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EA Thames Region Operational Investigation

No. OI/T/001

Investigation into macroinvertebrate sampling variability

Pond Action
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Executive summary

1. Background

This report describes the results of an Operational Investigation (No. 0I/T/001) undertaken by Pond Action for EA Thames Region between October 1993 and September 1994. The main objective of the project was to describe the effect of macroinvertebrate sampling variability on assessments of water quality made using the BMWP system and RIVPACS.

The data set for the study consisted of macroinvertebrate samples collected from 12 randomly selected EA Thames Region routine monitoring sites. The selection of sites was stratified to ensure that all four water quality bands of the 5M system were represented. Sites were sampled by randomly chosen samplers, drawn from a pool of four experienced biologists, in autumn 1993 and spring 1994.

2. Factors affecting the variability of water quality assessments

The effects of sampler, season and site on variability of water quality assessments were investigated. Assessments were made in terms of the variability of biotic indices (TAXA, BMWP, ASPT and their respective EQIs).

Sampler: the results show that there were statistically significant differences between samplers. The most practised sampler collected samples which gave average scores up to 7% higher than mean values, whereas the least practised sampler obtained scores up to 5% below mean values. In survey programmes, such as the EA routine monitoring programme, where samplers are not randomly assigned to sites, bias of this magnitude can directly affect water quality banding of sites.

Season: there was no systematic tendency for sites surveyed in one season to have higher (or lower) scores than sites surveyed in another season. However, there were significant non-systematic differences in biotic indices between seasons at individual sites. This may have reflected real changes in water quality, or have resulted from seasonal changes in factors such as the relative abundance of taxa, habitat availability etc.

Site: as would be expected, differences between sites explained the greatest amount of variation in the dataset.

3. Variability of TAXA, BMWP, ASPT and their respective EQIs

Estimates of TAXA, BMWP and their respective EQIs, were significantly more variable at sites with high water quality. ASPT and its EQI showed a significant decrease in variability with increasing mean water quality (combined samples only).

4. Variability and discrimination of biotic indices

The utility of a biotic index for banding sites of different water quality depends on two factors: the variability of the index and, a factor often overlooked, its discrimination, i.e. its ability to discriminate between sites of differing biological water quality. These two factors are inherently linked, since increased variability will reduce discrimination if other factors remain unchanged.

Of the indices, ASPT and ASPT.EQI were the least variable but also the least discriminatory. TAXA, TAXA.EQI, BMWP and BMWP.EQI were more variable, but also more discriminatory. Within the Thames region, TAXA, BMWP and their respective EQIs were found to be more effective indices for water quality banding than ASPT and ASPT.EQI . This contrasts with the widely held belief that ASPT and ASPT.EQI are superior indices because of their lower variability.

Other outputs from the BMWP system and RIVPACS analyses included:

- a series of 'look-up' tables, which allow the likelihood of an individual sample being associated with a particular water quality band of the EQI system to be checked from tabulated values.
- the conceptual framework for a mathematical model which can predict the likelihood of sites being placed in the correct 5M band (or other combined EQI banding system);
- suggested modifications for the existing EQI and 5M band systems.

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1. Introduction

1.1 Background to this report

This report describes the results of a study of the effects of macroinvertebrate sampling variability on water quality assessments made using the BMWP-RIVPACS system. The work was carried out as part of an EA Thames Region Operational Investigation undertaken by Pond Action between October 1993 and September 1994.

Biological water quality in rivers is routinely assessed by the Environment Agency using the BMWP (Biological Monitoring Working Party) scoring system in conjunction with RIVPACS (Sweeting *et al.* 1992). In the development of the BMWP-RIVPACS system there has been extensive testing of the effects of variation in laboratory sample processing and specimen identification but, to date, the effects of sampling variation have been less thoroughly investigated. Variation in field sampling of macroinvertebrates, like that in laboratory sample processing, influences the certainty with which a site can be assigned to a water quality class (NRA 1994) and understanding of this variation is, therefore, essential for the correct interpretation of biological monitoring survey results.

1.2 The effect of sampling variation on water quality assessment

Assigning a site to a particular water quality class, using BMWP/RIVPACS, is a four stage process. It involves (i) collection of invertebrate samples, (ii) processing those samples (sorting and identification in the laboratory, followed by calculation of TAXA, BMWP and ASPT scores), (iii) making RIVPACS predictions to derive Ecological Quality Indices and (iv) placing sites into water quality bands on the basis of those EQIs.

Sampling variation occurs in stage (i) when the samples are collected and affects stage (iii), when BMWP scores are calculated and RIVPACS predictions made. This variation is then passed on to stage (iv), the banding of sites. Additional variation can be added at stage (ii) sample processing, but was not the subject of this study.

Sample processing variation is more easily understood and controlled by laboratory procedures than field sampling variation. Samples are finite so that, in theory at least, it is possible to remove all families from a sample, identify all specimens correctly, and prepare a completely accurate list of taxa. It is also possible to retain a sample for resorting or quality control, specimens can be re-identified and taxa lists double checked.

Field sampling cannot be regulated in the same way, because field sites are inherently spatially variable. Thus, within the constraints of a three minute sample (i) two samples from the same site will never be the same and (ii) two samplers working at the site will rarely collect the same number or type of taxa. Measures for dealing with field and laboratory variation are, therefore, fundamentally different. Laboratory variation is controlled by good laboratory practice and checking results, and can largely be eliminated. Field sampling variation cannot be eliminated and must be controlled by careful survey design, training to minimise operator variability, and correct application of statistical procedures.

1.3 Specific objectives of the study

The specific objectives of this study were:

(i) to describe the sources of sampling variation which can affect water quality indices (e.g. variation within samplers, between samplers, between seasons, between sites, and variation in RIVPACS field measurements);

(ii) to assess whether or not variability was affected by water quality (i.e. are samples from poor quality sites more or less variable than those from higher quality sites?);

(iii) to assess which of the above factors have the greatest effect on variability - knowledge of the relative importance of factors can help to suggest which are most important to control;

(iv) to describe the overall variability of samples and use this information to describe the likelihood of a site being correctly placed in a particular water quality band;

(v) to determine whether different survey strategies affect the certainty with which sites can be banded. Three strategies were compared to represent the range of possibilities available to the EA:

- single season samples - EA routinely assesses the water quality of sites using single samples.

- combined season samples - EA routinely collects samples in two or three seasons, which are merged to give a single 'combined' season sample. This process was represented in the present study by combining samples from two seasons.
- dual season samples - EA does not, but could, adopt a policy of collecting more than one sample in the same season. In this study this option was investigated by combining two samples from each site from either autumn or spring.

(vi) to assess which of the three EQIs used with RIVPACS give the most statistically useful results - this was considered in terms of both the variability of samples and their ability to discriminate between sites. Variability measures how much spread there is in data from a single site; discrimination compares the magnitude of within site variation to that of variation seen over all sites. The most useful indices in terms of variability are those which combine low variability with high discrimination;

(vii) to use the results of the study to suggest more detailed planning of variability studies which could be undertaken.

Table 1.1 Terminology used in this report

The following abbreviations and acronyms are used throughout this report.

ANOVA	Analysis of Variance
ASPT	Average Score per Taxon
ASPT.EQI	Average Score per Taxon Ecological Quality Index
BMWP	Biological Monitoring Working Party score
BMWP system	All aspects of the Biological Monitoring Working Party system (including the use of BMWP score with Ecological Quality Indices derived using RIVPACS)
BMWP.EQI	Biological Monitoring Working Party score Ecological Quality Index
Dual sample	Sample composed of two standard (3-minute) samples taken by the same person on the same day
EQI	Ecological Quality Index. Observed/predicted BMWP, ASPT or TAXA. (BMWP.EQI, TAXA.EQI, ASPT.EQI)
5M	The 5M banding system for assigning sites to a particular water quality class
Pred. ASPT	Predicted ASPT (as predicted by RIVPACS)
Pred. BMWP	Predicted BMWP (as predicted by RIVPACS)
Pred. TAXA	Predicted TAXA (as predicted by RIVPACS)
RIVPACS	River InVertebrate Prediction And Classification System
TAXA	The number of taxa recorded in BMWP samples
TAXA EQI	TAXA Ecological Quality Index
Biotic indices	A general term for any/all of the biotic scores and indices listed above

2. Methods

2.1 Selection procedure for the sites surveyed

Site selection aimed to incorporate sites which were likely to be placed in each of the four EQI water quality bands (bands A, B, C and D of the 5M system). In this study, twelve sites were selected (three in each water quality band).

The following strategy was used to select sites for inclusion in the survey:

(i) Water quality data from 1992 for all the sites in the EA Thames Region were obtained from the EA database at Fobney Mead, Reading;

(ii) Sites in each of the four water quality bands were numbered and three sites from each selected with the use of random number tables. No replacement was allowed in the selection process, so no site could be selected twice;

(iii) These sites were checked with EA regional staff to ensure that they were not in any way unusual (e.g. that a specific pollution had affected the 1992 water quality assessment).

Only two sites in the EA's 1992 regional data set were in water quality band D. A further band D site was, therefore, selected by officers of the EA, from the Thames West region. The locations at which EA staff sampled the sites were also checked to ensure that this study worked at exactly the same sites.

Table 2.1 lists the sites selected, precise sampling location at each site, and survey dates.

2.2 Design of sampling programme, selection of surveyors and field and laboratory methods.

2.2.1 Selection of samplers

Four surveyors were used in the study: Richard Ashby-Crane, Jeremy Biggs, Dave Walker and Mericia Whitfield. All surveyors were fully experienced, but the amount of sampling routinely undertaken by each surveyor varied considerably (see Table 2.2).

The number of surveyors used was comparable with the small number of samplers routinely detailed to conduct biological water quality assessments in the western area of the EA Thames Region. The variation in extent of practice amongst surveyors should adequately mimic the range of skills present in the biological survey team in any region.

2.2.2 Design of sampling programme

The sampling programme was designed so that, at each site, and in each season, two people would take two aquatic macroinvertebrate samples on the same date. A detailed diagrammatic description of the sampling programme is shown in Appendix table 2.1. This table gives details, for every sample collected, of season of collection, sampler, sample order (whether first or second sample), sample name used in this study and EA RIVPACS code (this refers to the EA database held at Fobney Mead).

On each sampling occasion, each person made one assessment of the physical parameters necessary for RIVPACS predictions. The only exception to this was the River Thames (at Boveney Weir) where, in accordance with EA practice, a predetermined set of site attributes was used. There was no discussion on site of site attributes between co-workers.

The two aquatic macroinvertebrate samples were taken consecutively by each worker and labelled accordingly. Samplers worked at each site at the same time in order to reduce any possible bias between which sampler worked first or second. Note that this was a change from the original brief. Both samplers surveyed approximately the same area of river bed.

The person sampling any given site was randomly selected, without replacement. No attempt was made to equalise the number of site visits any particular person made. In the second season (spring) samplers were, again, randomly selected. No attempt was made to avoid or prefer samplers visiting the same site twice.

For the production of combined samples (for later analysis), spring samples were randomly selected (from a given site) to be combined with autumn samples. This was done without replacement so that all eight samples were represented in the four combined-season samples. Appendix table 2.2 shows which spring samples were combined with the autumn samples at each site. These same combinations were also used for RIVPACS predictions. Note that the number of combined-season predictions for any given site varied from two to four, depending on the random recombination of samples to which they referred.

2.2.3 Field sampling and laboratory sorting methods

The methods used to collect invertebrate samples and field data, and to sort invertebrate samples, were strictly in accordance with EA standard practice for RIVPACS related work.

At each survey station a sampling area which could be sampled adequately in three minutes was selected. Each sample collected was a time-limited, pond-net sample (collected using a Freshwater Biological Association standard 1 mm^2 mesh net). Areas of different perceived habitat (e.g. sandy substrate, emergent plants, riffles etc.) were estimated, and the three minutes sampling time divided between these on an area basis. The net was emptied into a bucket periodically to avoid clogging of the mesh. A separate brief search was conducted for animals unlikely to be sampled with a pond-net (e.g. animals which cling to large rocks). At the end of the three minutes sampling the bucket was labelled, sealed and transported back to the laboratory for analysis.

Physical parameters necessary for use with the RIVPACS model were estimated. Average width was estimated by measuring width (waters edge to waters edge) at between three and seven points along the stream and averaging these. Average depth was estimated by measuring depth on between three and seven transects of the stream at quarter, half and three quarters the distance across the stream. Depth recorded was from water surface to substrate surface. All these depths were then averaged.

Although each person collected two invertebrate samples at each site, it was not possible to make two consecutive independent assessments of some RIVPACS parameters (e.g. substrate) for the whole of the reach sampled.

Samples were sorted live in the laboratory, with specimens preserved in 70% industrial methylated spirits. Samples were sorted for a maximum of two hours. All samples were sorted within 24 hours of collection by Dave Walker or Mericia Whitfield. The abundance and species of all Tricladida were recorded at the time of sorting, as these animals do not preserve well.

Table 2.1 Sampling sites for macroinvertebrate sampling variability study (site name, National Grid reference, EA site reference, dates of survey, 1992 5M water quality band).

Site	Location	EA ref	Grid-ref	Autumn sampling date	Spring sampling date	1992 5m band
Bow Brook	Above Loddon, Hartley Wespall	PLDR.0127	SU67635883	5/11/93	15/3/94	A
River Thames	At Boveney Weir	PTHR.0079	SU94407775	15/10/93	2/3/94	A
River Coln	At Fossebridge	PUTR.0036	SP08091115	12/10/93	2/3/94	A
The Cut	At Pitts Bridge, Binfield	NRA070096	SU85257129	21/10/93	24/2/94	B
Lydiard Stream	Above Ray (Wilts)	PUTR.0251	SU12168683	12/10/93	15/3/94	B
Halfacre Brook	Below Clanfield	PUTR.0246	SP30150090	21/10/93	7/2/94	B
Roundmoor Ditch	At Lake End, Dorney	PTHR.0055	SU93027978	15/10/93	10/3/94	C
Summerstown Ditch	100m below Marsh Gibbon STW	PCHR.0164	SP64332239	5/11/93	15/3/94	C
Crendon Stream	Above Thame	PTAR.0110	SP70300791	21/10/93	10/3/94	C
Wheatley Ditch	Superstore car park	PTAR.0026	SP61100530	12/10/93	10/3/94	D
Crawters Brook	At Lowfield heath	PMLR.0006	TQ27654010	15/10/93	24/2/94	D
Catherine Bourne	Rabley park	PCNR.0010	TL20640108	5/11/93	7/2/94	D

Table 2.2 Relevant experience of field workers

Richard Ashby-Crane	Five years experience undertaking biological water quality samples for NRA (Thames Region) (1989 to 1992) and Halcrow Partnership 1992 to 1994. Current practice: takes c. 50 3-minute net samples pr year.
Jeremy Biggs	Nine years experience undertaking aquatic invertebrate sampling for Pond Action and others (1985-1994). Current practice: now takes c. 10 3-minute net samples pr year.
Dave Walker	Seven years experience undertaking aquatic invertebrate sampling for Pond Action (1987-1994). Current practice: takes c. 50 3-minute net samples pr year.
Mericia Whitfield	Six years experience undertaking aquatic invertebrate sampling for Pond Action (1988-1994). Current practice: takes c. 80 3-minute net samples pr year.

2.3 Calculation of biotic indices and water quality bands

For all samples collected, the macroinvertebrate data and RIVPACS measurements were used to calculate the following.

(i) Number of taxa (TAXA), BMWP score and ASPT - an example BMWP sheet is given in Appendix 2.3.

(ii) RIVPACS predicted scores for TAXA, BMWP and ASPT (abbreviated in the report to Pred. TAXA, Pred. BMWP and Pred. ASPT). Measured values for width, depth and substrate composition (measured as percentage boulders, cobbles and pebbles, etc.) were passed to EA Thames Region staff to make RIVPACS predictions for TAXA, BMWP and ASPT values. In all cases the RIVPACS predictions used are predictions of the mean from the Monte-Carlo permutations in the RIVPACS programme. Neither the variability of a single prediction as suggested by Monte-Carlo permutations nor the variability of the mean of the permutations are taken into account in this study.

In this study the environmental data used to make RIVPACS predictions were derived from either one or two-seasons data, a non-standard procedure which is discussed in detail in section 2.5 (below).

(iii) Ecological Quality Indices (EQIs) for TAXA, BMWP and ASPT.

The EQIs were used to place the samples in 5M water quality bands (Clarke *et al.* 1994). In order to band a sample or site, the three EQIs are first individually put into one of four EQI bands, denoted A to D, where A represents the best water quality and D the lowest. The different band ranges for single-season and two-season data for each of the three EQIs are given in Table 2.4. The three individual EQI bands are then combined to form a single 5M band in the following way. The symbols for the bands (A to D) are transposed into numbers (1 to 4) and the median of the three numbers is found. If this median is lower than, or equal to the ASPT.EQI band, then this median is taken to be the 5M band for the site. If the median is higher than the ASPT.EQI band, then the ASPT.EQI band is taken to be the 5M band of the site. This procedure effectively 'weights' the ASPT.EQI, which is generally considered to be the most reliable indicator of water quality. The 5M band is quoted as a letter (A to D).

Table 2.3 TAXA.EQI, BMWP.EQI and ASPT.EQI band ranges of the 5M system

	TAXA.EQI	BMWP.EQI	ASPT.EQI
Single-season data			
A	≥0.67	≥0.62	≥0.84
B	0.34 - 0.66	0.24 - 0.61	0.68 - 0.83
C	0.01 - 0.33	≤0.23	0.52 - 0.67
D	0.00	No band	≤0.51
Two-season data			
A	≥0.77	≥0.72	≥0.88
B	0.54 - 0.76	0.44 - 0.71	0.76 - 0.87
C	0.53 - 0.31	0.16 - 0.43	0.64 - 0.75
D	≤0.30	≤0.15	≤0.63

2.4 Constraints on the analysis

Predicted values of TAXA, BMWP and ASPT were calculated using environmental data collected in one or two seasons only as opposed to the three seasons normally required for use with the RIVPACS programme. The use of one- and two-season data was in accordance standard EA Thames Region practice at the time of the study, and was considered an acceptable methodological variation for this study.

In order to assess the effect of using one and two-season data on the interpretation of results, a comparison was made between the use of one- and three- season environmental data for the sites in this study. One-season data was chosen for this comparison as it is likely to differ more from three-season data in terms of variability. A brief summary of the results of this comparison are shown in Table 2.5. The table shows average EQIs for each site in each season and the coefficients of variation associated with each average. The three bottom rows show the average averages and coefficients of variation for spring, autumn and all data.

Some individual sites, e.g. Catherine Bourne in autumn, do show significant differences when three seasons of environmental data are used in comparison to one season. However, the main trends in the data, with regard to the differences between seasons and between EQIs are little affected by the use of either one or three seasons of environmental data. This indicates that the main conclusions drawn from this report would not be greatly affected had three seasons of environmental data been used throughout.

Table 2.4 Comparison of EQIs derived from single- or three-season data

Site	Average						Coefficient of variation					
	BMWP EQI 3S	BMWP EQI 1S	TAXA EQI 3S	TAXA EQI 1S	ASPT EQI 3S	ASPT EQI 1S	BMWP EQI 3S	BMWP EQI 1S	TAXA EQI 3S	TAXA EQI 1S	ASPT EQI 3S	ASPT EQI 1S
Autumn												
Bow Brook	1.184	1.179	1.154	1.152	1.030	1.019	18.23	17.96	13.18	13.15	6.34	6.17
River Thames	1.058	1.056	1.051	1.052	1.003	1.003	20.26	20.28	18.01	18.10	3.40	3.40
River Coln	1.573	1.651	1.422	1.457	1.111	1.141	12.50	11.01	8.26	7.55	4.69	3.14
The Cut	0.755	0.773	0.904	0.914	0.840	0.853	17.45	15.32	13.45	12.10	4.64	3.63
Lydiard Stream	1.001	0.975	1.051	1.037	0.959	0.939	8.99	8.98	5.75	5.94	3.92	3.92
Halfacre Brook	0.383	0.385	0.442	0.444	0.860	0.874	19.65	20.51	14.66	15.55	8.34	8.53
Roundmoor ditch	0.484	0.481	0.613	0.612	0.785	0.785	18.66	19.05	15.90	15.90	3.83	3.83
Summerstown Ditch	0.377	0.378	0.522	0.524	0.719	0.719	19.51	19.14	14.37	13.93	6.06	6.06
Crendon Stream	0.232	0.234	0.355	0.362	0.640	0.627	56.95	57.64	46.15	46.40	8.69	8.69
Wheatley Ditch	0.294	0.282	0.389	0.381	0.753	0.745	7.96	5.38	10.56	9.83	6.00	5.31
Crawters Brook	0.212	0.217	0.367	0.370	0.575	0.585	23.79	23.39	12.68	11.91	11.17	11.56
Catherine Bourne	0.537	0.502	0.654	0.630	0.829	0.800	7.85	11.49	5.07	7.57	3.16	4.54
Spring												
Bow Brook	1.361	1.363	1.306	1.304	1.039	1.050	7.61	7.57	6.30	6.58	3.80	3.90
River Thames	1.052	1.051	1.099	1.097	0.958	0.958	22.81	22.50	17.70	17.50	4.85	4.85
River Coln	1.723	1.717	1.507	1.507	1.146	1.146	8.96	8.76	7.99	7.77	3.16	3.16
The Cut	0.464	0.446	0.624	0.611	0.738	0.727	21.30	20.23	13.29	13.01	8.29	7.99
Lydiard Stream	1.175	1.158	1.235	1.228	0.952	0.942	5.96	6.56	6.29	6.28	0.81	1.63
Halfacre Brook	0.605	0.602	0.639	0.636	0.952	0.952	18.43	18.27	9.68	9.92	10.17	10.17
Roundmoor ditch	0.341	0.342	0.433	0.434	0.784	0.784	15.75	15.47	10.76	10.49	5.31	5.31
Summerstown Ditch	0.294	0.296	0.438	0.436	0.675	0.675	15.93	16.29	10.94	11.34	5.62	5.62
Crendon Stream	0.178	0.172	0.293	0.293	0.601	0.581	25.97	25.44	21.88	22.42	5.71	5.33
Wheatley Ditch	0.249	0.245	0.365	0.363	0.683	0.669	25.59	25.75	16.07	16.13	13.98	13.98
Crawters Brook	0.163	0.164	0.302	0.302	0.541	0.541	22.65	22.38	15.26	15.32	10.03	10.03
Catherine Bourne	0.504	0.497	0.637	0.628	0.798	0.790	13.64	14.50	9.56	10.53	5.52	4.67
Autumn average	0.674	0.676	0.744	0.745	0.842	0.841	19.32	19.18	14.84	14.83	5.85	5.73
Spring average	0.676	0.671	0.740	0.737	0.822	0.818	17.05	16.98	12.14	12.27	6.44	6.39
Both seasons average	0.675	0.673	0.742	0.741	0.832	0.829	18.18	18.08	13.49	13.55	6.15	6.06

3S = EQIs calculated using three seasons of environmental data
1S = EQIs calculated using one season of environmental data

2.5 Summary of statistical methods

2.5.1 Statistical methods used

The main statistical descriptors and techniques used in this report are standard deviation, coefficient of variation, regression analysis and analysis of variance (ANOVA). A brief summary of these techniques is given in Box 2.1. Other statistical techniques, such as nonparametric analyses and tests within ANOVAs are described in the relevant sections. Most statistical techniques require that the data being analysed meet certain assumptions. These assumptions are discussed below.

2.5.2 Statistical background and assumptions made in analysis.

Ordinal data

All the indices used in the analyses in this report are effectively measured on ordinal scales. TAXA as a measure of numbers of taxa, is of course on a ratio scale, but TAXA as a measure habitat quality, water quality or ecological quality, is ordinal in nature. Parametric statistical summarisation and tests require data on interval or ratio scales in order that all assumptions as to their validity are met. Nonparametric statistical tests do not require data to be on interval or ratio scales but the conclusions which can be drawn from such tests is limited. For example, it is possible to correlate variable X with variable Y using either parametric or nonparametric tests, but calculating a regression equation in order to be able to calculate a hitherto unknown value of y from a known value of x is an essentially parametric procedure.

In many cases in this study it was necessary to produce regression equations which explained Y in terms of X and a parametric approach was therefore unavoidable. In many of these cases, though a parametric approach was necessary to quantify a relationship between two variables, it was nevertheless possible to test the underlying correlation of the two variables both parametrically and nonparametrically, and this has been done.

ANOVA is one of the more robust of the statistical tests with respect to assumptions of scales. Nevertheless, where parametric analysis was not necessary nonparametric ANOVAs have been performed. Nonparametric ANOVAs have also been performed to back up the results of some parametric ANOVAs. However, where nested factorial ANOVA was required, or where the results of an ANOVA needed to be related to a nested factorial ANOVA, no nonparametric ANOVAs were performed as no satisfactory techniques for nonparametric nested factorial ANOVAs exist.

Much of the need to use parametric techniques with ordinal data in this study arose from the need to assess variability in relation to the EQI bands of the 5M system. These EQI bands were derived from consideration of the variability of EQIs in standard parametric terms. The use of parametric statistics in this study, therefore, corresponds with the statistics used in the development of the 5M system.

Outlying values

Occasionally in data sets, one or more values do not conform to the pattern of other data. These outlying values can affect statistical assessments of trends in the data, either making trends appear to be more, or less, significant. There are two basic responses to the presence of such data points. Firstly, to argue that if a response is made more or less significant, then that is a genuine result and that the reason that the value *appears* to be an outlier is that not enough data were collected in order for more of such points to be seen. The second response is to argue that the value is so unusual that it should be rejected from the data set.

In this analysis, the former approach is taken, for two reasons. Firstly, the whole study is concerned as much with variation as it is with trends and averages. Secondly, in those cases where unusual results were obtained, there is no indication that this not a natural (albeit infrequent) part of sampling variability. This is illustrated in Table 2.6 using the results of the Crendon Stream autumn samples and discussed briefly below.

Samples from the Crendon Stream in autumn were all very similar in composition. However, one sample, RA2A, although apparently not all that exceptional, was the most outlying value in the study in terms of the amount by which it increased the relative standard deviation for that site. The sample had (for that site) a relatively high score due to an increase in the total numbers of taxa recorded. This increase in taxa was paralleled by a general increase in numbers of specimens recorded. The disparity in BMWP score between this and the other samples was largely due to one water measurer (Hydrometridae), one Dwarf Pond Snail (Lymnaeidae), two cranefly larvae (Tipulidae) and two small water beetles (*Anacaena limbata*: Hydrophilidae). The sample was not particularly surprising, and as such, a similar result might well be expected at other times.

