An assessment of a Numerical Representation of Biological Water Quality

NRA

National Rivers Authority
Anglian Region

INTRODUCTION

It is important to comprehend that the accuracy with which the water quality of a site is determined can be enhanced considerably by regarding biological data. However, reporting and analysing biological water quality data can prove difficult in terms of assessing any significant change over time by use of statistical interpretation of results.

This investigation attempts to find an efficient and informative method of deciphering and evaluating the biological data in such a way as to allow for statistical analysis, versatility in representation, and sensitivity in interpretation.

The biological data refers to BMWP (Biological Monitoring Working Party) score, number of Taxa, and Average Score Per Taxa (ASPT).

Data from 22 sites on the River Nene have been used in this report, and the data from 1989, 1990, 1991, 1992, and Spring 1993, will be used for analysis.

The investigation involves data manipulation within several illustrative examinations, including:

(a) establishing water quality banding according to the National Biological classification Scheme for each site;

(b) banding/categorising each site according to the numeric representation method;

(c) comparison of 1 and 2;

(d) further investigation of the numeric representation, and development for future use, to include:

   (i) developement of a model based on the coefficients of variation to be usedt o expose sites likely to have experienced change in water quality

   (ii) applying the model to the River Nene data as an illustrative experiment to establish change in biological water quality

   (iii) application of the t-test to indicate whether transgressions of the categoric boundary are in fact significant in terms of change in water quality.

AREA OF STUDY

The investigation considers the freshwater areas of the River Nene. Biological data from 22 sampling stations was used in this study, with sites positioned upstream of Northampton, downstream of Northampton and downstream of Peterborough. Table 1 below lists the sample points used throughout the investigation.

	Sample point	Name	NGR	NRA No.
U/S N'HAMPTON	BFNENE020N	R.NENE NEWNHAM	SP579592	01 1079
	BFNENE035A	R.NENE A5 WEEDON	SP634596	01 0251
	BFNENE040F	R.NENE FLORE RD BRIDGE	SP645597	01 0256
	BFNENE050N	R.NENE NETHER HEYFORD	SP664589	01 0257
	BFNENE060B	R.NENE BUGBROOKE MILL	SP680588	01 0261
	BFNENE075U	R.NENE UPTON MILL	SP721591	01 0262
	BFNENE080D	R.NENE DUSTON MILL	SP729597	01 0266
	BFNENE110N	R.NENE NUNN MILLS RD BR	SP762599	01 0267
D/S N'HAMPTON	BFNENE180C	R.NENE COGENHOE	SP832614	01 0284
	BFNENE220H	R.NENE HARDWATER MILL	SP876637	01 0287
	BFNENE230W	R.NENE WOLLASTON MILL	SP888646	01 0292
	BFNENE250D	R.NENE D/S CHETTLES LTD (DITCHFORD MILL)	SP931684	01 1080
	BFNENE260D	R.NENE DITCHFORD MILL LOCK CHANNEL	SP930682	01 0293
	BFNENE300I	R.NENE IRTHLINGBOROUGH OLD RD BR	SP957706	01 0310
	BFNENE340R	R.NENE RINGSTEAD RD BR	SP974752	01 0312
	BFNENE360D	R.NENE DENFORD	SP993767	01 0317
	BFNENE420L	R.NENE LILFORD RD BR	TL026839	01 0319
	BFNENE495W	R.NENE WARMINGTON	TL074916	01 0320
	BFNENE510E	R.NENE ELTON-NASSINGTON RD. BR	TL085945	01 0337
	BFNENE550W	R.NENE WANSFORD OLD RD BR	TL075991	01 0338
	BFNENE605O	R.NENE ORTON STAUNCH	TL167973	01 0342
D/S P'BOROUGH	BFNENE630N	R.NENE NORTH BANK	TL235985	01 0343

COLLATING DATA

BIOLOGICAL DATA

Values of the Biological Monitoring Working Party (BMWP) score, number of scoring Taxa, and Average Score Per Taxa (ASPT), for the 22 sites on the River Nene were collated as hard copies of data from the Northern office. This information was transferred into an appropriate file in MINITAB (Appendix).

RIVPACS PREDICTIONS

RIVPACS (River InVertebrate Prediction And Classification System) was used in this investigation to predict values of the BMWP score, number of scoring taxa, and ASPT.

As the data concerned were samples collected for specific periods i.e. seasonally, single season predictions were to be carried out for all the samples at each site. The predictions required data on 8 core and a number of optional environmental variables. The RIVPACS manual suggests that values should be annual mean values and a minimum of three seperate seasonal sets of time variant environmental is recommended. However, the only environmental data availabe was that taken in 1990, so it was appropriate to take the mean values of this data, (corroborated by Julie Jeffrey, Thames NRA). The environmental data used for the predictions is shown in Table 2.

Once the observed and predicted biological data had been collated,the observed BMWP scores, Taxa, and ASPT could then compared with those predicted by RIVPACS. The ratio of the observed and predicted values produce an Ecological Quality Index (EQI), for each of the three variables:

$$EQI = \frac{OBSERVED_{BMWP}}{PREDICTED_{BMWP}}$$ and likewise for the number of taxa and ASPT.

Thus for each sample, three EQI values were determined:

EQI(BMWP score))
EQI(ASPT)) - EQI variables
EQI(No. Taxa))

It is these EQI variables that were the basis for the investigation.

TABLE 2

ENVIRONMENTAL DATA USED FOR RIVPACS PREDICTIONS

SAMPLE POINT	INVARIANT				VARIANT					
	ALT	DIS	SLOPE	D.C	WIDTH (m)	DEPTH (cm)	SUBSTRATE (%) B	G	Sa	Si
BFNENE020N	110	4.2	6.7	1	2	9.7	35	50	5	10
BFNENE035A	80	10	2.9	1	4.7	35	27	8	28	37
BFNENE040F	77	18.5	2.9	3	8.3	17	5	56	27	12
BFNENE050N	72	20	1.5	3	8.3	28.7	23	57	23	7
BFNENE060B	70	22	1.5	3	11	30	43	40	12	4
BFNENE075U	65	28	1.5	3	10.3	62.3	18	27	10	45
BFNENE080D	60	30	1	4	8.7	27.7	33	40	17	10
BFNENE110N	55	32	1	5	20	17.3	1	1	2	96
BFNENE180C	50	38	1	4	8.7	106.7	5	10	5	80
BFNENE220H	43	52	0.6	5	13.3	60	3	5	3	84
BFNENE230W	42	53.5	0.7	4	10	108.3	0	7	3	90
BFNENE250D	46	47	0.9	5	16	26.7	10	70	15	5
BFNENE260D	38	60	0.6	6	13.3	116.7	0	1	0	99
BFNENE300I	35	50	0.6	5	23.3	166.7	0	0	0	100
BFNENE340R	33	59	0.6	6	12.3	158.3	3	3	0	96
BFNENE360D	30	64	0.5	5	11	70	3	3	2	92
BFNENE420L	25	81	0.5	6	16.3	183.3	2	3	0	95
BFNENE495W	20	99	0.5	5	12.3	116.7	0	8	3	88
BFNENE510E	13	102	0.4	6	20.3	216.7	3	3	0	94
BFNENE550W	11	113	0.4	6	21.7	183.3	8	28	8	56
BFNENE605O	10	132	0.2	6	28.3	183.3	7	3	3	87
BFNENE630N	5	141	0.2	6	26.3	200	32	3	3	62

KEY TO ABBREVIATIONS

ALT = ALTITUDE
DIS = DISTANCE
D.C = DISCARGE CATEGORY

B = BOULDER
G = GRAVEL
Sa = SAND
Si = SILT

BANDING OR CLASSIFYING WATER OUALITY: TWO METHODS.

Banding or classifying water quality according to biological data will be determined by use of two different methods, one of which categorises alphabetically and the other provides a numerical index which in turn allows alphabetic banding.

BIOLOGICAL WATER QUALITY ACCORDING TO THE NATIONAL BIOLOGICAL CLASSIFICATION SYSTEM.

The environmental variables of a site are fed into RIVPACS. The package is then able to predict biological data such as the variety of invertebrates that should be found ,the BMWP score, Taxa, and ASPT. These predictions assume the site of sampling is unpolluted. The observed BMWP scores, Taxa, and ASPT are then compared with those predicted by RIVPACS, as described on page 3.

Once the EQIs have been determined a banding system is used to establish a classification of the site according to biological water quality. The biological classes, or bands, range from A to D, with A indicating the better quality.

The banding criteria used is shown below:

Biological Class	EQI (ASPT)	EQI (TAXA)	EQI (BMWP)
A	>0.89	>0.79	>0.75
B	0.77-0.88	0.58-0.78	0.50-0.74
C	0.66-0.76	0.37-0.57	0.25-0.49
D	<0.65	<0.36	<0.24

A class is determined for each variable, by a procedure refered to as the 5M rule. The overall class of the site is the median of the three results, unless the lowest EQI is that for ASPT then this would be the final answer (this bias is incorporated because of the greater statistical confidence in the ASPT score).

NUMERIC REPRESENTATION OF BIOLOGICAL WATER QUALITY

One of the limitations of the National Biological Classification System is that once the site has been banded as one of the alphabetic categories, it is very difficult to carry out any statistical interpretation of the results. A numeric representation method has been developed, which may be adopted as a routine approach to representing and analysing biological data.

The aim of the numeric representation of biological water quality is to produce a numeric system which theoretically duplicates the conventional 5M rule but gives a numeric scale. It is hoped that this will enable the use of statistical analysis on the categorisation. With this numeric system confidence limits can be computed for values which will indicate whether transgression of the categoric boundary is in fact significant in terms of change in water quality.

This method entails a series of equations consisting of calculations involving the EQI values for BMWP scores, Taxa, and ASPT, which are then combined to give a numerical index, or final score. Theoretically, the final score is determined by duplicating the 5M rule, but averaging the sum of the BMWP score, ASPT score, and Taxa score rather than taking a median. As in the case of the 5M rule, if the ASPT score is the lowest then this will be taken as the final result (this bias is incorporated because of the greater statistical confidence carried by the ASPT).

The numeric index can be computed as follows:

$$EQI_{BMWP} = \frac{BMWP_{OBSERVED}}{BMWP_{PREDICTED}}$$ and likewise for taxa and ASPT

$$SCORE_{BMWP} = 2 + \frac{(EQI_{BMWP} - Midpoint_{BMWP})}{Interval}$$

where "Midpoint" is the middle of the categoric scale, in the case of BMWP 0.495, and "interval" is the categoric interval i.e. 0.250.

This calculation is repeated for Taxa and ASPT and then the final score, or index is determined as follows:

$$SCORE_{FINAL} = \min(SCORE_{ASPT}, average(SCORE_{ASPT}, SCORE_{Taxa}, SCORE_{BMWP}))$$

This index has a simple continuous numeric scale, as shown below:

Value Of Index	Corresponding Biological Class
0 - 1	D
1 - 2	C
2 - 3	B
3 - 4	A
4 +	A (with EQIs over 100% i.e. the fauna is better than predicted)

Having obtained a final score, or numerical index, for each of the sites statistical techniques of analysis can be computed to establish whether transgression of the categoric boundaries are in fact significant in terms of a change in water quality, and thus whether or not there has been significant variation over the time period under investigation.

Initially the coefficients of variation can be computed for each site, and those with a high value can be illustrated graphically, primarily as a line graph (time,numerical index), scaled on the y-axis according to the categoric boudaries. It is the suggested that meaningful confidence limits are established and plotted on the same axis, thus giving an immediate visual impression and a view of where the significant changes, if any, have occurred.

