	Si	ToN	NO2	NO3	NH3	PO4	Salin.
SB23	910121	4.7	9.0	0.1	8.9	0.4	0.9	33.264
SB22	910121	4.9	6.5	0.1	6.4	0.2	1.1	33.317
SB20	910121	4.1	10.7	0.1	10.6	2.2	1.9	33.318
SB21	910121	2.5	6.9	0.1	6.8	0.5	0.9	33.334
SB19	910121	5.4	12.6	0.1	12.5	2.0	1.8	33.384
SB18	910121	4.7	11.1	0.1	11.0	0.6	1.5	33.506
SB17	910121	1.8	8.7	0.1	8.6	0.9	1.2	33.767
SB16	910121	*	15.2	0.3	14.9	2.7	2.3	33.837
SB14	910121	2.7	6.6	0.1	6.5	0.1	0.9	33.870
SB12	910121	2.4	8.0	0.1	7.9	0.1	0.9	33.875
SB13	910121	2.4	4.2	0.1	4.1	0.1	0.9	33.881
SB15	910121	1.4	5.8	0.1	5.7	0.6	0.9	33.893
SB11	910121	2.6	6.0	0.1	5.9	0.1	0.8	33.917
SB10	910121	1.8	50.1	0.1	50.0	0.1	0.7	33.946
SB9	910121	0.9	5.3	0.1	5.2	0.1	0.7	34.007
SB8	910121	0.7	5.9	0.1	5.8	0.1	0.7	34.026

Irish Sea

station	N:P	N:Si	Si:P
MA17	*	*	5.0556
I31	10.455	2.01754	5.1818
MA14	*	*	4.8750
I30	8.500	2.50000	3.4000
I29	7.857	3.14286	2.5000
I28	6.769	3.38462	2.0000
I27	143.000	1.74390	82.0000
I25	8.182	1.91489	4.2727
I24	5.294	1.83673	2.8824
I26	4.167	3.40909	1.2222
I23	194.000	2.17978	89.0000
I22	5.067	2.05405	2.4667
I17	4.286	1.76471	2.4286
I21	4.786	2.03030	2.3571
I18	4.538	1.73529	2.6154
I20	6.400	2.06452	3.1000
I16	6.300	2.10000	3.0000
I19	6.889	2.13793	3.2222
I15	49.000	*	*
I12	*	*	*
I11	48.000	2.28571	21.0000
I6	11.200	2.80000	4.0000
I7	8.571	2.85714	3.0000
I8	9.167	2.89474	3.1667
I10	58.000	2.00000	29.0000
I9	55.000	1.77419	31.0000
I1	23.000	0.88462	26.0000
I5	48.000	*	*
I13	24.000	2.66667	9.0000
I4	21.667	1.71053	12.6667
I3	42.000	0.87500	48.0000
I2	26.500	2.12000	12.5000
I14	6.417	3.34783	1.9167

W-E Coast

station	N:P	N:Si	Si:P
SB23	9.8889	1.8936	5.22222
SB22	5.8182	1.3061	4.45455
SB20	5.5789	2.5854	2.15789
SB21	7.5556	2.7200	2.77778
SB19	6.9444	2.3148	3.00000
SB18	7.3333	2.3404	3.13333
SB17	7.1667	4.7778	1.50000
SB16	6.4783	*	*
SB14	7.2222	2.4074	3.00000
SB12	8.7778	3.2917	2.66667
SB13	4.5556	1.7083	2.66667
SB15	6.3333	4.0714	1.55556
SB11	7.3750	2.2692	3.25000
SB10	71.4286	27.7778	2.57143
SB9	7.4286	5.7778	1.28571
SB8	8.2857	8.2857	1.00000

29	910115	10.4	23.8	0.6	23.2	1.1	1.70	31.356
27	910115	6.6	33.3	0.5	32.8	2.1	1.50	31.394
34	910115	4.1	31.4	0.5	30.9	•	1.70	31.433
25	910115	7.9	27.1	•	•	2.2	0.10	31.484
47	910115	5.9	18.9	0.3	18.6	1.6	1.20	31.517
24	910115	5.1	17.1	0.5	16.6	•	0.10	31.556
28	910115	8.0	30.7	0.5	30.2	1.4	1.50	31.597
30	910115	7.9	27.1	0.6	26.5	1.2	1.40	31.731
MA10	910209	10.1	16.0	•	•	•	2.40	31.790
23	910115	12.8	12.6	0.5	12.1	8.2	2.10	31.830
MA35	910215	12.0	17.6	•	•	•	1.70	32.030
MA26	910215	12.0	17.6	•	•	•	1.59	32.040
MA24	910215	12.0	17.6	•	•	•	1.64	32.040
MA23	910215	12.0	17.7	•	•	•	1.66	32.040
MA9	910205	12.9	18.8	•	•	•	3.40	32.070
MA27	910215	11.9	16.8	•	•	•	2.07	32.270
MA20	910213	9.1	18.6	•	•	•	1.80	32.370
MA28	910215	11.9	16.5	•	•	•	2.29	32.400
MA29	910215	12.0	16.4	•	•	•	2.51	32.440
MA22	910215	12.0	17.7	•	•	•	1.66	32.490
MA18	910213	8.8	17.9	•	•	•	1.70	32.540
MA19	910213	8.5	17.4	•	•	•	1.70	32.660
22	910115	6.1	19.1	0.3	18.8	0.6	1.70	32.736
7	910115	0.2	•	0.1	•	•	0.10	32.873
21	910115	1.3	5.3	0.2	5.1	0.6	1.30	33.115
11	910115	1.5	11.6	0.1	11.5	0.9	1.00	33.151
20	910115	5.8	12.9	0.1	12.8	1.9	1.10	33.191
8	910115	2.9	12.4	0.1	12.3	0.6	0.10	33.201
19	910115	5.3	8.6	0.1	8.5	0.6	0.90	33.210
9	910115	5.6	8.3	0.1	8.2	0.4	0.10	33.249
10	910115	6.3	7.2	0.1	7.1	0.3	1.10	33.265
17	910115	3.0	7.3	0.1	7.2	1.4	1.10	33.341
13	910115	6.8	9.9	1.3	8.6	0.6	0.90	33.449
12	910115	•	11.2	0.1	11.1	•	1.30	33.457
14	910115	1.8	9.5	0.1	9.4	0.1	1.20	33.467
16	910115	5.2	11.9	1.1	10.8	0.8	1.50	33.468
18	910115	3.3	8.6	0.1	8.5	0.5	0.90	33.505
15	910115	1.8	14.9	0.1	14.8	3.0	1.0[illegible]	33.600

N-S Coast

station	date	Si	TON	NO2	NO3	NH3	PO4	Salin.
71	910115	15.7	28.2	0.4	27.8	1.8	2.30	28.775
31	910115	6.0	6.8	0.1	6.7	1.2	2.00	29.262
75	910115	11.6	13.4	0.4	13.0	0.3	2.40	29.709
59	910115	6.0	17.4	0.6	16.8	0.9	2.00	29.876
69	910115	*	7.6	0.3	7.3	0.6	1.20	29.958
74	910115	11.2	14.9	0.3	14.6	1.2	1.70	30.006
70	910115	12.0	17.1	0.3	16.8	0.6	1.70	30.053
61	910115	8.0	23.5	0.9	22.6	6.6	1.50	30.089
72	910115	12.2	16.5	0.4	16.1	1.5	2.40	30.095
62	910115	12.1	14.5	0.5	14.0	1.4	2.70	30.157
73	910115	8.4	6.5	0.4	6.1	1.2	2.30	30.165
60	910115	5.5	9.6	0.2	9.4	1.1	2.90	30.183
68	910115	12.0	8.7	0.2	8.5	0.8	1.40	30.239
63	910115	11.9	21.4	0.5	20.9	2.5	2.90	30.322
64	910115	11.8	18.1	1.1	17.0	*	1.70	30.413
58	910115	13.2	15.0	0.8	14.2	0.9	4.20	30.484
65	910115	10.7	14.9	0.5	14.4	1.1	2.70	30.486
66	910115	5.7	13.6	0.3	13.3	0.4	2.50	30.609
67	910115	5.2	5.9	0.1	5.8	0.3	2.20	30.854
57	910115	12.9	17.2	0.9	16.3	0.1	4.60	30.881
43	910115	13.1	12.0	0.3	11.7	*	1.30	30.959
44	910115	11.2	19.9	0.6	19.3	0.5	2.00	30.991
42	910115	5.1	12.3	0.2	12 1	0.4	1.20	30.992
39	910115	9.8	13.4	0.6	12.8	5.5	2.10	31.016
40	910115	11.0	21.2	0.6	20.6	0.6	2.00	31.048
45	910115	11.4	21.1	0.5	20.6	*	1.50	31.066
38	910115	10.0	22.5	0.7	21.8	*	2.00	31.093
41	910115	23.9	16.0	0.6	15.4	0.6	1.10	31.099
56	910115	12.1	13.9	0.9	18.0	1.8	4.00	31.106
37	910115	8.6	16.9	0.6	16.3	1.4	2.20	31.112
50	910115	10.7	21.1	1.1	20.0	0.4	2.70	31.122
51	910115	7.3	25.1	1.1	24.0	1.5	2.00	31.177
36	910115	12.7	21.1	0.4	20.7	1.5	2.10	31.187
49	910115	3.1	14.1	0.7	13.4	0.7	1.90	31.203
53	910115	11.6	10.1	0.9	9.2	3.4	2.30	31.214
35	910115	7.6	14.6	0.4	14.2	0.9	1.50	31.216
55	910115	5 0	17.7	0.5	17.2	0.9	3.40	31.217
52	910115	7.0	17.4	1.1	16.3	1.1	2.50	31.230
46	910115	8.0	15.4	0.3	15.1	*	1.50	31.242
54	910115	5.2	*	0.5	*	1.1	1.60	31.259
33	910115	7.2	19.6	0.3	19.3	1.3	1.40	31.263
26	910115	10.2	39.8	0.5	39.3	2.5	1.50	31.298
32	910115	2.0	10.9	0.3	10.6	1.6	1.40	31.340
48	910115	9.9	11.3	0.4	10.9	6.4	1.00	31.352

N-S Coast

station	N:P	N:Si	Si:P
71	12.087	1.77070	6.8261
31	3.350	1.11667	3.0000
75	5.417	1.12069	4.8333
59	8.400	2.80000	3.0000
69	6.083	.	.
74	8.588	1.30357	6.5882
70	9.882	1.40000	7.0588
61	15.067	2.82500	5.3333
72	6.708	1.31967	5.0833
62	5.185	1.15702	4.4815
73	2.652	0.72619	3.6522
60	3.241	1.70909	1.8966
68	6.071	0.70833	8.5714
63	7.207	1.75630	4.1034
64	10.000	1.44068	6.9412
58	3.381	1.07576	3.1429
65	5.333	1.34579	3.9630
66	5.320	2.33333	2.2800
67	2.636	1.11538	2.3636
57	3.543	1.26357	2.8043
43	9.000	0.89313	10.0769
44	9.650	1.72321	5.6000
42	10.083	2.37255	4.2500
39	6.095	1.30612	4.6667
40	10.300	1.87273	5.5000
45	13.733	1.80702	7.6000
38	10.900	2.18000	5.0000
41	14.000	0.64435	21.7273
56	4.500	1.48760	3.0250
37	7.409	1.89535	3.9091
50	7.407	1.86916	3.9630
51	12.000	3.28767	3.6500
36	9.857	1.62952	6.0476
49	7.053	4.32258	1.6316
53	4.000	0.79310	5.0435
35	9.467	1.86842	5.0667
55	5.059	3.44000	1.4706
52	6.520	2.32857	2.8000
46	10.067	1.88750	5.3333
54	.	.	3.2500
33	13.786	2.68056	5.1429
26	26.200	3.85294	6.8000
32	7.571	5.30000	1.4286
48	10.900	1.10101	9.9000
29	13.647	2.23077	6.1176
27	21.867	4.96970	4.4000
34	18.176	7.53659	2.4118
25	.	.	79.0000
47	15.500	3.15254	4.9167
24	166.000	3.25490	51.0000
28	20.133	3.77500	5.3333
30	18.929	3.35443	5.6429
MA10	.	.	4.2083
20	5.762	0.94531	6.0952
MA25	.	.	7.0588
MA26	.	.	7.5472
MA24	.	.	7.3171
MA23	.	.	7.2289
MA9	.	.	3.7941
MA27	.	.	5.7488
MA20	.	.	5.0556
MA28	.	.	5.1965
MA29	.	.	4.7809
MA22	.	.	7.2289
MA18	.	.	5.1765
MA19	.	.	5.0000
22	11.059	3.08197	3.5882
7	.	.	2.0000
21	3.923	3.92308	1.0000
11	11.500	7.66667	1.5000
20	11.636	2.20690	5.2727
8	123.000	4.24138	29.0000
19	9.444	1.60377	5.8889
9	82.000	1.46429	56.0000
10	6.455	1.12698	5.7273
17	6.545	2.40000	2.7273
13	9.556	1.26471	7.5556
12	8.538	.	.
14	7.833	5.22222	1.5000
16	7.200	2.07692	3.4667
18	9.444	2.57576	3.6667
15	14.800	8.22222	1.8000