Table 2.5 **An example of the raw data which give rise to 'anomalous' results in the data set**

	CREN JB1A Number of individuals	CREN JB2A Number of individuals	CREN RA1A Number of individuals	CREN RA2A Number of individuals
Oligochaeta	6	12	61	52
Hydrobiidae	-	1	-	1
Lymnaeidae	-	-	-	1
Glossiphoniidae	-	1	-	1
Erpobdellidae	3	-	1	1
Asellidae	2	-	5	5
Gammaridae	31	62	44	86
Hydrometridae	-	-	-	1
Hydrophilidae	-	-	-	2
Tipulidae	-	-	-	2
Chironomidae	5	1	4	17
BMWP score	**15**	**15**	**15**	**39**
Number of specimens recorded	**47**	**77**	**115**	**159**

Normality of data

Statistical inference in many tests is based on the assumption that the data are normally distributed. In practice, tests such as regression analysis and the analysis of variance are quite robust with respect to data which depart from normality. In order to compare two populations of data, most statistical tests assume that the means of both populations are normally distributed. In the data set from this study the number of data points in each population is small (i.e. in one season there are only 4 data points for any site). Tests do exist to assess the normality of such small populations (and the likely normality of their means), but they are very sensitive, and most of the populations from the sites would be rejected using such tests.

For these reasons, no formal tests of the normality of data were made during this study. Where values appear to differ appreciably from normality, this is highlighted, and caution is used with respect to any statistical inference. As mentioned previously, where possible, nonparametric tests (which do not rely on normally distributed data) have been used. These are described in the relevant sections.

Homogeneity of variance

In order to compare two populations, most statistical tests require that the variances of the means are approximately equivalent. Once again, tests such as analysis of variance are fairly robust with respect to this requirement. Formal tests of homogeneity of variance have been performed on the core analyses of variance. In most cases, however, these tests show that the variances are not normal. Where homogeneity of variance is likely to be a problem, particularly where variance is likely to vary with the mean (see below), logarithmic transformations of the data have been used. In some cases these transformations appear to increase homogeneity, but in other cases the effect is the reverse. Many conclusions drawn in this study are, therefore, only made after the analyses of both the raw data and log transformed data have been considered.

Variation of variance with the mean.

Certain statistical tests are adversely affected if the variance of a population changes systematically in proportion to its mean (e.g. if samples with a longer taxa list have a greater variance than samples with a shorter list). This is a particular case of non-homogeneity of variance. In the current study, the variance of the biotic indices often *did* vary in proportion to their means. However, understanding the extent to which this occurred was, in fact, one of the main aims of the study. Once again, where necessary, data (e.g. the biotic indices) or derived data (e.g. the standard deviations of the indices) have been log transformed and the results of both types of analyses have been considered when inference is drawn.

The ability to transform the data to equal variance in this study is constrained to a large extent by a single data point (i.e. one autumn sample from the Crendon stream). All biotic indices from this site have a low mean and a high variance. During log transformations of the data the variance of the indices from sites with high means tends to be reduced, but the variance of the indices from the autumn Crendon Stream sample tends to be significantly increased in relation to other samples with low means. So amelioration of one problem exacerbates another.

Box 2.1 Statistical terminology used in this report

Standard deviation and coefficient of variation

The standard deviation of a set of data is a measure of the variability of the data about its mean. In this report where:(i) the variability of the data often changes with the mean and (ii) it is necessary to compare indices which have different absolute values, and therefore would be expected to have different standard deviations, it is useful to consider a second attribute, the coefficient of variation (CV). The CV is the ratio of the standard deviation (SD) to the mean and is perhaps more easily understood as relative standard deviation. In this report it is always quoted as a percentage (i.e. CV =100 x SD/mean).

Analysis of variance

Analysis of variance measures how different factors affect the total variation in a data set. By analysing this, the significance of differences between populations within those factors can be assessed. Four basic terms are used to describe analyses of variance (ANOVAs) in this report.

Ways/factors. ANOVAs are described as one, two etc. way ANOVAs. A one way ANOVA is an ANOVA where there is only one independent variable (factor). e.g. site. A two way ANOVA is an ANOVA where there are two independent factors (e.g. site and season).

Levels. ANOVAs are described as being two, three etc. level ANOVAs. A two level, one way ANOVA is one in which there is a single independent variable which has two populations (levels). Most of the one way ANOVAs in this report are twelve level ANOVAs, the 12 levels being the 12 different sites. The convention for expressing levels and ways is in the form 12 x 2 ANOVA. i.e. a two-way ANOVA (with 2 independent variables), one with 12 levels and one with two levels.

Nested. In some of the ANOVAs used in the analysis, independent variables (particularly sample and sampler) are included as 'nested' terms. Some factors are independent variables which may have a significant relationship worth analysing e.g. for a factor such as season, the difference between site results in different seasons would be analysable. In contrast the person who sampled any site was chosen randomly in the initial study set-up. Because this factor (sampler) is random, we do not wish to test the difference between sampler 1 and sampler 2 during the analysis as we might with a fixed factor such as season. As the relationship between sample and site is approximately random , we 'nest' sampler within site and therefore to assess the amount of variability caused by randomly varying the sampler, rather than using the same sampler all the time.

There would be two ways to treat many of the ANOVAs in this report, either as nested ANOVAs, in which sampler is included as a term, or a non-nested ANOVAs in which sampler is left out and all 4 samples from each site are considered to be random. Using sampler as a nested term improves the ability of an ANOVA to detect true differences between the levels of the factors involved (site and season). However, nesting in this way is not possible when combined samples are being considered and so, in order to compare single season ANOVAs with combined sample ANOVAs, the single season ANOVAs need to be performed without nesting, as this would alter the test statistics produced.

Interactions. In an ANOVA, the difference between the levels of a factor can be assessed. If there is more than one factor however, there is more variation in the data set than just that described by random error and the variation due to the differences in levels of the factors. This extra variation is termed an interaction. For example, it is possible that in our data set, that sites would not systematically differ between seasons. Individual sites might, however, differ between seasons (e.g. some might be higher in spring and some in autumn). These effects would cancel each other out in terms of a systematic difference, but this variation is termed an interaction and is usually written X x Y (e.g. site x season).

(continued over page)

Box 2.1. Statistical terminology used in this report (continued)

Repeated measures. In some situations we need to compare how a set of subjects is affected by a series of different treatments. If the subjects differ in some way at the beginning of treatments it would be reasonable to think that these original differences might be preserved during the course of treatment. For this reason, if we wish to assess the treatment, we should make allowances for the fact that the subjects differed at the beginning. This is done using a repeated measures design where each subject (e.g. site) is compared over a range of treatments (e.g. the calculation of CVs for that site). The repeated measures design enables us to allow for the fact that the CV of indices, in general, might be higher at some sites than others, and hence increases our ability to comment on the performance of indices, rather than the inherent differences between sites.

F values
The F value of an effect (e.g. the difference between sites) measures the magnitude of that effect (e.g. a high F for site would indicate that sites differ significantly). The F value can be used with the degrees of freedom of the analysis to calculate the statistical significance of the effect. In many of the comparisons made using ANOVAs in this report, the degrees of freedom are identical and the F values can be used as a comparison without translation into statistical significance (e.g. $p<0.005$). This method is used here for simplicity, and also because many of the significances found are extremely high and would be cumbersome to deal with (e.g. $p< 5\times10^{-7}$).

Regression analysis
Regression analysis is used in Section 5 to help assess the factors affecting the variability of RIVPACS predictions and in Section 6 to describe variation in standard deviations of EQIs. In addition to regression equations from these analyses the adjusted coefficient of determination (adjusted R^2 value - R^2adj) is also quoted. The adjusted coefficient of determination represents a conservative estimate of the amount of variation explained by the regression equation and is quoted here as a percentage. In the regression analyses in this report the adjustment serves to eliminate differences between the analyses caused solely by both differing numbers of samples and (in the case of the regressions in Section 5) the number of variables in the analysis.

3. The water quality at the 12 sites

3.1 Introduction

Taxa lists for all samples are given in Appendix 3.1. Values for BMWP system indices (TAXA, BMWP, ASPT, Pred. TAXA, Pred. BMWP, Pred. ASPT, TAXA. EQI, BMWP.EQI and ASPT.EQI.) were calculated for all sites and all samples. The results, which are the raw data for the rest of the report, are shown in Appendix table 3.2 (single-season data), Appendix table 3.3 (combined-season data) and Appendix table 3.4 (dual sample data), and described briefly below. RIVPACS environmental data (width, depth and substrate measured as phi) for all sites are given in Appendix table 3.5.

Results for actual and predicted TAXA, BMWP and ASPT, are summarised graphically in Figures 3.1 to 3.9.

3.2 TAXA, BMWP and ASPT values at the 12 sites

3.2.1 Single season samples (see Appendix table 3.2)

The number of taxa (TAXA) recorded in a single season varied from 4 in a Crendon Stream sample, to 34, recorded in several samples from the rivers Coln and Thames. The number of taxa recorded at each site in single-season samples in autumn and spring is shown in Figure 3.1.

Single season BMWP scores ranged from 12 in the Crendon Stream and Crawters Brook to 188 in the River Coln (see Figure 3.2). ASPTs (single-season) varied from 2.40 to 5.88 in the Crawters Brook and the River Coln, respectively (see Figure 3.3)[1]..

3.2.2 Combined sample biotic indices (see Appendix table 3.3)

Two 'combined' samples for each site were generated by merging a randomly selected spring sample with a randomly selected autumn sample to produce a cumulative list.

In combined-season samples numbers of taxa (TAXA) varied from 5 to 41. BMWP scores ranged from 15 to 234 and ASPTs ranged from 2.57 to 5.78 (see Figures 3.4, 3.5 and 3.6).

3.2.3 Dual sample biotic indices (see Appendix table 3.4)

Dual samples were created by combining the taxa lists of the two samples collected at each site by each person to produce a cumulative sample. The practical purpose of this analysis was to determine whether it was better to make water quality assessments using two samples collected in the same season or two samples collected in different seasons.

Numbers of taxa recorded in dual samples varied from 6 to 39. BMWP scores varied from 20 to 219. ASPTs varied from 2.63 to 5.76.

3.2.4 Comparison of single, combined and dual season samples

The average combined-season TAXA and BMWP for all samples were 22.7% and 27.2% higher, respectively, than the TAXA and BMWP for all single-season samples. ASPT was 4.5% higher in combined samples compared to single-season samples.

Dual season samples (where two samples collected on the same day by the same person were combined to give a cumulative sample) gave slightly lower TAXA (by 4.3%) and BMWP scores (by 5.2%) than combined-season samples. ASPT was also slightly lower in dual samples (by 1.0%) compared to combined-season samples.

3.2.5 Effectiveness of RIVPACS predictions

In general, the results highlight the fact that, as has been noted by the Institute of Freshwater Ecology (IFE), TAXA and BMWP are often underpredicted by RIVPACS at higher quality sites. ASPT is better predicted at high quality sites, perhaps due to the greater number of taxa on which this average is based, although on the River Coln an apparent under-prediction did occur.

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[1] It is normal to quote ASPT values to one decimal place when reporting the results of field surveys, because a greater number of decimal places suggests a degree of precision which does not exist. However, in this report, it is this precision which is being considered, and so ASPT values are quoted to two or three decimal places. This also avoids problems when quoting standard deviations of ASPT which, if quoted to one decimal place, would often be zero.

The combined and dual season data also supported the view that RIVPACS predictions are most reliable for ASPT although, as with single-season data, the predicted ASPTs on the River Coln are markedly below the observed values (see Figures 3.6 and 3.9).

Underprediction by RIVPACS of TAXA and BMWP scores has five possible causes:

(i) The RIVPACS database is composed of samples in which less sampling effort was expended than is normally put into sampling by river biologists routinely undertaking water quality monitoring (including those following RIVPACS methods);

(ii) The multivariate techniques used by RIVPACS to make predictions are less able to predict numbers of taxa than community composition (Clarke *et al.* 1994);

(iii) RIVPACS classes often contain sites from both the south and north of England and the former are often more species rich than the latter (J Murray-Bligh pers. comm.).

(iv) Not all sites included in the original RIVPACS database, with the community type(s) of sites in this study, were in 'pristine' condition;

(v) The sites included in the RIVPACS database *were* in pristine condition, but rivers in this study (such as the Coln) were slightly enriched and so had unusually long taxa lists.

It should be noted that these possible sources of error in TAXA and BMWP predictions cannot be distinguished.

3.3 Effect of sample combination on 5M banding

3.3.1 The difference between single- and combined/dual- season banding

Combined and dual samples were generally placed in lower 5M bands than single-season samples, whether from spring or autumn (see Appendix table 3.6). This was most noticeable in the sites with lower water quality with seven samples classed as band D with combined- and dual-sample data, compared with only 2 spring samples and no autumn samples.

It will be argued later that this may be partially explained by the use of equal band widths for all four bands, rather than making lower quality bands narrow to reflect the lower variability of poor quality sites. We understand that this problem is currently being addressed by IFE in RIVPACS II development work.

3.3.2 Results of this study compared with EA Thames Region banding of sites in 1992

In general, samples from this study were placed in higher 5M bands than samples collected in 1992 by EA staff. Overall, three sites moved clearly into higher bands, and one site moved into a lower band. Specifically, the following changes occurred between 1992 EA data and the *combined* data of this study:

(i) Band A: all sites banded A by EA remained band A;

(ii) Band B: one site (Lydiard Stream) moved up to band A in this study;

(iii) Band C: one site (Roundmoor Ditch) moved up to band B and one site (Crendon Stream) moved down to band D;

(iv) Band D: one site (Wheatley Ditch) moved up to band C and one site moved up to band B (Catherine Bourne).

The largest change was seen in the Catherine Bourne which moved from band D to B. The single sample data showed similar trends, with the exception of the two D band streams which moved up two bands (to band B), instead of one (to band C).

The results could be due to a number of different factors, which are not mutually exclusive:

(i) the samplers in this study were achieving higher values for BMWP, TAXA and ASPT than was typical for EA Thames Region staff;

(ii) there were real changes in water quality;

(iii) the changes were no more than would be expected by chance.

It should be noted that (i) grade D sites cannot decrease in water quality, so the comparison of numbers of sites increasing and decreasing in water quality in this study was biased in favour of sites apparently increasing in quality; and (ii) it was quite evident that the samples from the Catherine Bourne had changed significantly in community type from those taken in 1992. A period of low flows would probably account for the low results in 1992.

3.4 Conclusions

The study encompassed sites of a wide range of water qualities with BMWP scores up to 234 in a combined-season sample. Numbers of taxa (TAXA) were 22.7% higher in combined samples compared to single season samples. BMWP scores and ASPTs were 27.2% and 4.5% higher in combined-season samples, respectively.

There was clear evidence that TAXA and BMWP scores at high quality sites were underpredicted by RIVPACS. Predictions of ASPT were closer to observed values. Both trends have been noted by the Institute of Freshwater Ecology in RIVPACS II development work.

Combined-season samples generally placed sites and samples in lower 5M bands than did single-season samples.

The greatest movement in site banding between EA 1992 data and this study was from band D to band B.

There was no way of telling from the results of this study whether changes in the banding of sites were due to changes in water quality or differences in the way samples were collected in this study compared to EA Thames Region staff.

Figure 3.1 **Water quality indices for the 12 sites in this study: TAXA, autumn and spring single samples, and single season RIVPACS predictions**

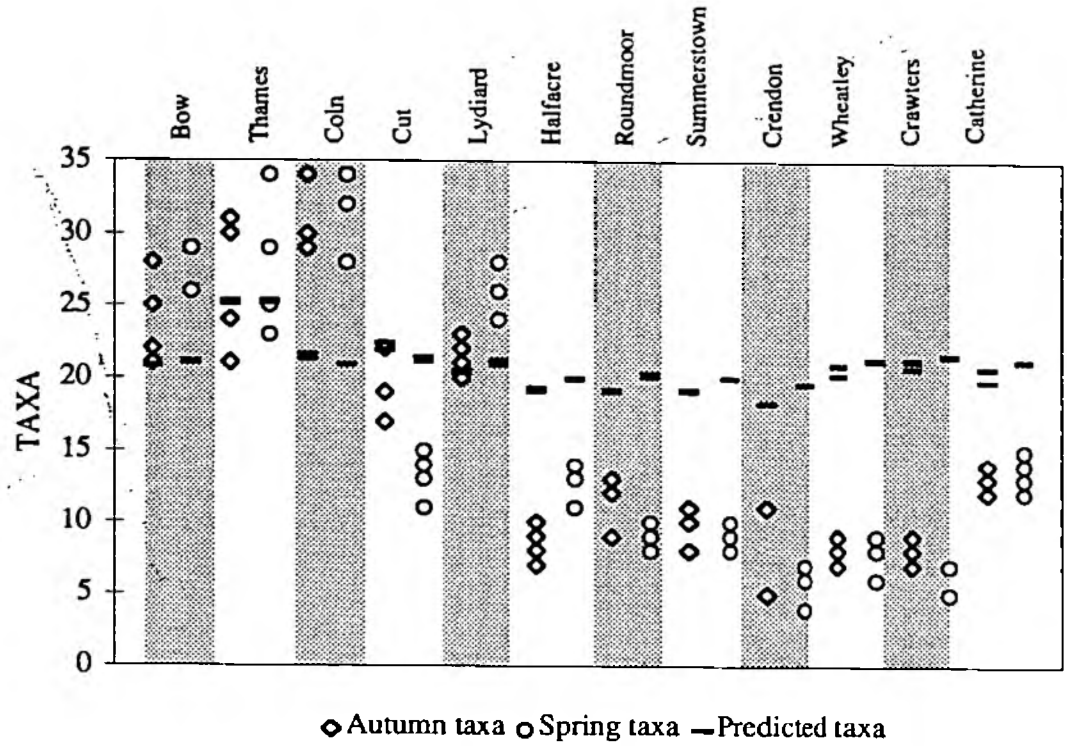


Figure 3.2 **Water quality indices for the 12 sites in this study: BMWP, autumn and spring single samples, and single season RIVPACS predictions**

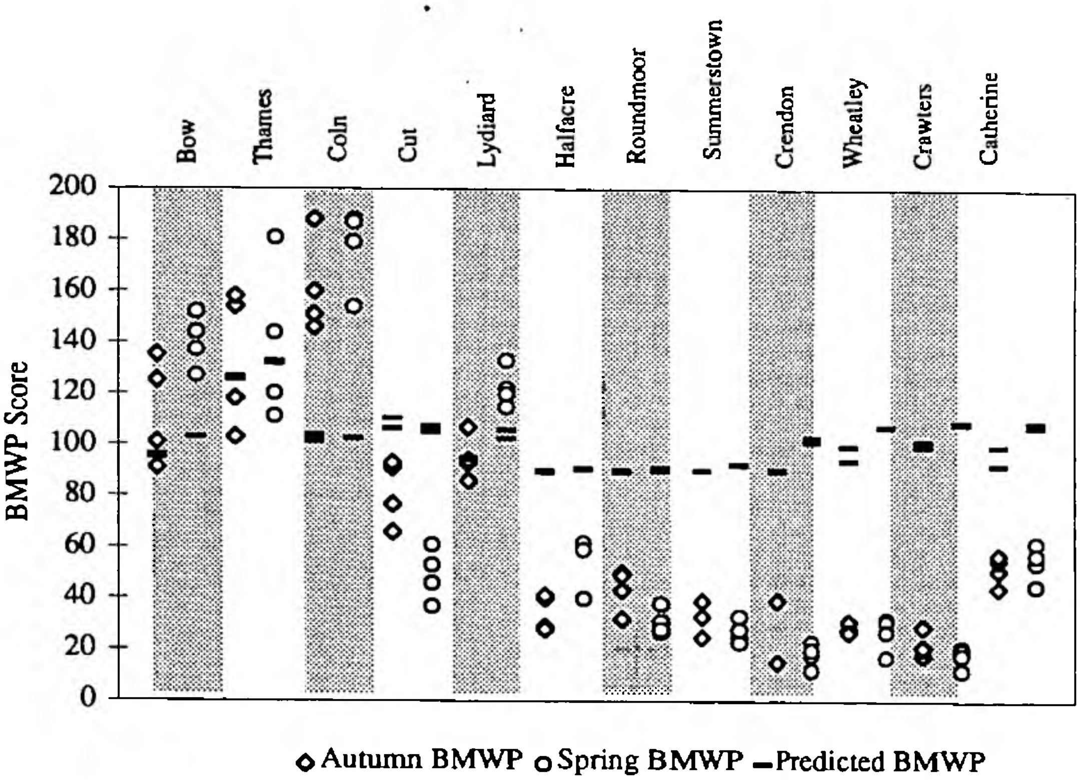


Figure 3.3 **Water quality indices for the 12 sites in this study: ASPT, autumn and spring single samples, and single season RIVPACS predictions**

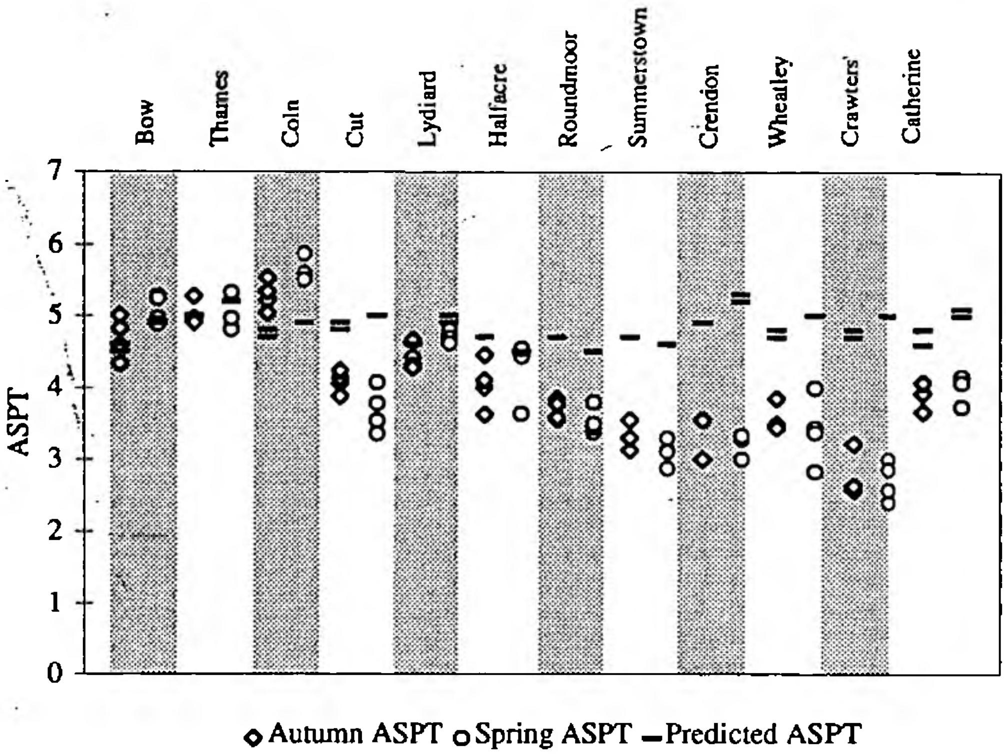


Figure 3.4 **Water quality indices for the 12 sites in this study: TAXA, autumn and spring samples combined, and combined season RIVPACS predictions**

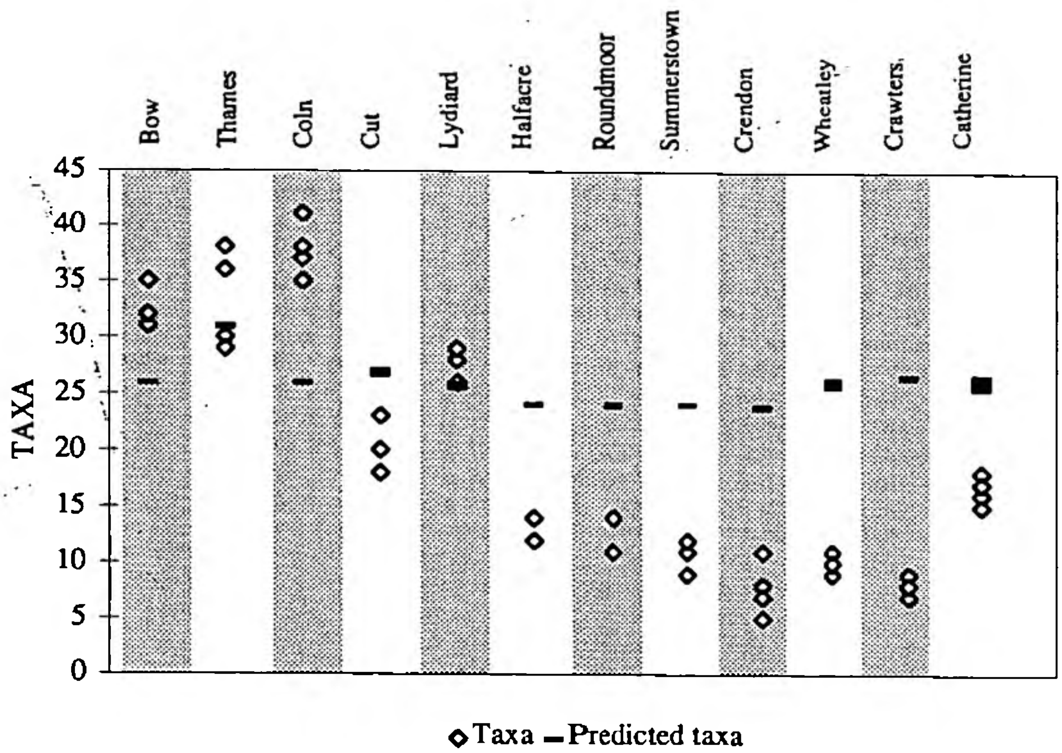


Figure 3.5 **Water quality indices for the 12 sites in this study: BMWP, autumn and spring samples combined, and combined season RIVPACS predictions**

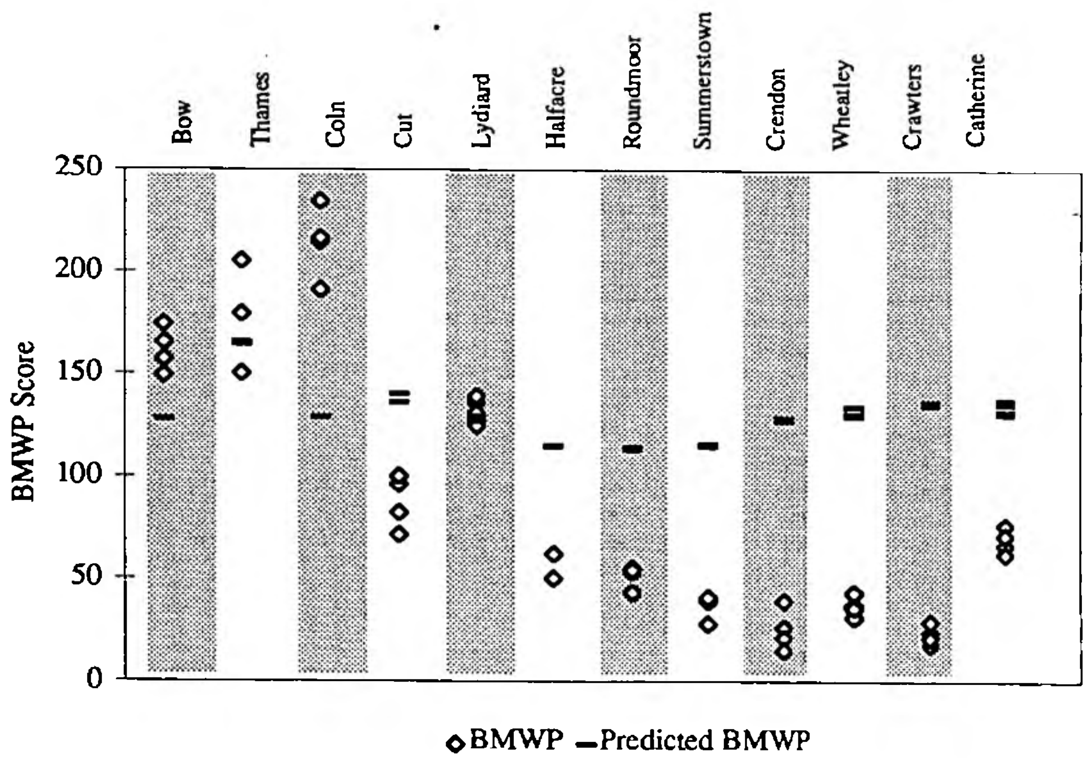


Figure 3.6 **Water quality indices for the 12 sites in this study: ASPT, autumn and spring samples combined, and combined season RIVPACS predictions**