BANDING ACCORDING TO THE BIOLOGICAL CLASSIFICATION SYSTEM

The EQI variables (Appendix 3), were used to determine bandings for each site in accordance with the Biological Classification System, following the procedure previously described on page 5.

RESULTS

Table 2

SITE CODE	SP' 89	SU' 89	AU' 89	SP' 90	SU' 90	AU' 90	SP' 91	SU' 91	AU' 91	SP' 92	SU' 92	AU' 92	SP' 93
020N	*	B	*	*	*	*	A	A	B	B	*	A	B
035A	*	A	*	B	B	B	B	B	B	B	*	B	B
040F	*	C	*	C	B	B	B	B	B	C	*	A	D
050N	*	C	*	B	B	B	B	B	A	B	*	A	B
060B	C	C	*	D	C	C	B	C	B	C	*	A	C
075U	C	B	*	B	A	A	A	B	B	B	*	*	B
080D	B	B	*	B	A	A	A	B	A	B	*	*	B
110N	C	D	*	C	B	B	B	A	C	B	*	A	B
180C	A	*	A	A	A	A	B	A	A	A	*	B	A
220H	B	*	B	B	B	B	*	*	*	*	B	A	*
230W	A	*	A	B	B	A	A	A	A	*	A	B	*
250D	*	B	B	*	*	*	C	B	B	B	*	*	*
260D	B	*	B	B	B	B	B	B	B	A	*	A	*
300I	*	B	B	B	C	B	B	A	B	*	B	B	*
340R	*	B	B	B	B	A	B	B	B	*	B	A	*
360D	*	C	A	A	A	A	A	A	A	*	A	A	*
420L	*	A	B	A	A	A	A	B	B	*	B	A	*
495W	*	*	A	A	A	B	A	A	B	A	*	A	*
510E	*	*	A	*	A	*	A	A	A	A	*	A	*
550W	*	B	A	A	A	A	A	A	B	A	*	A	*
605O	B	*	A	A	A	A	B	B	A	*	A	A	A
630N	B	*	*	A	A	A	A	B	A	*	A	A	A

* no data available

DISCUSSION

It has been suggested that in terms of change in water quality, transgression of the categoric boundaries are only significant if two boundaries are crossed, for example a change of category from A to C would be classed as a significant change. Taking this into consideration

the table showing the bandings according to the National Biological Classification Scheme reveals that there appear to be few significant changes.
The sites which do materialise as having experienced change include:

R.Nene Flore Rd Bridge (BFNENE040F) ,from Au'92 (A), to Sp'93 (D);

R.Nene Bugbrooke Mill (BFNENE060B), from Autumn '92 (A), to Spring '93 (C);

R.Nene Nunn Mills Rd Br. (BFNENE110N), Summer'91 (A) to Autumn'91 (C);

and R.Nene Denford (BFNENE360D), improved from Sum'89 (C) to Au'89 (A);

All the sites experienced fluctuation in class/categories, most only crossing one categoric boundary, and this fact should not be disregarded. However, because the categories are alphabetic, the investigation of water quality tends to conclude here as it proves to be very difficult to carry out any further interpretation of the results to establish whether or not the changes are statistically significant (for example at a 95% level of confidence). It is hoped that this limitation will be overcome by the method of numeric representation.

BANDING ACCORDING TO THE NUMERIC REPRESENTATION

In order to establish the biological class according to the numeric representation the EQI variables were inputed into an appropriate spreadsheet in the statistical package, MINITAB, and a simple command file was created (Appendix 4) to carry out the necessary computations as described on page 6. The final scores (numeric index) were established and the corresponding biological class was allocated to each sample (according to the table on page 6).

RESULTS

Table 4 below shows the banding according to the numeric representation method.

Table 4

SITE CODE	SP'89	SU'89	AU'89	SP'90	SU'90	AU'90	SP'91	SU'91	AU'91	SP'92	SU'92	AU'92	SP'93
020N	*	B	*	*	*	*	A	A	A	A	*	A	B
035A	*	A	*	B	B	B	B	B	B	B	*	B	B
040F	*	C	*	C	B	C	C	B	B	C	*	B	D
050N	*	C	*	C	B	B	B	B	A	A	*	A	B
060B	C	C	*	D	C	C	B	C	B	C	*	B	C
075U	C	B	*	B	A	A	A	B	B	B	*	*	B
080D	B	B	*	B	A	A	A	B	A	B	*	*	B
110N	C	D	*	C	B	B	B	A	B	B	*	A	B
180C	A	*	A	A	A	A	B	A	A	A	*	B	A
220H	B	*	A	A	B	B	*	*	*	*	B	A	*
230W	A	*	A	A	A	A	A	A	A	*	A	B	*
250D	*	B	B	*	*	*	C	B	B	B	*	*	*
60D	B	*	B	B	B	A	B	B	B	A	*	A	*
300I	*	B	B	B	C	B	B	A	B	*	B	B	*
340R	*	B	B	B	B	A	B	B	A	*	B	A	*
360D	*	C	A	A	A	A	A	A	A	*	A	A	*
420L	*	A	B	A	A	A	A	A	A	*	B	A	*
495W	*	*	A	A	A	B	A	A	A	A	*	A	*
510E	*	*	A	*	A	*	A	A	A	A	*	A	*
550W	*	B	A	A	A	A	A	A	A	A	*	A	*
605O	B	*	A	A	A	A	A	B	A	*	A	A	A
630N	B	*	*	A	A	A	A	B	A	*	A	A	A

* no data available.

DISCUSSION

The table reveals that there are only two incidents when the change in banding crosses two categoric boundaries:

R.Nene Flore Rd Bridge (BFNENE040F), from autumn'92 (B) to spring'93 (D);
R.Nene Denford (BFNENE360D), from summer'89 (C) to autumn'89 (A).

However, as with the National Biological Classification System,all the sites experienced fluctuation in categories/bandings, most only crossing one categoric boundary. It is hoped that with the numeric representation the investigation can continue to the extent of interpreting the results to establish whether transgression of the categoric boundaries are in fact significant in terms of change in water quality.

COMPARISON OF NATIONAL BIOLOGICAL CLASSIFICATION SYSTEM BANDING AND THE NUMERIC REPRESENTATION BANDING.

Table 3 (banding according to the National Classification System),and Table 4 (banding according to the numeric method),were compared to determine whether or not the two methods of banding give the same results.

The table below illustrates the degree of variation between Table 3 and Table 4.

SITE CODE	SP'89	SU'89	AU'89	SP'90	SU'90	AU'90	SP'91	SU'91	AU'91	SP'92	SU'92	AU'92	SP'93
020N	*	B	*	*	*	*	A	A	B (A)	B (A)	*	A	B
035A	*	A	*	B	B	B	B	B	B	B	*	B	B
040F	*	C	*	C	B	B (C)	B (C)	B	B	C	*	A (B)	D
[illegible]50N	*	C	*	B (C)	B	B	B	B	A	B (A)	*	A	B
060B	C	C	*	D	C	C	B	C	B	C	*	A (B)	C
075U	C	B	*	B	A	A	A	B	B	B	*	*	B
080D	B	B	*	B	A	A	A	B	A	B	*	*	B
110N	C	D	*	C	B	B	B	A	C (B)	B	*	A	B
180C	A	*	A	A	A	A	B	A	A	A	*	B	A
220H	B	*	B (A)	B (A)	B	B	*	*	*	*	B	A	*
230W	A	*	A	B (A)	B (A)	A	A	A	A	*	A	B	*
250D	*	B	B	*	*	*	C	B	B	B	*	*	*
[illegible]50D	B	*	B	B	B	B (A)	B	B	B	A	*	A	*
300I	*	B	B	B	C	B	B	A	B	*	B	B	*
340R	*	B	B	B	B	A	B	B	B (A)	*	B	A	*
360D	*	C	A	A	A	A	A	A	A	*	A	A	*
420L	*	A	B	A	A	A	A	B (A)	B (A)	*	B	A	*
495W	*	*	A	A	A	B	A	A	B (A)	A	*	A	*
510E	*	*	A	*	A	*	A	A	A	A	*	A	*
550W	*	B	A	A	A	A	A	A	B (A)	A	*	A	*
605O	B	*	A	A	A	A	B (A)	B	A	*	A	A	A
630N	B	*	*	A	A	A	A	B	A	*	A	A	A

A = banding according to National Biological Classification System
(A) = banding according to numeric representation method.

The fact that Table 3 and Table 4 show different bandings in some cases i.e. the two different methods fail to reach the same categorisation, should be noted. It is important that anyone reporting or receiving a report which involves biological banding should be fully aware of this fact, to eliminate the possibility of comparing the methods of banding rather than carrying out a comparison of data.

FURTHER INVESTIGATION OF THE NUMERIC REPRESENTATION OF BIOLOGICAL WATER QUALITY.

The numeric representation document (appendix), suggests that once the scores have been determined, the coefficients of variation should then be calculated for each site. So, this was the next stage of the investigation, (Appendix). It is suggested that the sites with high coefficients of variation merit further examination as these are likely to have experienced change.

USING COEFFICIENTS OF VARIATION TO DETERMINE WHICH SITES ARE MOST LIKELY TO HAVE EXPERIENCED A CHANGE IN BIOLOGICAL WATER QUALITY.

Sites with small coefficients of variation are generally considered to be of a medium to high quality, and have no evidence of change, either systematic or acute. So once the coefficients of variation have been established, it might be considered a fair assumption that only the sites with a high coefficient of variation require further investigation. Generally, those sites with poor water quality i.e. having a low score, have a high coefficient of variation and, therefore, may have evidence of change. However, it is important that this assumption is not the sole factor used to make the decision as to whether or not a particular site requires further examination.

In order to incorporate the high scoring sites, which initially may not appear to have a high degree of variation but have in fact experienced change, a model for the coefficients of variation was developed. This is to allow predictions of coefficients of variation by use of the score, as well as being used to establish whether a calculated coefficient of variation is above the expected value - in which case the site would merit further inquiry as change in water quality may have been experienced.

The coefficients of variation were calculated for each site and a frequency chart showing the coefficients of variation plotted (Figure 1). From this it would be feasible to take the median value (15-20%), and define any site with a coefficent of variation above this value as having a high degree of variation and, therefore, probably having experienced change. But, in order to establish a more accurate and applicable model the intended procedure was to plot the coefficients of variation against score (values shown in Appendix 5), and determine the regression line which could, in turn, be used to predict coefficients of variation for other sites. Initially, Spearman's Rank correlation test was applied to establish whether or not the correlation between these two factors was significant enough validate establishing a regression line as a model.(With $n=22$ and $r=-0.764$, the correlation is significant at a 95% level).

The regresson equation was found to be:

$$CoV = 49.7 - 10.5Score$$

and the regression line was plotted. The regression line is determined by substituting Score values into the regression equation to find the CoV, or plotted as $ax + b = c$).

This is effectively a model which can be used to predict the coefficients of variation corresponding to a given score, but perhaps more importantly, determines whether or not a site has a coefficient of variation that is higher than expected i.e.the computed value lies above the regression line, in which case it is likely that the site has experienced change.