APPENDIX 2

BASIC RESULTS

SiO_2-Si

	n	M	MEAN	St.Dev.	S.E.	MIN	MAX
Solway	15	4	19.65	15.17	3.92	2.70	49.6
Ribble	19	0	32.89	31.64	7.26	4.70	111.1
Mersey*	44	1	35.82	38.97	5.88	3.00	164.0
Dee	22	2	54.42	40.38	8.61	9.20	126.8
Irish Sea	30	3	3.86	2.08	0.38	1.80	9.10
N-S Coast	80	2	8.58	3.99	0.45	0.20	23.90
W-E Coast	15	1	2.87	1.52	0.39	0.70	5.40

NO_3-N

	n	M	MEAN	St.Dev.	S.E.	MIN	MAX
Solway	13	6	46.80	39.20	10.90	10.9	115.4
Ribble	18	1	76.90	84.60	19.90	9.7	315.8
Mersey*	45	0	76.69	62.84	9.37	3.8	241.0
Dee	24	0	88.30	71.60	14.60	8.8	249.7
Irish Sea	30	3	7.26	3.32	0.61	2.3	19.4
N-S Coast	66	16	15.54	6.94	0.85	5.1	39.3
W-E Coast	16	0	10.68	10.89	2.72	4.1	50.0

NH_3-N

	n	M	MEAN	St.Dev.	S.E.	MIN	MAX
Solway	14	5	3.83	2.32	0.62	1.40	8.1
Ribble	19	0	23.79	23.50	5.39	3.80	79.0
Mersey*	44	1	59.80	105.30	15.90	0.10	357.1
Dee	14	10	0.20	0.00	0.00	0.20	0.2
Irish Sea	29	4	0.21	0.43	0.08	0.10	1.9
N-S Coast	60	22	1.49	1.59	0.20	0.10	8.2
W-E Coast	16	0	0.71	0.92	0.23	0.10	2.7

.../...

PO_4-P

	n	M	MEAN	St.Dev.	S.E.	MIN	MAX
Solway	15	4	1.52	0.41	0.11	1.10	2.40
Ribble	19	0	3.98	4.82	1.11	0.80	16.30
Mersey*	44	1	2.61	1.67	0.25	0.10	9.60
Dee	24	0	1.32	0.20	0.04	1.00	1.90
Irish Sea	33	0	0.79	0.61	0.11	0.10	1.80
N-S Coast	82	0	1.78	0.84	0.09	0.10	4.60
W-E Coast	16	0	1.13	0.48	0.12	0.70	2.30

Salinity

	n	M	MEAN	St.Dev.	S.E.	MIN	MAX
Solway	19	0	22.96	5.47	1.26	13.08	29.71
Ribble	18	1	23.84	9.29	2.19	1.13	31.17
Mersey*	40	5	26.31	6.94	1.10	4.25	32.96
Dee	21	3	24.64	7.99	1.74	8.22	34.06
Irish Sea	33	0	34.14	0.60	0.10	32.56	34.97
N-S Coast	82	0	31.51	1.21	0.13	26.77	33.60
W-E Coast	16	0	33.70	0.28	0.07	33.26	34.03

Where: n = number of sampling points
M = number of missing data
St.Dev. = Standard Deviation
S.E. = Standard Error of the mean
MIN = minimum concentration
MAX = maximum concentration
N, P and Si are in μmol/l
Salinity is in o/oo
* = sampling points from various sources

.../...

N:P

	n	M	MEAN	St.Dev.	S.E.	MIN	MAX
Solway	13	6	35.74	34.56	9.58	5.42	96.17
Ribble	18	1	42.10	71.60	16.90	0.70	315.80
Mersey*	44	1	40.55	64.32	9.70	2.24	362.00
Dee	24	0	63.23	45.17	9.22	8.00	142.07
Irish Sea	28	0	28.57	42.34	7.73	4.17	194.00
N-S Coast	66	16	14.53	25.54	3.14	2.64	166.00
W-E Coast	16	0	11.14	16.13	4.03	4.56	71.43

N:Si

	n	M	MEAN	St.Dev.	S.E.	MIN	MAX
Solway	13	6	2.44	1.21	0.33	1.11	5.24
Ribble	18	1	3.10	2.00	0.47	0.17	8.83
Mersey*	44	1	2.73	1.33	0.20	0.47	9.13
Dee	22	2	1.52	0.33	0.07	0.75	1.97
Irish Sea	28	5	2.22	0.65	0.12	0.87	3.41
N-S Coast	64	18	2.42	1.65	0.21	0.64	8.22
W-E Coast	15	1	4.90	6.59	1.70	1.31	27.78

Si:P

	n	M	MEAN	St.Dev.	S.E.	MIN	MAX
Solway	15	4	14.86	13.41	3.92	3.46	41.33
Ribble	19	0	16.15	24.98	5.73	2.76	111.00
Mersey*	43	2	14.82	23.73	3.62	3.54	160.00
Dee	22	2	38.42	25.36	5.41	8.36	77.40
Irish Sea	30	3	14.09	22.38	4.09	1.22	89.00
N-S Coast	80	2	7.37	11.75	1.31	1.00	79.00
W-E Coast	15	1	2.68	1.14	0.29	1.00	5.22

Where: n = number of sampling points
M = number of missing data
St.Dev. = Standard Deviation
S.E. = Standard Error of the mean
MIN = minimum concentration
MAX = maximum concentration
N, P and Si are in μmol/l
Salinity is in o/oo
* = sampling points from various sources

APPENDIX 3

LINEAR REGRESSION RESULTS

SiO_2 -Si

	n	Equation	R^2	p
Solway	15	Si = 67.4 - 2.01 S	59.4	0.000
Ribble	18	Si = 113.0 - 3.30 S	92.6	0.000
Mersey*	39	Si = 183.0 - 5.58 S	90.0	0.000
Dee	19	Si = 179.0 - 4.95 S	98.5	0.000
Irish Sea	30	Si = 84.0 - 2.35 S	45.7	0.000
N-S Coast	80	Si = 56.6 - 1.52 S	19.8	0.000
W-E Coast	15	Si = 151.0 - 4.40 S	68.9	0.000

NO_3-N

	n	Equation	R^2	p
Solway	13	N = 182.0 - 5.82 S	84.7	0.000
Ribble	17	N = 256.0 - 7.50 S	65.7	0.000
Mersey*	40	N = 277.0 - 7.56 S	63.1	0.000
Dee	21	N = 306.0 - 8.58 S	85.2	0.000
Irish Sea	30	N = 155.0 - 4.32 S	42.0	0.000
N-S Coast	66	N = 62.1 - 1.49 S	6.1	0.026
W-E Coast	15	N = - 147.0 + 4.70 S	0.0	0.652

NH_3-N

	n	Equation	R^2	p
Solway	14	N = 12.30 - 0.36 S	90.6	0.000
Ribble	18	N = 83.90 - 2.49 S	93.2	0.000
Mersey*	39	N = 445.0 - 14.50 S	83.4	0.000
Dee	11	all readings = 0.2	n/a	n/a
Irish Sea	29	N = 6.99 - 0.20 S	2.0	0.219
N-S Coast	60	N = 4.39 - 0.09 S	0.0	0.563
W-E Coast	16	N = 41.30 - 1.20 S	7.6	0.157

.../...

PO_4-P

	n	Equation	R^2	p
Solway	15	P = 0.52 + 0.04 S	32.4	0.016
Ribble	18	P = 12.90 - 0.37 S	45.0	0.004
Mersey*	39	P = 8.43 - 0.22 S	75.6	0.000
Dee	21	P = 1.82 - 0.02 S	56.0	0.000
Irish Sea	33	P = 22.90 - 0.65 S	38.0	0.000
N-S Coast	82	P = 11.50 - 0.31 S	18.7	0.000
W-E Coast	15	P = 24.20 - 0.68 S	10.1	0.123

Where: S = Salinity in o/oo
n = number of sampling points
p = probability
* = sampling points from various sources
R^2 is in %, corrected for degree of freedom
N, P and Si are in μmol/l