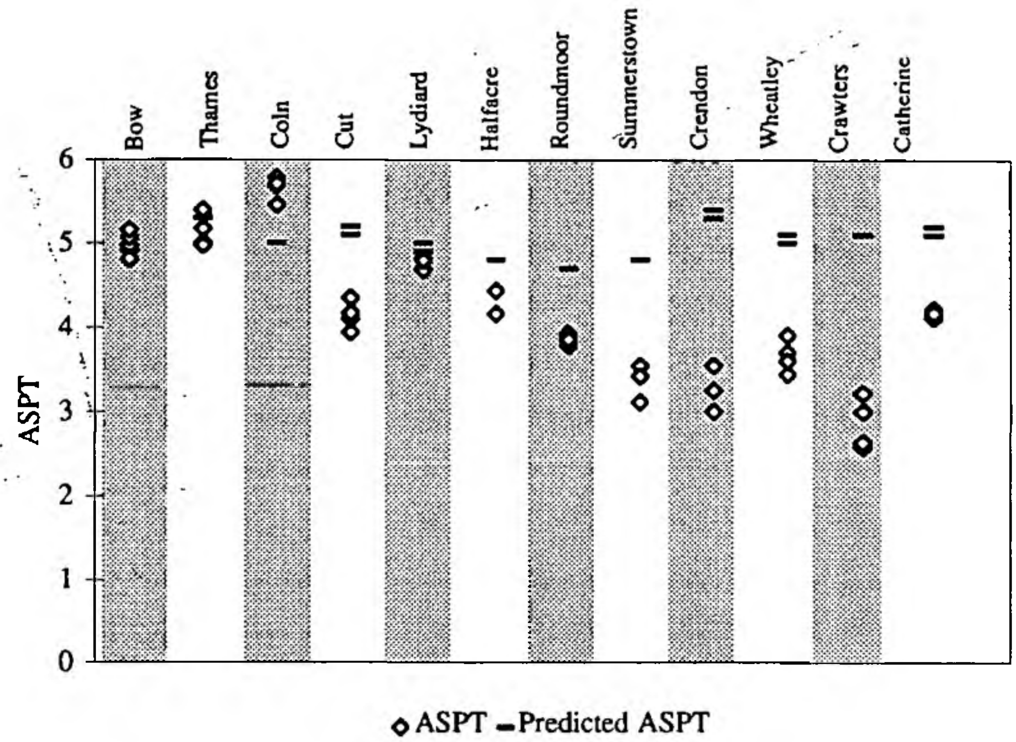


Figure 3.7 **Water quality indices for the 12 sites in this study: TAXA, autumn and spring dual samples, and RIVPACS predictions.**

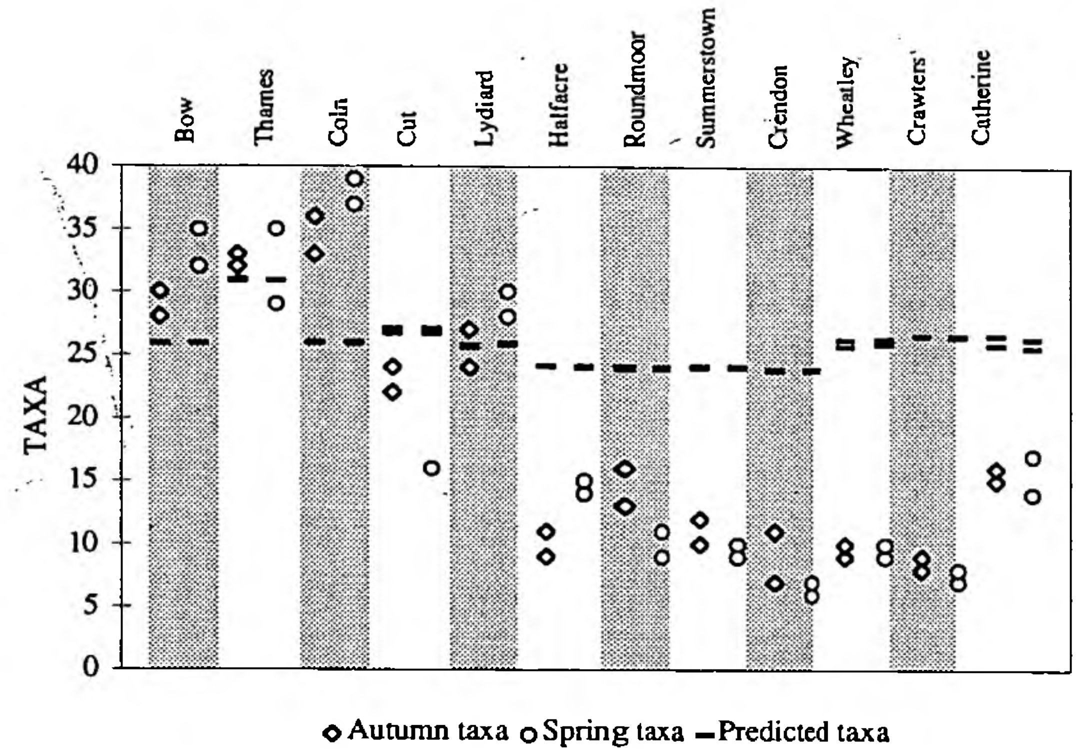


Figure 3.8 **Water quality indices for the 12 sites in this study: BMWP, autumn and spring dual samples, and RIVPACS predictions.**

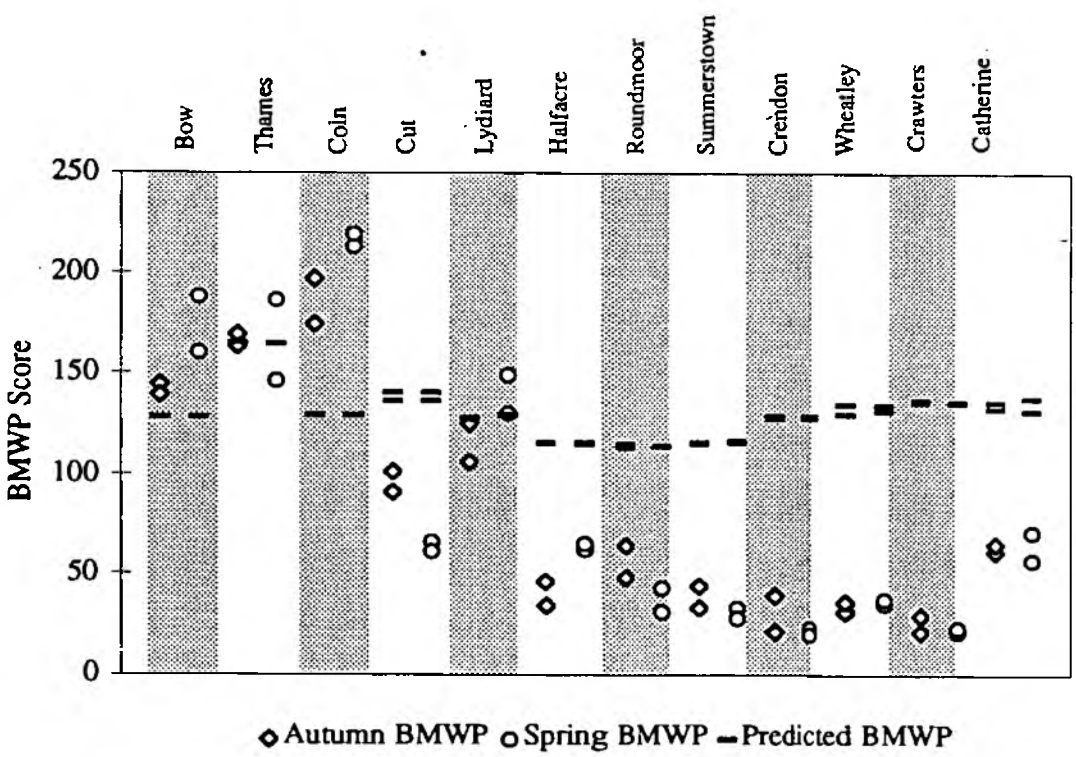
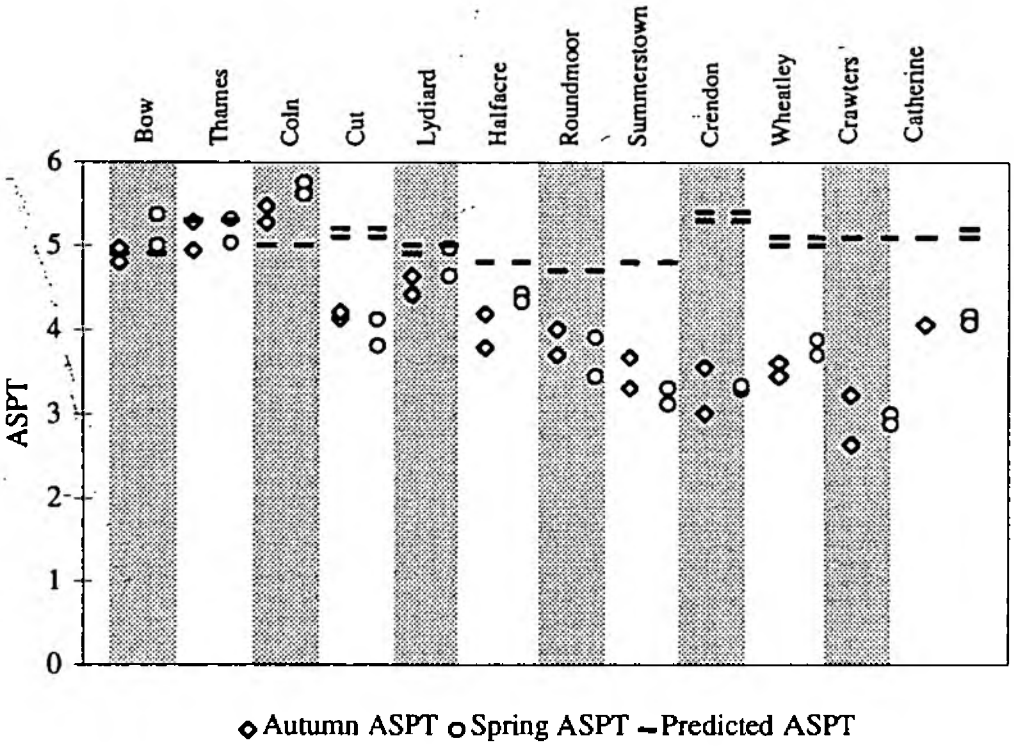


Figure 3.9 **Water quality indices for the 12 sites in this study: ASPT, autumn and spring dual samples, and RIVPACS predictions.**



4. Sampler biases and variability: effects on biotic indices and RIVPACS field measurements

4.1 Introduction

This section describes the variability introduced by differences in the way individuals collect samples. The following aspects of variability are considered:

(i) differences between samples collected by the same person (in terms of TAXA, BMWP, and ASPT);

(ii) differences between samplers (in terms of all biotic indices and measurement of RIVPACS field data);

(iii) the variability of different people (in term of all biotic indices).

These differences fall into two categories, bias and variation, and these are discussed below. The overall importance of sampler variability in assessing biotic scores, compared to differences between seasons and sites, is described in Chapter 7.

4.2 Methods

4.2.1 The difference between bias and variation

The individual collecting a sample may affect the results of surveys in two ways: (i) by introducing bias; and (ii) by introducing variability. Note that although bias is described separately (and has a specific technical interpretation), its effect is to increase the *total variability* seen in the study.

4.2.2 Bias

Bias between samples collected by the same person (within-person bias)

Bias between samples occurs when a particular person systematically records more or fewer invertebrates in a second sample. In this study a duplicate sample was taken by each person at each site. The collection of two samples in this way was necessary to investigate whether using different samplers had an effect on variability. This could only be done by comparing differences between samplers with the internal variability within sampler. Collection of two samples also allowed the 'dual sample' option (a cumulative sample composed of two samples collected on the same day) to be compared with the combined season option during the study. Currently the EA does not usually take more than one sample on any one occasion and, because of this, including within- sampler bias in the study increased the variability seen here above that seen in normal operational practice by the EA.

The magnitude of within-person bias can only be assessed with samples collected at the same site, on the same day, and by the same person. This eliminates variation due to abiotic factors (such as changes in weather conditions, time of day, pollution events) which could otherwise change within or between sites.

Sample bias in this study is the ratio of the biotic index of the second invertebrate sample taken by each person (Sample 2) to the biotic index of the fist sample (Sample 1).

$$\text{Bias between samples} = \frac{\text{Sample 2 biotic index}}{\text{Sample 1 biotic index}}$$

Bias between different people

Bias between people occurs when one person systematically collects samples containing more or fewer invertebrates (or different types of invertebrate) than another person. This kind of bias would be expected to occur during routine invertebrate surveys, to a greater or lesser extent. Understanding how large this effect can be is of particular interest.

In this study, bias between people (for any given biotic index) was the ratio of the average biotic index value achieved by one person to the average index value achieved by both people who sampled together at a site in any season, i.e.

$$\text{Person bias (for Person 1)} = \frac{\text{Person 1 mean biotic index}}{\text{Person 1 and 2 mean biotic index}}$$

Note that the bias for Person 2 will be the reciprocal of the bias for Person 1, and so the average bias seen for both people will be 1.

4.2.3 Variability

Variability indicates how widely dispersed around the mean a sampler's results are. A systematic difference in variability between samplers might be expected during normal EA practice. During this study samplers were randomised so that any differences in sampler variability were controlled. However, the EA does not currently randomise its sampling programme, so differences in variability between samplers are potentially important.

The value used to describe variability in this study is the ratio of the standard deviation of the mean of Person 1 observations, compared to that of both people at any site in a given season.

$$\text{Personnel variability} = \frac{\text{standard deviation of mean index, Person 1}}{\text{standard deviation of mean index, Person 1 and 2}}$$

The analysis takes account of the fact that some sites may be more prone to variation than others, so comparisons need to be made site-by-site, rather than over the whole set of samples collected by each person. Unlike the comparison of sample bias and between person bias, where the ratio of one sample to another should (ideally) be 1, there is no absolute value expected for the personnel variability (this is due to the method of calculation of standard deviation).

4.2.4 Biotic indices investigated for the effect of bias and variation

Bias and variation were assessed for TAXA, BMWP, and ASPT. Bias and variation were not assessed for EQIs. This was because the predicted TAXA, BMWP and ASPT scores for each person at a site were based on a single set of RIVPACS environmental data and, therefore, had no variation. Since the RIVPACS data and the predicted values for Sample 1 and Sample 2 of each person have no variation, between sample bias and variation in EQIs is due entirely to the bias and variability of the observed TAXA, BMWP and ASPT.

4.3 Bias between samples taken by the same person

This section describes the degree to which biotic indices differed for two invertebrate samples collected by the same person, at the same site, on the same day. A Student t-test and a one-sample nonparametric test (run as a Wilcoxon ranked pairs test against a dummy population all with value one) were used to assess whether there were any significant biases (deviations from 1). The test results are shown in rows 5 and 6 of the tables in Table 4.1. The occurrence of any significant differences over all four samplers and all samples considered together ('All Samplers' in the Table 4.1) was tested using standard ANOVA and the nonparametric Kruskal-Wallis ANOVA. The significance of these tests is given in the first cell of rows 7 and 8 in the tables in Table 4.1. An estimate of which, if any, samplers differed significantly from the others was made within the standard ANOVA using a Scheffé test, shown in row 7 of the tables (where significant differences occur).

Scheffé tests assess the differences between means within ANOVAs (e.g. sample bias means in this case). The test compensates for the fact that several comparisons are being made simultaneously, which might, otherwise, randomly produce some significant results. The Scheffé test is generally considered to be conservative, i.e. it errs on the side of caution. No tests were performed within the Kruskal-Wallis ANOVA by ranks.

4.3.1 The effect of between sample bias on number of taxa (TAXA) recorded and BMWP score

Three survey personnel (Jeremy Biggs (JB), Dave Walker (DW) and Mericia Whitfield (MW)) had relatively little bias between samples. Second samples were, on average, between 1% lower (bias =0.99) and 8% higher (bias = 1.08) than first samples. However, all Richard Ashby-Crane's (RAC) second samples had TAXA and BMWP scores higher than or equal to the first sample ($p<0.0209$ and $p<0.0281$, in a Student t test respectively). On average, 34% more taxa and a 44% higher BMWP score were recorded in his second sample compared to the first (see Table 4.1).

The results for RAC are, to some extent, influenced by a 'rogue' sample from the Crendon Stream (taxa from RAC's two samples from this site are listed in Table 2.3). Nevertheless, even, analysing the results using the non-parametric Wilcoxon test (which uses ranked data and will not be as affected by this extreme value) gives $p<0.0117$ for TAXA and $p<0.0077$ for BMWP.

None of the other three samplers showed a statistically significant bias between the BMWP scores of the first and second samples. However, there was a non-significant tendency for second samples to be higher than first samples (see Table 4.1).

When the results from all individuals' first and second samples were combined, there was a significant bias for a greater number of taxa and a higher BMWP in the second sample. If RAC's results are removed from the analysis, however, the Student's t-test is not significant for either parameter.

4.3.2 The effect of between sample bias on ASPT

No *individual* sampler showed a statistically significant bias in ASPT. However, for *all samplers combined* there was a consistent and statistically significant trend (averaging 4%) to record higher ASPT values in the second sample ($p<0.0124$ in a Student t test).

4.3.3 Discussion

The overall bias between first and second samples collected by the same person is a potential problem for the statistical analysis of the study. This type of systematic bias would not occur with the survey strategy currently used by the EA (single samples in one, two or three seasons), and so the variations seen in this study are probably greater than those normally seen in EA practice.

In theory, it would be possible to remove the between-sample bias from the data set before analysis. However, in the absence of a concrete theory as to why the bias occurred, this is difficult to justify.

If the bias were due to a 'learning' effect on site, then it would be legitimate to reduce the average second sample of RAC to the level of the first sample: this would, theoretically, remove the bias whilst retaining the normal variation associated with his sampling. However, further analysis showed that RAC's results were, on average, lower than his partner at any given site for the first sample and higher for the second sample. Reducing the second sample to the level of the first would, therefore, give the impression that RAC systematically recorded far fewer invertebrates than any other recorder, which was not the case.

That the bias is due to a low first sample and high second sample also calls into question whether the bias can simply be due to a 'learning' effect. It would be possible to equalise the average of the first and second samples to the average mean of the two samples. However, without knowing the precise cause of the bias it is difficult to justify doing this; and it *is* possible that any variation shown by RAC normally is in some way absorbed into this bias. For this reason it was decided not to alter the data in any way. Problems caused by between-sample bias are discussed in the relevant sections as they arise.

A similar study to the one presented here was conducted on the River Axe by Furse *et al.* (1981). These workers used three samplers who each took two samples at each of four sites on the river. Results of this study are given at family level and species level. Though no recording list is given, it is likely that the family level identification is similar to the BMWP family level data in this study (with a few more families included). Analysis of the results presented in the paper shows no evidence of the overall bias seen in this study. The three samplers had average biases of 0.89, 1.01 and 1.02 (overal bias = 0.98 ± 0.17), similar to the bias seen in this study if the results for RAC are omitted (1.01 ± 0.16).

Table 4.1 Bias between samples collected by the same person (within person bias)

Row	TAXA	All samplers	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
(1)	TAXA: mean for all samples	15.75	17.83	16.32	12.65	16.56
	Upper confidence limit	1.12	1.13	1.11	1.07	1.57
(2)	**Taxa mean bias**	**1.08**	**1.05**	**1.01**	**0.99**	**1.34**
	Lower confidence limit	1.03	0.97	0.90	0.91	1.10
(3)	Average TAXA for Sample 2	16.32	18.27	16.38	12.60	18.95
(4)	Average TAXA for Sample 1	15.18	17.40	16.26	12.71	14.16
(5)	One sample Student t-test	p<.0363	ns	ns	ns	p<.0209
(6)	One-sample Wilcoxon test	p<.0345	ns	ns	ns	p<.0117
(7)	ANOVA/Scheffé Test	p<.0019	RAC>DW,JB&MW			
(8)	Kruskal-Wallis test	p<0.0107				

Row	BMWP	All samplers	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
(1)	BMWP: means for all samples	69.89	80.04	75.11	51.35	75.00
	Upper confidence limit	1.20	1.19	1.25	1.17	1.77
(2)	**BMWP mean bias**	**1.13**	**1.08**	**1.07**	**1.03**	**1.44**
	Lower confidence limit	1.06	0.97	0.89	0.90	1.12
(3)	Average BMWP for Sample 2	74.21	83.09	77.58	52.16	88.64
(4)	Average BMWP for Sample 1	65.57	77.00	72.64	50.53	61.36
(5)	One sample t-test	p<.0115	ns	ns	ns	p<.0281
(6)	One-sample Wilcoxon test	p<.0258	ns	ns	ns	p<0.0077
(7)	ANOVA/Scheffé Test	P<.0220	RAC>DW,JB&MW			
(8)	Kruskal-Wallis test	p<.0322				

Row	ASPT	All samplers	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
(1)	ASPT: means for all samples	4.01	4.10	4.11	3.76	4.11
	Upper confidence limit	1.06	1.06	1.12	1.09	1.13
(2)	**ASPT mean bias**	**1.04**	**1.02**	**1.04**	**1.03**	**1.06**
	Lower confidence limit	1.02	0.99	0.97	0.98	1.00
(3)	Average ASPT for Sample 2	4.09	4.15	4.19	3.82	4.24
(4)	Average ASPT for Sample 1	3.93	4.05	4.02	3.70	3.98
(5)	One sample t-test	p<.0124	ns	ns	ns	ns
(6)	One-sample Wilcoxon test	p<.0322	ns	ns	ns	ns
(7)	ANOVA/Scheffé Test	ns				
(8)	Kruskal-Wallis test	ns				

	All samplers	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
Number of sample pairs	48	12	14	13	9

Biases in the table are quoted as proportions and not in the units of the particular index. Ratios greater than one indicate a positive bias towards the second sample.

4.4 Bias between different samplers

4.4.1 Situations where between sampler bias occurs

This section describes the differences between individual samplers, and in particular whether at any site one person collected more or fewer invertebrates than another. The sampling design made it possible to assess bias between samplers in all the measurements made (i.e. biotic indices, including EQIs, *and* RIVPACS field measurements).

The effects of bias between samplers can be controlled by ensuring that sampling is done as part of a random survey design. In a randomly designed survey, each person sampling should have an equal chance of visiting any site; which sites are visited should be decided by randomly allocating each person to particular sites.

Much of the routine sampling programme of the EA appears not to fulfil this requirement. Individual staff members may have a set of sites for which they are responsible and will, in addition, work only within their own regions. Ideally, however, staff should be randomly allocated sites throughout England and Wales, or at least within a region. Clearly, since it would obviously be impractical to achieve this ideal, the practical alternative would be to gain a greater understanding of biases within the EA datasets and correct the results accordingly.

It should be noted that the occurrence of between-sampler bias does not affect the conclusions which can be drawn from the present study. This is because the sampling programme used random assignment of personnel to take account of the bias or variation associated with individuals.

The relative importance of differences between samplers (as a random term) compared to other sources of variation (e.g. site and season) is considered in Chapter 7.

4.4.2 Effects of between-sampler bias on TAXA, BMWP and ASPT (see Table 4.2a)

The results for TAXA, BMWP and ASPT were similar with Mericia Whitfield (MW) recording, on average, higher scores than her partner (i.e. the person with whom she visited any particular site), and Dave Walker (DW) and Jeremy Biggs (JB) recording, on average, lower scores than their partners. Richard Ashby-Crane's (RAC) results were, on average, similar to those of his partners. MW's values varied from about 2% above (for ASPT) to 7% above (for TAXA and BMWP) the mean for the site (see row 1 in the subsections of Table 4.2(a)). JB's and DW's values were between 2% below (for ASPT) and 4% below (for TAXA and BMWP) mean values for the site.

ANOVAs showed that MW recorded significantly higher TAXA and BMWP values than JB and higher ASPT values than DW and JB (see rows 5 and 6 in each subsection of Table 4.2(a)).

If this variation is described in terms of the hypothetical average sample for the study, the following ranges of values for TAXA, BMWP and ASPT would be seen between the four samplers (see row 2 in each subsection of Table 4.2a):

(i) TAXA: 15.1 to 16.6;

(ii) BMWP: 66.9 to 75.1;

(iii) ASPT: 3.93 to 4.09

This indicates the differences which might be seen between sites due solely to sampler. In a large area (a catchment, for example) covered by one sampler alone, these results indicate that one might have had BMWPs which were, on average, 10.9% lower than if the same area had been covered by another sampler.

4.4.3 Effects of between-sampler bias on RIVPACS predicted scores

The results for predicted scores are very consistent (see Table 4.2 (b)). The greatest range of means is seen for predicted BMWP (0.8%). DW's predictions were 0.3% below average and JB's predictions were 0.5% above average.

4.4.4 Effects of between-sampler bias on EQIs (see Table 4.2c)

The results for the three EQIs paralleled those for their respective indices. The largest difference between different samplers (measured as means) was for BMWP EQI (0.08 for an average sample), equivalent to 11.1%.

Once again, MW obtained significantly higher EQI values than JB and DW. RAC showed no significant differences with any of his partners.

4.4.5 Effects of between-sampler bias on width, depth and substrate composition for RIVPACS (see Table 4.2d)

This analysis deals with the field-measured RIVPACS variables, width, depth and substrate composition (median particle size in ϕ units). Note that, as ϕ units = $-\log_2$ particle diameter in millimetres, median particle size in ϕ units ranges about zero, the values used are 'estimate for sampler' *minus* 'average estimate for site'.

Significant differences between personnel occurred only with respect to depth. Differences in assessment of depth are suggested by all analyses except the Students t test. Translated into the hypothetical average site for the study, 7m wide and 55cm deep, estimates of the width would vary by 23cm, depth by 5 cm and median particle size by 0.75 ϕ.