FIGURE 1
RIVER NENE 1989-1993
Frequency Distribution Of Coefficients Of Variation

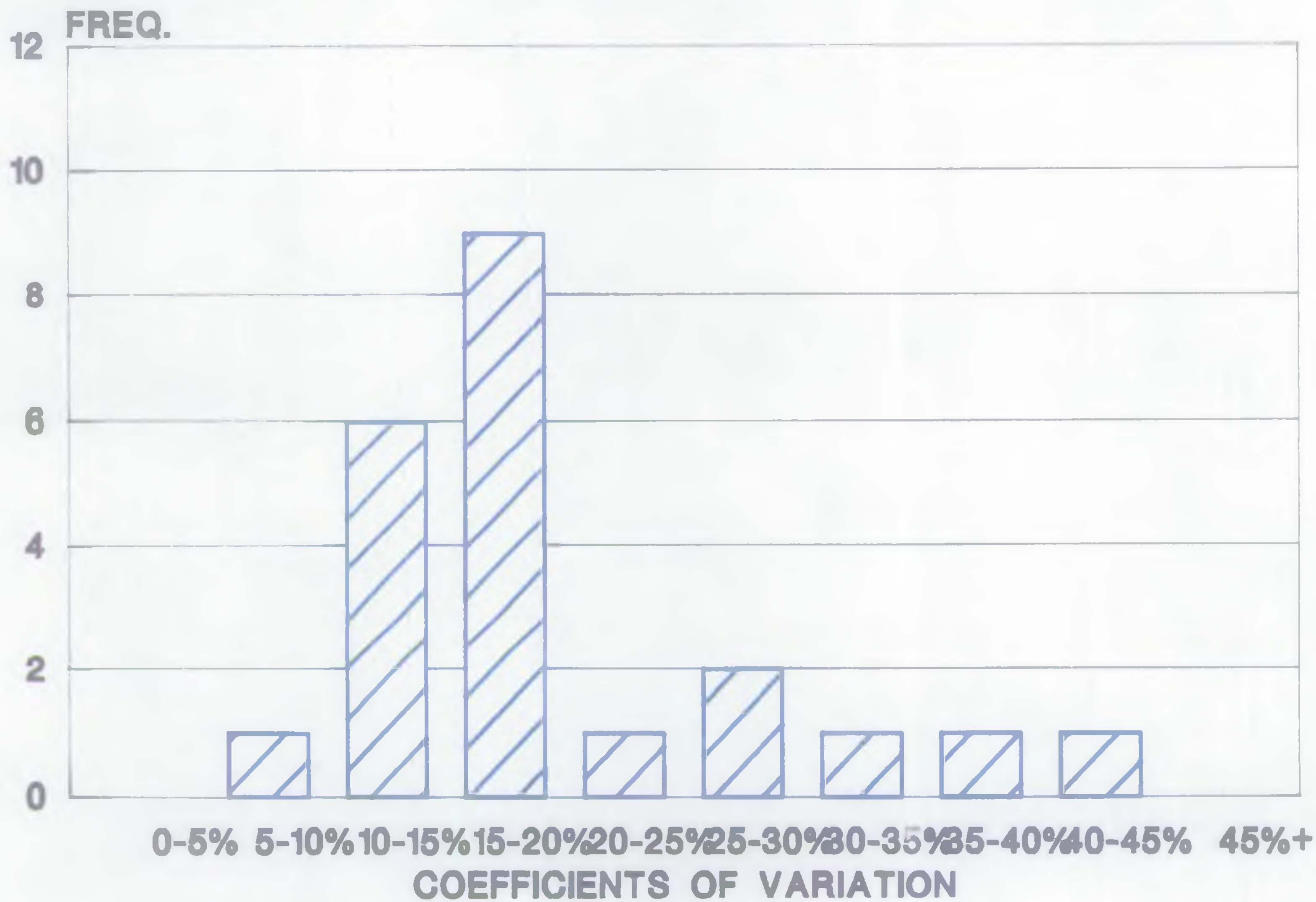
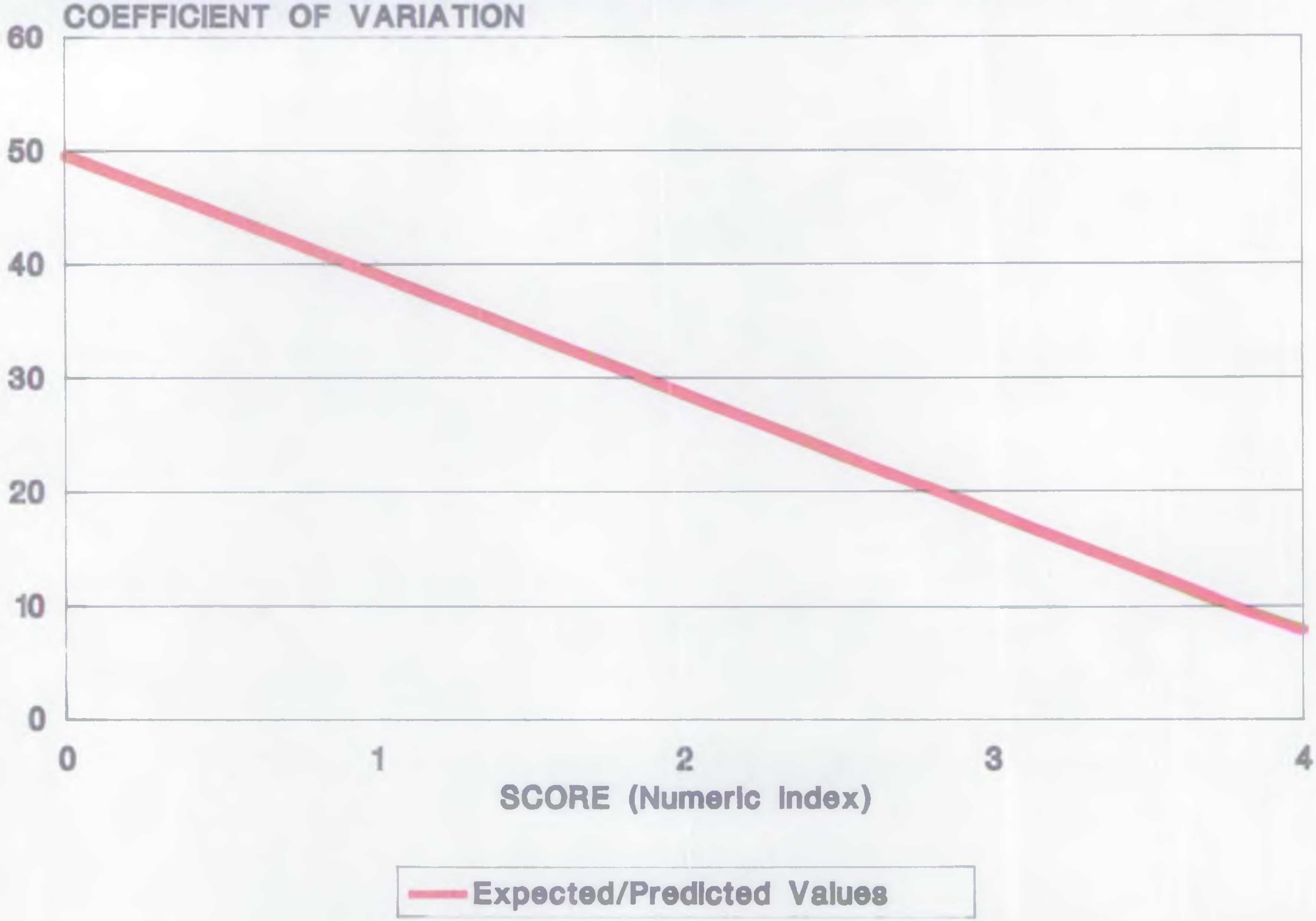


FIG.3

Model For Predicting Coefficients of Variation
(Also used to assess if a site has experienced a high degree of variation).

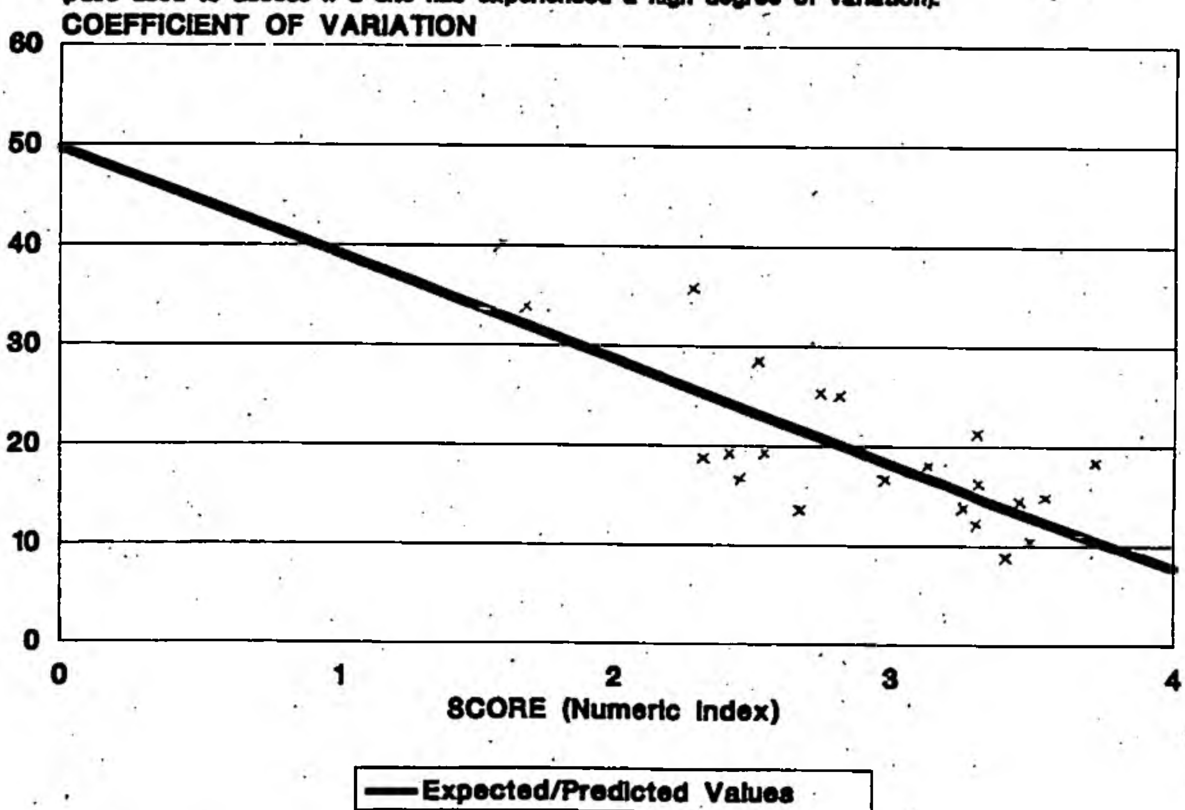


ASSESSING CHANGE OVER TIME.

Once the coefficient of variation model had been established it was applied to the River Nene data. However, it must be noted that as this data was used to construct the model, therefore the following section is not really viable but is an **illustrative** experiment and serves the purpose to explain the proceeding stages of applying the numerical representation. Ideally, the model would be applied to data from an alternative study area, (although shortage of time restricted the investigation).

The model was applied to determine which sites had probably experienced a change in water quality. This entails either using the score to find the predicted coefficient of variation using the equation CoV = 49.7 - 10.5score, and if the actual value is higher than the predicted the site warrants further examination; or plotting the actual values for coefficient of variation against score and comparing with the graphical representation of the model to achieve a visual impression of the sites with a high degree of variation (see figure 4 below):

FIG.4
Model For Predicting Coefficients of Variation
(Also used to assess if a site has experienced a high degree of variation).