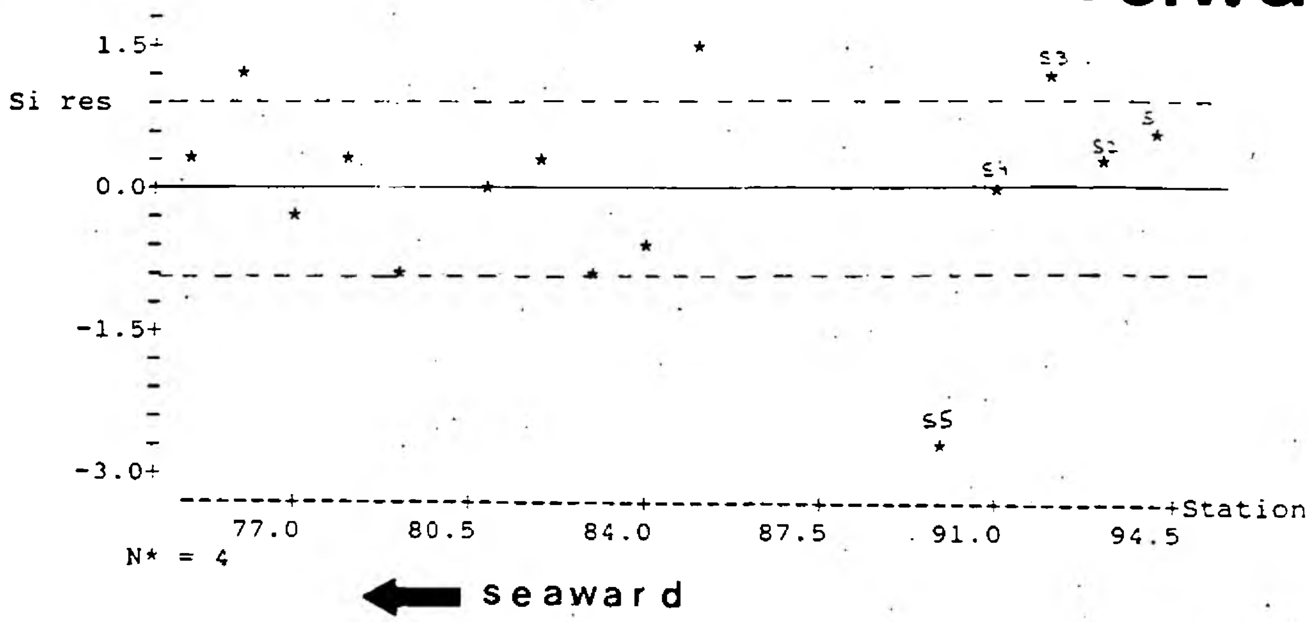
APPENDIX 4

RESIDUAL PLOTS

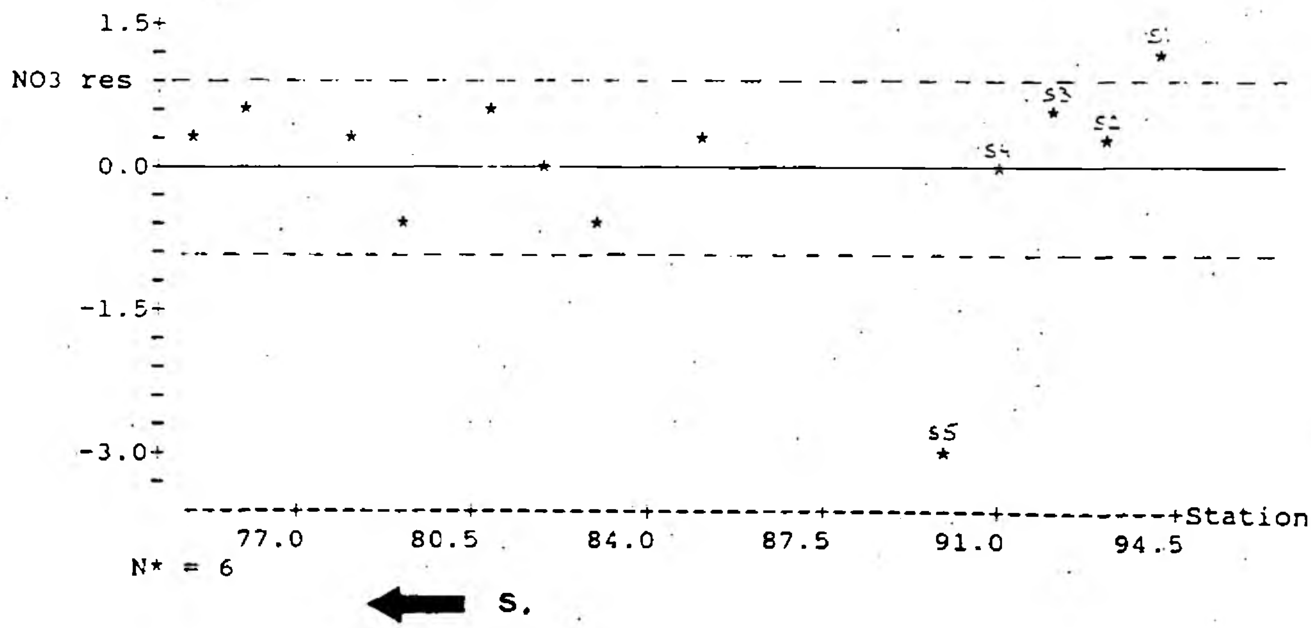
KEY:

res	residual values, i.e. difference between the observed and expected values, derived from the linear regression equations in Appendix 3.
———	residual equals to zero
- - -	residual standard deviation limits
N*	Number of missing data points
s.	seaward
N —▸ S	North to South Coastal run
W —▸ E	West to East Coastal run

Solway

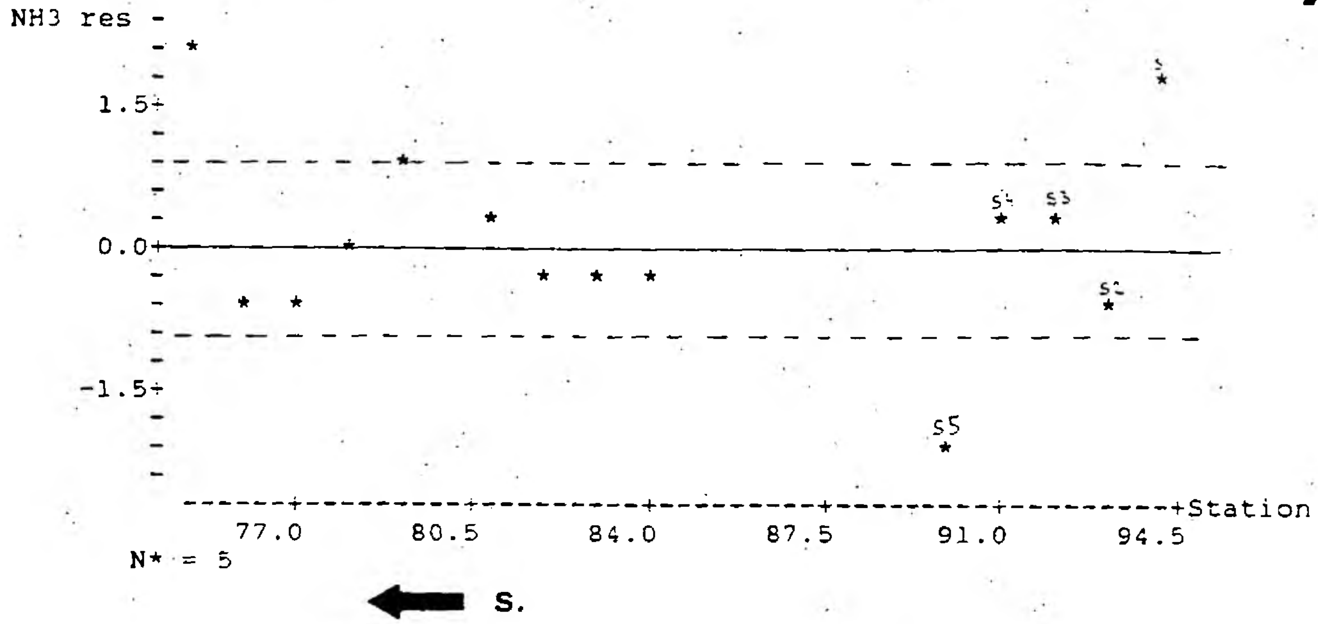


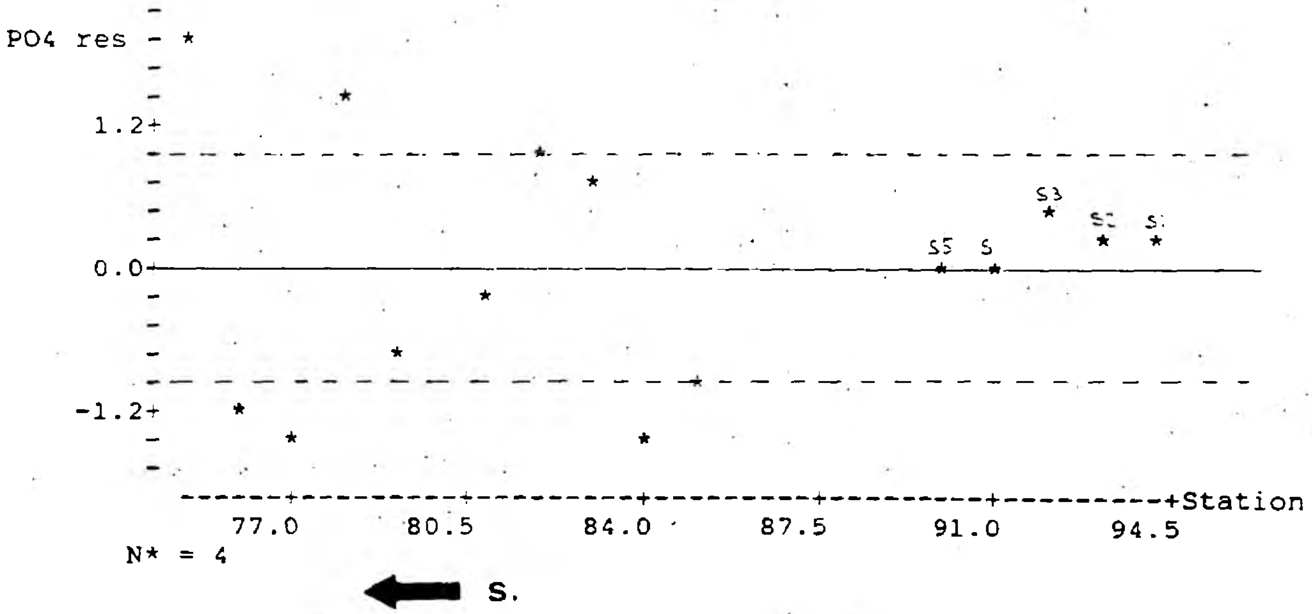
1.5
Si res
0.0
-1.5
-3.0
S3
S
S2
S4
S5
77.0
80.5
84.0
87.5
91.0
94.5
Station
N* = 4
seaward



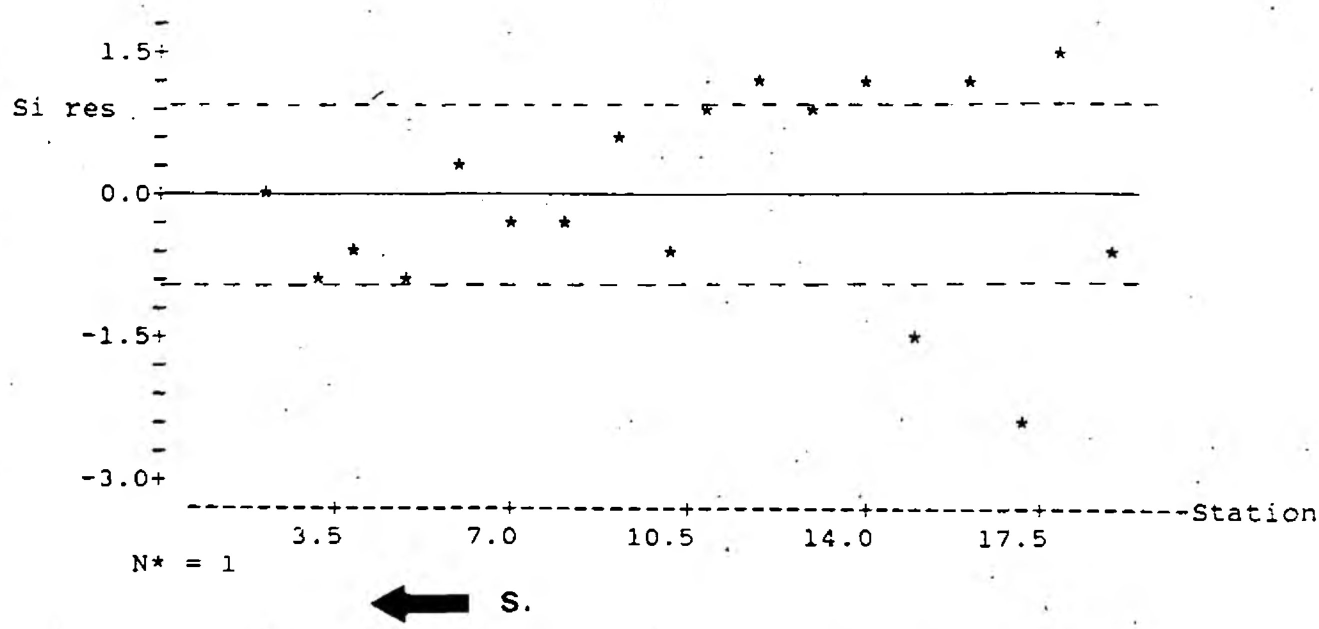
1.5
NO3 res
0.0
-1.5
-3.0
S1
S3
S2
S4
S5
77.0
80.5
84.0
87.5
91.0
94.5
Station
N* = 6
s.

Solway

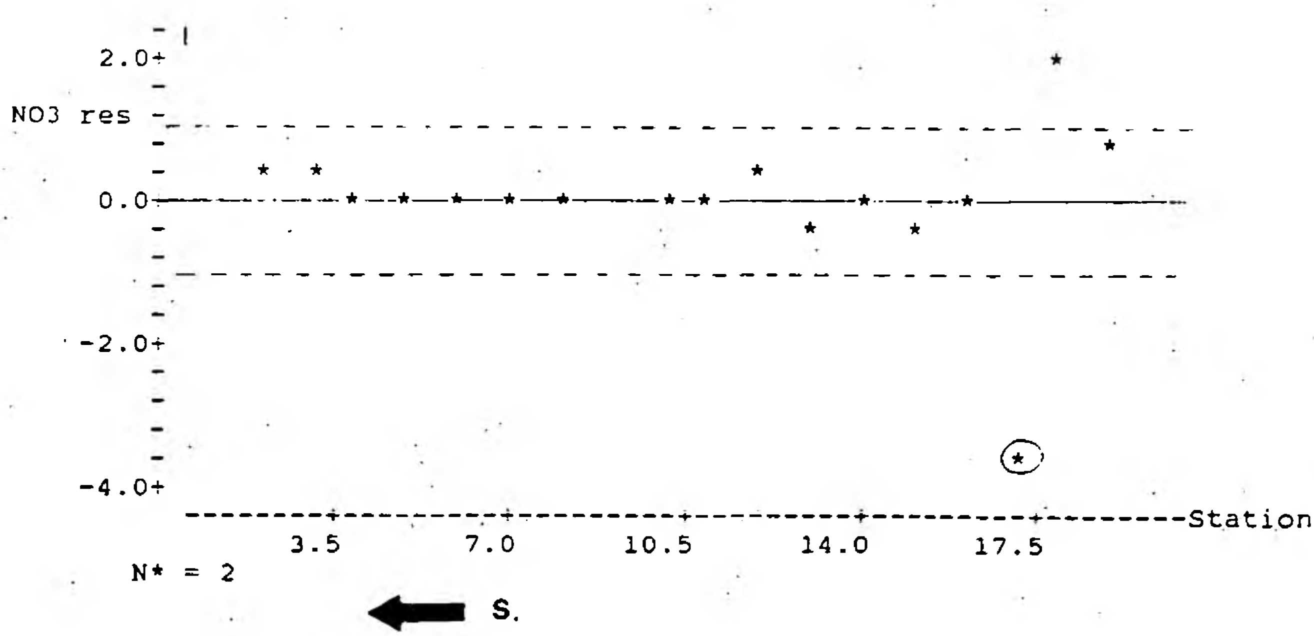

NH3 res
1.5
0.0
-1.5
S5
S4 S3
S2
77.0 80.5 84.0 87.5 91.0 94.5
Station
N* = 5
S.