Table 4.2 (a) Biases between personnel: TAXA, BMWP, and ASPT

		Person collecting samples			
Row	TAXA	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
	Upper confidence limit	1.001	1.011	1.082	1.082
(1)	**Mean bias**	**0.983**	**0.960**	**1.057**	**1.002**
	Lower confidence limit	0.966	0.910	1.032	0.922
(2)	TAXA of a hypothetical average sample (see text)	15.487	15.124	16.644	15.785
(3)	One sample t test	ns	ns	P<.0007	ns
(4)	One-sample Wilcoxon test	ns	ns	p<.0047	ns
(5)	ANOVA	p<.0019	MW>JB		
(6)	Kruskal-Wallis	p<.0104			

		Person collecting samples			
Row	BMWP	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
	Upper confidence limit	0.987	1.023	1.104	1.109
(1)	**Mean bias**	**0.963**	**0.957**	**1.075**	**1.007**
	Lower confidence limit	0.939	0.892	1.047	0.906
(2)	BMWP of a hypothetical average sample (see text)	67.298	66.897	75.148	70.382
(3)	One sample t test	P<.0110	ns	P<.0002	ns
(4)	One-sample Wilcoxon test	p<.0229	ns	p<.0030	ns
(5)	ANOVA	P<.0155	MW>JB		
(6)	Kruskal-Wallis	p<.0061			

		Person collecting samples			
Row	ASPT	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
	Upper confidence limit	0.990	1.014	1.033	1.025
(1)	**Mean bias**	**0.980**	**0.996**	**1.021**	**1.002**
	Lower confidence limit	0.970	0.978	1.009	0.980
(2)	ASPT of a hypothetical average sample (see text)	3.930	3.995	4.093	4.019
(3)	One sample t test	p<.0096	ns	p<.0052	ns
(4)	One-sample Wilcoxon test	p<.0120	ns	p<.0131	ns
(5)	ANOVA	P<0.0072	MW>JB&DW		
(6)	Kruskal-Wallis	p<.0120			

	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
Number of sample pairs	12	14	13	9

Biases in the table are quoted as proportions and not in the units of the particular index. Ratios greater than one indicate a bias towards the named sampler/surveyor

Table 4.2 (b) Biases between personnel: RIVPACS predicted indices

		Person collecting samples			
Row	Pred. TAXA	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
	Upper confidence limit	1.003	1.006	1.004	1.003
(1)	**Mean bias**	**0.998**	**1.002**	**1.000**	**0.999**
	Lower confidence limit	0.993	0.998	0.997	0.996
(2)	TAXA of a hypothetical average sample (see text)	20.831	20.918	20.879	20.861
(3)	One sample t test	ns	ns	ns	ns
(4)	One-sample Wilcoxon test	ns	ns	ns	ns
(5)	ANOVA	ns			
(6)	Kruskal-Wallis	ns			

		Person collecting samples			
Row	Pred. BMWP	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
	Upper confidence limit	1.006	1.011	1.004	1.004
(1)	**Mean bias**	**0.997**	**1.005**	**0.998**	**0.999**
	Lower confidence limit	0.988	0.999	0.993	0.993
(2)	BMWP of a hypothetical average sample (see text)	101.051	101.859	101.192	101.241
(3)	One sample t test	ns	ns	ns	ns
(4)	One-sample Wilcoxon test	ns	ns	ns	ns
(5)	ANOVA	ns			
(6)	Kruskal-Wallis	ns			

		Person collecting samples			
Row	Pred. ASPT	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
	Upper confidence limit	1.004	1.007	1.002	1.001
(1)	**Mean bias**	**0.999**	**1.003**	**0.999**	**0.999**
	Lower confidence limit	0.993	0.999	0.996	0.997
(2)	ASPT of a hypothetical average sample (see text)	4.820	4.840	4.821	4.821
(3)	One sample t test	ns	ns	ns	ns
(4)	One-sample Wilcoxon test	ns	ns	ns	ns
(5)	ANOVA	ns			
(6)	Kruskal-Wallis	ns			

	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
Number of sample pairs	12	14	13	9

Biases in the table are quoted as proportions and not in the units of the particular index. Ratios greater than one indicate a bias towards the named sampler/surveyor.

Table 4.2 (c) Biases between personnel: EQIs

Row	TAXA EQI	Person collecting samples: Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
	Upper confidence limit	1.002	1.008	1.082	1.083
(1)	**Mean bias**	**0.985**	**0.958**	**1.057**	**1.003**
	Lower confidence limit	0.969	0.908	1.031	0.922
(2)	TAXA EQI of hypothetical average sample (see text)	0.731	0.711	0.784	0.744
(3)	One sample t test	ns	ns	p<.0008	ns
(4)	One-sample Wilcoxon test	ns	ns	p<.0046	ns
(5)	ANOVA	p<.018	MW>JB&DW		
(6)	Kruskal-Wallis	p<.0098			

Row	BMWP EQI	Person collecting samples: Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
	Upper confidence limit	0.990	1.017	1.107	1.111
(1)	**Mean bias**	**0.966**	**0.952**	**1.077**	**1.008**
	Lower confidence limit	0.942	0.888	1.047	0.906
(2)	BMWP EQI of hypothetical average sample (see text)	0.652	0.643	0.727	0.681
(3)	One sample t test	p<.0173	ns	p<.0003	ns
(4)	One-sample Wilcoxon test	p<.0376	ns	p<.0037	ns
(5)	ANOVA	P<.0122	MW>JB&DW		
(6)	Kruskal-Wallis	p<.0050			

Row	ASPT EQI	Person collecting samples: Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
	Upper confidence limit	0.993	1.011	1.035	1.027
(1)	**Mean bias**	**0.981**	**0.993**	**1.022**	**1.003**
	Lower confidence limit	0.970	0.976	1.009	0.980
(2)	ASPT EQI of hypothetical average sample (see text)	0.817	0.827	0.850	0.835
(3)	One sample t test	p<.0101	ns	p<.0051	ns
(4)	One-sample Wilcoxon test	p<.0120	ns	p<.0071	ns
(5)	ANOVA	p<.0072	MW>JB&DW		
(6)	Kruskal-Wallis	p<.0064			

	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
Number of sample pairs	12	14	13	9

Biases in the table are quoted as proportions and not in the units of the particular index. Ratios greater than one indicate a bias towards the named sampler/surveyor.

Table 4.2 (d) Biases between personnel: RIVPACS variables

Row	WIDTH (m)	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
		Person collecting samples			
	Upper confidence limit	1.035	1.041	1.032	1.007
(1)	**Mean bias**	**1.005**	**1.012**	**0.995**	**0.981**
	Lower confidence limit	0.976	0.984	0.958	0.954
(2)	Width of a hypothetical average sample (see text)	7.412	7.463	7.338	7.230
(3)	One sample t test	ns	ns	ns	ns
(4)	One-sample Wilcoxon test	ns	ns	ns	ns
(5)	ANOVA	ns			
(6)	Kruskal-Wallis	ns			

Row	DEPTH (cm)	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
		Person collecting samples			
	Upper confidence limit	1.053	1.016	1.021	1.136
(1)	**Mean bias**	**1.028**	**0.969**	**0.961**	**1.066**
	Lower confidence limit	1.003	0.923	0.902	0.996
(2)	Depth of a hypothetical average sample (see text)	56.316	53.109	52.674	58.399
(3)	One sample t test	ns	ns	ns	ns
(4)	One-sample Wilcoxon test	p<.0408	p<.0281	ns	ns
(5)	ANOVA	p<.0490	No individual contrasts significant		
(6)	Kruskal-Wallis	p<.007			

Row	Median substrate (ϕ)	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
		Person collecting samples			
	Upper confidence limit	0.792	0.555	0.749	0.818
(1)	**Mean bias**	**-0.072**	**-0.105**	**0.121**	**0.084**
	Lower confidence limit	-0.936	-0.766	-0.506	-0.649
(2)	Median substrate (ϕ) of a hypothetical average sample (see text)	-0.241	-0.353	0.407	0.284
(3)	One sample t test	not applicable			
(4)	One-sample Wilcoxon test	not applicable			
(5)	ANOVA	ns			
(6)	Kruskal-Wallis	ns			

	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
Number of sample pairs	12	14	13	9

Biases in the table are quoted as proportions and not in the units of the particular index.

4.5 Variability of different personnel

4.5.1 Methods

The variability of personnel was assessed by comparing the ratio of the standard deviation of the scores of an individual at a site, with the standard deviation of the scores obtained by both people. This is:

$$\text{Variability of person 1} = \frac{\text{Standard deviation of Person 1 observations}}{\text{Standard deviation of observations of Person 1 \& 2}}$$

Measurement of variability was concerned with describing how variable personnel were compared to each other. The overall variability due to sampler is considered in Chapter 7.

4.5.2 Results

Individual samplers had standard deviations that were between 67% and 100% of the total standard deviations for the sites (see Table 4.3). Despite this, ANOVAs showed that none of the samplers was *significantly* more variable than any other.

This result is of interest as it might have been expected that the bias of RAC would have created much more variable data than other samplers. This result, then, further justifies the lack of transformation of RAC's data.

4.6 Conclusions

4.6.1 Sources of variation due to personnel differences

This section contains an analysis of the way in which differences between samplers affected the results from a site. Three sources of variation were considered. In most routine monitoring programmes only two of the three sources of variation described occur:

(i) The differences between people measuring the same value (sampler bias - section 4.4);

(ii) How much variation there is in each persons observations (variability - section 4.5).

The third source of variation, the difference between samples collected by the same person, is important if sampling programmes use two or more samples collected from the same site on the same day.

4.6.2 Controlling variation due to personnel differences

The results show that there are significant differences between the scores which different people obtained at the same site. However, different people (at least in this study) were equally variable. This means that two people could get a different result for the same site, but that the variability with which they measured that result would, on average, be the same.

For practical purposes, it is impossible to separate these sources of variation. The only practical way of controlling them is to randomise the sampling programme. On a national scale this would clearly be very difficult. However, a limited randomisation, perhaps between seasons when combined-season sampling was the objective, would help to control bias at a local level.

Table 4.3 Variability of samplers

Mean TAXA	All	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
Upper confidence limit	0.93	1.02	1.16	1.02	1.38
Standard deviation	**0.82**	**0.77**	**0.86**	**0.70**	**1.00**
Total Standard Deviation					
Lower confidence limit	0.71	0.52	0.56	0.38	0.62
Mean BMWP	**All**	**Dave Walker**	**Jeremy Biggs**	**Mericia Whitfield**	**Richard Ashby-Crane**
Upper confidence limit	0.94	1.01	1.16	1.07	1.34
Standard deviation	**0.83**	**0.76**	**0.88**	**0.76**	**0.93**
Total Standard Deviation					
Lower confidence limit	0.72	0.51	0.60	0.45	0.52
Mean ASPT	**All**	**Dave Walker**	**Jeremy Biggs**	**Mericia Whitfield**	**Richard Ashby-Crane**
Upper confidence limit	0.88	0.97	1.06	1.19	1.18
Standard deviation	**0.77**	**0.67**	**0.80**	**0.85**	**0.76**
Total Standard Deviation					
Lower confidence limit	0.66	0.37	0.54	0.51	0.34
	All samplers	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
Number of sample pairs	48	12	14	13	9

Biases in the table are quoted as proportions and not in the units of the particular index.

5. The effect of sampler variability on RIVPACS results: field measurements and RIVPACS predictions

5.1 Methods

5.1.1 RIVPACS field measurements

During each site visit, both samplers made a single independent assessment of the physical attributes of the river for RIVPACS predictions. In this study, analysis of variation in RIVPACS measurements was concerned only with those variables that are free to vary in the field, namely river width, depth and substrate composition. The study was not concerned with variations in information extracted from existing databases or maps.

5.1.2 RIVPACS predictions

The field procedure used for collecting the RIVPACS environmental data is given in Section 2.2.3 and details of single and combined-season RIVPACS predictions of TAXA, BMWP and ASPT are given in Section 2.2.2. A discussion of the difference between the results given in this report and the results which would have been achieved had three seasons of environmental data been used can be found in Section 2.4.

Estimating a RIVPACS prediction for dual samples

RIVPACS does not have a facility for making dual-sample predictions since the RIVPACS model does not use data originally collected in this way. An alternative approach to obtaining taxon frequencies, in order to obtain a predicted score for dual samples, was tested, using the combined probabilities of individual taxon occurrences for a single season. This approach, however, gave inconsistent results and was rejected.

For the purposes of these analyses therefore, *combined-season* predictions were used to estimate the EQIs of the *dual-sample* data. In these cases, the dual samples from autumn were matched with the first of the two combined predictions for autumn data for that sampler. The same was done for spring combinations. The results produced using this method are internally consistent and can be used for comparative estimates of variability. However, the *absolute* water quality values produced from dual samples are clearly not valid.

5.2 Results: Variation of RIVPACS predictions

5.2.1 Data analysed

Appendix table 3.4 gives the physical data gathered to make RIVPACS predictions. The variability of this data, treated as standard deviations and coefficients of variation (which are equivalent to relative standard deviation) of individual sites, is shown in Appendix tables 5.1 and summarised in Table 5.1.

5.2.2 Variation in RIVPACS predictions

Comparing the mean variation of autumn, spring and combined-seasons, Table 5.1 shows that variation was greatest in RIVPACS predictions for autumn samples. Spring-sample predictions showed least variation. Variations in combined-season predictions were intermediate, but generally closer to those of spring. For example, the coefficients of variation (CVs) for predicted BMWP scores were 1.46%, 0.69% and 0.75% of their respective means for autumn, spring and combined-season, respectively.

BMWP scores is a product of TAXA and ASPT and therefore has the errors of both. There was, therefore, a consistent trend for BMWP to be more variable than ASPT and TAXA predictions. For example, coefficients of variation for all single-sample predictions were 1.08% for BMWP, 0.61% for ASPT and 0.63% for TAXA..

The greatest relative variation seen in the RIVPACS prediction data were 3.1%, 5.4% and 3.0% for TAXA, BMWP and ASPT respectively (all from the Catherine Bourne in autumn - see Appendix table 3.1a). At some sites there was no variability in RIVPACS predictions (see for example Bow Brook, autumn predicted TAXA).

Table 5.1 **Average variability of RIVPACS predictions and field data from all sites (measured as standard deviation and coefficient of variation): single season**

	Predicted TAXA		Predicted BMWP		Predicted ASPT		WIDTH (m)		DEPTH (cm)		Median substrate size (ϕ)
	ST.DEV	CV%	ST.DEV	CV%	ST.DEV	CV%	ST.DEV	CV%	ST.DEV	CV%	ST.DEV
Autumn samples											
Mean	0.172	0.82	1.249	1.25	1.250	0.70	0.130	4.48	2.841	6.65	0.541
Standard error of the mean	0.048	0.23	0.386	0.40	0.395	0.23	0.036	1.24	1.165	2.46	0.187
Spring samples											
Mean	0.063	0.30	0.592	0.56	0.564	0.28	0.196	5.50	2.405	7.41	0.414
Standard error of the mean	0.018	0.09	0.179	0.17	0.172	0.15	0.058	1.00	0.752	2.62	0.122
Autumn and spring samples: summary											
Mean	0.117	0.56	0.920	0.91	0.907	0.49	0.163	4.99	2.623	7.03	0.478
Standard error of the mean	0.027	0.13	0.219	0.22	0.223	0.14	0.034	0.79	0.679	1.76	0.110
Combined-seasons											
Mean	0.126	0.49	0.987	0.75	0.023	0.44	0.111	3.54	1.966	6.35	0.386
Standard error of the mean	0.038	0.15	0.290	0.21	0.008	0.159	0.027	0.88	0.523	1.57	0.114

5.2.3 Factors affecting variation in RIVPACS predictions

Stepwise regression was used to investigate which of the physical parameters (width, depth, substrate) were most closely related to the variability of RIVPACS predictions. Regressions were performed for both standard deviations and coefficients of variation of predicted TAXA, BMWP and ASPT. Width, depth and median substrate size and their respective standard deviations and coefficients of variation were all used as predictor variables. Analyses were carried out separately on single-season data and combined-season data. Full details of these regressions are given in Appendix table 5.2 and a summary in Table 5.2.[1]

The results of the regression analysis indicated that the main factor correlated with variation in RIVPACS predictions was median substrate size. The amount of variation in predicted values explained by this single variable was high, ranging from 43.5% (see regression 9 in Table 5.2) to 65.9% (see regression 8, Table 5.2). In most cases the variability of predicted BMWP (estimated by standard deviation or coefficient of variation) was better predicted than that of predicted TAXA or ASPT. Only with single-season data for TAXA and BMWP was another factor (variability of width) of significance.

The total amount of variation (as standard deviation or coefficient of variation) in RIVPACS predictions explained by the regression was generally 45-65%. Some of the remaining variation will be explained by variation (both from sampling variability and the mathematical model) currently inherent within the RIVPACS method itself.

The results suggest that estimation of median substrate size (and to a much lesser extent width) is the most critical factor in producing consistent estimates of predicted TAXA, BMWP and ASPT. This conclusion is similar to that reached by IFE (Clarke *et al.* 1994).

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[1] Note that, unlike many of the results in this study where the variation of a parameter was proportional to its mean, regression analysis showed no relationship between standard deviations of RIVPACS predicted values and their means.

Table 5.2 Factors affecting variability in RIVPACS predictions[1]

(1)	**Standard deviation of single-season predicted TAXA**		
STEP	Variable included	R^2 adjusted	F for inclusion
1	Standard deviation of median substrate size	50.3%	24.3
2	Coefficient of variation of width	60.3%	18.5
(2)	**Standard deviation of single-season predicted BMWP**		
STEP	Variable included	R^2 adjusted	F for inclusion
1	Standard deviation of median substrate size	62.8%	39.8
2	Coefficient of variation of width	69.9%	27.7
(3)	**Standard deviation of single-season predicted ASPT**		
STEP	Variable included	R^2 adjusted	F for inclusion
1	Standard deviation of median substrate size	47.3%	21.6
(4)	**Coefficient of variation of single-season predicted TAXA**		
STEP	Variable included	R^2 adjusted	F for inclusion
1	Standard deviation of median substrate size	49.1%	23.2
2	Coefficient of variation of width	58.0%	16.9
(5)	**Coefficient of variation of single-season predicted BMWP**		
STEP	Variable included	R^2 adjusted	F for inclusion
1	Standard deviation of median substrate size	60.3%	36.0
2	Standard deviation of width	67.1%	24.5
(6)	**Coefficient of variation of single-season predicted ASPT**		
STEP	Variable included	R^2 adjusted	F for inclusion
1	Standard deviation of median substrate size	47.3%	21.6
(7)	**Standard deviation of combined-season predicted TAXA**		
STEP	Variable included	R^2 adjusted	F for inclusion
1	Standard deviation of median substrate size	50.8%	12.4
(8)	**Standard deviation of combined-season predicted BMWP**		
STEP	Variable included	R^2 adjusted	F for inclusion
1	Standard deviation of median substrate size	65.9%	22.2
(9)	**Standard deviation of combined-season predicted ASPT**		
STEP	Variable included	R^2 adjusted	F for inclusion
1	Standard deviation of median substrate size	43.5%	9.47
(10)	**Coefficient of variation of combined-season predicted TAXA**		
STEP	Variable included	R^2 adjusted	F for inclusion
1	Standard deviation of median substrate size	49.0%	11.6
(11)	**Coefficient of variation of combined-season predicted BMWP**		
STEP	Variable included	R^2 adjusted	F for inclusion
1	Standard deviation of median substrate size	63.8%	20.4
(12)	**Coefficient of variation of combined-season predicted ASPT**		
STEP	Variable included	R^2 adjusted	F for inclusion
1	Standard deviation of median substrate size	45.7%	10.3

[1] The tables show the R^2 adjusted term which is an estimate of the amount of variation explained by the included variable in step 1, or included variables where there is a second step. Variables not included did not add significant predictive power to the regression equation. The F to enter for the analysis was 4 and the F values for the inclusion of variables are also shown. The number of values used with single season data was 24 and the number for combined season data was 12. The F values are not, therefore, directly comparable between single and combined season analyses. Where the probability of inclusion drops below the p = <0.001 level this is also shown.

5.3 The discrimination of RIVPACS predictions

5.3.1 Introduction

Standard deviation and coefficient of variation of biotic indices are useful descriptors of variability and relative variation of biotic indices. However, the usefulness of a biotic index can also be assessed in terms of its ability to discriminate between sites. In this study the F values from ANOVA were used as estimates of this ability to discriminate.

F values are an estimate of the variation between sites in relation to the variation within sites. The higher the F value, the higher the variability between sites, compared to within sites, and the greater the ability of an index to discriminate between two or more sites. The ability of the three RIVPACS predicted indices to discriminate between sites is considered in this section, in the light of the analyses performed. The discriminatory power of the width, depth and median substrate measurements (as ϕ) are also considered. As elsewhere in this report, it is the variability of the indices per se which is discussed and not any relation which the indices may have to water quality. Further discussion of the significance of discrimination is given in the conclusions (Section 9).

It should be noted that F values between different factors and different types of analyses cannot be compared directly. Where such comparisons would be useful, they are mentioned separately.

5.3.2 Analytical methods

ANOVAs were first performed using all single-season predictions and physical parameters (two factor, 12 x 2 ANOVAs), with site and season as factors. Table 5.3 gives the F values from these analyses. In most cases F values were highly significant. Where not, they are indicated (ns).

Table 5.3 F values from 2 factor (site and season) ANOVAs

Variable	F for site	F for season	F for site x season interaction
Predicted TAXA	245.4	56.4	10.1
Predicted BMWP	151.5	131.7	8.53
Predicted ASPT	43.6	120.3	17.8
Width	9,257.4	19.8	34.6
Depth	640.8	0.08 (ns)	13.0
Phi	63.6	0.95 (ns)	1.59 (ns)

5.3.3 Discrimination between sites

All the F values for site were high for all the RIVPACS predictions (p=<0.0001). This indicated that all of the predicted indices were able to discriminate between sites, as would be expected. Predicted TAXA gave greatest discrimination, followed by predicted BMWP. Predicted ASPT gave least discrimination. It should be noted that the lack of discrimination of predicted ASPT may simply have been caused by the reporting of RIVPACS predictions to only one decimal place. This problem becomes greater as the size of the index decreases. A decimal place of an ASPT of 5 represents an inherent 2% imprecision in reporting compared to an imprecision of 0.5% for a TAXA value of 20, or 0.1% for the corresponding value of BMWP.

5.3.4 Differences between seasons

The analysis summarised in Table 5.3 indicated that, between seasons, there was a significant difference in the predicted RIVPACS values. Whether this was due to changes in the physical measurements between seasons, or derived from the original RIVPACS database, it is not possible to say. The difference in discrimination of different seasons is considered more fully below (Section 5.3.6).

5.3.5 Site x season interaction

The main factors of the analysis of variance (site and season) assess systematic trends. Systematic trends are those where, overall, all sites or all seasons show a particular trend. However, it is quite possible for one site to vary between seasons in the opposite direction to the general trend, and this is analysed as an *interaction*. In this case it appears that both RIVPACS predictions and field measurements of width and depth showed interactions (or non-systematic variation) (see Table 5.3).

All parameters except median substrate size (as ϕ) show some non-systematic variation between seasons. For predicted TAXA and BMWP this is small in comparison to the main effect of site, but for predicted ASPT the effect is quite large in relation to the site effect. So for ASPT the change seen between seasons is quite significant in comparison to the difference between sites. The degrees of freedom for this interaction are equivalent to those for site and so they can be compared directly.

5.3.6 Differences in discrimination between single and combined-seasons

In order to compare the ability of the autumn, spring and combined-season predictions, to discriminate between sites, three separate ANOVAs were run for autumn, spring and combined-season data (summarised in Table 5.4). The results show that combined-seasons data are more discriminatory than either autumn or spring data, and that spring data are much more discriminatory than autumn data. In all combinations of samples, ASPT was predicted with less discrimination than TAXA and BMWP. The analysis was a single factor (site) 12 level analysis. All F values were highly significant ($p<.001$).

It is not possible to say if the differences between spring, autumn and combined data are an effect of the RIVPACS model itself, or the result of variability of the RIVPACS measurements. The autumn predicted ASPT F values, though highly significant ($p=<0.0002$), are nevertheless rather low, and might be expected to have an effect on the discrimination of the ASPT.EQI in this season.

RIVPACS is designed to be run using environmental data averaged from three seasons of study. It might be expected from the results of this analysis that the inclusion of an extra season's data would make the predictions even more discriminatory. The use of one- and two-seasons environmental data in this study is also considered in Section 2.5.

Table 5.4 F values for ANOVAs of single-season and combined-season data

Variable	Autumn	Spring	Combined
Predicted TAXA	90.0	373.6	474.2
Predicted BMWP	46.3	228.9	384.1
Predicted ASPT	8.1	98.5	127.6
Width	8,018	3,270	36,689
Depth	249.9	474.4	2,287
Phi	28.2	41.4	165.2

5.4 Conclusions

RIVPACS predictions were made for single- and combined-season samples. It was not possible to make a specific prediction for dual samples since RIVPACS is not based on dual-sample data.

Variation in RIVPACS predictions was greatest in autumn (compared to spring and combined seasons). The average variability of all predicted indices was quite low, with coefficients of variation up to 1.5%. At individual sites, predicted indices varied by up to 5%.

Predicted BMWP was more variable (in terms of CV) than predicted TAXA, which was more variable than predicted ASPT.

Three factors (width, depth and substrate) were investigated for their effect on variability of RIVPACS predictions. Variability of substrate predictions (as standard deviation of median substrate size) explained most variation in RIVPACS predictions. There was very little variation in width or depth measurements.

Estimation of median substrate size (and to a lesser extent width) may be critical in producing consistent estimates of predicted TAXA, BMWP and ASPT.

6. Variability of biotic indices: basic statistical relationships and the banding of EQIs

6.1 Introduction

The section describes the variability of biotic indices and EQIs and uses this information to predict the likelihood of sites being correctly placed in particular water quality bands of the 5M system. A full analysis of the behaviour of the 5M system is given, as this provides important indications of the requirements of water quality banding systems generally. The overall aims of the chapter are:

(i) to describe the relationship between the standard deviations of biotic indices and their means, which has implications for understanding and using the data collected in the study;

(ii) to develop a technique based on regression analysis for modelling the EQIs of single samples;

(iii) to use the modelled variability of EQIs to predict the likelihood of a site being placed in a particular water quality band, in terms of its EQIs;

(iii) to demonstrate the application of this system using the EA Thames Region biological monitoring data for 1992;

(iv) to assess the behaviour of the 5M banding system, focusing on (a) the likelihood of replicate samples from the same site being placed in the same 5M band and (b) the differences in 5M banding of single-season and combined-season samples;

(vi) to develop a model for describing the variability of water quality banding systems, such as the 5M which summarise, in a single value, inter-related EQIs.

6.2 Methods

6.2.1 Describing the relationship between the mean and standard deviation of indices

The first part of this chapter describes the relationship between the means and standard deviations of the six biotic indices considered in this study (TAXA, BMWP, ASPT, TAXA.EQI, BMWP.EQI and ASPT.EQI). It also considers the relationship between the means and the coefficients of variation of these indices. This description of basic statistical features of the data provides the foundation for the second half of the chapter which describes, in greater detail, the variability of EQIs. It has already been noted that there is no relationship between the variability of *predicted* TAXA, BMWP and ASPT and their means, so these were not included in the analysis.