This reveals that 11 sites:

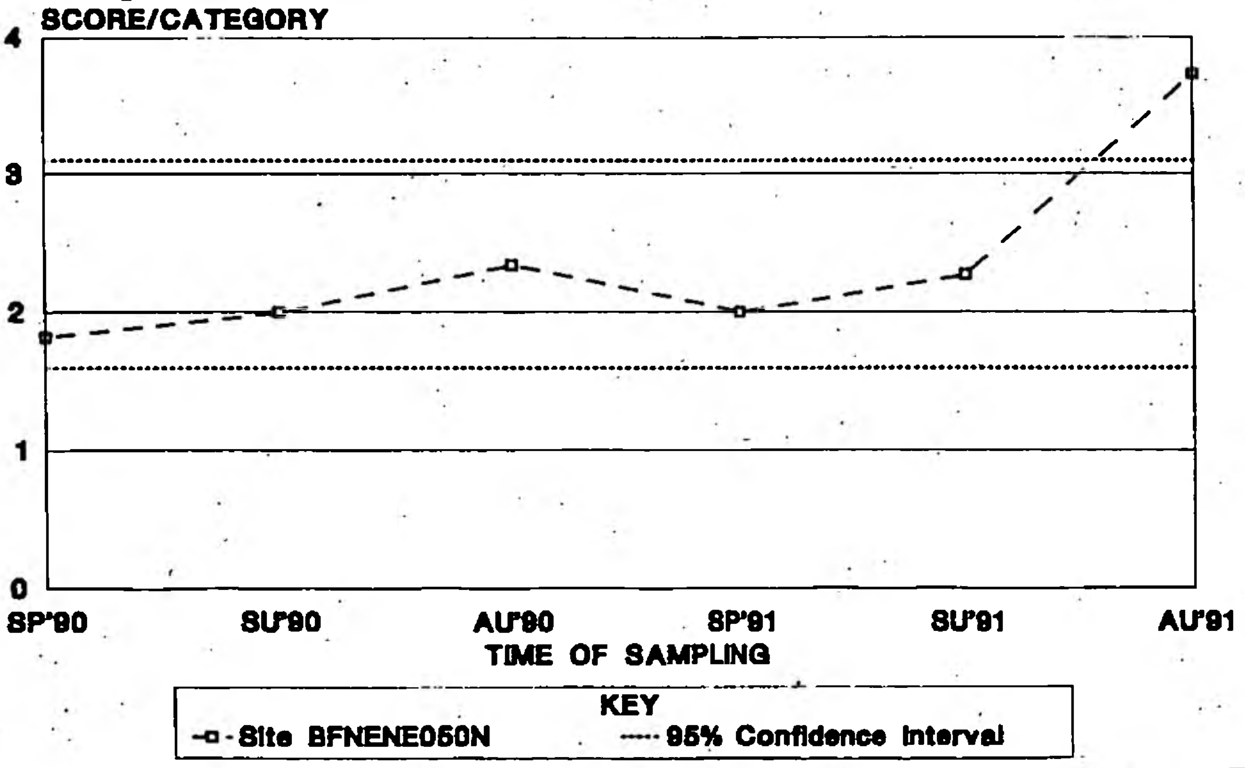
R.Nene Bugbrooke Mill (BFNENE060B)
R.Nene Cogenhoe (BFNENE180C)
R.Nene Nunn Mills Rd Bridge (BFNENE110N)
R.Nene Upton Mill (BFNENE075U)
R.Nene Wansford Old Rd Bridge (BFNENE550W)
R.Nene Wollaston Mill (BFNENE230W)

R.Nene Denford (BFNENE360D)
R.Nene Flore Rd Bridge (BFNENE040F)
R.Nene Newmham (BFNENE020N)
R.Nene Nether Heyford (BFNENE050N)
R.Nene Orton Staunch (BFNENE605O);
had a coefficient of variation over the predicted and, therefore, required further examination. Initially the numeric index (score) for each site was plotted graphically against time of sampling. The categoric boundaries correspond to the y-axis values in order to give a visual impression of the variation of water quality classification over time (see figures 5A,B,C and D). The next stage of the investigation is to find the significance of any apparent changes.

IS THE CHANGE SIGNIFICANT?

The 'Numeric Representation Of Biological Water' document (Appendix), states that care must be taken in calculating meaningful confidence intervals, with reference to establishing any significant change from graphical representation of the data. Initially, when experimenting with just 1990-91 data, it seemed reasonable to establish 95% confidence intervals for each site and display them visually on the line charts alongside the graphical representation of the water quality according to the numeric index (as shown in figure 6 below):

FIG.6
R.Nene 1990-91
Numeric representation of WQ of a site with a high coefficient of variation showing 95% confidence intervals.



hence, certain points beyond this 95% confidence interval (for example, Autumn 1991 in the graph above), might then be considered to be significantly different from the mean.

However, as a consequence of extending the period of time over which the sites were investigated, the interval obviously becomes narrower i.e. the greater the number of samples, the greater the degree of confidence, thus giving the impression that many of the samples indicate a change in the biological water quality - which may in fact be very misleading. So, the only legitimate way of determining if a change is significant is by the application of the t-test.

The t-test can be applied to establish the confidence of significance of a change in the water quality. The graphical representation illustrates which sites have experienced a change of class i.e.cross the categoric boundary, and at what time. The t-test can then be carried out on these points to establish the confidence that the result is actually statistically different. This procedure was carried out and the results are shown on figures 5A-D.

FIGURE 5A
River Nene 1989-1993
Numeric Representation Of Biological WQ.

Sites with large coefficients of variation.

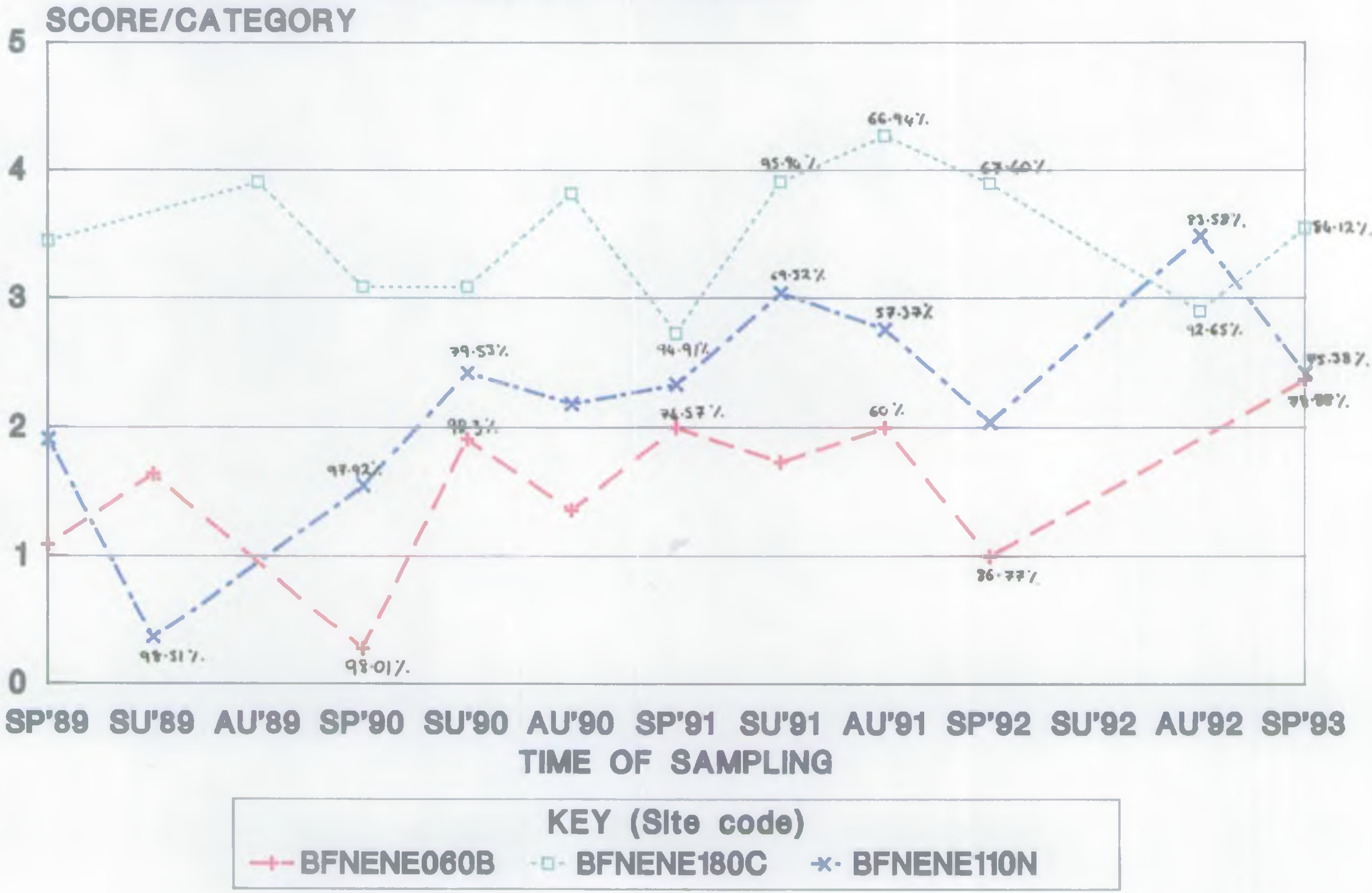


FIGURE 5B

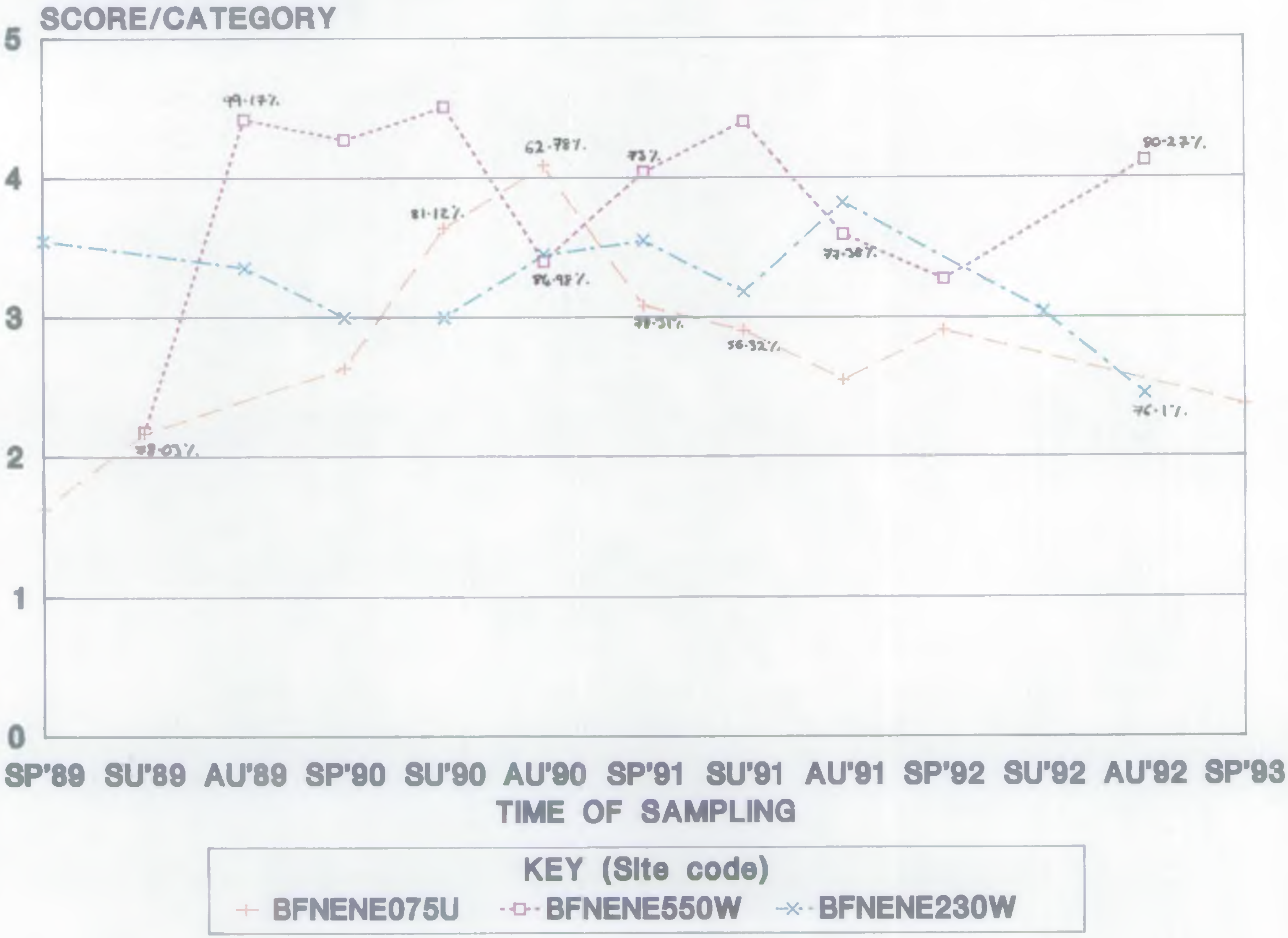

SCORE/CATEGORY
5
4
3
2
1
0
SP'89
SU'89
AU'89
SP'90
SU'90
AU'90
SP'91
SU'91
AU'91
SP'92
SU'92
AU'92
SP'93
TIME OF SAMPLING
KEY (Site code)
BFNENE075U
BFNENE550W
BFNENE230W