PO4 res
1.2
0.0
-1.2
S3
S5 S
77.0 80.5 84.0 87.5 91.0 94.5
Station
N* = 4
S.

Ribble

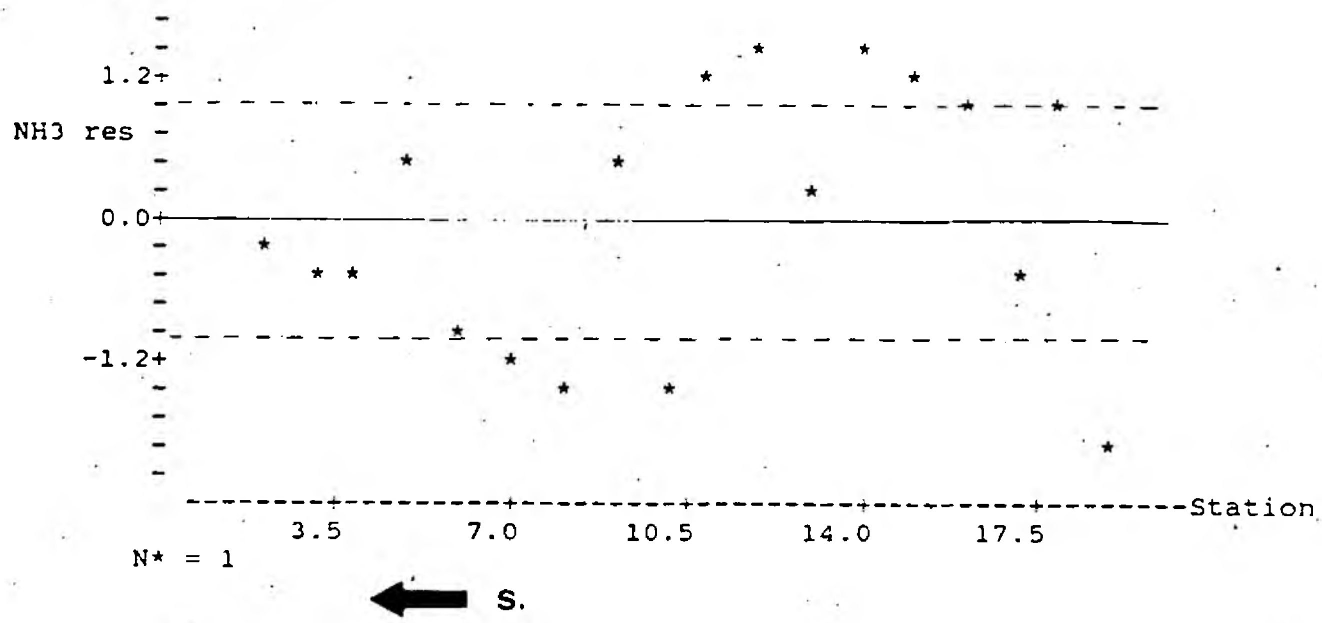


1.5+
Si res
0.0+
-1.5+
-3.0+
Station
3.5
7.0
10.5
14.0
17.5
N* = 1
S.

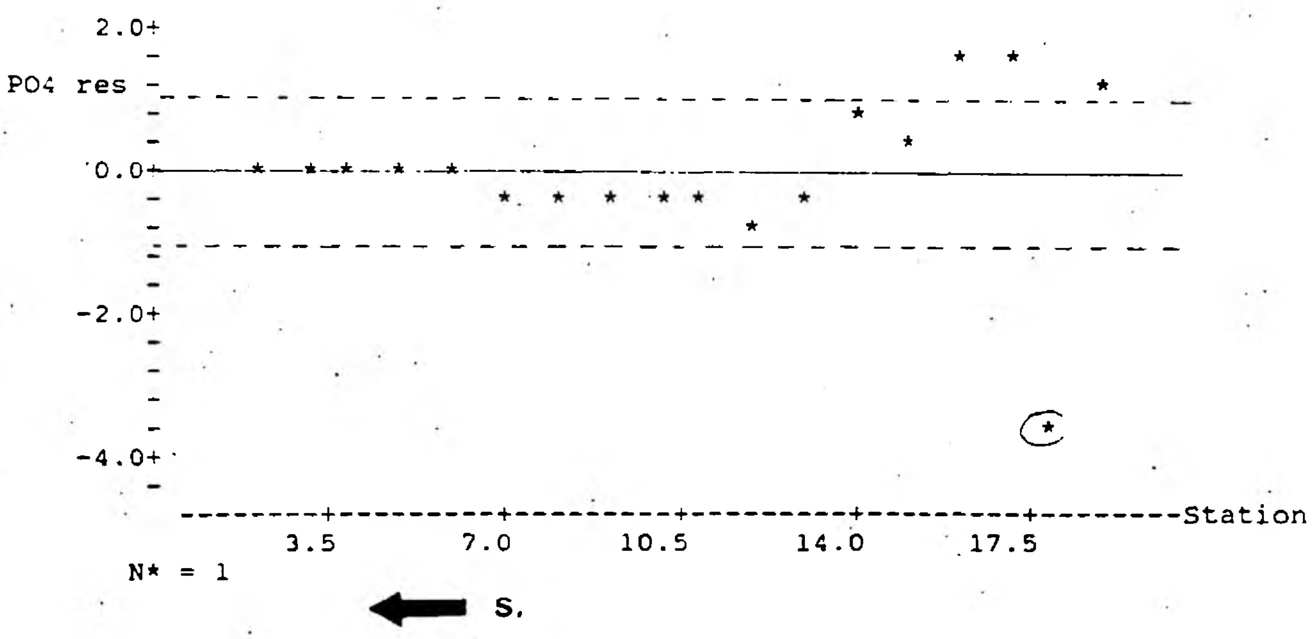


2.0+
NO3 res
0.0
-2.0+
-4.0+
Station
3.5
7.0
10.5
14.0
17.5
N* = 2
S.

Ribble

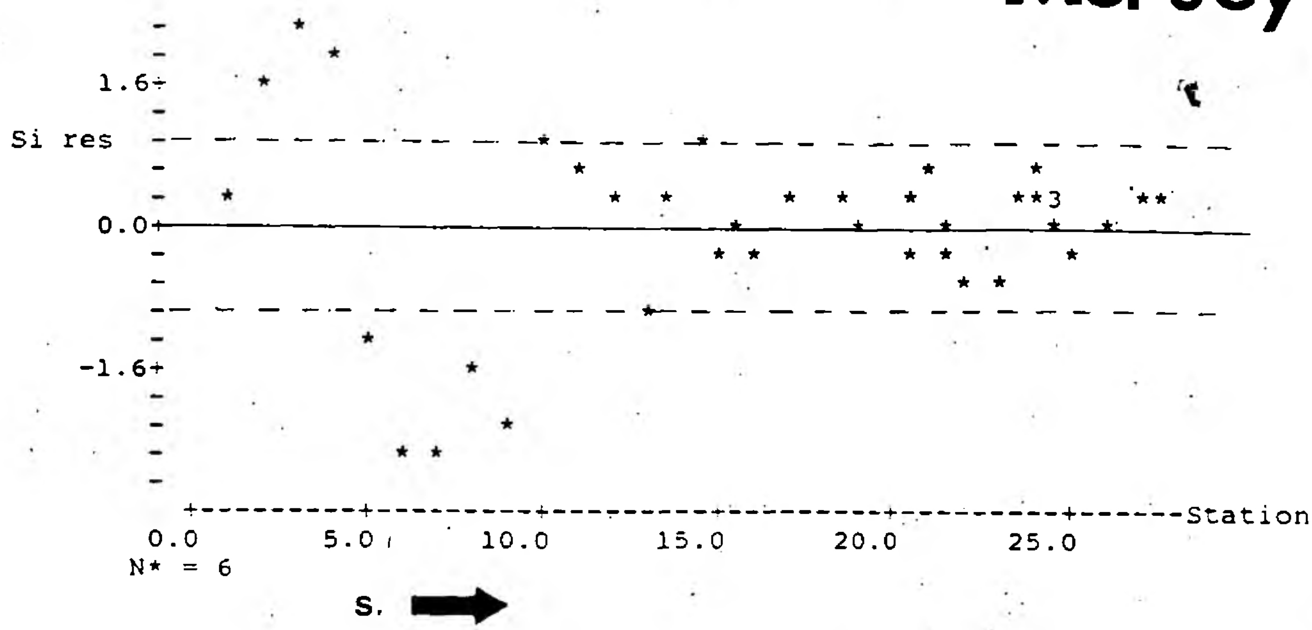


1.2+
NH3 res
0.0+
-1.2+
Station
3.5
7.0
10.5
14.0
17.5
N* = 1
S.

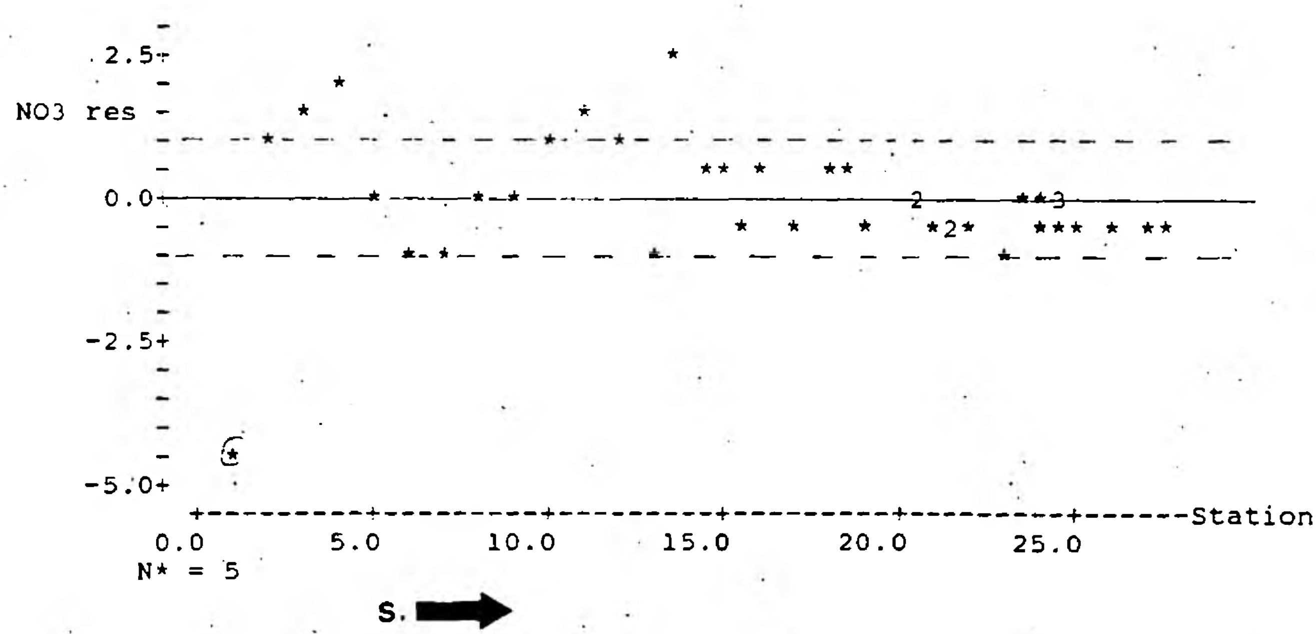


2.0+
PO4 res
0.0+
-2.0+
-4.0+
Station
3.5
7.0
10.5
14.0
17.5
N* = 1
S.