The relationship between mean and standard deviation/coefficient of variation was investigated by rank correlation analysis. The variability of three data sets was examined for each index: single-season (one sample), dual-samples (two samples collected on the same day) and combined-season (a combined spring and autumn sample). Variation in the six biotic indices was treated in two different ways: as standard deviation and coefficient of variation. In order to reduce problems arising from (i) non-homogeneity of variance (ii) outlying values and (iii) non-normal data, a nonparametric approach was taken with the initial analyses, using Spearman's rank correlation coefficient.

6.2.2 Predicting the likelihood of a sample being placed in a particular EQI band

The aim of this section was to provide a predictive equation for the likelihood that a sample, with a given EQI and index, would be correctly placed within its EQI band. Predictive equations were generated for the three EQIs of single and combined-season data, using regression analysis. This was a parametric analysis and so both standard deviation and coefficient of variation, and their $\log_{10}$ transformed values, were used in the analysis.

6.3 Results

6.3.1 Variation of standard deviation with the mean: TAXA, BMWP, and ASPT

Overall, there was a tendency for the standard deviation of an index to increase with the mean value of that index (for example, sites with high TAXA scores had higher sampling variability than sites with low TAXA scores). This tendency was most significant in single-season data, almost certainly because of the greater number of data points. It can be seen quite clearly in Figures 3.1 to 3.9. All Spearman's rank correlation coefficients are summarised for convenience in Table 6.1.

Single-season data

Single-season data showed significant correlations between the mean value of an index and its standard deviation for TAXA ($p<0.0026$) and BMWP ($p<0.0002$). ASPT did not show a significant correlation (see Table 6.1).

Dual-sample data

Dual-sample data also showed significant correlations between TAXA ($p<0.0479$) and BMWP ($p<0.0176$) means and standard deviation. For ASPT there were no significant correlations between means and standard deviation (see Table 6.1).

Combined-season data

With combined-season data, BMWP ($p<0.0075$) showed a significant correlation between mean and standard deviation. Both TAXA and ASPT had almost significant ($p<0.06$) correlations.

6.3.2 Variation of standard deviation with the mean : TAXA.EQI, BMWP.EQI, ASPT.EQI

Single-season data

Means and standard deviations of TAXA.EQI ($p<0.0119$) and BMWP.EQI ($p<0.0007$) were significantly correlated. There was no significant correlation between ASPT.EQI mean and standard deviation (see Table 6.1).

Dual-sample data

Only for BMWP.EQI ($p<0.0431$) was there a significant correlation between mean and standard deviation with dual-samples (see Table 6.1).

Combined-season

There was no significant correlation between TAXA.EQI mean and standard deviation. BMWP.EQI ($p<0.023$) ASPT.EQI ($p<0.026$) showed significant correlations (positive for BMWP.EQI and negative for ASPT.EQI) (see Table 6.1).

6.3.3 Variation of coefficient of variation with the mean: TAXA, BMWP, and ASPT

Single-season data

Single-season values for all biotic indices (TAXA, BMWP, ASPT) showed a significant negative correlation between their coefficients of variation and their means. This indicated that, even where the standard deviation of these indices significantly increased with the mean, the *relative* increase was less at higher values of the mean (as coefficient of variation = standard deviation / mean) (see Table 6.1).

Dual-sample data

There was a significant negative correlation between TAXA ($p<0.0479$) and BMWP ($p<0.0176$) means and coefficients of variation (see Table 6.1). There was no correlation with ASPT. Again, this indicated that even though standard deviation generally increased with the mean, there was some tailing off in the rate of increase at higher mean TAXA and BMWP values (see Table 6.1).

Combined-season data

The combined-season data showed a negative relationship between means and coefficients of variation for BMWP, and ASPT ($p<0.025$ and $p<0.026$, respectively). However for TAXA the relationship with combined-season data was not significant ($p<0.126$). This result, taken together with the non-significant correlation between TAXA and its standard deviation with combined-season data, suggests that the relationship between TAXA and its standard deviation is rather random. Overall it should probably be concluded that there was a non-significant increase in the standard deviation of TAXA with the mean (see Table 6.1).

6.3.4 Variation of coefficient of variation with the mean: TAXA.EQI, BMWP.EQI, ASPT.EQI

Single-season data

All three EQIs showed significant correlations between means and coefficients of variation. Levels of significance were: TAXA.EQI ($p<0.0096$), BMWP.EQI ($p<0.004$) and ASPT.EQI ($p<0.0041$) (see Table 6.1).

Dual-sample data

TAXA.EQI ($p<0.0169$) and BMWP.EQI ($p<0.0288$) dual-sample data showed significant negative relationships between means and coefficients of variation. There was no relationship with ASPT.EQI (see Table 6.1).

Combined-season data

For combined-season data significant relationships between means and coefficients of variation occurred for: BMWP.EQI ($p<0.0204$) and ASPT.EQI ($p<0.0169$). Like TAXA alone, TAXA.EQI coefficient of variation was not correlated with the mean (see Table 6.1).

6.3.5 The significance of the relationship between means, standard deviations and coefficients of variation

If, as is the case, the coefficient of variation is correlated with the mean, this implies that the relationship between standard deviation and mean is curvilinear and might be better modelled using polynomial regression or more complex models. This possibility is considered further in the section 6.4, dealing with EQIs.

Table 6.1 Levels of significance for correlation between the mean and two measures of variation (standard deviation and coefficient of variation) of biotic indices

	Single sample		Combined sample		Dual-sample	
	Standard deviation of index	Coefficient of variation of index	Standard deviation of index	Coefficient of variation of index	Standard deviation of index	Coefficient of variation of index
TAXA	0.0026	*0.0170*	ns	*ns*	0.0479	*0.0102*
BMWP	0.0002	*0.0056*	0.0075	*0.0250*	0.0176	*0.0479*
ASPT	ns	*0.0014*	ns	*0.0260*	ns	ns
TAXA EQI	0.0119	*0.0096*	ns	*ns*	ns	*0.0168*
BMWP EQI	0.0007	*0.004*	0.0230	*0.0204*	0.0431	*0.0288*
ASPT EQI	ns	*0.0041*	*0.026*	*0.0169*	ns	ns

Negative relationships are shown in italics. Single sample n = 24. Combined samples n = 12.

6.4 Regression analysis of EQIs

6.4.1 Introduction and approach

Most routine biological survey work undertaken by EA requires the collection of only a single sample during each site visit. Because of this it is not normally possible to estimate the variability of an EQI from routine survey data. In this section of the report, estimates of variability of replicate samples from the present study are used to develop a model that can *predict* the variability of the EQIs of single samples from routine monitoring programmes.

The first stage in the development of the model was to describe the variability of EQIs using regression analysis. The objective of this analysis was to find the best predictor of the variability of EQIs, using the individual biotic indices (TAXA, BMWP, ASPT) and their EQIs as the predictors. Once a regression equation able to predict the standard deviation of an EQI had been developed it was then possible to estimate standard deviation for each EQI, and calculate the likelihood of that EQI being correctly placed in a particular water quality band. Regressions were only performed within the data sets from which they were derived (e.g. standard deviation of TAXA.EQI from single-season data was not regressed against any indices from dual-sample data).

6.4.2 TAXA.EQI regressions for single-season data

Standard deviations of TAXA.EQI are better correlated with TAXA, BMWP and ASPT than their respective EQIs (see Table 6.2). Of the three indices, TAXA and BMWP are the best predictors of variability. Modelling of the expected standard deviation of TAXA.EQI is therefore best done using TAXA or BMWP rather than their EQIs. In practice, TAXA was chosen for this purpose. It is also clear that log transformed standard deviations are better correlated with their means than untransformed standard deviations.

The small, but significant, negative correlation between log coefficient of variation of TAXA.EQI and the means of the three EQIs, implies that the relationship of mean with standard deviation began to level out as mean increased. It also implied that a polynomial fit of log standard deviation to mean might provide a better model than a simple regression. However, a polynomial regression of standard deviation TAXA.EQI against mean TAXA, failed to include $TAXA^2$ as a significant term; indeed, when $TAXA^2$ was included as a non-significant term, that term was positive. So, whilst it seems likely that the increase of log standard deviation TAXA.EQI with TAXA was not strictly linear, there was not enough data available to justify a more complex model of the relationship. For this reason, for the purposes of modelling standard deviations of TAXA EQI, a simple model was used (Figure 6.1).

The regression of TAXA.EQI standard deviation used in the analysis is:

Log standard deviation TAXA.EQI = 0.0152 TAXA - 1.350 (Equation 6.1)

6.4.3 TAXA.EQI combined-season regressions

For combined-season data, TAXA.EQI was again better predicted by mean TAXA and BMWP than by the mean EQIs. Log transformed data also gave better results (Figure 6.2). As can be seen from the figure, there was an outlying value in this relationship at the top left of the plot. Removal of this value (from the Crendon Stream) increased the adjusted R^2 of the log standard deviation TAXA.EQI against TAXA regression to 58.5% with a concomitant increase in the significance of the relationship to $p=<0.0037$. This compared with an adjusted R^2 of 28% for the original data (see Table 6.2). Nevertheless, as has been argued previously, outlying values, such as the Crendon Stream point, are real and should be left in the dataset when estimating predictive equations. The predictive equation used in estimating the standard deviation of TAXA.EQI with combined-season data is given over the page, with the regression plot in Figure 6.2. It should be noted that in the nonparametric analysis (section 6.3.3), this relationship was not significant. However, there did appear to be a clear trend in the data with standard deviation increasing with mean, which the nonparametric analysis was too conservative to detect.

There were no significant relationship between coefficient of variation of TAXA.EQI and any indices or EQIs. Because of this, the summary regression statistics were not included in Table 6.2.
The regression of log standard deviation TAXA.EQI against mean TAXA (combined-season data) is described by:

Log standard deviation TAXA.EQI = 0.0114 TAXA - 1.417 (Equation 6.2)

6.4.4 BMWP.EQI single-season regressions

Relationship between BMWP.EQI standard deviation and the mean indices

The standard deviation of BMWP.EQI was better correlated with TAXA and BMWP than its respective EQIs (see Table 6.2). As with TAXA EQI, this suggests that it is some element of the richness of the fauna (as TAXA and BMWP), rather than water or ecological quality (as assessed by EQIs), which affects variability. Of all indices, BMWP was the best predictor. Modelling of the expected standard deviation of BMWP.EQI was, therefore, done using BMWP, rather than BMWP.EQI.

Transformed and untransformed standard deviation

Untransformed standard deviations of BMWP.EQI were slightly better correlated with their means than log transformed standard deviations (see Table 6.2). However, when the regression plots are considered (see Figures 6.3 and 6.4) it can be seen that in the untransformed plot the variation about the regression line increased markedly as the mean increased (i.e. the variation of the standard deviation increased with mean). For this reason, log transformed data were used to model variation of BMWP.EQI.

Coefficient of variation

There was a significant negative correlation with coefficient of variation, implying that the relationship of mean with standard deviation began to level out as the mean increased, and also implying that a polynomial fit of log standard deviation to mean would be a better model. Polynomial regression of standard deviation BMWP.EQI against mean BMWP, however, failed to include $BMWP^2$ as a significant term. Whilst it seems likely that the increase of log standard deviation BMWP.EQI with BMWP is not strictly linear, there was not enough data available to justify a more complex model of the relationship. For this reason, for the purposes of calculating standard deviations of BMWP.EQI, a simple linear model was used. The regression of log standard deviation BMWP.EQI against mean BMWP (single-season data) is:

$$\text{log standard deviation BMWP.EQI} = 0.00378\ \text{BMWP} - 1.335 \quad \text{(Equation 6.3)}$$

6.4.5 BMWP.EQI combined-season regressions

Better predictions of standard deviation BMWP.EQI for combined data were gained by using BMWP or TAXA than by using their EQIs (see Table 6.2). Log transformation of the standard deviations did not significantly improve the regressions, either in their predictive ability or in the distribution of values about the regression line. The best predictor of standard deviation BMWP.EQI (combined-seasons) appeared to be BMWP. The coefficient of variation of BMWP.EQI was negatively correlated with mean BMWP.EQI suggesting that the standard deviation did not increase linearly with BMWP.EQI but that the slope of the regression line became less steep at higher mean BMWPs.

BMWP was, therefore, used to model the standard deviation of BMWP.EQI (combined-season). A polynomial fit to the regression did not increase the predictive power of the regression (R^2 adjusted = 50.0%). Fitting $BMWP^2$ to standard deviation BMWP.EQI did increase the predictive power slightly, however (R^2 adjusted = 55.0), but this was not considered enough to justify the more complex model. Figure 6.5 shows a plot of BMWP against standard deviation of BMWP.EQI. The regression equation for standard deviation BMWP.EQI (combined-season) against BMWP is:

$$\text{Standard deviation BMWP.EQI} = 0.0004716\ \text{BMWP} + 0.03185 \quad \text{(Equation 6.4)}$$

6.4.6 ASPT.EQI single-season regressions

There were no significant relationships between standard deviation ASPT.EQI or log standard deviation ASPT EQI and the various indices. The standard deviation of ASPT.EQI for single-season samples was, therefore constant, across all ASPT.EQIs.

6.4.7 ASPT.EQI combined-season regressions

There was only one significant correlation with standard deviation ASPT.EQI for combined-season data, i.e. the correlation with mean ASPT.EQI. This was a negative correlation showing standard deviation *decreasing* as ASPT.EQI increased. The regression plot for this relationship is shown in Figure 6.6.

The regression of standard deviation ASPT.EQI against mean ASPT.EQI (combined-season data) is:

$$\text{standard deviation ASPT EQI} = -0.0537\ \text{ASPT EQI} + 0.0774 \quad \text{(Equation 6.5)}$$

Table 6.2 Summary of regression statistics describing relationships between EQI variation and biotic indices

TAXA.EQI. Single-season regressions.

Measure of variability	TAXA R^2adj	TAXA p=<	BMWP R^2adj	BMWP p=<	ASPT R^2adj	ASPT p=<	TAXA.EQI R^2adj	TAXA.EQI p=<	BMWP.EQI R^2adj	BMWP.EQI p=<	ASPT EQI R^2adj	ASPT EQI p=<
Standard deviation	31.2	0.003	31.6	0.003	25.3	0.007	23.2	0.010	22.3	0.011	17.5	0.024
Log standard deviation	35.1	0.001	35.3	0.001	29.3	0.004	29.0	0.004	28.0	0.005	21.5	0.013
Coefficient of variation	*9.6*	*ns*	*7.7*	*ns*	*10.2*	*ns*	*12.5*	*ns*	*11.4*	*ns*	*14.9*	*0.035*
Log coefficient of variation	*14.9*	*0.038*	*12.4*	*ns*	*15.2*	*0.034*	*20.2*	*0.016*	*18.7*	*0.020*	*21.5*	*0.013*

Negative relationships are shown in italics.

TAXA.EQI. Combined-season regressions

Measure of variability	TAXA R^2adj	TAXA p=<	BMWP R^2adj	BMWP p=<	ASPT R^2adj	ASPT p=<	TAXA.EQI R^2adj	TAXA.EQI p=<	BMWP.EQI R^2adj	BMWP.EQI p=<	ASPT EQI R^2adj	ASPT EQI p=<
Standard deviation	25.0	ns	24.8	ns	15.5	ns	16.2	ns	13.6	ns	4.1	ns
Log standard deviation	28.4	.043	27.6	.046	19.7	ns	22.3	ns	19.0	ns	9.2	ns

Negative relationships are shown in italics.

BMWP.EQI. Single-season regressions.

Measure of variability	TAXA R^2adj	TAXA p=<	BMWP R^2adj	BMWP p=<	ASPT R^2adj	ASPT p=<	TAXA.EQI R^2adj	TAXA.EQI p=<	BMWP.EQI R^2adj	BMWP.EQI p=<	ASPT EQI R^2adj	ASPT EQI p=<
Standard deviation	53.1	0.001	53.5	0.001	48.6	0.001	44.7	0.001	45.2	0.001	43.3	0.001
Log standard deviation	51.3	0.001	51.0	0.001	48.6	0.001	46.5	0.001	45.9	0.001	44.8	0.001
Coefficient of variation	*16.1*	*0.030*	*14.1*	*0.040*	*18.2*	*0.022*	*19.3*	*0.018*	*18.0*	*0.022*	*22.3*	*0.012*
Log coefficient of variation	*20.0*	*0.016*	*18.4*	*0.021*	*22.1*	*0.012*	*25.6*	*0.007*	*24.2*	*0.009*	*25.8*	*0.007*

Negative relationships are shown in italics.

Table 6.2 Summary of regression statistics describing relationship between EQI variation and indices (continued)

BMWP.EQI. Combined-season regressions.

	TAXA		BMWP		ASPT		TAXA.EQI		BMWP.EQI		ASPT EQI	
Measure of variability	**R^2adj**	**p=<**	**R^2adj**	**p=<**	**R^2adj**	**p=<**	**R^2adj**	**p=<**	**R^2adj**	**p=<**	**R^2adj**	**p=<**
Standard deviation	50.1	0.006	52.4	0:0047	40.3	0.016	39.7	0.017	39.1	0.018	25.5	0.054
Log standard deviation	48.6	0.007	50.0	0.006	40.7	0.015	40.7	0.015	39.5	0.017	27.0	0.048
Coefficient of variation	*22.1*	*ns*	*19.3*	*ns*	*32.6*	*0.031*	*26.7*	*0.049*	*025.2*	*ns*	*45.4*	*0.010*
Log coefficient of variation	*30.4*	*0.037*	*27.2*	*0.047*	*40.7*	*0.016*	*38.7*	*0.018*	*36.7*	*0.022*	*53.0*	*0.044*

Negative relationships are shown in italics.

ASPT.EQI. Combined-season regressions

	TAXA		BMWP		ASPT		TAXA.EQI		BMWP.EQI		ASPT EQI	
Measure of variability	**R^2adj**	**p=<**	**R^2adj**	**p=<**	**R^2adj**	**p=<**	**R^2adj**	**p=<**	**R^2adj**	**p=<**	**R^2adj**	**p=<**
Standard deviation	*14.0*	*ns*	*12.2*	*ns*	*28.0*	*ns*	*18.2*	*ns*	*16.2*	*ns*	*28.1*	*0.044*
Log standard deviation	*-3*	*ns*	*-4*	*ns*	*5.8*	*ns*	*0.34*	*ns*	*-1.6*	*ns*	*10.5*	*ns*

Negative relationships are shown in italics.

6.5 Predicting the standard deviation of EQIs and developing look-up tables for the likelihood of assigning sites to water quality bands

6.5.1 The approach to predicting EQIs

For TAXA.EQI and BMWP.EQI, the best equations for estimating the standard deviation of any sample included, respectively, TAXA and BMWP as the x term. The equations that were chosen from the range investigated are listed together, for convenience, in Table 6.3.

For ASPT.EQI, there was no correlation between single-season sample standard deviations and any of the indices investigated, so the predicted standard deviation is the same for all values of ASPT.EQI. With combined-season samples, ASPT.EQI standard deviations were directly related to ASPT.EQI, so that the EQI itself was the x term in the equation (see Table 6.3).

6.5.2 The approach to developing look-up tables

The modelled standard deviations of the EQIs were used as the basis for a series of look-up tables which, for a value of an index (e.g. BMWP) and its EQI, allow the likelihood of a sample being correctly placed in a particular water quality band to be read off a table (see Appendices 6.1 to 6.5). The likelihood that an EQI will be correctly placed within its band depends on two factors: (i) the estimated standard deviation of the EQI and (ii) the distance of the EQI from the boundaries of the band in which it has been placed. The stages in the development of the look-up tables were therefore:

(i) Calculation of predicted standard deviations for a series of values of each EQI and its index. For example, for combined-season BMWP.EQI, standard deviations were first calculated for a range of BMWP scores from 0 to 160, in steps of 10. For example, a BMWP score of 150 predicts a BMWP.EQI standard deviation which is:

$$\text{Standard deviation of BMWP.EQI} = 0.0004716\ \text{BMWP} + 0.03185$$
$$= 0.0004716\,(150) + 0.03185$$
$$= 0.10259$$

(ii) Calculation of the probability of each EQI being correctly associated with a particular EQI band (as throughout this report, the EQI bands of the 5M banding system). This was a two stage calculation:

(a) the standard normal variable, z, for any EQI boundary was calculated. The standard normal variable describes the distribution of values around an estimated mean (in this case, the value of the EQI). This was calculated as:

$$z = \frac{(\text{EQI - EQI boundary value})}{\text{standard deviation of EQI}}$$

The probability that a site will be placed a distance of z away from the known EQI value can then be estimated from tables of z, which can be used to determine the probability that the EQI will fall more than the distance z from the known value of the EQI.

(b) the probability of a site falling in any band is then calculated. For example, the probability that any site will be placed in band D, is given by the following equations where p(z) is the probability that the sample will fall a distance greater than z away from the original EQI value:

probability of site falling in band D = 0.5 - $p(z_3)$	(= p band D)
probability of site falling in band C = 0.5 - $p(z_2)$ - p band D	(= p band C)
probability of site falling in band B = 0.5 - $p(z_2)$ - p band D - p band C	(= p band B)
probability of site falling in band A = 1.0 - p band D - p band C - p band B	(= p band A)

z_1, z_2 and z_3 denote the z value between a sample and the D/C, C/B, and B/A EQI boundaries respectively. Note that if z is negative then p(z) will also be negative.

The formulae in stages (i) and (ii) above were used to calculate the values given in the tables in Appendices 6.1 to 6.5. A small extract of the Appendix 6.3 is given in Table 6.5 for a range of BMWP.EQIs at a single value of BMWP.

6.5.3 Using the look-up tables (see Appendices 6.1 to 6.5)

Appendices 6.1 to 6.5 contain look-up tables for estimating the likelihood of EQIs being placed in particular water quality bands for single- and combined-season samples for TAXA.EQI, BMWP.EQI and ASPT.EQI.

The tables are used by taking the respective index value for the sample to be classified (i.e. the TAXA or BMWP), reading down the table until the samples EQI value is found, and then reading off the probability of association with a particular water quality band. For ASPT.EQI, no index value (ASPT) is necessary.

For example, for a sample with a single-season BMWP score of 40, and an EQI of 0.61 (see Appendix 6.3) the probabilities of inclusion in 5M water quality bands would be as follows:

Band A = 44%

Band B = 56%

Band C = 0%

There is no band D for BMWP.EQI for single-season samples in the 5M system.

It should be noted that although the variation in EQIs would be expected to follow the trends indicated in the tables, there remains the possibility that some sites will have an inherently higher variation.

Although the tables include values for TAXA, BMWP and ASPT given in steps, it would be straightforward to develop a computer application which could calculate the probability of association with bands for all values of an index.

For brevity in Appendices 6.1 to 6.5, columns of bands which have zero probability (in practice less than 0.5%) have sometimes been omitted. The tables do not necessarily include estimates of variation for combinations of indices (e.g. TAXA and TAXA.EQI) which are not likely to exist in practice, as judged by the NRA 1992 routine water quality monitoring data. For example for single-season samples the combination of TAXA = 20 and TAXA.EQI <0.67 was well outside the range found by NRA (because pred.TAXA was never as high as 33). Some of these 'impossible' combinations are left in the tables for simplicity.