FIGURE 5C

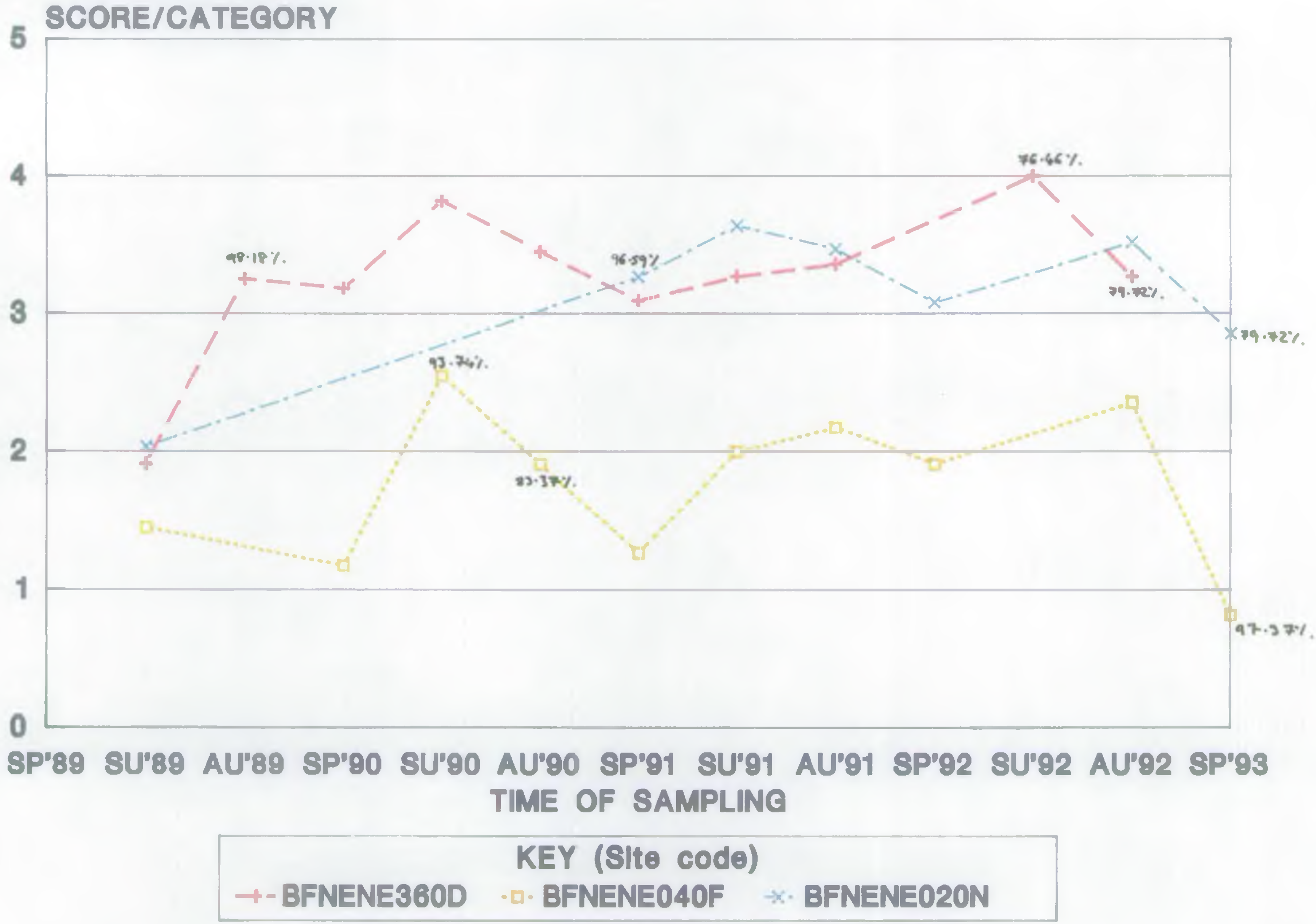
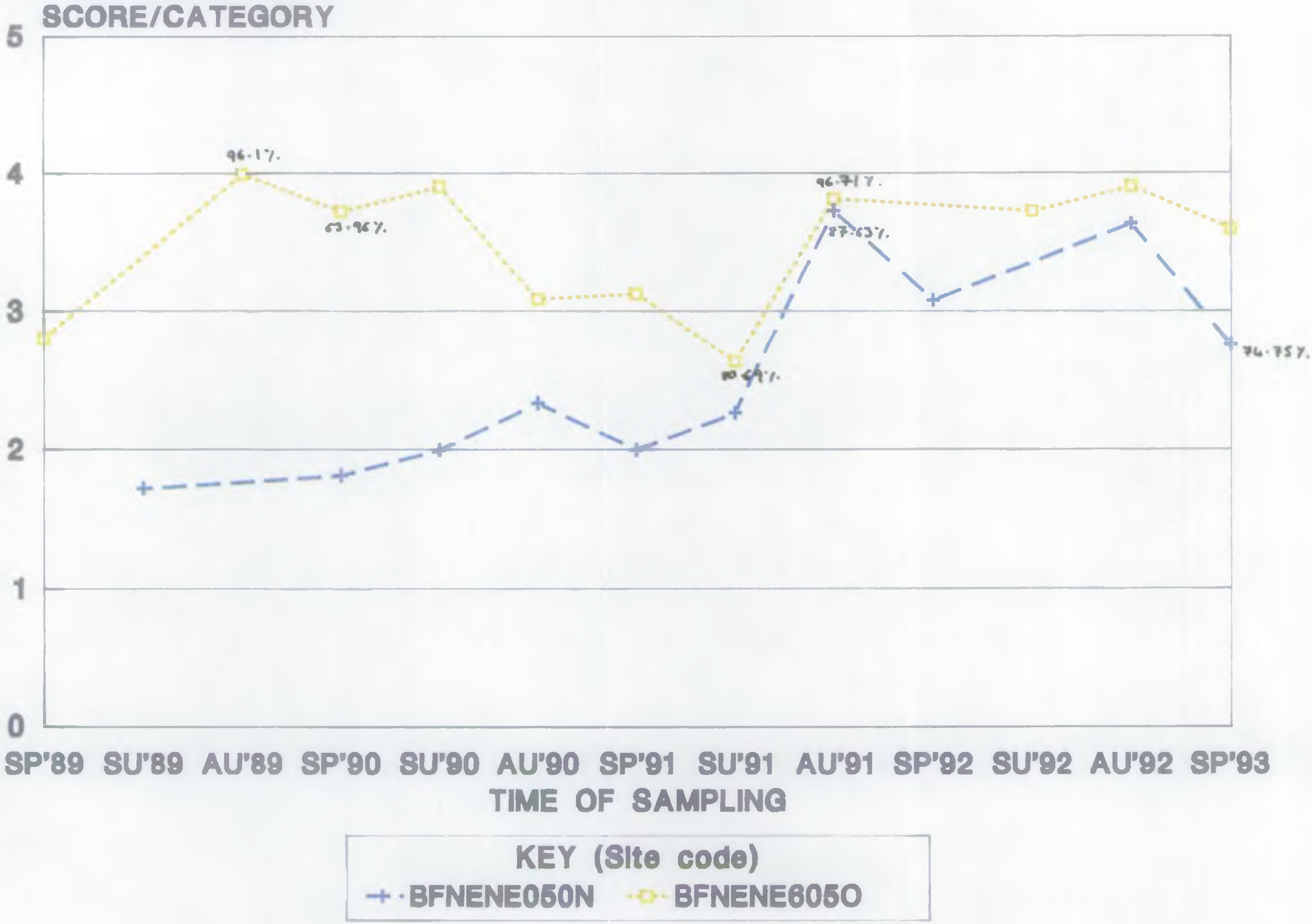

SCORE/CATEGORY
5
4
3
2
1
0
SP'89 SU'89 AU'89 SP'90 SU'90 AU'90 SP'91 SU'91 AU'91 SP'92 SU'92 AU'92 SP'93
TIME OF SAMPLING
KEY (Site code)
BFNENE360D
BFNENE040F
BFNENE020N

FIGURE 5D


SCORE/CATEGORY
5
4
3
2
1
0
96.1%
96.71%
87.63%
76.75%
SP'89 SU'89 AU'89 SP'90 SU'90 AU'90 SP'91 SU'91 AU'91 SP'92 SU'92 AU'92 SP'93
TIME OF SAMPLING
KEY (Site code)
BFNENE050N
BFNENE605O

Numerical Representation of Biological Water Quality

- At present, Biological Water Quality is generally expressed on a four point alphabetic scoring system, where A represents good, and D very poor. These categories are computed by taking sample statistics (number of taxa, BMWP score, ASPT), and comparing them with their equivalent RIVPACS predictions to compute an EQI for each value. These EQI's are then each banded onto a suitable categoric scale, and these 3 categorics combined into one by a simple rule known as *5M*.

- It is not the purpose of this document to question the suitability of any step in the existing methodology save the use of categoric variables. While categoric values are easy to report, they make the statistical interpretation of results very difficult.

  The problem is compounded by the realisation that as many as 20% of samples may be misclassified due to the imprecision of the methodology, particularly in the categorisation.

  With a numeric system, confidence limits can be computed for values which will indicate whether transgressions of the categoric boundary are in fact significant in terms of change in water quality.

- An equivalent numeric index can be computed as follows -

$$EQI_{BMWP} = \frac{BMWP_{Observed}}{BMWP_{Predicted}}$$ and likewise for number of taxa and ASPT

$$SCORE_{BMWP} = 2 + \frac{(EQI_{BMWP} - Midpoint_{BMWP})}{Interval_{BMWP}}$$

where *Midpoint* is the middle of the categoric scale, in this case 0.495, and *Interval* is the categoric interval i.e. 0.250

$$SCORE_{Final} = \min(SCORE_{ASPT}, \text{average}(SCORE_{ASPT}, SCORE_{Taxa}, SCORE_{BMWP}))$$

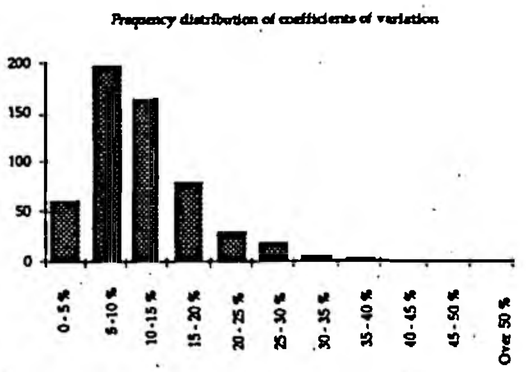
This procedure duplicates the conventional categoric *5M* in all points except that it uses *average* rather than *median* in the final aggregation. This seems intuitively more suitable, but is not essential.