Mersey

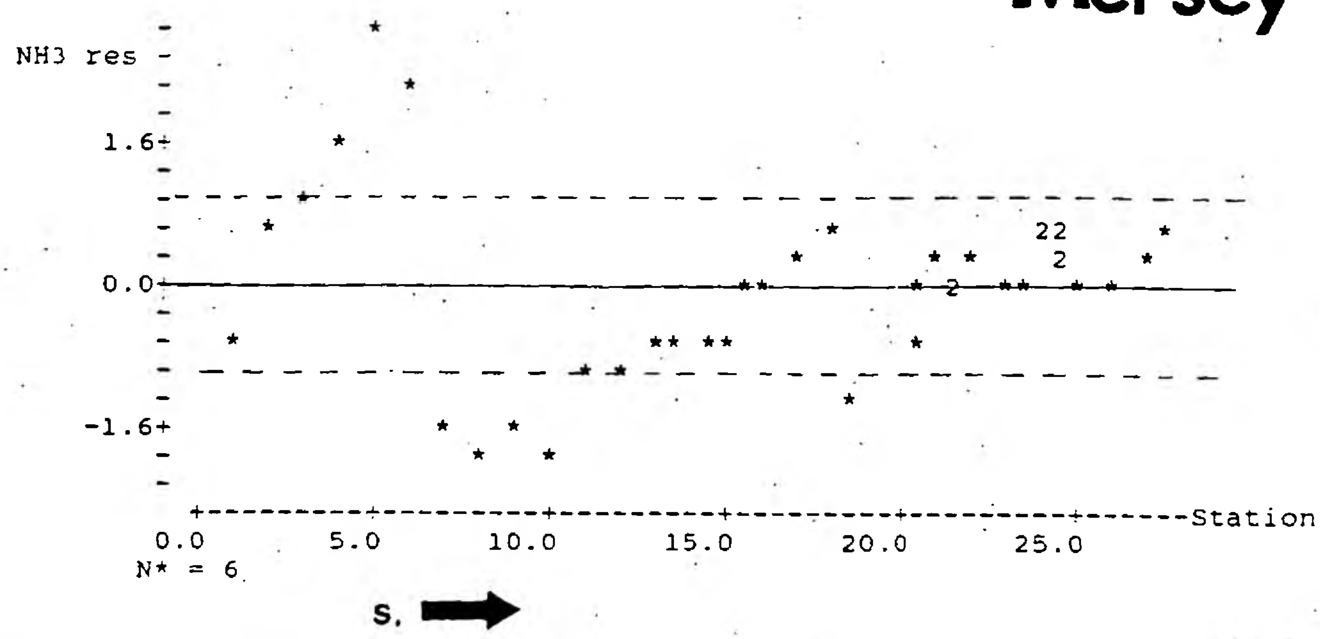


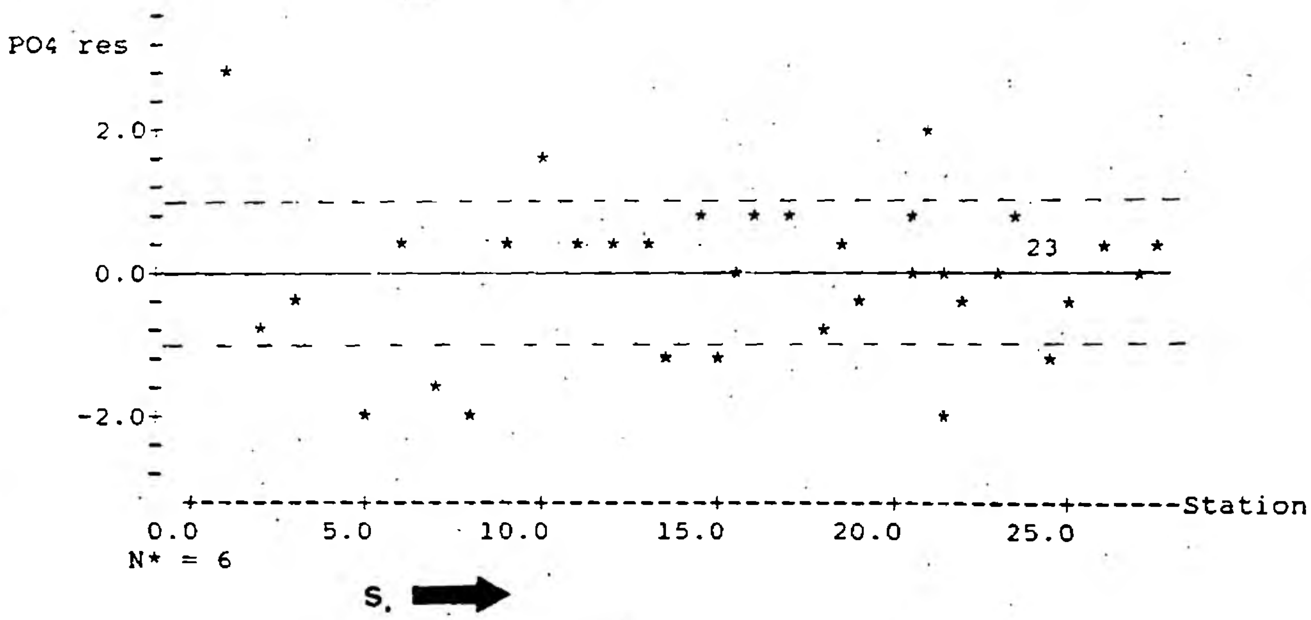
Si res
1.6
0.0
-1.6
0.0
5.0
10.0
15.0
20.0
25.0
Station
N* = 6
S.



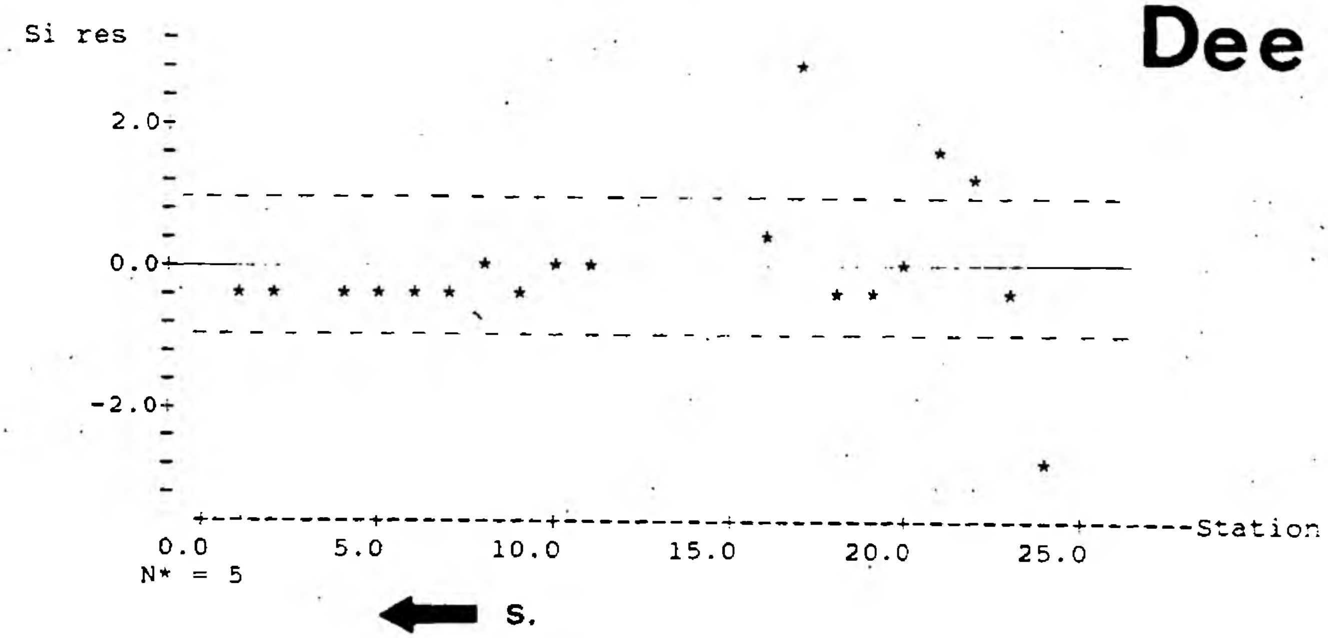
NO3 res
2.5
0.0
-2.5
-5.0
0.0
5.0
10.0
15.0
20.0
25.0
Station
N* = 5
S.

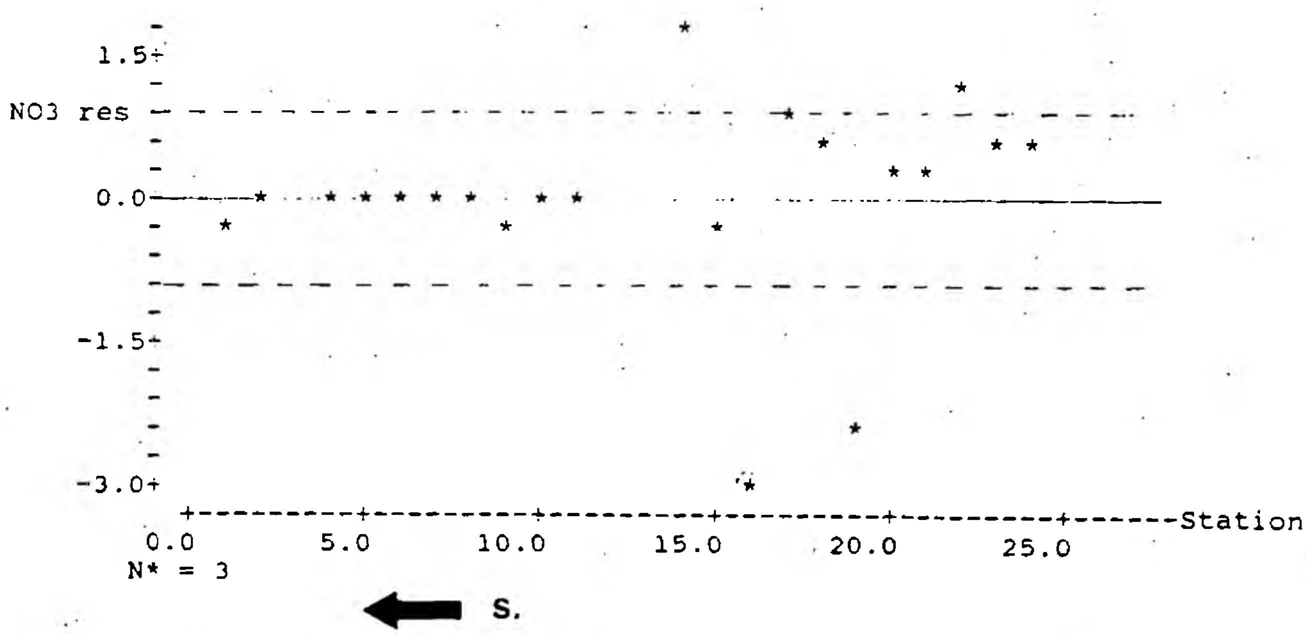
Mersey


NH3 res
1.6
0.0
-1.6
Station
0.0
5.0
10.0
15.0
20.0
25.0
N* = 6
S.