Table 6.3 Equations for predicting the standard deviations of TAXA.EQI, BMWP.EQI and ASPT.EQI (single- and combined-season data)

Single-season samples

(i) Standard deviation TAXA.EQI = $10^{(0.0152\ \mathrm{TAXA} - 1.350)}$

(ii) Standard deviation BMWP.EQI = $10^{(0.00378\ \mathrm{BMWP} - 1.335)}$

(iii) Standard deviation ASPT.EQI = 0.0483

Combined-season samples

(iv) Standard deviation TAXA.EQI = $10^{(0.0114\ \mathrm{TAXA} - 1.417)}$

(v) Standard deviation BMWP.EQI = 0.0004716 BMWP + 0.03185

(vi) Standard deviation ASPT.EQI = -0.0537 ASPT.EQI + 0.0774

Table 6.4 Examples of BMWP.EQIs for a range of BMWP scores

BMWP score (substituted into Equation (v) in Table 6.3)	Standard Deviation of BMWP.EQIs (combined-season) from Equation (v) Table 6.3
25	0.04364
50	0.05543
100	0.07901
150	0.10259
250	0.14975

Table 6.5 Example of matrix of BMWP.EQIs, with standard deviations and likelihood of a sample being in a particular water quality band (single-season data)

	Standard deviation of BMWP.EQI when BMWP = 50	Probability (%) of inclusion in the four 5M bands			
BMWP.EQI		A	B	C	D
0.60	0.05543	39	61	0	0
0.59	0.05543	34	66	0	0
0.58	0.05543	29	71	0	0
0.57	0.05543	24	76	0	0
0.56	0.05543	20	80	0	0
0.55	0.05543	16	84	0	0
0.54	0.05543	13	87	0	0
0.53	0.05543	10	90	0	0
0.52	0.05543	8	92	0	0
0.51	0.05543	6	94	0	0
0.50	0.05543	5	95	0	0

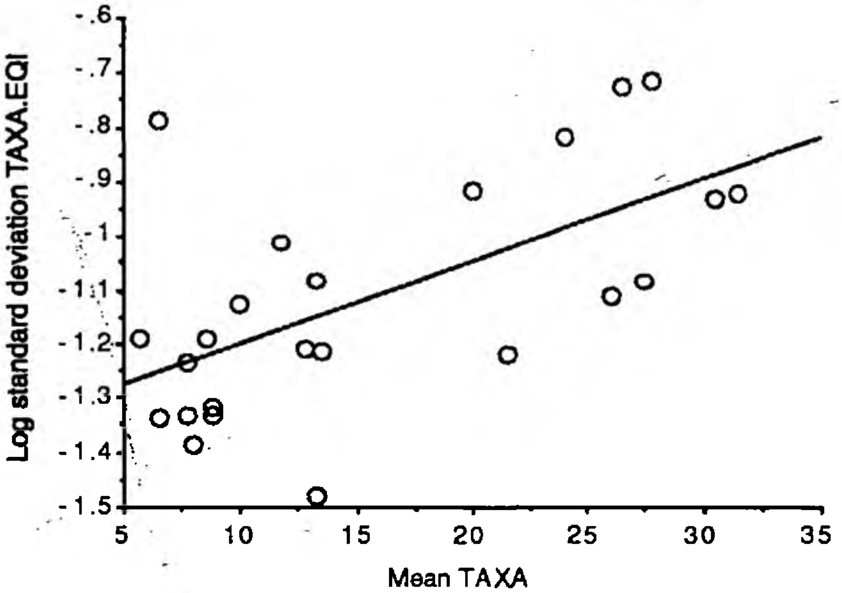


Figure 6.1 Regression of log standard deviation TAXA.EQI against mean TAXA: single-season data

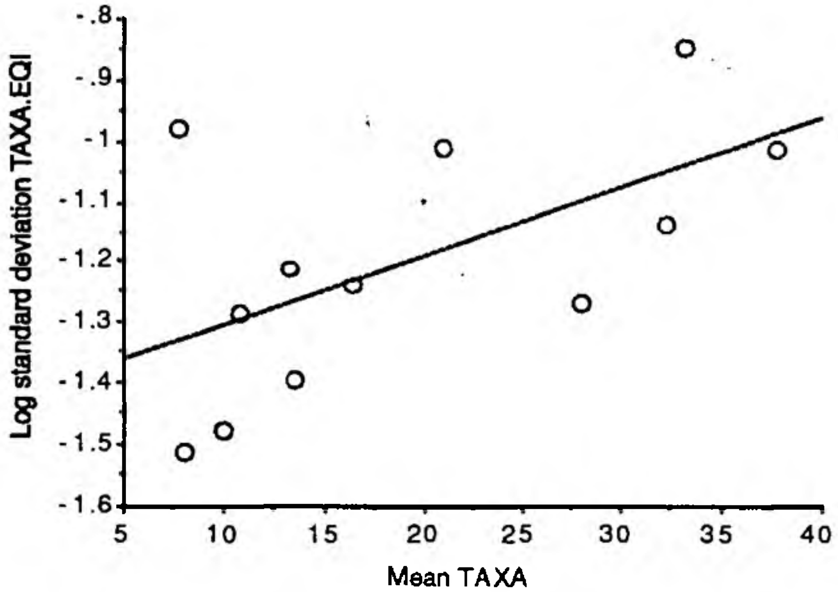


Figure 6.2 Regression of log standard deviation TAXA.EQI against mean TAXA: combined-season data

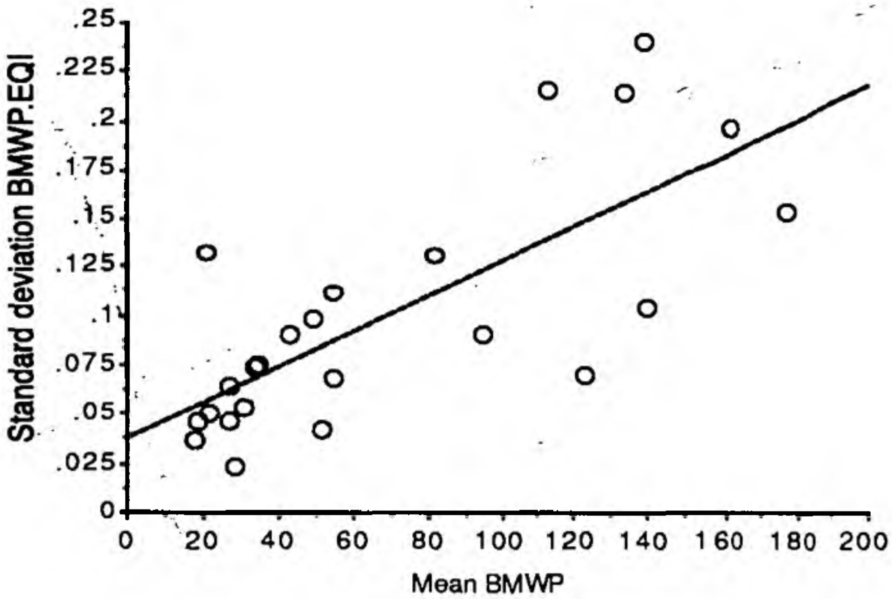


Figure 6.3 **Regression of standard deviation BMWP.EQI (untransformed) against mean BMWP: single-season data**

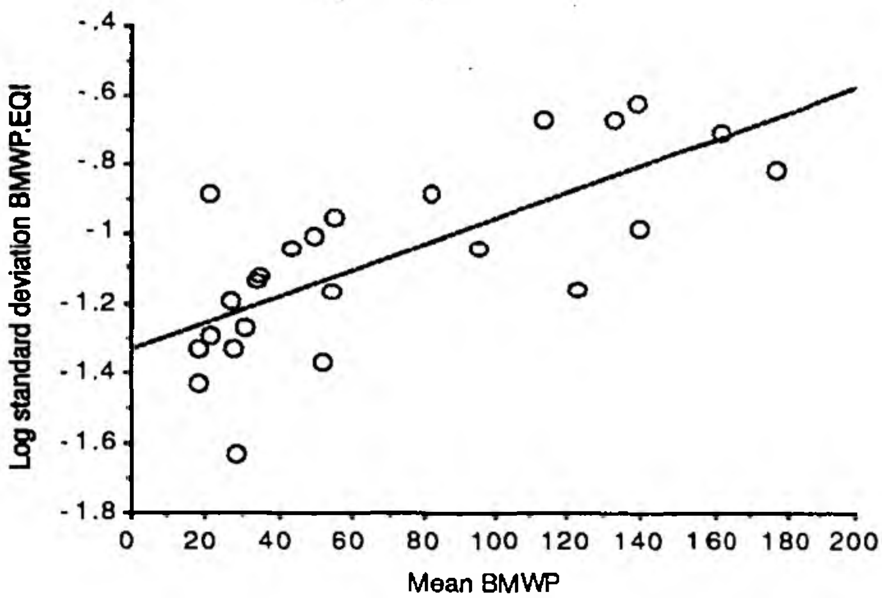


Figure 6.4 **Regression of log standard deviation BMWP.EQI against mean BMWP: single-season data**

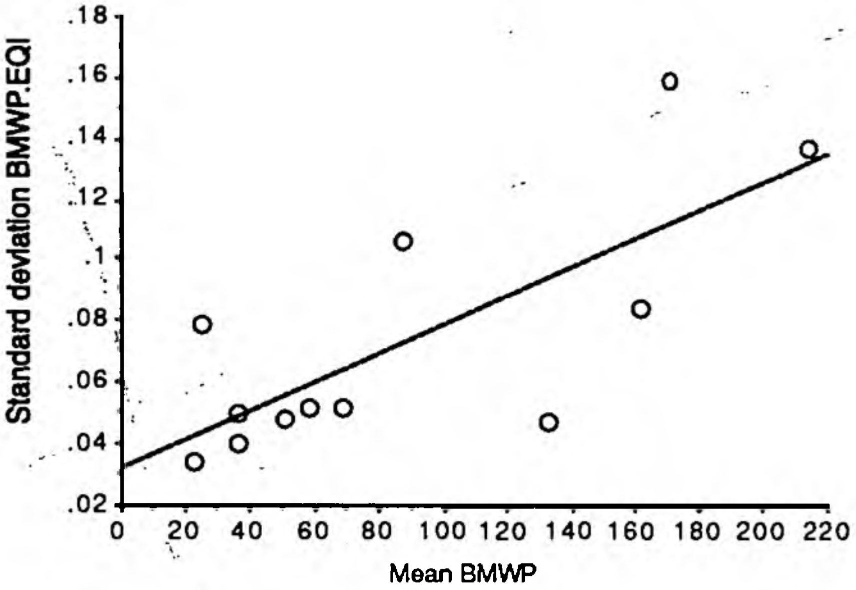


Figure 6.5 Regression of standard deviation BMWP.EQI (untransformed) against mean BMWP: combined-season data

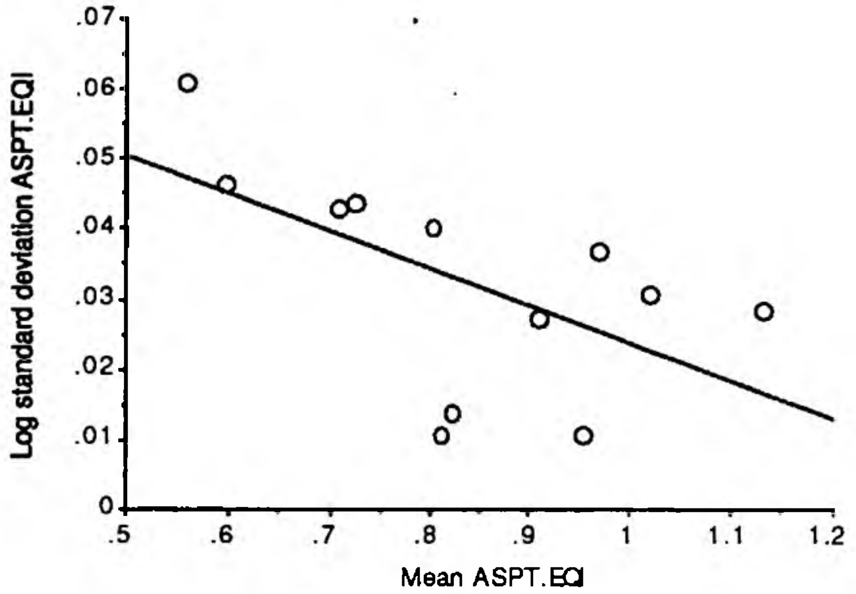


Figure 6.6 Regression of log coefficient of variation ASPT.EQI against mean ASPT.EQI: combined-season data

6.6 Estimated variability of EA Thames Region 1992 biological samples

6.6.1 Introduction to the analysis

The model developed to estimate the confidence of placement of samples in EQI bands was applied to all EA Thames Region biological samples collected during 1992. The results of this analysis were summarised in terms of:

(i) the probability of samples moving to a band *other than* the one to which they were allocated;

(ii) an analysis of the direction of sample movement (i.e. the probability of samples moving up a band, and the probability of samples moving down).

6.6.2 Results

Interpretation of results

Tables 6.6 to 6.9 show the likely direction of movement out of band for single- and combined-season samples. Tables 6.6 and 6.7 show the actual number of samples, and Tables 6.8 and 6.9 show percentages. These tables show the probability that a sample will move *out of band*. Moving from left to right, the probability of a sample moving out of band *increases*. For example, for ASPT.EQI single-season data (Table 6.6) 45 samples were not likely to move out of band A, 5 had a 5-10% chance of moving down from band A, 6 had a 10-20% chance of moving down from band A and 26 had a 20-50% chance of moving out of band A. Note that in band A all movements are inevitably downwards. Tables 6.10 to 6.13 show the cumulative numbers and percentages of samples remaining within band at four levels of probability.

Movement of samples between bands

Sites assessed using two seasons of sampling had a greater chance of being correctly placed within their EQI bands for all biotic indices. Also, sites in band A usually had a higher chance of being correctly placed than sites in band B, which in turn were more likely to be correctly placed than sites in band C or D.

For single-season assessments the percentage of sites which were highly likely to be correctly placed in band A (95% confidence, shown in the tables as <5% chance of moving out of band) varied between 55% (ASPT.EQI) and 60% (TAXA.EQI) (see Table 6.12). For combined-season sampling a higher percentage of sites was highly likely to be correctly placed (between 84% for TAXA.EQI and 91% for ASPT.EQI) (see Table 6.13). The percentage of sites highly likely to be correctly placed in band C was generally much lower, varying from 44%, for combined-seasons BMWP.EQI, to 0% for ASPT.EQI in single- *and* combined-seasons (see Tables 6.12 and 6.13).

The difference between bands was largely a result of the distribution of the EQIs. Band A is open at the top and so would be expected to have fewer samples falling outside it. Also, as has been noted (Chapter 3), there appears to be an underprediction by RIVPACS for some of the sites, which would ensure that EQIs in good quality sites were well above the boundary for band B. With the exception of ASPT.EQI, there were few sites which fell into band C, and most of those sites had a high probability of being misplaced into a higher band. There was, therefore, no real spread of sites across band C, and this may have contributed to the high percentage of sites likely to be misplaced in this band.

At all degrees of confidence for *single-season data*, TAXA.EQI and BMWP.EQI were approximately similar in their likelihood of their remaining within EQI Band. ASPT.EQI band however, was *less likely* to be assessed correctly. For *combined-seasons* data, all indices were similar in their likelihood of remaining within band although there was a suggestion that ASPT.EQI was more likely to be faithful to band B than other indices (see Table 6.13). This was due, in part, to the decrease in variability of ASPT.EQI with the mean of ASPT.EQI.

Overall, the results suggest that a degree of caution should be used when assessing the banding of NRA Thames Region 1992 data. In fact, only combined-season samples in band A can be regarded as placed with reasonable confidence. This was because most assessments of band A were fairly likely to be correct using combined-seasons data. In this band 92% to 95% of samples were likely to be correctly placed 80% of the time (i.e. they had a chance of <=20% of going out of band) (see Table 6.13). However, with single-season data only 68% to 85% of samples were fairly likely to be assigned correctly to band A (see Table 6.12). Bands below A were even more likely to be incorrectly assigned. The implications of the results are discussed further in Chapter 11 (Conclusions).

Table 6.6 Number of single-season samples allocated to 5M bands

		TAXA.EQI				BMWP.EQI				ASPT.EQI			
		Probability of moving from band											
		<5	<10	<20	>=20	<5	<10	<20	>=20	<5	<10	<20	>=20
5M band	Direction												
A	None	43	-	-	-	38	-	-	-	45	-	-	-
A	Down	-	10	8	11	-	8	4	16	-	5	6	26
B	Up	-	3	10	14	-	10	5	10	-	0	14	14
B	None	27	-	-	-	28	-	-	-	0	-	-	-
B	Down	-	2	7	4	-	3	4	8	-	5	2	6
C	Up	-	1	1	4	-	1	3	5	-	0	4	9
C	None	2	-	-	-	4	-	-	-	0	-	-	-
C	Down	-	0	0	0	-	-	-	-	-	3	1	4
D	Up	-	0	0	0	-	0	0	0	-	0	1	2

Table 6.7 Number of combined-season samples allocated to 5M bands

		TAXA.EQI				BMWP.EQI				ASPT.EQI			
		Probability of moving from band											
		<5	<10	<20	>=20	<5	<10	<20	>=20	<5	<10	<20	>=20
5M band	Direction												
A	None	120	-	-	-	112	-	-	-	114	-	-	-
A	Down	-	4	8	11	-	4	3	11	-	3	3	6
B	Up	-	3	1	3	-	2	3	10	-	3	8	3
B	None	1	-	-	-	1	-	-	-	0	-	-	-
B	Down	-	1	4	5	-	4	3	4	-	10	3	2
C	Up	-	0	2	2	-	0	0	5	-	0	2	3
C	None	0	-	-	-	4	-	-	-	0	-	-	-
C	Down	-	0	1	0	-	-	-	-	-	0	4	1
D	Up	-	0	0	0	-	0	0	0	-	0	0	1

Table 6.8 Percentage of single-season samples allocated to 5M bands

		TAXA.EQI				BMWP.EQI				ASPT.EQI			
		Probability of moving from band											
		<5	<10	<20	>=20	<5	<10	<20	>=20	<5	<10	<20	>=20
5M band	Direction												
A	None	59.7	-	-	-	57.6	-	-	-	54.9	-	-	-
A	Down	-	13.9	11.1	15.3	-	12.1	6.06	24.2	-	6.1	7.32	31.7
B	Up	-	4.48	14.9	20.9	-	14.7	7.35	14.7	-	0	34.1	34.1
B	None	40.3	-	-	-	41.2	-	-	-	0	-	-	-
B	Down	-	2.99	10.4	5.97	-	4.41	5.88	11.8	-	12.2	4.88	14.6
C	Up	-	12.5	12.5	50	-	7.69	23.1	38.5	-	0	19	42.9
C	None	25	-	-	-	30.8	-	-	-	0	-	-	-
C	Down	-	0	0	0	-	0	0	0	-	14.3	4.76	19
D	Up	-	0	0	0	-	0	0	0	-	0	33.3	66.7

Table 6.9 Percentage of combined-season samples allocated to 5M bands

		TAXA.EQI				BMWP.EQI				ASPT.EQI			
		Probability of moving from band											
		<5	<10	<20	>=20	<5	<10	<20	>=20	<5	<10	<20	>=20
5M band	Direction												
A	None	83.9	-	-	-	86.2	-	-	-	90.5	-	-	-
A	Down	-	2.8	5.59	7.69	-	3.08	2.31	8.46	-	2.38	2.38	4.76
B	Up	-	16.7	5.56	16.7	-	7.41	11.1	37	-	10.3	27.6	10.3
B	None	5.56	-	-	-	3.7	-	-	-	0	-	-	-
B	Down	-	5.56	22.2	27.8	-	14.8	11.1	14.8	-	34.5	10.3	6.9
C	Up	-	0	40	40	-	0	0	55.6	-	0	20	30
C	None	0	-	-	-	44.4	-	-	-	0	-	-	-
C	Down	-	0	20	0	-	0	0	0	-	0	40	10
D	Up	-	0	0	0	-	0	0	0	-	0	0	100

Table 6.10 Cumulative total number of single-season samples staying within 5M bands

	TAXA.EQI				BMWP.EQI				ASPT.EQI			
	Probability of moving from band											
	<5	<10	<20	>=20	<5	<10	<20	>=20	<5	<10	<20	>=20
5M band												
A	43	53	61	72	38	46	50	66	45	50	56	82
B	27	32	49	67	28	41	50	68	0	5	21	41
C	2	3	4	8	4	5	8	13	0	3	8	21
D	0	0	0	0	0	0	0	0	0	0	1	3
All bands	72	88	114	147	70	92	108	147	45	58	86	147

Table 6.11 Cumulative total number of combined-season samples staying within 5M bands

	TAXA.EQI				BMWP.EQI				ASPT.EQI			
	Probability of moving from band											
	<5	<10	<20	>=20	<5	<10	<20	>=20	<5	<10	<20	>=20
5M band												
A	120	124	132	143	112	116	119	130	114	117	120	126
B	1	5	10	18	1	7	13	27	0	13	24	29
C	0	0	3	5	4	4	4	9	0	0	6	10
D	0	0	0	0	0	0	0	0	0	0	0	1
Total bands	121	129	145	166	117	127	136	166	114	130	150	166

Table 6.12 Cumulative percentage of single-season samples staying within 5M bands

	TAXA.EQI				BMWP.EQI				ASPT.EQI			
	Probability of moving from band											
	<5	<10	<20	>=20	<5	<10	<20	>=20	<5	<10	<20	>=20
5M band												
A	59.7	73.6	84.7	100	57.6	69.7	75.7	100	54.9	61.0	68.3	100
B	40.3	47.8	73.1	100	41.2	60.3	73.5	100	0	12.2	51.2	100
C	25	37.5	50	100	30.8	38.5	61.5	100	0	14.3	38.1	100
D	0	0	0	0	0	0	0	0	0	0	25	100
All bands	49.0	59.9	77.6	100	47.6	62.6	73.5	100	30.6	39.5	58.5	100

Table 6.13 Cumulative percentage of combined-season samples staying within 5M bands

	TAXA.EQI				BMWP.EQI				ASPT.EQI			
	Probability of moving from band											
	<5	<10	<20	>=20	<5	<10	<20	>=20	<5	<10	<20	>=20
5M band												
A	83.9	86.7	92.3	100	86.2	89.2	91.5	100	90.5	92.9	95.2	100
B	5.56	27.8	55.6	100	3.70	25.9	48.2	100	0	44.8	82.8	100
C	0	0	60	100	44.4	44.4	44.4	100	0	0	60	100
D	0	0	0	0	0	0	0	0	0	0	0	100
All bands	72.9	77.1	87.4	100	70.5	76.1	81.9	100	68.7	78.3	90.4	100

6.7 Variability of the 5M banding system

6.7.1 Objectives

This section describes variation in the 5M banding of sites (i.e. the likelihood of a site normally banded B, being banded A, C or D). Variability of 5M bands is illustrated using data from the 12 sites in this study with single- and combined-season samples.

6.7.2 The 5M system

As originally conceived, the 5M system placed a site in one of four bands based on the values of TAXA.EQI, BMWP.EQI and ASPT.EQI for that site. Bands were provided for one, two or three season combined samples. Although the 5M system is currently being revised by the EA, and is expected to be superseded, an analysis of the system still provides valuable insights into the design of banding systems generally.

6.7.3 Methods used to describe the likelihood of a site being placed in a 5M band

At each site in this study, eight samples were collected (four in autumn and four in spring, each set being collected on the same day at roughly the same time) and the 5M band of each single- or combined-season sample calculated in the standard way (see Tables 3.1 and 3.2). The *modal* 5M band for each site was then identified (from eight samples for single-season data, and four samples for combined-season data). The number of sites *not* in the modal band was tabulated, to illustrate the likelihood of a site being given a 5M band *other than* the modal value. A worked example, showing how single-season tables were derived, is given in Table 6.14.

6.7.4 Results: likelihood of a site being placed in a particular 5M band

Single-season data

With single-season data, 5M band A ('Good' ecological quality) showed least variability with no sites deviating from the mode value (see Table 6.15). This in part reflected the fact that there is no upper limit to band A.

5M bands B and C were more variable. Four out of five of the sites in band B, and all three sites in band C, had samples which deviated from the mode value (see Table 6.15). None of the sites were classed as 5M band D using single-season data so it was not possible to assess the variability of this band.

Combined-season data

For combined samples, sites in 5M band A and band C were least variable, with no sites differing from the modal value. In the remaining bands no site had more than 1 sample deviating from the modal value. Note however that there were fewer combined samples than single-season samples (see Table 6.16).

Overall 5M bands derived from combined-season data appeared to be *less variable* than bands derived from single-season data. However, with the small number of sites in the study it was difficult to be certain of this trend.

6.7.5 The effect of using single- or combined-season samples to band sites

Differences in banding resulting from the use of combined and single-season samples were investigated further using a paired comparison of samples.

Methods of analysis

A paired comparison was made using 48 combined-season samples and 48 randomly drawn single samples (one from each sampler at each site, giving two samples for comparison at each site, see Table 6.17). At each site a comparison of the 5M band for the single sample with the 5M band for the combined-season sample was made. For each 5M band the number of single samples that were not in the same band as the combined samples was noted (e.g. for single samples in band B, how many of the combined samples were in bands A, C or D?). The analysis was then reversed (e.g. for combined samples in band B, how many single samples were in bands A, C or D?).

Results

The analysis suggested that combined-season data produced generally lower estimates of water quality than single-season data (see Table 6.18). For single-season samples placed in band A, 15% of the combined samples with which they were compared were placed in lower bands. This trend was even more pronounced for bands B and C where between a third and half of the combined-season samples were placed in a band lower than their single-season equivalent.

Discussion of results

The results of this section of the study suggested that combined-season samples banded in the 5M system were of lower water quality than single-season samples. This result is, in fact, an artefact of the 5M system. The 5M system has a larger band width for single-season than combined-season data to reflect the greater variability of single-season data. This strategy, though rational in terms of the confidence which can be placed in either single- or combined-season samples, has significant drawbacks when comparing results derived from the two types of sample. The *EQIs* for a given water quality remain approximately constant, irrespective of the number of samples taken (i.e. the EQI for a site should be approximately the same whether it is measured using single- or combined-season data). That this is the case can be shown by the fact that average single- and combined-seasons EQIs for the whole data-set in this study are very similar, and identical to two decimal places (0.74, 0.67 and 0.83 for TAXA.EQI, BMWP.EQI and ASPT.EQI respectively). Banding of those EQIs should not, therefore, lead to differences in the apparent water quality, depending on whether single- or combined-season samples are used to generate the banding.

That this occurs, with combined-season 5M banding apparently giving lower estimates of water quality than single-season samples, is due to the design of the 5M system. The reason that lower water quality gradings are given using combined-season data is that the EQI band levels, used to decide which 5M band an EQI is placed in, are ***higher*** for combined-season data. In other words, the same EQI value will appear to have a lower banding in the combined-season system than the single-season system.

This disparity between single- and combined-season bands is greater for the lower bands. So for TAXA, for example, the ratios of single- to combined-season band cut levels for the A/B, B/C and C/D transitions are 1.15, 1.59 and 31.00 respectively. Therefore, 5M bands assessed from single- or combined-seasons data will *also* differ more at lower water qualities.

Effectively, the 5M system provides three completely different water quality assessment systems depending on whether one, two or three seasons data is used.

Table 6.14 The technique used to describe the deviation of samples from the 5M modal band: single-season samples

SITE	5M band of individual-samples (data derived from Table 3.1)	Mode 5M band for site	Number of samples falling outside modal band
Bow Brook	A,A,A,A,A,A,A,A	A	0
River-Thames	A,A,A,A,A,A,A,A	A	0
River Coln	A,A,A,A,A,A,A,A	A	0
The Cut	B,B,A,A,B,B,C,B	B	3
Lydiard Stream	A,A,A,A,A,A,A,A	A	0
Halfacre Brook	B,B,B,B,B,A,A,A	B	3
Roundmoor Ditch	B,B,B,B,B,B,B,B	B	0
Summerstown Ditch	B,B,C,B,C,C,C,C	C	3
Crendon Stream	C,C,C,B,C,C,C,C	C	1
Wheatley Ditch	B,B,B,B,C,B,C,B	B	2
Crawters Brook	C,C,C,C,D,C,C,D	C	2
Catherine Bourne	B,B,B,A,B,B,B,B	B	1

Table 6.15 Variability of single-sample 5M bands

Mode 5M band of site	No. of samples falling outside mode band	% of sites with 0,1,2,3 or 4 samples falling outside the mode band. 0	1	2	3	4	Total number of sites
A		100	0	0	0	0	4
B		20	20	20	40	0	5
C		0	33	33	33	0	3
D		0	0	0	0	0	0

Table 6.16 Variability of combined sample 5M bands

Mode 5M band of site	No. of samples falling outside mode band	% of sites with 0, 1, or 2 samples falling outside the mode band. 0	1	2	Total number of sites
A		100	0	0	4
B		50	50	0	4
C		100	0	0	2
		50	50	0	2

Table 6.17 Dataset for paired comparison of combined-season samples with single-season samples

Samples combined to give a cumulative combined-season sample		5M Band for combined sample	5M band for random single sample
BOWB JB1A	BOWB DW2S	A	A
BOWB JB2A	BOWB DW1S	A	A
BOWB DW1A	BOWB JB1S	A	1
BOWB DW2A	BOWB JB2S	1	1
THAM DW1A	THAM RA2S	1	1
THAM DW2A	THAM JB2S	1	1
THAM RA1A	THAM RA1S	1	1
THAM RA2A	THAM JB1S	1	1
COLN DW1A	COLN JB1S	1	1
COLN DW2A	COLN JB2S	1	1
COLN MW1A	COLN RA2S	1	1
COLN MW2A	COLN RA1S	1	1
CUT. JB1A	CUT. RA2S	2	2
CUT. JB2A	CUT. RA1S	3	1
CUT. RA1A	CUT. MW1S	2	2
CUT. RA2A	CUT. MW2S	2	3
LYDI DW1A	LYDI DW2S	1	1
LYDI DW2A	LYDI JB2S	1	1
LYDI MW1A	LYDI DW1S	1	1
LYDI MW2A	LYDI JB1S	1	1
HALF JB1A	HALF JB2S	2	2
HALF JB2A	HALF MW1S	2	2
HALF RA1A	HALF MW2S	2	1
HALF RA2A	HALF JB1S	2	1
ROUN RA1A	ROUN DW2S	3	2
ROUN RA2A	ROUN MW2S	2	2
ROUN MW1A	ROUN MW1S	2	2
ROUN MW2A	ROUN DW1S	2	2
SUMM MW1A	SUMM DW1S	3	2
SUMM MW2A	SUMM JB2S	3	2
SUMM JB1A	SUMM DW2S	3	3
SUMM JB2A	SUMM JB1S	3	3
CREN JB1A	CREN MW2S	4	3
CREN JB2A	CREN MW1S	4	2
CREN RA1A	CREN JB2S	4	3
CREN RA2A	CREN JB1S	3	3
WHEA DW1A	WHEA JB1S	3	2
WHEA DW2A	WHEA MW2S	3	2
WHEA MW1A	WHEA JB2S	3	3
WHEA MW2A	WHEA MW1S	3	2
CRAW MW1A	CRAW RA2S	4	3
CRAW MW2A	CRAW MW1S	4	3
CRAW DW1A	CRAW MW2S	4	3
CRAW DW2A	CRAW RA1S	4	3
CATH DW1A	CATH DW1S	2	2
CATH DW2A	CATH MW1S	2	2
CATH JB1A	CATH MW2S	2	2
CATH JB2A	CATH DW2S	2	2

Table 6.18 The effects of sample season on 5M banding of sites: the banding of single-season samples in relation to the banding of combined-season samples

Single sample 5M band	% of samples in combined-season 5M band. Band A	Band B	Band C	Band D	Number of samples
Band A	84.2%	10.5%	5.3%	-	19
Band B	-	61.1%	33.3%	5.6%	18
Band C	-	9.1%	36.4%	54.5%	11
Band D	-	-	-	-	0

6.8 Modelling the variability of 5M bands

6.8.1 Introduction

A mathematical model is developed in this chapter of the probability of a site being placed in a particular 5M water quality band. It includes a description of the rationale behind the model and illustrates the main computational steps. The model is conceptually complete and now requires further testing for use under operational conditions.