The index has a continuous numeric scale with values from 0-1 corresponding to Biological Class D, 1-2 corresponding to C, 2-3 corresponding to B, 3-4 corresponding to A. Values over 4 correspond to Class A samples where the EQI's are over 100% (i.e. the fauna is better than predicted).

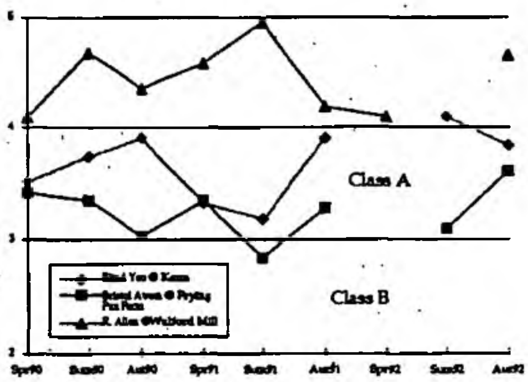
This index can be applied readily to single samples or annual aggregates using the categoric tables provided by IFE for single and multiple samples.

- I can see no fundamental reason why this index should not behave in a more or less statistically normal manner, and I have insufficient data to prove either way. In the absence of any evidence to the contrary, parametric statistics would appear to be the more straightforward approach to utilising these values.

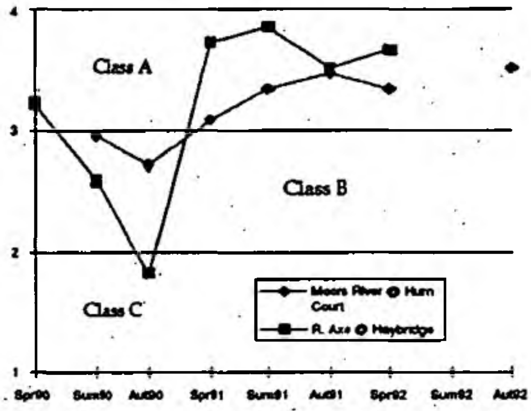
- Sites with a small coefficient of variation are common in our surveys. They are generally of a medium to high quality, and have no evidence of change, either systematic or acute.



- In this figure are three sites with very similar coefficients of variation, yet in two cases the values cross a categoric boundary. The numeric system clearly reveals these to be marginal events and confidence limits could be calculated and applied to corroborate this.



- In this figure, corroborative evidence leads us to believe that the R. Axe suffered an actual pollution, and the Moors River is recovering progressively from an earlier pollution. In both instances the coefficients of variation are much larger than in the first example. Care must be taken in calculating meaningful confidence intervals.



Dave Cooling
Biologist, NRA Wessex Region

April 1, 1993

BMWP SCORES

	SITE	SPR.89	SUM.89	AUT.89	SPR.90	SUM.90	AUT.90	SPR.91	SUM.91	AUT.91
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
1	NENE020N	*	73	*	71	*	*	106	93	64
2	NENE035A	*	81	*	47	63	71	74	68	47
3	NENE040F	*	57	*	43	70	81	66	66	71
4	NENE050N	*	62	*	72	50	60	73	75	118
5	NENE060B	56	69	*	37	57	37	83	73	69
6	NENE075U	51	51	*	76	103	110	77	97	94
7	NENE080D	87	66	*	90	90	137	123	105	127
8	NENE110N	35	29	*	52	67	70	87	87	60
9	NENE180C	112	*	137	105	99	120	91	152	123
10	NENE220H	99	*	95	82	78	96	89	81	97
11	NENE230W	118	*	97	95	92	120	117	108	121
12	NENE250D	*	66	60	67	63	*	59	89	60
13	NENE260D	71	*	73	82	81	97	68	90	81
14	NENE300I	*	96	75	79	68	68	76	94	60
15	NENE340R	*	68	67	91	80	118	59	90	80
16	NENE360D	*	67	88	125	136	114	90	118	90
17	NENE420L	*	127	63	112	100	119	90	110	78
18	NENE495W	*	*	138	*	110	65	120	121	71
19	NENE510E	*	*	100	*	*	131	120	114	106
[illegible]	NENE550W	*	70	140	158	143	101	125	132	90
21	NENE605O	97	*	123	104	125	101	84	86	110
22	NENE630N	97	*	82	85	92	80	105	119	94

Last Column: C16   Last Row: 22

	SPR.92	SUM.92	AUT.92	SPR.93	SUM.93	AUT.93
	C11	C12	C13	C14	C15	C16
1	77	*	92	73	*	*
2	57	*	50	61	*	*
3	83	*	77	37	*	*
4	79	*	102	71	*	*
5	42	*	88	51	*	*
6	83	*	*	79	*	*
7	72	*	*	112	*	*
8	59	*	93	71	*	*
9	109	*	74	118	*	*
10	*	81	95	*	*	*
11	*	81	76	*	*	*
12	58	*	*	*	*	*
13	109	*	93	*	*	*
14	*	78	61	*	*	*
15	*	71	87	*	*	*
16	*	111	82	*	*	*
17	*	90	96	*	*	*
18	89	*	113	*	*	*
19	91	*	85	*	*	*
20	123	*	119	*	*	*
21	*	124	122	105	*	*
22	*	89	106	107	*	*

Last Column: C16

TAXA SCORES

	SITE	SPR.89	SUM.89	AUT.89	SPR.90	SUM.90	AUT.90	SPR.91	SUM.91	AUT.91
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
1	NENE020N	*	17	*	16	*	*	21	20	15
2	NENE035A	*	18	*	12	15	18	18	17	13
3	NENE040F	*	16	*	12	18	21	18	18	18
4	NENE050N	*	17	*	19	14	15	18	19	25
5	NENE060B	16	19	*	12	16	10	20	20	18
6	NENE075U	14	13	*	19	23	24	18	23	23
7	NENE080D	20	17	*	20	21	29	26	25	27
8	NENE110N	9	10	*	14	16	18	19	20	14
9	NENE180C	24	*	29	23	23	25	21	31	24
10	NENE220H	23	*	22	17	20	22	20	20	22
11	NENE230W	25	*	21	21	21	26	26	24	26
12	NENE250D	*	17	15	14	17	*	15	21	14
13	NENE260D	17	*	17	18	20	22	16	21	20
14	NENE300I	*	23	19	20	18	18	19	21	15
15	NENE340R	*	18	17	22	20	26	14	22	18
16	NENE360D	*	18	19	27	28	25	20	26	20
17	NENE420L	*	27	15	24	22	24	19	25	15
18	NENE495W	*	*	29	*	24	14	25	27	15
19	NENE510E	*	*	22	*	*	27	25	24	24
	NENE550W	*	17	27	30	27	21	24	25	22
21	NENE605O	23	*	26	22	26	24	18	21	24
22	NENE630N	23	*	19	20	21	17	22	27	22

Last Column: C16 Last Row: 22

	SPR.92	SUM.92	AUT.92	SPR.93	SUM.93	AUT.93
	C11	C12	C13	C14	C15	C16
1	14	*	18	14	*	*
2	14	*	11	14	*	*
3	21	*	19	11	*	*
4	17	*	22	15	*	*
5	12	*	21	14	*	*
6	19	*	*	19	*	*
7	16	*	*	25	*	*
8	15	*	18	17	*	*
9	22	*	17	25	*	*
10	*	19	21	*	*	*
11	*	19	19	*	*	*
12	13	*	*	*	*	*
	23	*	21	*	*	*
14	*	19	16	*	*	*
15	*	17	19	*	*	*
16	*	22	18	*	*	*
17	*	20	21	*	*	*
18	17	*	25	*	*	*
19	20	*	19	*	*	*
20	26	*	23	*	*	*
21	*	27	26	22	*	*
22	*	20	24	22	*	*

Last Column: C16

ASPT scores

	SITE	SPR.89	SUM.89	AUT.89	SPR.90	SUM.90	AUT.90	SPR.91	SUM.91	AUT.91
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
1	NENE020N	*	4.29	*	4.44	*	*	5.05	4.65	4.27
2	NENE035A	*	4.50	*	3.92	4.20	3.94	4.11	4.00	3.62
3	NENE040F	*	3.56	*	3.58	3.89	3.86	3.67	3.67	3.94
4	NENE050N	*	3.65	*	3.79	3.57	4.00	4.06	3.95	4.72
5	NENE060B	3.50	3.63	*	3.08	3.56	3.56	4.15	3.65	3.83
6	NENE075U	3.64	3.92	*	4.00	4.48	4.58	4.28	4.22	4.09
7	NENE080D	4.35	3.88	*	4.40	4.29	4.72	4.73	4.20	4.70
8	NENE110N	3.89	2.90	*	3.71	4.19	3.89	4.58	4.35	4.29
9	NENE180C	4.67	*	4.72	4.57	4.30	4.80	4.33	4.90	5.13
10	NENE220H	4.30	*	4.32	4.82	3.90	4.36	4.45	4.05	4.41
11	NENE230W	4.72	*	4.62	4.52	4.38	4.62	4.50	4.50	4.65
12	NENE250D	*	3.88	4.00	4.79	3.71	3.93	4.24	4.29	4.29
13	NENE260D	4.18	*	4.29	4.56	4.05	4.41	4.25	4.29	4.05
14	NENE300I	*	4.17	3.95	3.95	3.78	3.78	4.00	4.48	4.00
15	NENE340R	*	3.78	3.94	4.14	4.00	4.54	4.21	4.09	4.44
16	NENE360D	*	3.72	4.63	4.63	4.86	4.56	4.50	4.54	4.50
17	NENE420L	*	4.70	4.20	4.67	4.55	4.96	4.74	4.40	5.20
18	NENE495W	*	*	4.76	*	4.58	4.64	4.80	4.48	4.73
19	NENE510E	*	*	4.55	*	*	4.85	4.80	4.75	4.42
20	NENE550W	*	4.12	5.19	5.27	5.30	4.81	5.21	5.28	5.00
21	NENE605O	4.22	*	4.73	4.73	4.81	4.21	4.67	4.10	4.58
22	NENE630N	4.22	*	4.32	4.25	4.38	4.71	4.77	4.41	4.27

Last Column: C16 Last Row: 22

	SPR.92	SUM.92	AUT.92	SPR.93	SUM.93	AUT.93
	C11	C12	C13	C14	C15	C16
1	5.50	*	5.11	5.21	*	*
2	4.07	*	4.55	4.36	*	*
3	3.95	*	4.05	3.36	*	*
4	4.65	*	4.64	4.73	*	*
5	3.50	*	4.19	3.64	*	*
6	4.37	*	*	4.16	*	*
7	4.50	*	*	4.48	*	*
8	3.93	*	5.17	4.18	*	*
9	4.95	4.59	4.35	4.72	*	*
10	*	4.26	4.52	*	*	*
11	*	4.26	4.00	*	*	*
12	4.46	*	*	*	*	*
13	4.74	*	4.43	*	*	*
14	*	4.11	3.81	*	*	*
15	*	4.18	4.58	*	*	*
16	*	5.05	4.56	*	*	*
17	*	4.47	4.57	*	*	*
18	5.24	*	4.52	*	*	*
19	4.55	*	4.47	*	*	*
20	4.73	*	5.17	*	*	*
21	*	4.59	4.69	4.77	*	*
22	*	4.45	4.42	4.86	*	*