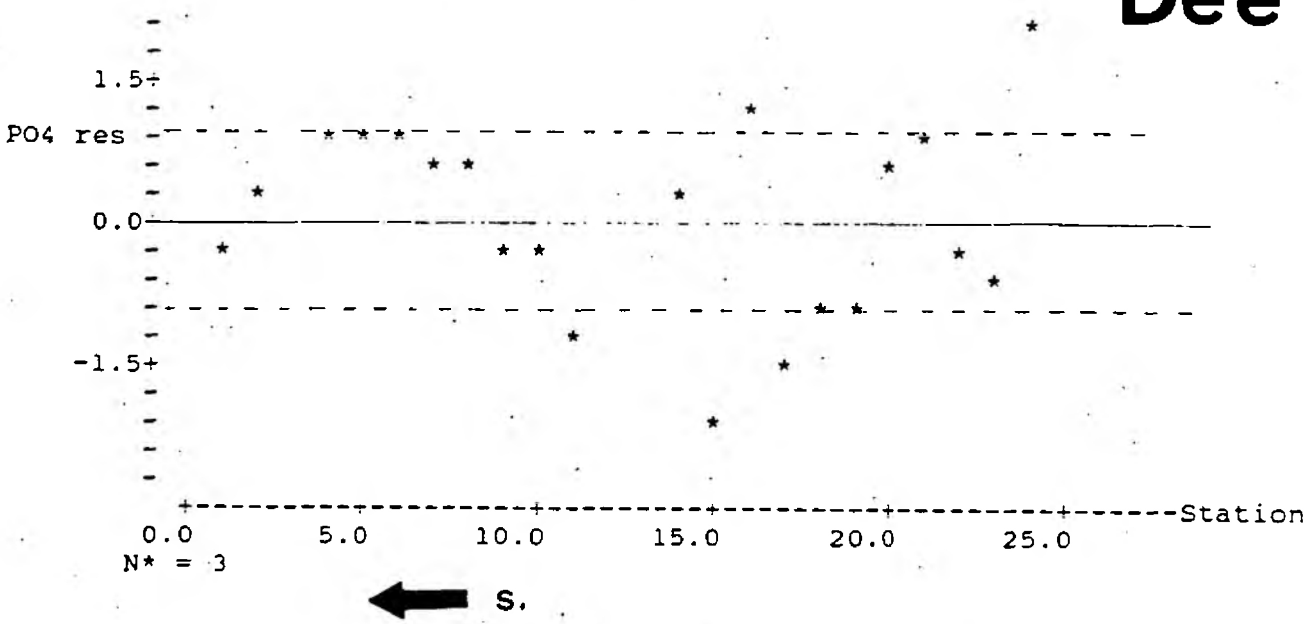

PO4 res
2.0
0.0
-2.0
Station
0.0
5.0
10.0
15.0
20.0
25.0
N* = 6
S.

Dee

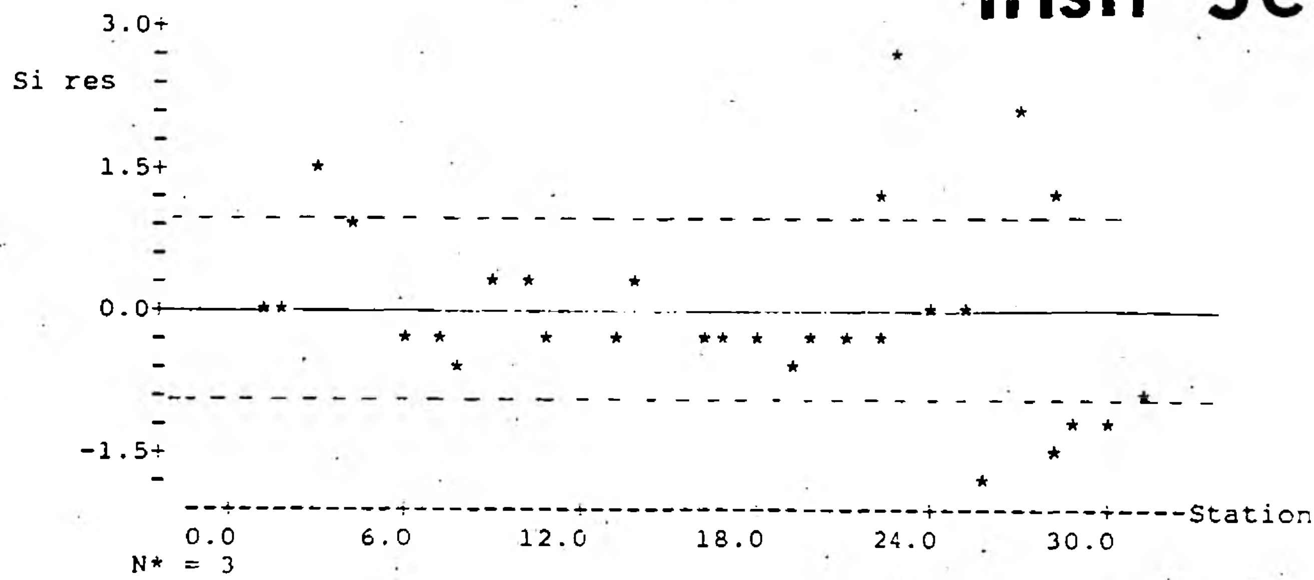

Si res
2.0
0.0
-2.0
0.0
5.0
10.0
15.0
20.0
25.0
Station
N* = 5
S.


NO3 res
1.5
0.0
-1.5
-3.0
0.0
5.0
10.0
15.0
20.0
25.0
Station
N* = 3
S.

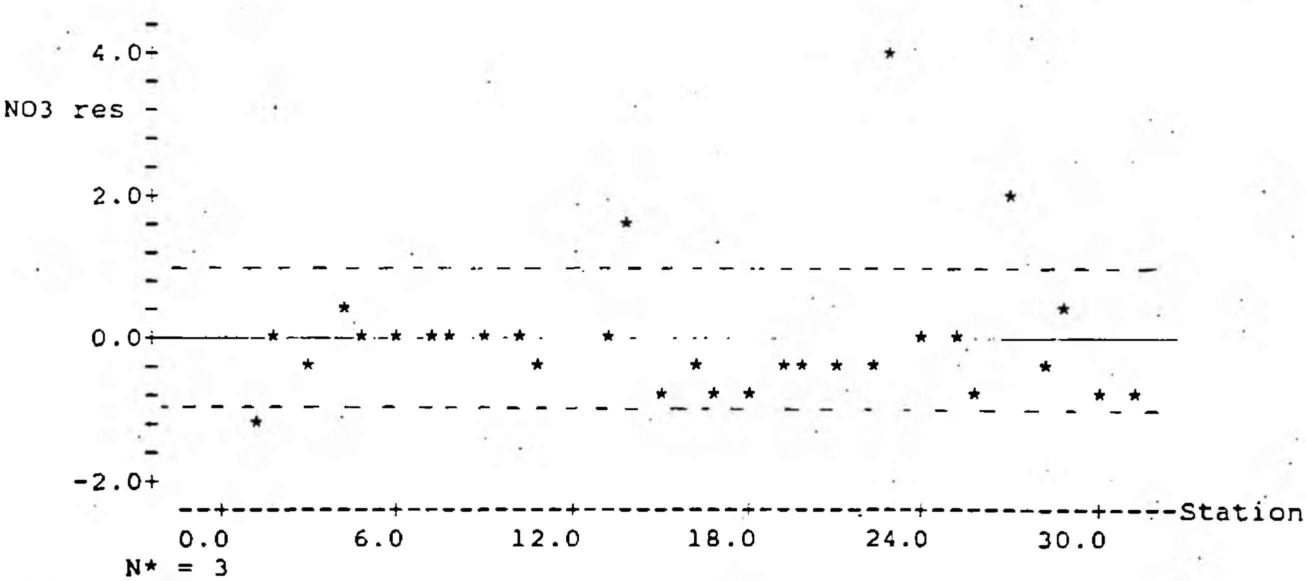
Dee



Irish Sea

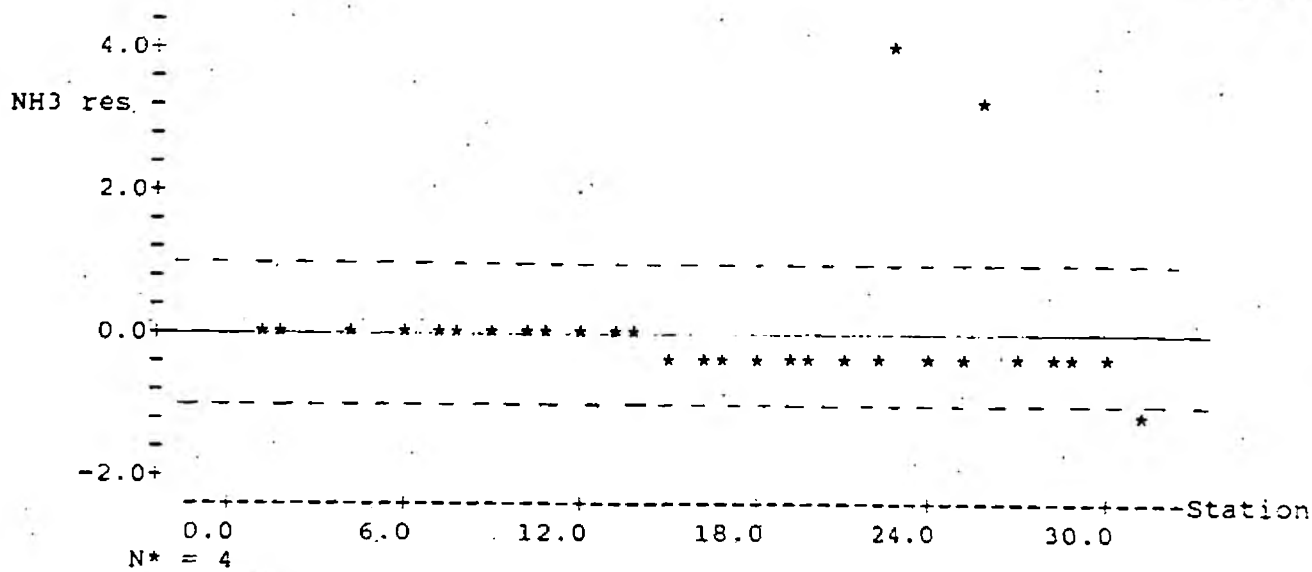


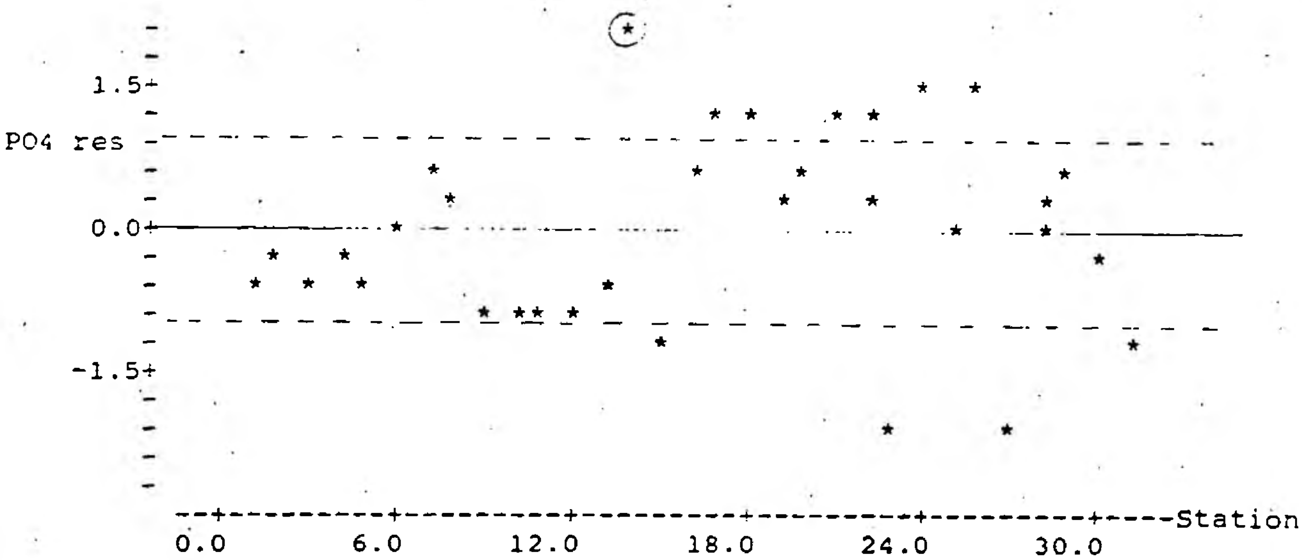
Si res
3.0+
1.5+
0.0+
-1.5+
Station
0.0 6.0 12.0 18.0 24.0 30.0
N* = 3