When a sample is placed in water quality bands, it will usually have a probability of being associated with more than one band, because of the variability of the indices used. For example, a site might have an 80% probability of being associated with 5M band B and a 20% probability of being associated with band A. Any subsequent changes in the banding of sites may be due either to real changes in water quality or to variation in samples. Consequently, interpreting changes in water quality (for example, between one season and another) requires an understanding of the variability of the indices being banded.

Describing the variability of *individual indices* can be done using standard statistical methods as has been shown in Section 6.5.

However, where there is a need to *summarise* the variability of TAXA.EQI, BMWP.EQI and ASPT.EQI in a single index, calculating the probability of a site being associated with a particular water quality band is more complex. This is because the variability of the individual indices is inter-related and cannot be described using simple statistical techniques. The model described in this chapter introduces a method for describing the *simultaneous* variation of the three indices. This makes it possible to describe the probability of a site being assigned to a particular water quality band in systems, such as the 5M system, where that banding is based on a summary of two or more EQIs.

6.8.2 Approach to the development of the model

The BMWP system, when used with RIVPACS, produces three EQIs. Although biologists have generally considered all three useful, it is often necessary to summarise the three as a single water quality band. This was the basis for the 5M system, developed by IFE for the EA. Although the 5M system is likely to be superseded, a single value summarising biological water quality, using more than one of the indices of the BMWP/RIVPACS system, is still likely to be required.

As demonstrated in section 6.5, describing the variability of the three separate EQIs is straightforward using standard statistical methods. However, these techniques cannot be used to describe the variation of banding systems which summarise the variation in the three EQIs as a single variable. This is because (i) TAXA.EQI, BMWP.EQI and ASPT.EQI are not independent variables, variation in any one affecting the magnitude of the other two, and (ii) the 5M banding system is governed by a set of probability rules which are not continuously variable.

6.8.3 The model of simultaneous variation in TAXA.EQI, BMWP.EQI and ASPT.EQI

Modelling the variability of a real sample

The objective of the model was to describe the likelihood of any sample being placed in a particular 5M water quality band. The model works initially with variation in TAXA.EQI and BMWP.EQI, and then links the joint variation of these two indices to the variation of ASPT.EQI. In the following section this is exemplified for the sample: TAXA.EQI = 0.601, BMWP.EQI = 0.430 and ASPT.EQI = 0.723. This sample was taken from the autumn survey results of the study (see Table 6.19). The relationship of this data point to the rest of the data set is shown in Figure 6.7, which shows the correlation of TAXA.EQI and BMWP.EQI for combined-season data. The data point TAXA.EQI = 0.601, BMWP.EQI = 0.430 is shown as a hatched diamond.

Table 6.19 Statistics of the data point used to explain the model of simultaneous variation of TAXA.EQI and BMWP.EQI

	Value	Regression equation (see Section 6.4)	Standard deviation
TAXA.EQI	0.601	Standard deviation TAXA.EQI = $10^{(0.0152\ \text{TAXA} - 1.350)}$	0.0656
TAXA	11		
BMWP.EQI	0.430	Standard deviation BMWP.EQI = $10^{(0.00378\ \text{BMWP} - 1.335)}$	0.0649
BMWP	39		
ASPT.EQI	0.723	Standard deviation ASPT.EQI = 0.0483	0.0483

Describing the variation of TAXA.EQI and BMWP.EQI

The first step in modelling the variation of all three indices was to estimate the variation of TAXA.EQI and BMWP.EQI separately. Using the regression equations described in section 6.5 the standard deviations of TAXA.EQI and BMWP.EQI were calculated. These are listed in Table 6.19. The standard deviations were, in turn, used to calculate the likely distribution of values around the mean (as has been done for the NRA Thames data in Section 6.6)..

The variability of TAXA.EQI and BMWP.EQI at this example data point is shown diagrammatically in Figures 6.8 and 6.9. The two figures represent a small section of the graph shown in Figure 6.7, with TAXA.EQI variation in the horizontal plane (x axis) and BMWP.EQI variation in the vertical (y-axis) plane. The figures show the possible variability of the two indices over the most likely part of their range (from 0.475 - 0.750 for TAXA.EQI and 0.280 - 0.580 for BMWP.EQI), for the chosen data point. As a precursor to later stages of the model, the range of variation is divided into a series of bands. For example, the third band from the left of Figure 6.8 shows the probability of values lying in the range 0.500-0.525 (as the example is illustrative the actual probabilities have not been provided). As would be expected, the highest probability of occurrence is close to the data point itself, with the probability decreasing further away from the data point (dark shading indicating a high probability of occurrence and light shading a low probability of occurrence).

Describing the joint variation of TAXA.EQI and BMWP.EQI

Figures 6.8 and 6.9 represent the variation of TAXA.EQI and BMWP.EQI separately. Linking the variability of the two together, and assuming that the two EQIs are independent, their joint variability is described conceptually by Figure 6.10. Linking the variability of the two together is most easily understood by dividing the area over which both vary into cells, each of which has a probability of having a range of values of TAXA.EQI and BMWP.EQI associated with it. For example, the top left hand cell in Figure 6.10 covers the range of TAXA.EQI from 0.450 - 0.475 and the range of BMWP.EQI from 0.580 - 0.605. In both dimensions cells are 0.025 EQI units square.

However, TAXA.EQI and BMWP.EQI are not free to vary independently, and when both are plotted together, as in Figure 6.7, the ability of each to vary is constrained by the other. This is because as one index increases or decreases, so the other is also constrained to increase or decrease with it (see Figure 6.11 for further explanation). Figure 6.7 is a graph of the results of the study, with a polynomial plot summarising the relationship between BMWP.EQI and TAXA.EQI. Although samples from the same site (which are plotted with the same symbols) vary considerably, this variation is always constrained to 'follow' the main curve of the plot.

Adding the variation of ASPT.EQI to the variation of TAXA.EQI and BMWP.EQI

The constraint which TAXA.EQI and BMWP.EQI place on each other is governed by the relationship between them, i.e. by the ASPT. Therefore in order to understand how BMWP.EQI and TAXA.EQI vary together the variation in ASPT.EQI must also be added as a term to the distribution function. Adding this term enables one to describe the variation in all three indices simultaneously.

Having represented the joint variability of TAXA.EQI and BMWP.EQI as a series of cells, with a range of probabilities, it is then possible to calculate the range of values of ASPT.EQI for each of those cells. This is shown diagrammatically in Figure 6.12. As TAXA.EQI and BMWP.EQI vary together, ASPT.EQI remains more or less constant. Because of this the values of ASPT.EQI associated with cells lying along the diagonal axis of the TAXA.EQI/BMWP.EQI grid tend to have the highest probability of occurrence.[1] This is shown by the diagonal line of densely shaded cells. As one moves further away from the central diagonal, the occurrence of

[1] The full range of ASPT.EQIs in adjacent cells overlap (ASPT.EQI will be highest in the top left hand corner of the cell and lowest in the bottom right). Therefore, the range of ASPT.EQIs at the average BMWP.EQI for the cell has been used.

ASPT.EQIs characterised by those cells is increasingly unlikely. This distribution function of ASPT.EQI effectively limits the distribution function of TAXA.EQI and BMWP.EQI.

Putting these two distribution functions together (the TAXA.EQI/BMWP.EQI function and the ASPT.EQI function) (Figure 6.13) shows that the variation of TAXA.EQI and BMWP.EQI is constrained to vary within a broadly ellipsoidal shape. Values associated with cells in the top left of the grid, for example, are highly unlikely to occur because ASPT.EQI cannot vary enough to allow those values to occur. Consequently, variation in all three indices tends to make values close to the diagonal of the grid most likely. The confidence limits on all three indices together can be viewed as ellipsoids, represented in Figure 6.13 by the areas of different shading density.

6.8.4 Calculating the probability of 5M bands

Knowing the values of TAXA.EQI, BMWP.EQI and ASPT.EQI for cells it is possible to give each cell a 5M band. Figure 6.14 shows the 5M bands associated with each cell. Each of the cells also has a distinct probability of occurrence. This allows the probabilities to be summed over all cells with the same 5M bands to calculate an overall probability for each 5M band.

In an operational model of the variability it would probably be necessary to extend the number of cells used to a greater range of TAXA.EQIs and BMWP.EQIs in order not to 'miss out' some of the less likely occurrences (which might, additively, become significant). Also in an operational model it would be necessary to make the cells smaller. This is because cells which are too large would be likely to 'cross' any one of the 3 sets of 5M boundaries (i.e. for TAXA.EQI, BMWP.EQI, or ASPT.EQI). The size of cell would certainly need to be less than 0.01 EQI units. The exact size of the cells, however, would be arrived at following testing of an actual model (i.e. by reducing the cell size until the model gave consistent results).

6.8.5 Other banding systems

Though the 5M banding system has been considered here, the model proposed could be used with any banding system.

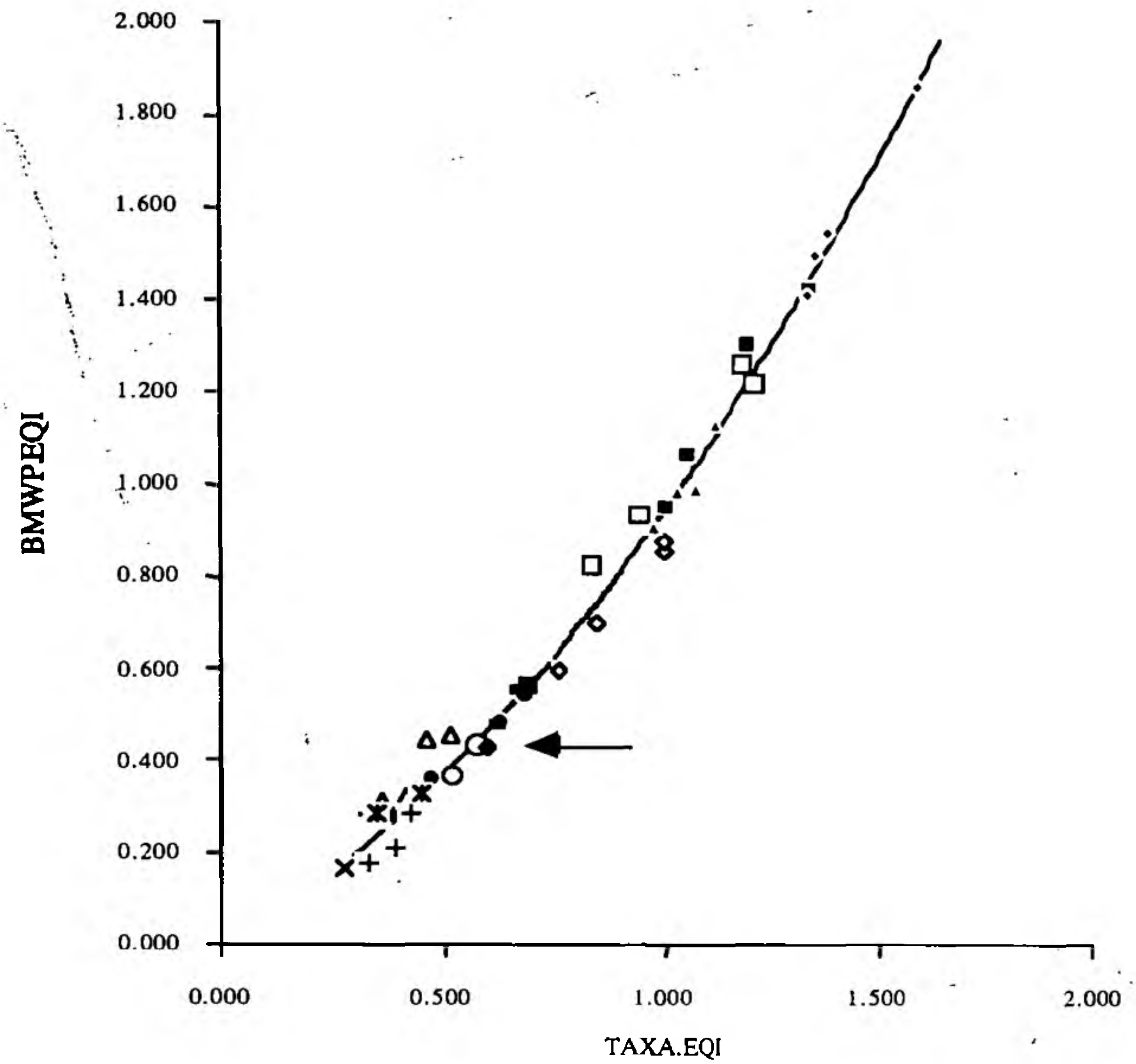


Figure 6.7 Correlation of TAXA.EQI and BMWP.EQI. Single season (autumn) data.

Legend
Different symbols represent samples from the 12 different sites. The hatched diamond (arrowed) represents the co-ordinates of a site with TAXA.EQI and BMWP.EQI of 0.601 and 0.430 respectively (see text)

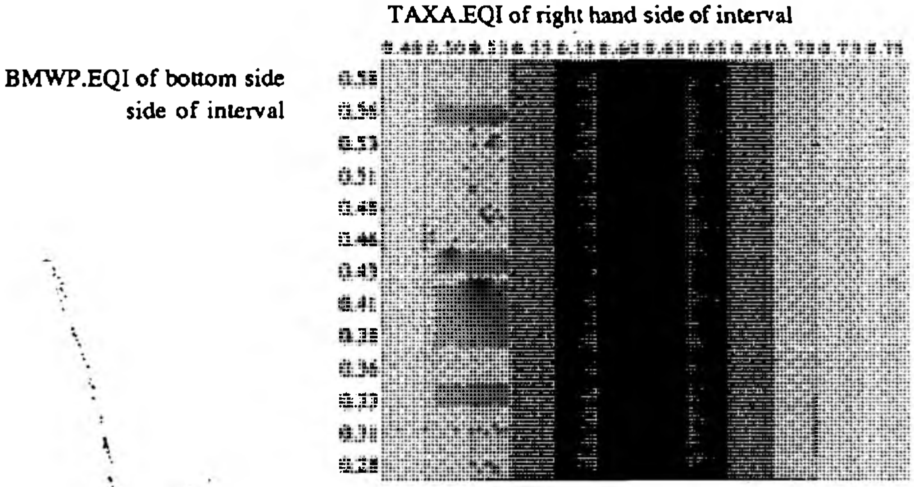


Figure 6.8. TAXA.EQI variation

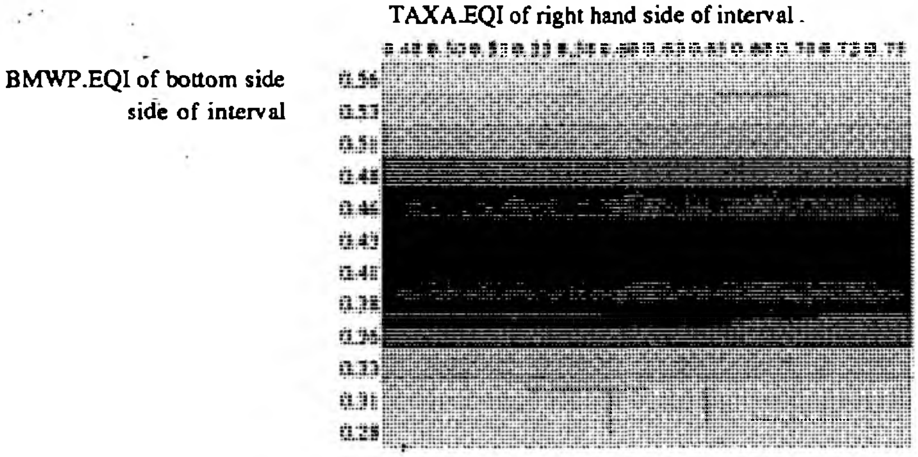


Figure 6.9 BMWP.EQI variation

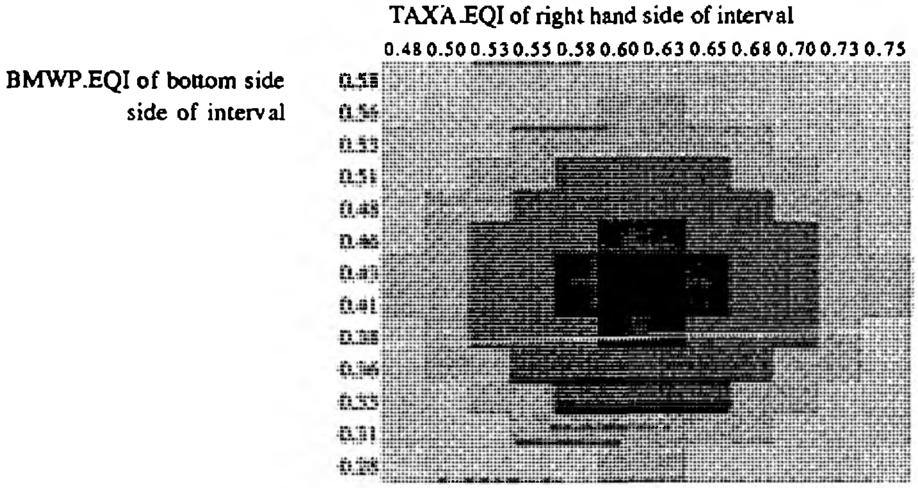
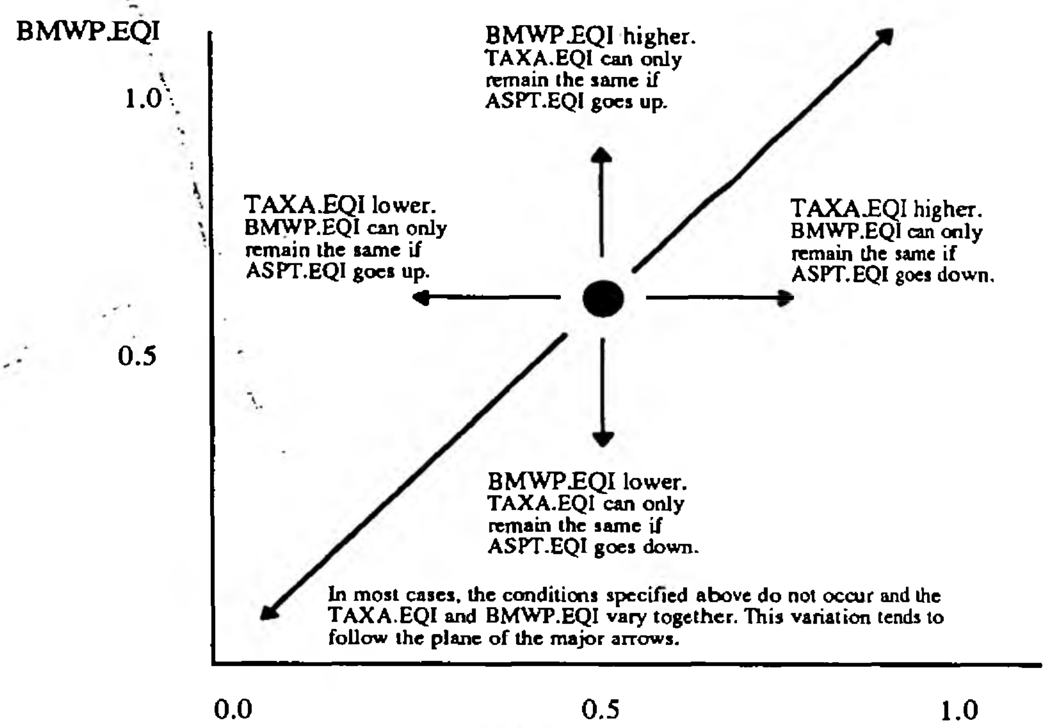


Figure 6.10 BMWP.EQI & TAXA.EQI variation

Figures 6.8 to 6.10 illustrate probabilistic variation of indices for a sample with TAXA.EQI=0.601; BMWP.EQI=0.430; ASPT.EQI=0.723. See also Figure 7

Figure 6.11 Diagrammatic representation of the inter-related variation of TAXA.EQI and BMWP.EQI



Figures 6.12 to 6.14 illustrate probabilistic variation of indices for a sample with TAXA.EQI=0.601; BMWP.EQI=0.430; ASPT.EQI=0.723. See also Figure 7

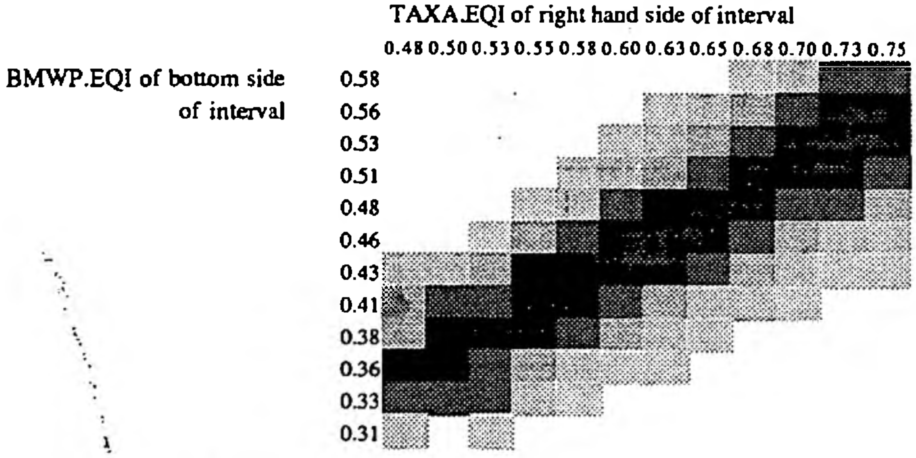


Figure 6.12. ASPT.EQI variation

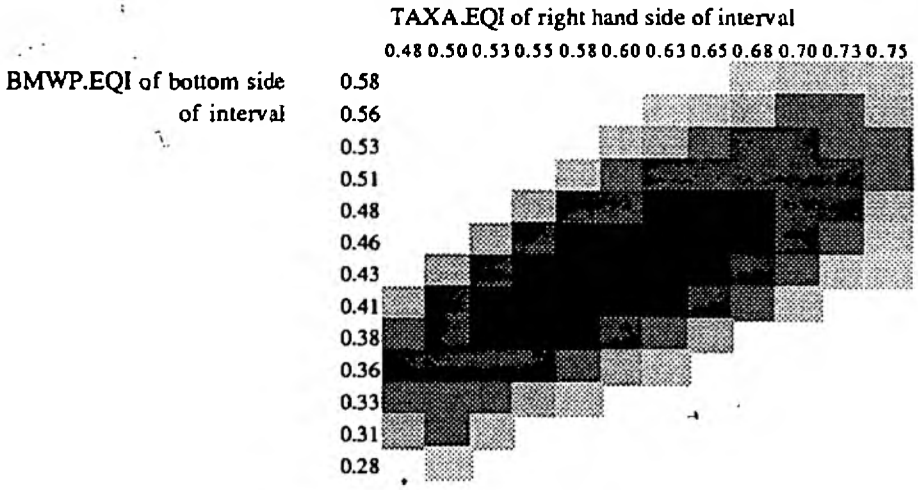


Figure 6.13 BMWP.EQI, TAXA.EQI & ASPT.EQI variation

TAXA.EQI of right hand side of interval

BMWP.EQI of bottom side of interval	0.48	0.50	0.53	0.55	0.58	0.60	0.63	0.65	0.68	0.70	0.73	0.75
0.58	B	B	B	B	B	B	B	B	A	B	B	B
0.56	B	B	B	B	B	B	B	B	B	B	B	B
0.53	B	B	B	B	B	B	B	B	B	B	B	B
0.51	B	B	B	B	B	B	B	B	B	B	B	B
0.48	B	B	B	B	B	B	B	B	B	B	C	C
0.46	B	B	B	B	B	B	B	B	C	C	C	C
0.43	B	B	B	B	B	B	B	C	C	C	C	C
0.41	B	B	B	B	B	B	C	C	C	C	C	C
0.38	B	B	B	B	C	C	C	C	C	C	C	C
0.36	B	B	B	C	C	C	C	C	C	D	D	D
0.33	B	C	C	C	C	C	C	D	D	D	D	D
0.31	C	C	C	C	C	D	D	D	D	D	D	D
0.28	C	C	C	D	D	D	D	D	D	D	D	D

Vertical line shows TAXA.EQI A/B boundary

Figure 6.14 5M Band probabilities

7. The relative importance of factors affecting the variability of water quality indices

7.1 Introduction

The relative contribution of four factors, sampler, person, season and site, to the *total* variability of water quality indices are described, in *general* terms, in this chapter. The differences shown by *each* biotic index and each combination of samples (e.g. single-season or combined-season) are considered, in more detail, in Chapter 8.

The results of the analyses described in this chapter have several important practical implications. In particular:

(i) if between or within person sampling variations explains a relatively large amount of the variation of any water quality index, this suggests a need for sampling strategies or personnel training which reduce this effect;

(ii) seasonal trends are relevant because it is of interest to know whether there are either systematic trends (i.e. spring samples generally indicate higher water quality for sites than autumn samples) or non-systematic trends (i.e. some sites have higher water quality indices or scores in spring than autumn or vice versa). Both of these seasonal differences would add variation to a sampling programme in which only single samples were taken. Note that the question of whether or not the *overall variability* of samples changes in different seasons is addressed in Chapter 8.

7.2 Methods of statistical analysis

The data were investigated by analysis of variance using single-season data. Three sets of data were analysed: (i) spring and autumn single-season samples together, (ii) autumn data alone and (iii) spring data alone. Variation in terms of TAXA, BMWP, ASPT, TAXA.EQI, BMWP.EQI, and ASPT.EQI was investigated in the analysis. Both untransformed and log transformed data were used. Full ANOVA tables for these analyses are presented in Appendix table 7 and summaries of the analyses are presented in Tables 7.1 to 7.3.

7.3 Results

Note that the discussion below relates to general trends shown by all/most of the biotic indices. The specific differences *between* indices are developed and discussed in Chapter 8.