Last Column: C16

	C1	EQIBSP89 C2	EQIBSU89 C3	EQIBAU89 C4	EQIBSP92 C5	EQIBSU92 C6	EQIBAU92 C7	EQIBSP93 C8
1	NENE020N	*	0.66	*	0.64	*	0.82	0.61
2	NENE035A	*	0.82	*	0.55	*	0.53	0.59
3	NENE040F	*	0.49	*	0.72	*	0.67	0.32
4	NENE050N	*	0.57	*	0.71	*	0.92	0.63
5	NENE060B	0.50	0.63	*	0.37	*	0.78	0.48
6	NENE075U	0.48	0.49	*	0.78	*	*	0.24
7	NENE080D	0.77	0.61	*	0.63	*	*	0.99
8	NENE110N	0.28	0.23	*	0.46	*	0.77	0.56
9	NENE180C	0.97	*	1.22	0.95	*	0.66	1.03
10	NENE220H	0.86	*	0.81	*	0.71	0.81	*
11	NENE230W	1.05	*	0.88	*	0.72	0.69	*
12	NENE250D	*	0.61	0.51	0.53	*	*	*
13	NENE260D	0.57	*	0.59	0.87	*	0.75	*
14	NENE300I	*	0.76	0.64	*	0.62	0.52	*
15	NENE340R	*	0.53	0.53	*	0.55	0.69	*
16	NENE360D	*	0.58	0.77	*	0.97	0.72	*
17	NENE420L	*	1.00	0.50	*	0.70	0.77	*
18	NENE495W	*	*	1.20	0.76	*	0.97	*
19	NENE510E	*	*	0.83	0.74	*	0.70	*
20	NENE550W	*	0.56	1.11	0.99	*	0.95	*
21	NENE605O	0.83	*	1.06	*	1.04	1.07	0.90
22	NENE630N	0.83	*	*	*	0.75	0.88	0.91

Last Column: C73 Last Row<F1> for HELP

	MIDBMWP C9	INTBMWP C10	BMSCSP89 C11	BMSCSU89 C12	BMSCAU89 C13	BMSCSP92 C14	BMSCSU92 C15	BMSCAU92 C16
1	0.495	0.25	*	2.66	*	2.58	*	3.30
2	0.495	0.25	*	3.30	*	2.22	*	2.14
3	0.495	0.25	*	1.98	*	2.90	*	2.70
4	0.495	0.25	*	2.30	*	2.86	*	3.70
5	0.495	0.25	2.02	2.54	*	1.50	*	3.14
6	0.495	0.25	1.94	1.98	*	3.14	*	*
7	0.495	0.25	3.10	2.46	*	2.54	*	*
8	0.495	0.25	1.14	0.94	*	1.86	*	3.10
9	0.495	0.25	3.90	*	4.90	3.82	*	2.66
10	0.495	0.25	3.46	*	3.26	*	2.86	3.26
11	0.495	0.25	4.22	*	3.54	*	2.90	2.78
12	0.495	0.25	*	2.46	2.06	2.14	*	*
13	0.495	0.25	2.30	*	2.38	3.50	*	3.02
14	0.495	0.25	*	3.06	2.58	*	2.50	2.10
15	0.495	0.25	*	2.14	2.14	*	2.22	2.78
16	0.495	0.25	*	2.34	3.10	*	3.90	2.90
17	0.495	0.25	*	4.02	2.02	*	2.82	3.10
18	0.495	0.25	*	*	4.82	3.06	*	3.90
19	0.495	0.25	*	*	3.34	2.98	*	2.82
20	0.495	0.25	*	2.26	4.46	3.98	*	3.82
21	0.495	0.25	3.34	*	4.26	*	4.18	4.30
22	0.495	0.25	3.34	*	*	*	3.02	3.54

Last Column: C73 Last Row: 22

	BMSCSP93		EQIASP89	EQIASU89	EQIAAU89	EQIASP92	EQIASU92	EQIAAU92
	C17	C18	C19	C20	C21	C22	C23	C24
1	2.46		*	0.84	*	1.04	*	1.000
2	2.38		*	0.96	*	0.81	*	0.990
3	1.30		*	0.71	*	0.76	*	0.810
4	2.54		*	0.74	*	0.93	*	0.950
5	1.94		0.67	0.73	*	0.66	*	0.840
6	0.98		0.73	0.82	*	0.87	*	*
7	3.98		0.84	0.78	*	0.85	*	*
8	2.26		0.76	0.59	*	0.79	*	1.060
9	4.14		0.93	*	0.98	0.99	0.96	0.910
10	*		0.84	*	0.88	*	0.87	0.920
11	*		0.94	*	0.92	*	0.89	0.820
12	*		*	0.78	0.78	0.86	*	*
13	*		0.79	*	0.84	0.91	*	0.890
14	*		*	0.87	0.82	*	0.84	0.790
15	*		*	0.77	0.79	*	0.84	0.920
16	*		*	0.76	0.94	*	1.03	0.910
17	*		*	0.92	0.86	*	0.89	0.914
18	*		*	*	0.99	1.05	*	0.940
19	*		*	*	0.91	0.89	*	0.910
20	*		*	0.79	1.04	0.91	*	1.030
21	3.62		0.86	*	0.99	*	0.96	0.980
22	3.66		0.84	*	0.88	*	0.91	0.900

Last Column: C73   Last Row: 22

	EQIASP93	MIDASPT	INTASPT	ASSCSP89	ASSCSU89	ASSCAU89	ASSCSP92	ASSCSU92
	C25	C26	C27	C28	C29	C30	C31	C32
1	0.98	0.77	0.11	*	2.63636	*	4.45455	*
2	0.89	0.77	0.11	*	3.72727	*	2.36364	*
3	0.64	0.77	0.11	*	1.45455	*	1.90909	*
4	0.89	0.77	0.11	*	1.72727	*	3.45455	*
5	0.73	0.77	0.11	1.09091	1.63636	*	1.00000	*
6	0.85	0.77	0.11	1.63636	2.45455	*	2.90909	*
7	0.86	0.77	0.11	2.63636	2.09091	*	2.72727	*
8	0.82	0.77	0.11	1.90909	0.36364	*	2.18182	*
9	0.94	0.77	0.11	3.45455	*	3.90909	4.00000	3.72727
10	*	0.77	0.11	2.63636	*	3.00000	*	2.90909
11	*	0.77	0.11	3.54545	*	3.36364	*	3.09091
12	*	0.77	0.11	*	2.09091	2.09091	2.81818	*
13	*	0.77	0.11	2.18182	*	2.63636	3.27273	*
14	*	0.77	0.11	*	2.90909	2.45455	*	2.63636
15	*	0.77	0.11	*	2.00000	2.18182	*	2.63636
16	*	0.77	0.11	*	1.90909	3.54545	*	4.36364
17	*	0.77	0.11	*	3.36364	2.81818	*	3.09091
18	*	0.77	0.11	*	*	4.00000	4.54545	*
19	*	0.77	0.11	*	*	3.27273	3.09091	*
20	*	0.77	0.11	*	2.18182	4.45455	3.27273	*
21	0.95	0.77	0.11	2.81818	*	4.00000	*	3.72727
22	0.95	0.77	0.11	2.63636	*	3.00000	*	3.27273

Last Column: C73   Last Row: 22

	ASSCAU92	ASSCSP93		EQIFSP89	EQIFSU89	EQIFAU89	EQIFSP92	EQIFSU92
	C33	C34	C35	C36	C37	C38	C39	C40
1	4.09091	3.90909		*	0.79	*	0.62	*
2	4.00000	3.09091		*	0.85	*	0.67	*
3	2.36364	0.81818		*	0.72	*	0.95	*
4	3.63636	3.09091		*	0.78	*	0.77	*
5	2.63636	1.63636		0.73	0.86	*	0.57	*
6	*	2.72727		0.65	0.59	*	0.89	*
7	*	2.81818		0.92	0.78	*	0.74	*
8	4.63636	2.45455		0.37	0.39	*	0.59	*
9	3.27273	3.54545		1.04	*	1.23	0.97	*
0	3.36364	*		1.01	*	0.92	*	0.81
1	2.45455	*		1.13	*	0.95	*	0.81
2	*	*		*	0.78	0.65	0.62	*
3	3.09091	*		0.72	*	0.70	0.95	*
4	2.18182	*		*	0.87	0.78	*	0.74
5	3.36364	*		*	0.69	0.68	*	0.67
6	3.27273	*		*	0.77	0.81	*	0.94
7	3.30909	*		*	1.09	0.59	*	0.78
8	3.54545	*		*	*	1.21	0.73	*
9	3.27273	*		*	*	0.91	0.83	*
0	4.36364	*		*	0.71	1.07	1.08	*
1	90909	3.63636		0.96	*	1.08	*	1.10
2	3.18182	3.63636		0.99	*	0.78	*	0.83

Last Column: C73 Last Row: 22

	EQIFAU92	EQIFSP93	MIDFAM	INTFAM	FASCS89	FASCSU89	FASCAU89	FASCSP92
	C41	C42	C43	C44	C45	C46	C47	C48
1	0.82	0.62	0.575	0.21	*	3.02381	*	2.21429
2	0.54	0.66	0.575	0.21	*	3.30952	*	2.45238
3	0.83	0.50	0.575	0.21	*	2.69048	*	3.78571
4	0.98	0.71	0.575	0.21	*	2.97619	*	2.92857
5	0.93	0.66	0.575	0.21	2.73810	3.35714	*	1.97619
6	*	0.87	0.575	0.21	2.35714	2.07143	*	3.50000
7	*	1.15	0.575	0.21	3.64286	2.97619	*	2.78571
8	0.73	0.69	0.575	0.21	1.02381	1.11905	*	2.07143
9	0.74	1.10	0.575	0.21	4.21429	*	5.11905	3.88095
0	0.88	*	0.575	0.21	4.07143	*	3.64286	*
1	0.82	*	0.575	0.21	4.64286	*	3.78571	*
2	*	*	0.575	0.21	*	2.97619	2.35714	2.21429
3	0.89	*	0.575	0.21	2.69048	*	2.59524	3.78571
4	0.79	*	0.575	0.21	*	3.40476	2.97619	*
5	0.92	*	0.575	0.21	*	2.54762	2.50000	*
6	0.93	*	0.575	0.21	*	2.92857	3.11905	*
7	0.91	*	0.575	0.21	*	4.45238	2.07143	*
8	0.94	*	0.575	0.21	*	*	5.02381	2.73810
9	0.91	*	0.575	0.21	*	*	3.59524	3.21429
0	1.03	*	0.575	0.21	*	2.64286	4.35714	4.40476
1	0.98	0.90	0.575	0.21	3.83333	*	4.40476	*
2	0.98	0.96	0.575	0.21	3.97619	*	2.97619	*