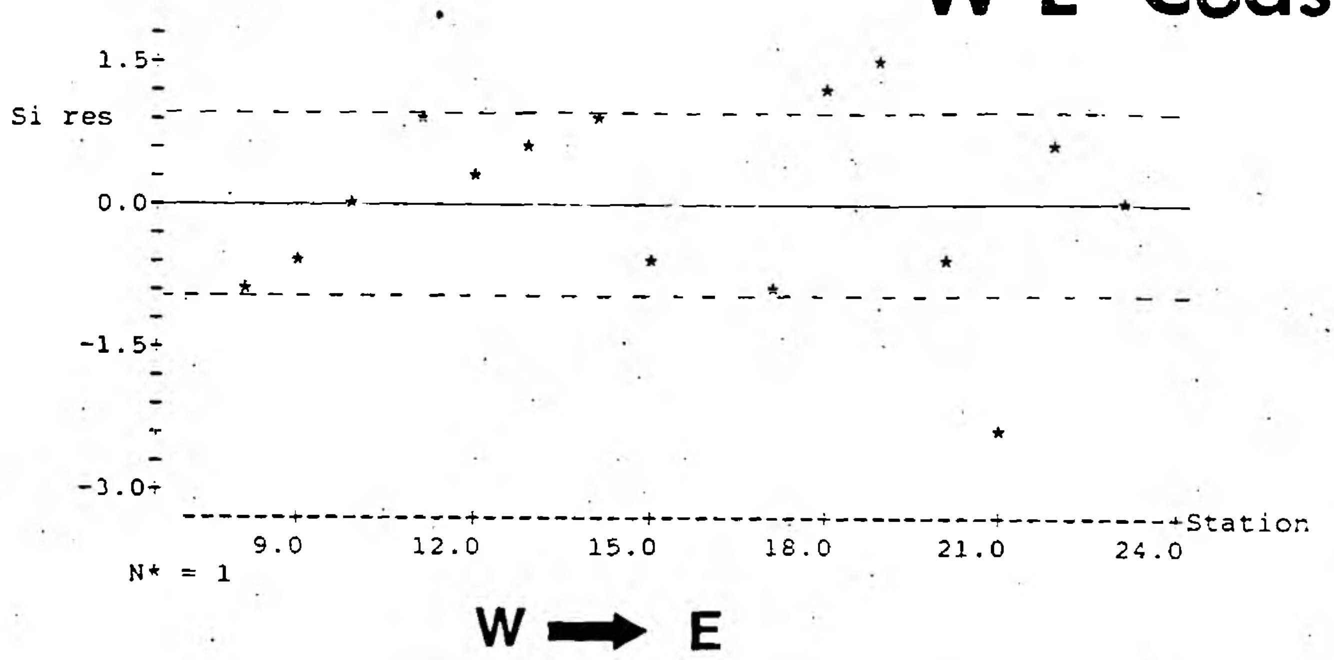
NO3 res
4.0+
2.0+
0.0+
-2.0+
Station
0.0 6.0 12.0 18.0 24.0 30.0
N* = 3

Irish Sea

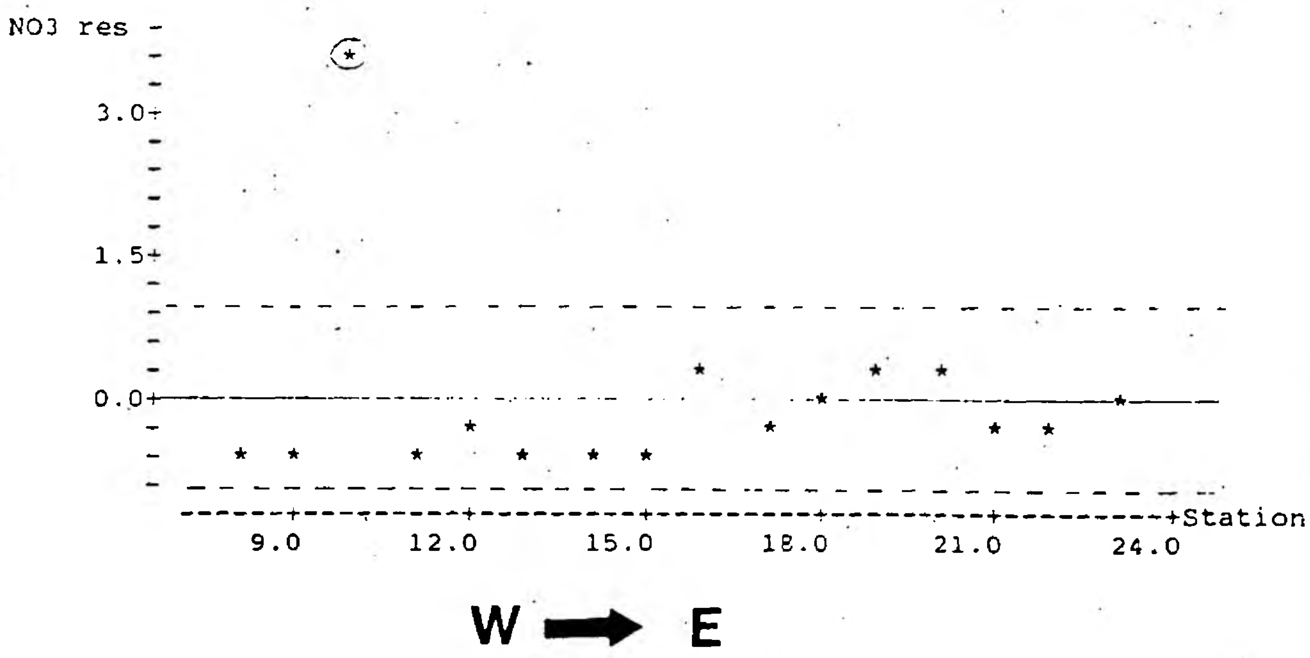

4.0
NH3 res
2.0
0.0
-2.0
Station
0.0
6.0
12.0
18.0
24.0
30.0
N* = 4


1.5
PO4 res
0.0
-1.5
Station
0.0
6.0
12.0
18.0
24.0
30.0

W-E Coast

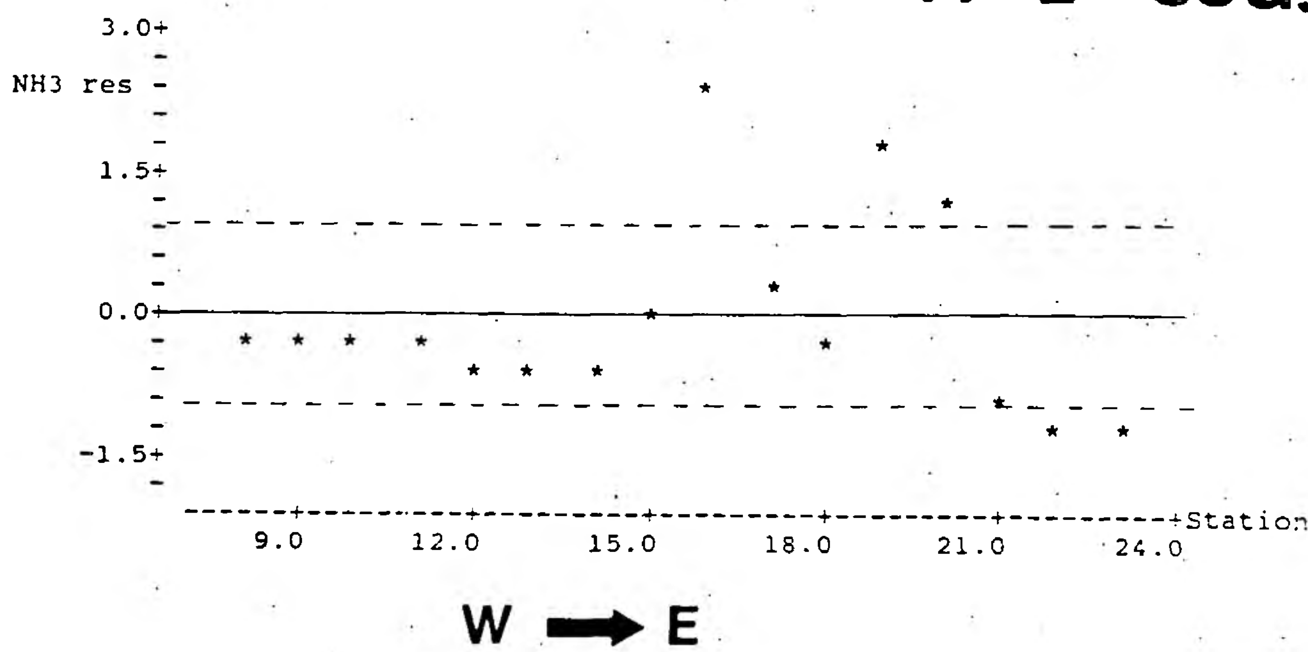


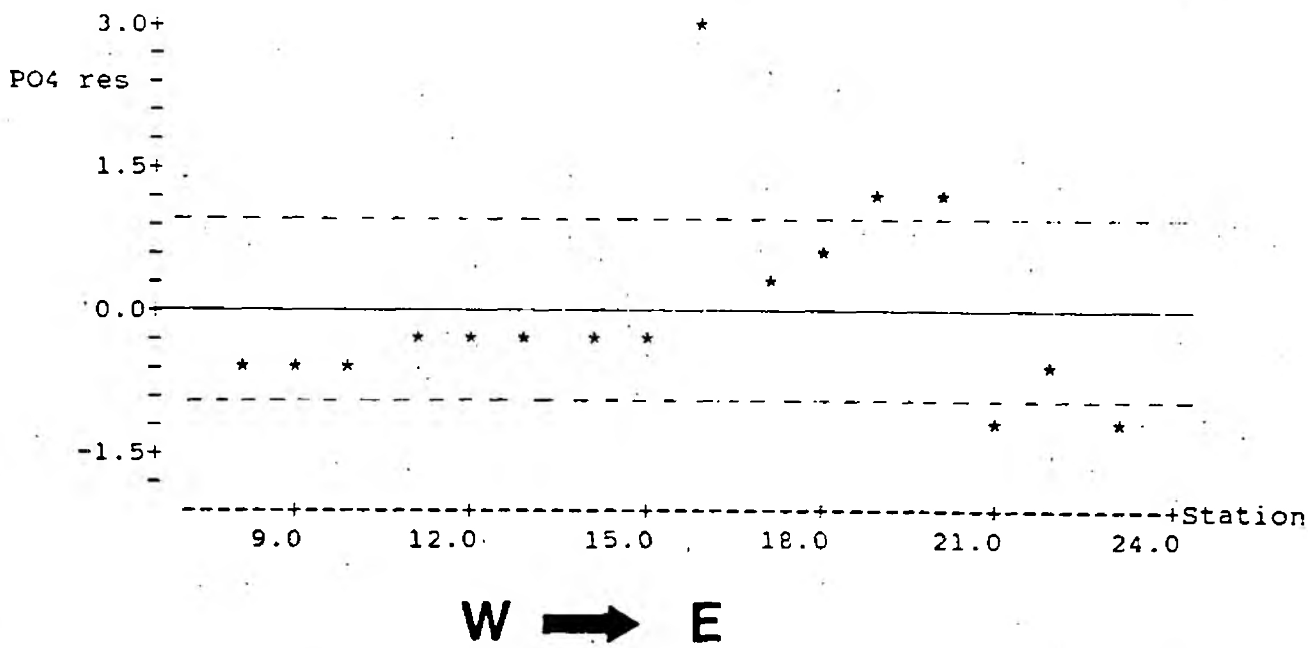
1.5
Si res
0.0
-1.5
-3.0
Station
9.0
12.0
15.0
18.0
21.0
24.0
N* = 1
W
E



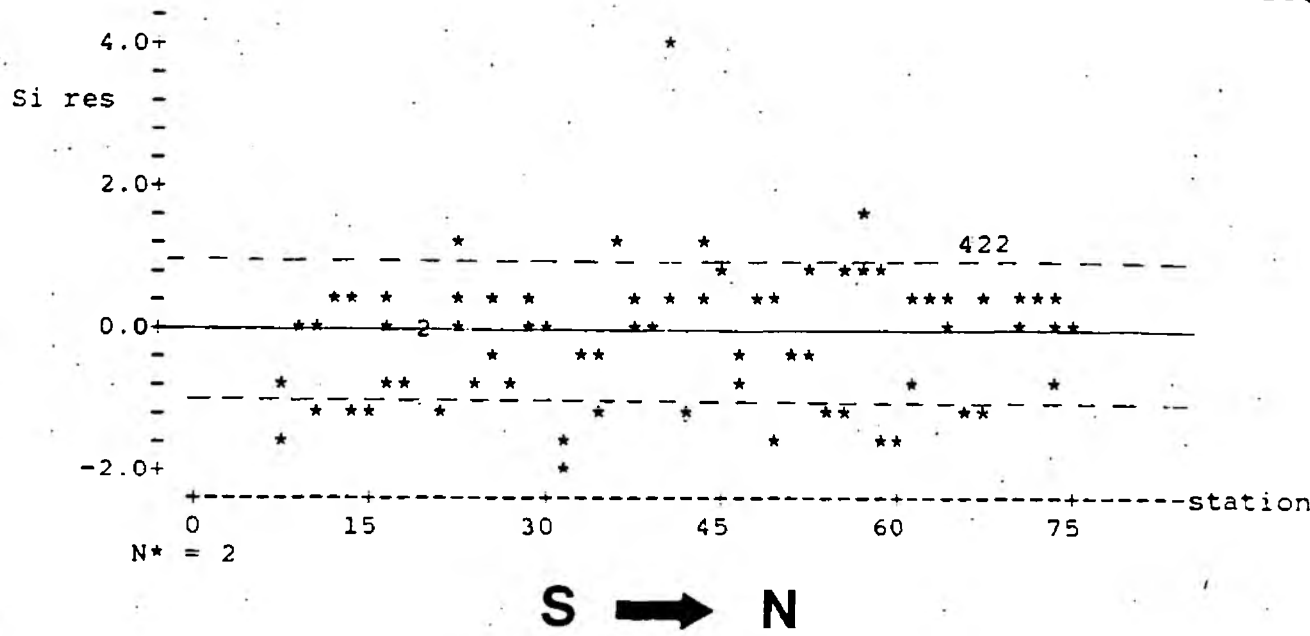
NO3 res
3.0
1.5
0.0
Station
9.0
12.0
15.0
18.0
21.0
24.0
W
E

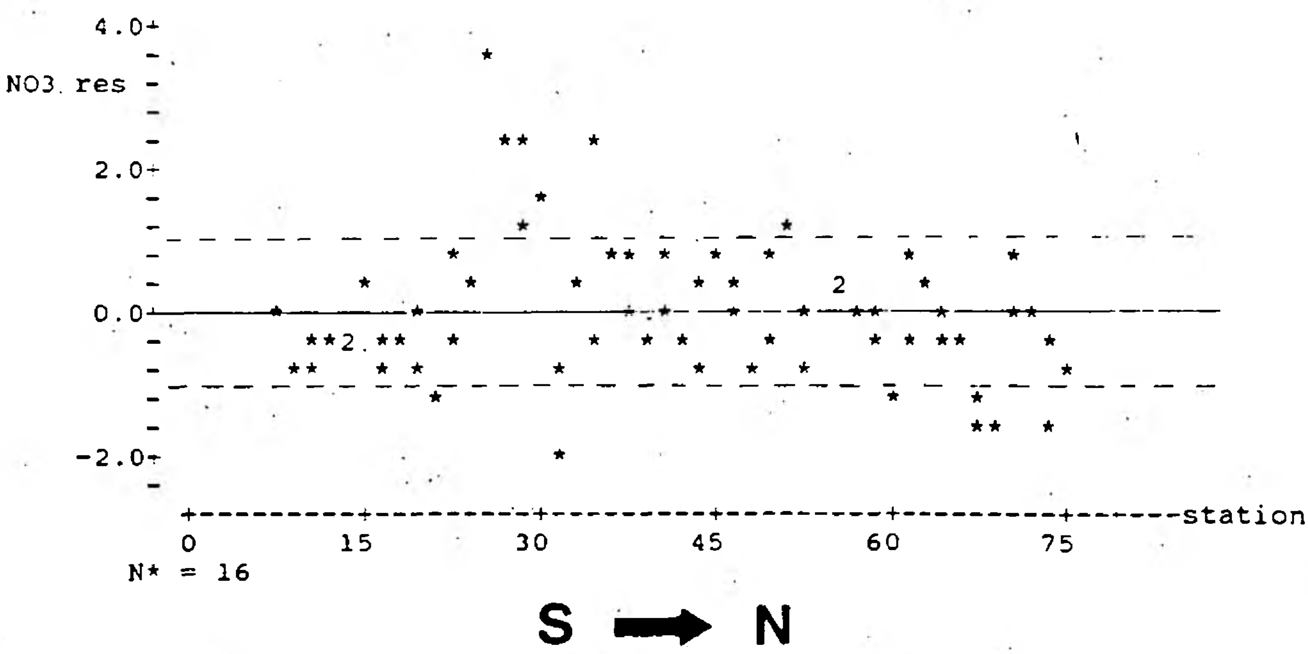
W-E Coast


3.0+
NH3 res
1.5+
0.0+
-1.5+
9.0
12.0
15.0
18.0
21.0
24.0
Station
W → E

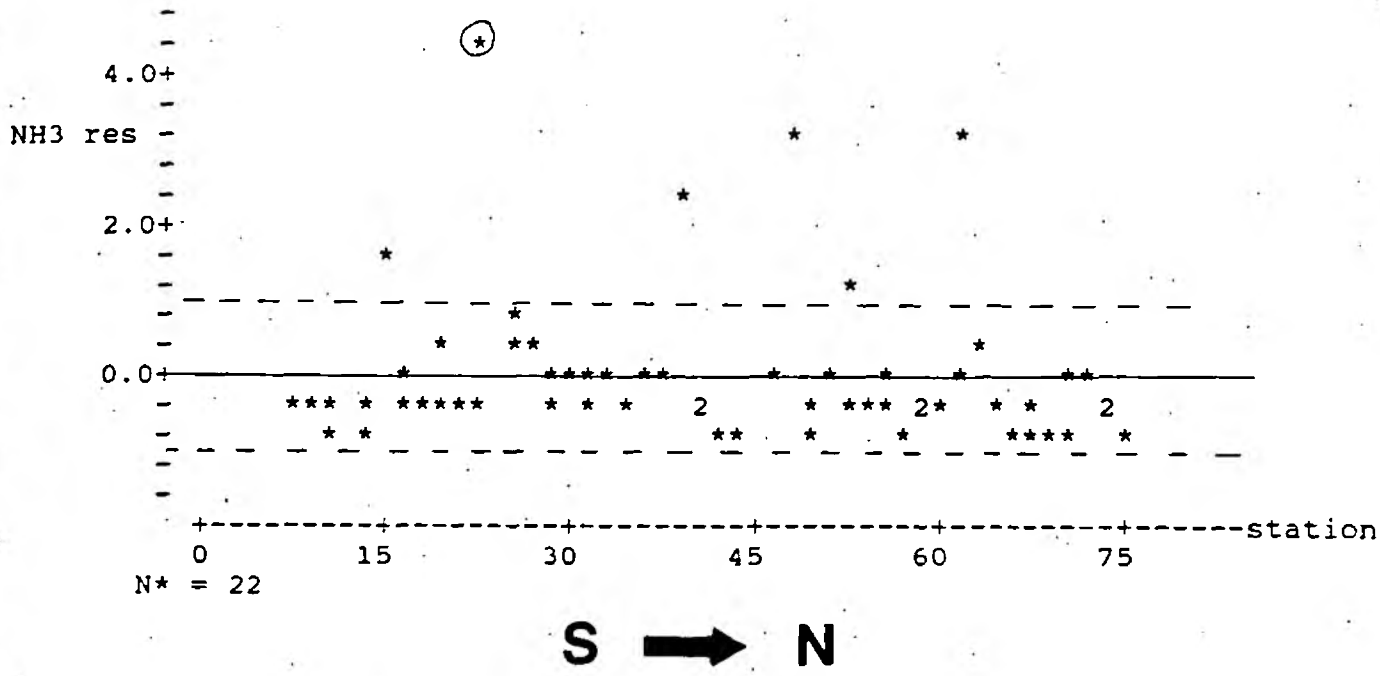

3.0+
PO4 res
1.5+
0.0+
-1.5+
9.0
12.0
15.0
18.0
21.0
24.0
Station
W → E

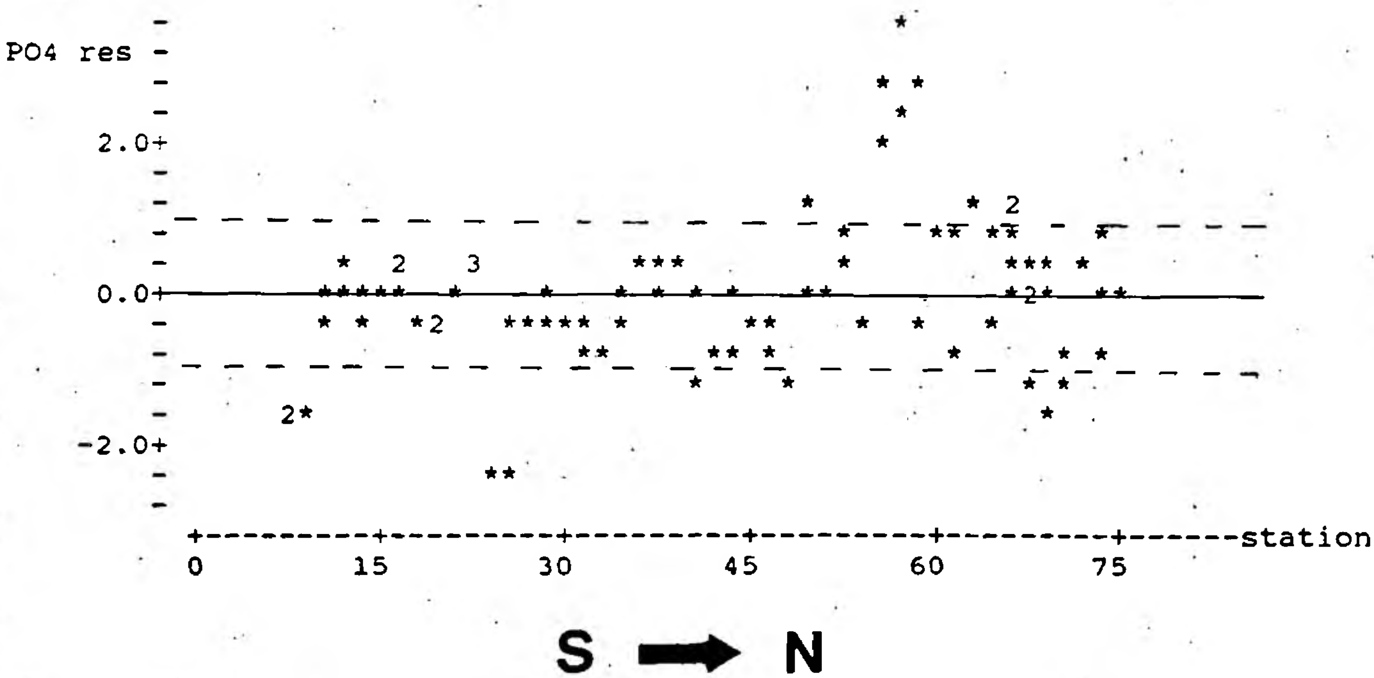
N-S Coast


4.0
Si res
2.0
422
0.0
2
-2.0
station
0
15
30
45
60
75
N* = 2
S
N


4.0
NO3 res
2.0
2
0.0
2
-2.0
station
0
15
30
45
60
75
N* = 16
S
N

N-S Coast


NH3 res
4.0+
2.0+
0.0+
station
0 15 30 45 60 75
N* = 22
S N


PO4 res
2.0+
0.0+
-2.0+
station
0 15 30 45 60 75
S N