Last Column: C73 Last Row: 22

	FASCSU92	FASCAU92	FASCSP93		ASPTSP89	MEANSP19	F_SCSP89	ASPTSU89
	C49	C50	C51	C52	C53	C54	C55	C56
1	*	3.16667	2.21429		*	*	*	2.63636
2	*	1.83333	2.40476		*	*	*	3.72727
3	*	3.21429	1.64286		*	*	*	1.45455
4	*	3.92857	2.64286		*	*	*	1.72727
5	*	3.69048	2.40476		1.09091	1.94967	*	1.63636
6	*	*	3.40476		1.63636	1.97784	*	2.45455
7	*	*	4.73810		2.63636	3.12641	*	2.09091
8	*	2.73810	2.54762		1.90909	1.35763	*	0.36364
9	*	2.78571	4.50000		3.45455	3.85628	3.45	*
10	3.11905	3.45238	*		2.63636	3.38926	2.64	*
11	3.11905	3.16667	*		3.54545	4.13610	3.55	*
12	*	*	*		*	*	*	2.09091
13	*	3.50000	*		2.18182	2.39076	2.18	*
14	2.78571	3.02381	*		*	*	*	2.90909
15	2.45238	3.64286	*		*	*	*	2.00000
16	3.73810	3.69048	*		*	*	*	1.90909
17	2.97619	3.59524	*		*	*	*	3.36364
18	*	3.73810	*		*	*	*	*
19	*	3.59524	*		*	*	*	*
20	*	4.16667	*		*	*	*	2.18182
21	[illegible].50000	3.92857	3.54762		2.81818	3.33051	2.81	*
22	3.21429	3.92857	3.83333		2.63636	3.31752	*	*

Last Column: C73   Last Row: 22

	MEANSU89	F_SCSU89	ASPTAU89	MEANAU89	F_SCAU89	ASPTSP92	MEANSP92	F_SCSP92
	C57	C58	C59	C60	C61	C62	C63	C64
1	2.77339	*	*	*	*	4.45455	3.08294	*
2	3.44560	*	*	*	*	2.36364	2.34534	*
3	2.04167	*	*	*	*	1.90909	2.86494	*
4	2.33449	*	*	*	*	3.45455	3.08104	*
5	2.51117	*	*	*	*	1.00000	1.49206	*
6	2.16866	*	*	*	*	2.90909	3.18303	*
7	2.50903	*	*	*	*	2.72727	2.68433	*
8	0.80756	*	*	*	*	2.18182	2.03775	*
9	*	*	3.90909	4.64271	3.91	4.00000	3.90032	3.90
10	*	*	3.00000	3.30095	3.00	*	*	*
11	*	*	3.36364	3.56312	3.36	*	*	*
12	2.50903	2.09	2.09091	2.16935	2.09	2.81818	2.39082	2.82
13	*	*	2.63636	2.53720	2.54	3.27273	3.51948	3.27
14	[illegible].12462	2.91	2.45455	2.67025	2.45	*	*	*
15	2.22921	2.00	2.18182	2.27394	2.18	*	*	*
16	2.39255	1.91	3.54545	3.25483	3.25	*	*	*
17	3.94534	3.36	2.81818	2.30320	2.30	*	*	*
18	*	*	4.00000	4.61460	4.00	4.54545	3.44785	3.45
19	*	*	3.27273	3.40266	3.27	3.09091	3.09506	3.09
20	2.36156	2.18	4.45455	4.42390	4.42	3.27273	3.88583	3.27
21	*	*	4.00000	4.22159	4.00	*	*	*
22	*	*	3.00000	*	*	*	*	*

Last Column: C73   Last Row: 22

	ASPTSU92 C65	MEANSU92 C66	F_SCSU92 C67	ASPTAU92 C68	MEANAU92 C69	F_SCAU92 C70	ASPTSP93 C71	MEANSP93 C72
1	*	*	*	4.09091	3.51919	*	3.90909	2.86113
2	*	*	*	4.00000	2.65778	*	3.09091	2.62522
3	*	*	*	2.36364	2.75931	*	0.81818	1.25368
4	*	*	*	3.63636	3.75498	*	3.09091	2.75792
5	*	*	*	2.63636	3.15561	*	1.63636	1.99371
6	*	*	*	*	*	*	2.72727	2.37068
7	*	*	*	*	*	*	2.81818	3.84543
8	*	*	*	4.63636	3.49149	*	2.45455	2.42072
9	3.72727	*	*	3.27273	2.90615	2.90	3.54545	4.06182
10	2.90909	2.96271	2.91	3.36364	3.35867	3.36	*	*
11	3.09091	3.03665	3.04	2.45455	2.80040	2.45	*	*
12	*	*	*	*	*	*	*	*
13	*	*	*	3.09091	3.20364	3.09	*	*
14	2.63636	2.64069	2.64	2.18182	2.43521	2.18	*	*
15	2.63636	2.43625	2.44	3.36364	3.26216	3.26	*	*
16	4.36364	4.00058	4.00	3.27273	3.28773	3.27	*	*
17	3.09091	2.96237	2.96	3.30909	3.33478	3.31	*	*
18	*	*	*	3.54545	3.72785	3.55	*	*
19	*	*	*	3.27273	3.22932	3.23	*	*
20	*	*	*	4.36364	4.11677	4.12	*	*
21	3.72727	4.13576	3.73	3.90909	4.04589	3.91	3.63636	3.60133
22	3.27273	3.16900	*	3.18182	3.55013	*	3.63636	3.70990

Last Column: C73 Last Row: 22

	F_SCSP93 C73
1	*
2	*
3	*
4	*
5	*
6	*
7	*
8	*
9	3.55
10	*
11	*
12	*
13	*
14	*
15	*
16	*
17	*
18	*
19	*
20	*
21	3.60
22	*

```
LET C11=(C2-C9)/C10+2
LET C12=(C3-C9)/C10+2
LET C13=(C4-C9)/C10+2
LET C14=(C5-C9)/C10+2
LET C15=(C6-C9)/C10+2
LET C16=(C7-C9)/C10+2
LET C17=(C8-C9)/C10+2
LET C28=(C19-C26)/C27+2
LET C29=(C20-C26)/C27+2
LET C30=(C21-C26)/C27+2
LET C31=(C22-C26)/C27+2
LET C32=(C23-C26)/C27+2
LET C33=(C24-C26)/C27+2
LET C34=(C25-C26)/C27+2
LET C45=(C36-C43)/C44+2
LET C46=(C37-C43)/C44+2
LET C47=(C38-C43)/C44+2
LET C48=(C39-C43)/C44+2
LET C49=(C40-C43)/C44+2
LET C34=(C25-C26)/C27+2
LET C45=(C36-C43)/C44+2
LET C46=(C37-C43)/C44+2
LET C47=(C38-C43)/C44+2
LET C48=(C39-C43)/C44+2
LET C49=(C40-C43)/C44+2
LET C50=(C41-C43)/C44+2
LET C51=(C42-C43)/C44+2
LET C53=C28
LET C54=(C11+C28+C45)/3
LET C56=C29
LET C57=(C12+C29+C46)/3
LET C59=C30
LET C60=(C13+C30+C47)/3
LET C62=C31
LET C63=(C14+C31+C48)/3
LET C65=C32
LET C66=(C15+C32+C49)/3
LET C68=C33
LET C69=(C16+C33+C50)/3
LET C71=C34
LET C72=(C17+C34+C51)/3
END
```

"FINA SCORES" FROM NUMERICAL REPRESENTATION OF BIOLOGICAL WATER QUALITY

SITE CODE	SPR 1989	SUM 1989	AUT 1989	SPR 1990	SUM 1990	AUT 1990	SPR 1991	SUM 1991	AUT 1991	SPR 1992	SUM 1992	AUT 1992	SPR 1993	MEAN	S.D	C %
020N	*	2.04	*	*	*	*	3.27	3.64	3.47	3.08	*	3.52	2.86	3.13	.549	17.5
035A	*	3.44	*	2.02	2.09	2.64	2.09	2.36	2.45	2.35	*	2.66	2.63	2.47	.415	16.8
040F	*	1.45	*	1.18	2.55	1.91	1.27	2.00	2.18	1.91	*	2.36	0.82	1.76	.560	31.8
050N	*	1.73	*	1.82	2.00	2.34	2.00	2.27	3.73	3.08	*	3.64	2.76	2.54	.733	28.9
060B	1.09	1.64	*	0.27	1.91	1.36	2.00	1.73	2.00	1.00	*	2.64	1.64	1.57	.629	40.1
075U	1.64	2.17	*	2.64	3.64	4.09	3.08	2.91	2.55	2.91	*	*	2.37	2.80	.706	25.2
080D	2.64	2.09	*	2.70	3.36	3.91	3.18	2.91	3.64	2.68	*	*	2.82	2.99	.536	17.9
110N	1.91	0.36	*	1.55	2.42	2.18	2.33	3.04	2.76	2.04	*	3.49	2.42	2.23	.819	36.7
180C	3.45	*	3.91	3.09	3.09	3.82	2.73	3.91	4.27	3.90	*	2.90	3.55	3.51	.498	14.19
220H	2.64	*	3.00	3.02	2.00	2.91	*	*	*	*	2.91	3.36	*	2.83	.425	15.02
230W	3.55	*	3.36	3.00	3.00	3.45	3.55	3.18	3.82	*	3.04	2.45	*	3.24	.390	21.3
250D	*	2.09	2.09	*	*	*	1.55	2.45	2.55	2.82	*	*	*	2.26	.446	19.73
260D	2.18	*	2.54	2.75	2.97	3.00	2.44	2.82	2.18	3.27	*	3.09	*	2.72	.378	13.9
300I	*	2.91	2.45	2.09	1.64	2.00	2.36	3.31	2.55	*	2.64	2.18	*	2.41	.478	19.83
340R	*	2.0	2.18	2.27	2.18	3.27	2.12	2.36	3.00	*	2.44	3.26	*	2.51	.482	19.2
360D	*	1.91	3.25	3.18	3.82	3.45	3.09	3.27	3.36	*	4.00	3.27	*	3.26	.554	16.99
420L	*	3.36	2.30	3.36	3.23	3.93	3.14	3.00	3.72	*	2.96	3.31	*	3.23	.443	13.72
495W	*	*	4.00	4.09	3.55	2.78	3.55	3.45	3.39	3.45	*	3.55	*	3.53	.376	10.65
510E	*	*	3.27	*	3.91	*	3.55	3.62	3.27	3.09	*	3.23	*	3.42	.285	8.33
550W	*	2.18	4.42	4.27	4.51	3.4	4.04	4.40	3.59	3.27	*	4.12	*	3.82	.725	18.98
605O	2.81	*	4.00	3.73	3.91	3.09	3.13	2.64	3.82	*	3.73	3.91	3.60	3.49	.482	13.81
630N	2.64	*	*	3.09	3.09	3.40	4.16	2.82	3.55	*	3.17	3.18	3.64	3.27	.435	13.3

CONCLUSION

The numeric representation of biological water quality shows great potential for being a successful approach to representing and analysing biological data. It enables the use of statistical analysis on the categorisation. With this numeric system, levels of confidence can be computed for values which indicate whether transgression of the categoric boundaries are in fact significant in terms of change in biological water quality. Further refinement is neccessary to ensure that the coefficients of variation model is applicable to any site. Also, the discussion document (Appendix 1), requires further explaination concerning confidence intervals.

FUTURE RECOMMENDATIONS

The coefficients of variation model illustrated in this report is very specific to the R. Nene data. It would be beneficial to collate data from several areas and establish a model that is more reliable and applicable. This could then be employed for future use to serve the purpose of exposing sites which are likely to have experienced change in water quality.

An investigation of an area that has experienced a pollution incident in the past could be used to determine whether or not the numeric representation procedure gives an accurate account of the events that occurred.

The 5M rule could be used to determine numeric values before conversion to alphabetic categories, and the results compared with those obtained in this investigation.

Confidence of improvement of water quality could be established by use of the ASPT scores (there is greater statistical confidence in the ASPT than the BMWP score) and this, once again, compared with the results obtained by this investigation. If the results corresponded the further computations involved in the numeric representation may not be necessary.

PC JUNE 1993