7.3.1 Variation within samplers and between different samplers

Analysis of variance was used to investigate the amount of variation between duplicate samples taken by a *single* person, compared with the variation in samples taken by *different* people at a site. F values generated by all three analyses (autumn, spring, both seasons), and all six indices, varied around one (Column 1, Tables 7.1, 7.2 and 7.3). None of these F values were significant (Column 2 in the Tables 7.1, 7.2 and 7.3). This indicates that the sampling variation seen between different people was similar to the variation shown by a single person sampling, which suggests, in turn, that the effect of sampler was minimal.

This was an unexpected result, caused largely by the significant tendency for the first sample collected by a person to be poorer in taxa than the second sample (see Chapter 4). The overall variation due to person and sampler is unlikely to be underestimated by this tendency, but, due to this effect, it is more difficult to comment on the relative contribution of person to sampling variability.

7.3.2 Variability due to systematic trends between season

Comparison of spring and autumn data across all sites showed that there was generally little difference between the biotic indices of *all* samples collected in autumn compared to *all* samples collected in spring (see Table 7.1, Columns 3 and 4). The single exception was for ASPT EQI (log transformed data only) which suggested significantly greater values for ASPT.EQI in autumn (see Column 3, Table 7.1). Between seasons Wilcoxon signed rank tests on the six indices showed no significant differences at the p=<0.05 level. Overall this suggests that though there was a tendency for ASPT.EQI to be higher in autumn (means for autumn and spring are 0.84 and 0.82 respectively), systematic variation between seasons did not contribute greatly to the amount of variation in the data set as a whole, and, in practical terms, there was no tendency for indices to give higher water quality values in one season than another.

7.3.3 Variability due to non-systematic differences between seasons.

In contrast, most biotic indices did show significant differences between their values at *any one* site in spring, and their values in autumn (see Column 6, Table 7.1). In a sampling programme in which samples were collected either in spring or in autumn this non-systematic variation would lessen the ability to detect differences between water quality assessments at the sites. This effect will be seen later when different sampling strategies are compared. Though this effect is significant, it is, nevertheless, small when compared to the main effect of site.

That some sites do show a significant change in biotic index value (i.e. water quality results) between seasons is perhaps not surprising, since factors such as relative abundance of taxa, habitat availability, site homogeneity and water quality itself may all change seasonally at a site.

Further work would be required to assess how much of the perceived seasonal changes in biotic index value at any site was indeed due to an absolute water quality change (and in particular pollution) and how much due to other factors such as habitat availability.

7.3.4 Variation between sites

As would be expected, the amount of variation in the analysis due to site is far greater than for any of the other effects (sample, person, season). For example, F values for log transformed indices in autumn where the median value is about 37 (see Table 7.2, Column 3) suggest that, on average, 89% of variation in the whole data set is explained by site.

The differences in F values within the three analyses (spring, autumn, both seasons) suggest that most of the indices show greater differences (discrimination) between sites in spring than in autumn. The higher F values using both seasons' data shows that greater discrimination can be achieved using two samples from different seasons. This is similar to, but not the same as, the increased discrimination seen using combined-season data (See Chapter 8).

This chapter is not primarily concerned with differences seen between individual biotic indices. However, to facilitate comparisons with Chapter 8 ANOVAs (using non-nested data) it is also worth noting that the current analysis (using nested ANOVAs) generated F values for ASPT and ASPT.EQI which were generally lower than for the other four indices/scores.

7.4 Conclusions and implications: the relative importance of factors affecting variability

The analysis above indicates the following relationship between factors causing variability at any site:

for both seasons' season data:	site >> season > between samplers = within sampler
for single-season data:	site >> between samplers = within sampler

Unexpectedly, the analysis showed no difference between the variability of samples taken by one person and those taken by two or three people. However, as noted previously, this result was strongly affected by the bias for the first sample taken by person to collect significantly fewer taxa than his/her second sample at a site.

The value of biotic indices of sites often changed significantly between season, but in a non systematic manner. The effect of season, overall, therefore adds some variability to the data from both seasons, and would be expected to increase the variability of data sets composed of either, spring or autumn data, or combined-season data. Further work would be required to indicate how much of the perceived seasonal changes in biotic index value at a site was due to a real water quality change/ pollution and how much due to other factors such as seasonal changes in habitat availability etc.

There is no statistically significant trend for the value of biotic indices to increase or decrease systematically between autumn and spring. Thus, in practical terms, there was no tendency for indices to give higher water quality values in one season compared to the other.

Table 7.1 Summary of analysis of variance results using autumn and spring data

Index	Effect							
	Variance between samplers compared to within samplers		Variance between autumn and spring compared to variance between samplers		Variance between site and season compared to variance between samplers		Variance between sites compared to variance between samplers	
	(1) F value	(2) probability level	(3) F value	(4) probability level	(5) F value	(6) probability level	(7) F value	(8) probability level
TAXA	1.1934	0.294428	0.0711	0.791954	3.8397	0.002834	118.4650	<0.0000001
BMWP	1.1851	0.301301	1.4188	0.245247	3.3643	0.006261	117.8642	<0.0000001
ASPT	0.86164	0.646202	0.42709	0.519632	2.33658	0.039841	99.23650	<0.0000001
TAXA.EQI	1.1877	0.299133	0.0365	0.850175	3.8408	0.002829	110.6343	<0.0000001
BMWP.EQI	1.1715	0.312937	0.0033	0.954714	2.9872	0.012088	116.9457	<0.0000001
ASPT.EQI	0.9479	0.543925	3.60425	0.069721	1.95436	0.082369	90.34180	<0.0000001
Log TAXA	1.26235	0.241502	0.51416	0.480263	3.56977	0.004422	97.48569	<0.0000001
Log BMWP	1.1334	0.346967	0.3013	0.588153	3.2881	0.007136	106.3144	<0.0000001
Log ASPT	0.73065	0.795353	0.00072	0.978801	2.08318	0.064402	95.31119	<0.0000001
Log TAXA.EQI	1.25011	0.25032	2.00578	0.169549	3.46013	0.005318	84.92967	<0.0000001
Log BMWP.EQI	1.14845	0.333256	3.31116	0.081308	3.03893	0.011028	95.22703	<0.0000001
Log ASPT.EQI	0.7733	0.749026	5.99374	0.022045	2.00751	0.074410	93.18062	<0.0000001

The ANOVA for both seasons was a 12 x 2 (site x season) nested analysis with sample (random) nested within sampler, and sampler (random) nested within site.

Table 7.2 Summary of analyses of variance results, autumn data only

INDEX	EFFECT			
	Variance between samplers compared to within samplers		Variance between sites compared to variance between samplers	
	(1) F	(2) p-level	(3) F	(4) p-level
TAXA	0.84	0.611861	58.16411	<0.0000001
BMWP	0.65867	0.772173	69.62161	<0.0000001
ASPT	1.24941	0.308558	38.25613	<0.0000001
TAXA.EQI	1.0075	0.4718	43.48418	<0.0000001
BMWP.EQI	0.87524	0.581072	50.86769	<0.0000001
ASPT.EQI	1.39006	0.237056	35.03983	<0.0000001
Log TAXA	1.23342	0.317748	37.71750	<0.0000001
Log BMWP	1.42526	0.22164	37.45439	<0.0000001
Log ASPT	1.33184	0.264676	33.09945	<0.0000001
Log TAXA.EQI	1.21225	0.330261	31.15038	<0.0000001
Log BMWP.EQI	1.40611	0.229912	32.95475	<0.0000001
Log ASPT.EQI	1.40594	0.229986	32.75241	<0.0000001

The ANOVA for separate autumn data was a one way, 12 level (site) nested analysis with sample and sampler nested as for autumn and spring samples together.

Table 7.3 Summary of analyses of variance results, spring data only

INDEX	EFFECT			
	Variance between samplers compared to within samplers		Variance between sites compared to variance between samplers	
	(1) F	(2) p-level	(3) F	(4) p-level
TAXA	1.84564	0.097328	63.66248	<0.0000001
BMWP	2.15577	0.052782	55.54035	<0.0000001
ASPT	0.63198	0.794749	65.45861	<0.0000001
TAXA.EQI	1.5071	0.189287	73.52946	<0.0000001
BMWP.EQI	1.72939	0.122459	68.63893	<0.0000001
ASPT.EQI	0.67168	0.760982	60.50953	<0.0000001
Log TAXA	1.30791	0.276823	69.54645	<0.0000001
Log BMWP	0.83787	0.613734	84.68886	<0.0000001
Log ASPT	0.42553	0.937498	73.47512	<0.0000001
Log TAXA.EQI	1.3101	0.275688	63.32476	<0.0000001
Log BMWP.EQI	0.88676	0.571123	75.18643	<0.0000001
Log ASPT.EQI	0.45306	0.922847	70.90830	<0.0000001

The ANOVA for separate autumn data was a one way, 12 level (site) nested analysis with sample and sampler nested as for autumn and spring samples together.

8. Variability and discrimination of biotic indices

8.1 Introduction

In Chapter 7 the relative contribution of sampler and season effects to overall biotic index variability was described. In Chapter 8 these trends are described in more detail, focusing on differences in the variability of individual indices (TAXA, BMWP, ASPT and the EQIs of each of these), and differences in the variability of different sampling strategies.

8.1.1 Approach to the analysis

In the analysis the variability of each index was assessed using different combinations of samples chosen to reflect operational options available to the EA. These were: (i) autumn data alone, (ii) spring data alone, (iii) single- season autumn *or* spring data, (iv) dual-sample data (two samples from the same season) and (v) combined-seasons (two samples from different seasons).

Different sampling strategies (i.e. single samples, dual samples, combined samples) required a number of different combinations of samples to enable comparisons to be made. These are listed in Table 8.1.

The aims and implications of the analysis were

(i) to identify the *biotic indices* with the greatest utility for measuring water quality

(ii) to identify the *sampling* strategies which provided the the greatest utility (e.g. single- season, combined-season or dual samples)

The utility of an index or sampling strategy was assessed in terms of three statistics: standard deviation, coefficient of variation and F values from analysis of variance. Standard deviation and coefficient of variation are absolute and relative measures of *variability*. F values from analysis of variance were used to describe the ability of an index or combination of samples to *discriminate* between sites of different water quality - as measured by the various water quality indices. The use of each of these three statistical methods, together with a description of the 'ideal' features of an index is described in Box 8.1. A more detailed account of the statistical methods used in this report is given in Box 2.1.

8.1.2 Data analysis

As noted above, the variability of indices was measured in terms of standard deviation (SD) and the coefficient of variation (CV). Means, and upper and lower confidence limits for these are given in the relevant results tables, based on a Student t distribution.

Differences *between* seasons and sampling strategies with respect to individual indices were compared using a Wilcoxon signed rank test. This test allows for individual sites to differ in respect of variability and coefficient of variation and is more powerful than the use of simple confidence limits. Differences between indices *within* a season or sampling strategy were compared using a Scheffé multiple comparison within a repeated measures ANOVA at the $p=<0.05$ level. This is a conservative test of differences between groups of data.

A description of data analysis relating specifically to discrimination assessment is given in Section 8.6.1.

Table 8.1 Details of sample combinations for investigating variability of different seasons and sampling strategies

Single-sample comparisons between spring and autumn (Section 8.3)

A simple comparison of the variability and discrimination seen between and within these two seasons using:

- 48 samples from 12 sites in spring
- 48 samples from 12 sites in autumn

Dual-sample comparisons between spring and autumn (section 8.4)

A simple comparison of the variability and discrimination seen using dual samples in these two seasons.

- 24 dual samples from 12 sites in spring (each dual sample is cumulative sample from two single samples)
- 24 samples from 12 sites in autumn

Comparison of sampling strategies (section 8.5)

- 48 single samples from 12 sites in spring or autumn
- 48 dual samples from 12 sites in spring or autumn.
- 48 combined samples from 12 sites in spring and autumn (each combined sample is a cumulative sample from spring and autumn).

Box 8.1 Statistical approach to describing variation in this study

Standard deviation

Standard deviation (SD) is a measure of the variability of data. An index with low standard deviation will lead to estimates of water quality which are less likely to be dispersed over a number of water quality bands. Ideally, indeces should show low variability. For example, standard deviations of ASPT.EQI in this study are generally lower than those for TAXA.EQI or BMWP.EQI, reflecting the fact that measures of ASPT.EQI at the same site are less variable than those of TAXA.EQI or BMWP.EQI. Note that EQIs, unlike the indices (TAXA etc.) from which they are derived, would be expected to be similar in terms of absolute value.

Coefficient of variation

The coefficient of variation (CV) is a measure of relative variability (CV = standard deviation / mean). Since the standard deviation of many sets of data increases with the mean (as in this study - see Chapter 6) a relative measure of variation is useful. Ideally, indices shoul have a low CV. For example, if the SD of an index *does* increase with its mean, then the increase would at least be linear and therefore show a low CV. The use of CV also allows a comparison of indices, such as BMWP and ASPT which, unlike their EQIs have very different absolute values.

Discrimination

The discrimination of an index is measured here in terms of its F value in analyses of variance. Ideally, indices should have a relatively high F value indicating a high degree of discrimination between sites.

To take an example; when using ASPT as an index, if the F value for sites in *spring* is 80 (i.e. on average, there is 20 times greater variance *between sites* than *between the samples* at any site) and F value in *autumn* is only 40, then spring sites clearly show much greater variance between sites (or less variance within sites) than in autumn. Spring ASPT results will therefore show less overlap between (samples from) different sites, and conversely it is easier to separate sites into discrete water quality bands.

8.2 Differences in the variability of single-sample (spring and autumn) data

Standard deviations of coefficients of variation of the six indices at each site are given in Appendix tables 8.1 and 8.2. These Appendix tables are summarised for convenience in Table 8.2.

8.2.1 Differences in the variability of biotic indices in autumn and spring

Most indices showed a *non-significant* (Wilcoxon signed rank test) tendency to be slightly more variable in autumn than in spring. For example, BMWP had a mean standard deviation of 11.18 in autumn compared to 9.80 in spring (see Appendix tables 8.1 and 8.2, Column 2). These standard deviations were about 19% and 17% of the mean, respectively, measured as coefficients of variation (see Column 8 in Appendix tables 8.1 and 8.2).

For ASPT and ASPT EQI standard deviations and coefficients of variation were virtually the same in autumn and spring (see Columns 3, 6, 9 and 12 in Appendix tables 8.1 and 8.2). The mean standard deviation for ASPT in autumn was 0.22, compared to 0.24 in spring. These values represented 5.8% and 6.4% of the mean, respectively.

8.2.2 The variability of indices within season

Autumn

In autumn, the average standard deviations of TAXA and TAXA.EQI over all sites were 2.03 and 0.097, representing about 15% of the mean in both cases (see Appendix table 8.1, Columns 1, 4, 7 and 10). BMWP and BMWP.EQI had average standard deviations of 11.18 and 0.111, respectively. These values represented about 19% of the mean (see Appendix table 8.1, Columns 2, 5, 8 and 11). ASPT and ASPT.EQI had average standard deviations of 0.22 and 0.047, respectively. These values represented about 6% of the mean.

A Scheffé comparison test within a repeated measures ANOVA showed that there was no significant difference between TAXA and BMWP (and their respective EQIs), but that these indices did have significantly higher variability than ASPT and ASPT EQI.

Spring

In spring, the average standard deviations of TAXA and TAXA.EQI over all sites were 1.70 and 0.08, representing about 12% of the mean in both cases (see Appendix table 8.2, Columns 1, 4, 7 and 10). BMWP and BMWP.EQI had average standard deviations of 9.8 and 0.09, respectively. These values represented about 17% of the mean (see Appendix table 8.2, Columns 2, 5, 8 and 11). ASPT and ASPT.EQI had average standard deviations of 0.24 and 0.05, respectively. These values represented about 6.4% of the mean.

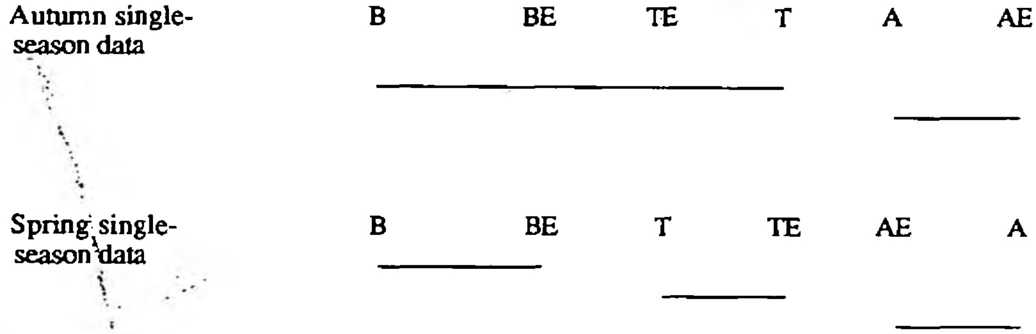
In spring there were significant differences between TAXA, BMWP and ASPT (and their respective EQIs) (Scheffé comparison test).

Differences in variability of indices

Taking both seasons together the analysis showed that overall there was a trend for BMWP and BMWP.EQI to be the most variable indices (i.e. they had the highest coefficient of variation). ASPT and ASPT.EQI were the least variable, with TAXA and TAXA.EQI intermediate. The relative variability of each biotic index in different seasons and for different survey strategies is shown in Figure 8.1 below. In the figure, the biotic index with the highest variability is given on the left, and the index with the lowest variability on the right. Bars link all indices which were similar. Indices *not* connected by a bar were statistically *significantly different* in the Scheffé test.

Key

A	= ASPT	B	=	BMWP	T	=	TAXA
AE	= ASPT.EQI	BE	=	BMWP.EQITE	TE	=	TAXA.EQI



Note: Bars link all indices which were similar. Indices *not* connected by a bar were statistically *significantly different*. For example in the first analysis, B and BE were not statistically separable from each other, but both had a statistically higher variability than TE etc.

Figure 8.1 Significance of differences in coefficients of variation: single-season data

8.3 Difference in the variability of dual-sample data

Differences between seasons using dual-sample data (*two* samples from the same season) were assessed. Dual-sample data from autumn was compared with dual-sample data from spring.

Standard deviation of coefficients of variation of the six indices at each site are given in Appendix tables 8.3 and 8.4. These Appendix tables are summarised for convenience in Table 8.2.

8.3.1 Differences in the variability of biotic indices in autumn and spring

As with the results from the single- sample analysis, dual samples were generally more variable in autumn than in spring. For example, the mean standard deviation for TAXA in autumn was 1.47 (representing 10% of the mean). In contrast, the mean standard deviation of TAXA in spring was 1.36, representing 8% of the mean (see Appendix tables 8.3 and 8.4, columns 1 and 7).

However all differences were, once again, small and not significant for any individual measure of water quality (Wilcoxon signed rank).

8.3.2 The variability of indices within season

As with single samples, both autumn and spring data sets showed a general trend in the data for BMWP and BMWP.EQI to be more variable than TAXA and TAXA.EQI. ASPT and ASPT.EQI were least variable. ASPT standard deviation was between 4% and 5% of the mean in the two seasons, compared with between 10% and 15% for BMWP.

However, in a Scheffé multiple comparison test, only the most extreme differences (i.e. BMWP compared to ASPT) were significant at the $p=<0.05$ level. The difference was significant in both seasons.

8.4 The effect of sampling strategy on variability

In the previous section differences in the variability of indices in different seasons were investigated. This section describes differences in variability caused by combining samples in different ways. Three combinations of sample (sampling strategies) are possible: single samples, dual samples and combined samples. These are compared pair wise in the following combinations:

	Single	Dual	Combined
Single	na	X	X
Dual	-	na	X
Combined	-	-	na

The three combinations of samples that were compared are shown in Appendix tables 8.5, 8.6 and 8.7 and summarised in Table 8.2. The single- sample data in these analyses were a random selection of samples from both spring and autumn.

8.4.1 Single-season samples compared with dual samples

Variability of all indices was lower using dual samples rather than single samples (see Appendix tables 8.5 and 8.6). However, the only difference that was statistically significant was between the coefficients of variation of TAXA.EQI with the two sampling strategies (Wilcoxon signed rank test). The dual-samples standard deviation for TAXA.EQI was 0.086 (which was 14% of the mean), compared to 0.118 for single-samples (17.7% of the mean) (see Appendix tables 8.5 and 8.6. columns 4 and 10).

8.4.2 Single-season samples compared with combined samples

All standard deviations and coefficients of variation were lower in combined samples than single samples. Differences between all indices, except TAXA, were significant (Wilcoxon signed rank test). The differences between the two sample combinations is illustrated by the values for BMWP. The mean standard deviation for single samples was 14.07 (22% of the mean) and for combined samples 9.80 (which was 14% of the mean) (see Appendix tables 8.5 and 8.7, columns 2 and 8). The standard deviation and CV of all the single samples is much higher than in spring or autumn alone (Appendix tables 8.1, 8.2 compared to 8.5). This increase in variation is due to the seasonal differences noted in Chapter 7. It might also be noted that the variability of any one season is also higher than that in combined-seasons (though much less so than for the spring or autumn data set).

8.4.3 Dual- and combined-season samples

The variability of all combined-sample indices was lower than for dual samples but no differences were statistically significantly (Wilcoxon signed rank test).

All coefficient of variations are lower for combined samples compared to dual samples though no individual water quality index is significantly lower using the Wilcoxon signed rank test.

8.4.4 Difference in variability between indices

Figure 8.2 shows the difference in variability between the three strategies above (single, dual and combined samples). In summary this shows the following trend of increasing variability:

Least variable	ASPT and ASPT.EQI
	TAXA and TAXA.EQI
Most variable	BMWP and BMWP.EQI

In all sample combinations the variability of ASPT and ASPT.EQI was significantly lower than all other water quality indices (Scheffé test within repeated measures ANOVA). No other pair-wise differences tested significantly.

Key

A = ASPT	B = BMWP	T = TAXA
AE = ASPT.EQI	BE = BMWP.EQI	TE = TAXA.EQI

Single-sample (spring or autumn)	B	BE	TE	T	A	AE
Dual sample (spring or autumn)	BE	B	TE	T	A	AE
Combined-season sample	BE	B	TE	T	AE	A

Figure 8.2 Comparison of sampling strategies

8.5 Summary of variability observations

8.5.1 Season

Results from both single and dual samples *suggest* that spring samples gave more consistent (less variable) estimates of water quality indices than autumn. This trend was evident for both standard deviation and for coefficient of variation. However no individual indices showed statistically significant differences between seasons.

8.5.2 Sampling strategy

For both spring and autumn there was a trend for standard deviation and coefficient of variation to be lowest in combined samples and highest in single samples, with dual samples intermediate. Within this series, however, statistically significant differences were mainly restricted to comparisons between the two extremes (single samples and combined samples). Sampling in a single season alone (either spring *or* autumn) reduces the variability of single samples, but not to the level of combined samples.

It should also be noted that during this survey, samplers were randomly assigned to sites in both seasons. At the time of the study, current practice in EA Thames Region was for the same sampler to visit the same site in any one year. This would be likely to increase the variability of *combined* samples compared to the results from this study.

8.5.3 Biotic indices

There is a consistent trend in the variability of the six indices. The indices are arranged in order of increasing variability:

Least variable	ASPT and ASPT.EQI
	TAXA and TAXA.EQI
Most variable	BMWP and BMWP.EQI

This trend was seen for all sampling strategies considered (single, dual, combined), and within both seasons. The occurrence of this series in all comparisons, suggests that we can be fairly confident of its validity.

Table 8.2 Standard deviations and coefficients of variation of indices (summary)

	Standard Deviation (SD)						Coefficient of variation (CV)					
	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Autumn single-samples												
Mean	2.03	11.18	0.22	0.097	0.111	0.047	14.89	19.33	5.77	14.87	19.32	5.85
Standard error of the mean	0.342	2.14	0.020	0.015	0.019	0.004	3.04	3.77	0.741	3.07	3.75	0.712
Spring single-samples												
Mean	1.70	9.80	0.243	0.079	0.091	0.050	12.15	16.93	6.43	12.14	17.05	6.44
Standard error of the mean	0.314	2.19	0.034	0.012	0.017	0.007	1.38	1.97	1.02	1.39	2.00	1.04
Autumn dual-samples												
Mean	1.47	8.07	0.199	0.058	0.064	0.042	10.09	14.54	5.33	10.05	14.62	5.57
Standard error of the mean	0.203	1.29	0.037	0.009	0.011	0.006	2.24	3..31	1.24	2.23	3.25	1.13
Spring dual-samples												
Mean	1.36	8.19	0.155	0.054	0.062	0.030	8.01	9.93	3.75	8.46	10.30	3.57
Standard error of the mean	0.319	2.46	0.026	0.010	0.017	0.006	1.27	1.80	0.639	1.29	1.91	0.639
Spring or autumn single-samples												
Mean	2.52	14.07	0.268	0.118	0.126	0.053	17.35	22.42	6.88	17.69	22.13	6.53
Standard error of the mean	0.462	2.81	0.026	0.018	0.023	0.009	2.86	3.44	0.710	2.92	3.95	1.12
Spring or autumn dual-samples												
Mean	2.21	12.66	0.210	0.086	0.098	0.042	13.92	18.06	5.29	14.04	18.24	5.24
Standard error of the mean	0.298	1.96	0.017	0.011	0.015	0.003	2.28	2.60	0.568	2.24	2.51	0.530
Combined-season samples												
Mean	1.82	9.80	0.159	0.070	0.074	0.033	10.95	1420	4.23	11.10	14.37	4.34
Standard error of the mean	0.297	1.90	0.023	0.010	0.012	0.004	2.08	2.72	0.847	2.06	2.69	0.850

8.6 Discrimination of biotic indices

As outlined at the beginning of the chapter, in assessing the utility of an index it is necessary to consider not only its variability but also its ability to discriminate. Ideally an index should have high discriminatory ability i.e. show a large separation (and little overlap) between the scores from any sites.

8.6.1 Methods of analysis

Techniques of analysis of variance used

The analyses of variance used to describe discrimination are one factor 12-level ANOVAs. In order to make the ANOVAs comparable (i.e. the same number of samples in each data set), ANOVAs were not nested sampler within site (cf. Chapter 7).

Analyses which use nested data remove some of the inherent variation in the data set because *mean* values are used. So, for example, the variability/bias in this study between a persons 1st and 2nd samples is averaged out. In ANOVAs which do not use nested values, this variability remains.
To investigate the robustness of the non-nested ANOVA results in this chapter, the results are compared with similar analyses in Chapter 7 which were carried out using nested analysis of samples.

Jackknife techniques

A jackknife technique was used to facilitate comparison of F values (from the ANOVAs). Comparison of data sets for each biotic index were undertaken using a Wilcoxon matched pairs test. Comparisons between the Jackknife Fs of indices within a data set were made using a Scheffé multiple comparison test within a repeated measures ANOVA.

ANOVAs were run using raw data and log transformed data, and the results compared to ensure reliability of results.

8.6.2 Results

Jackknife values for F are given in Appendix tables 8.8 to 8.14. These Appendix tables are summarised in Table 8.4 for convenience. Results of the Wilcoxon test are cited in the text and results from the Scheffé test are shown in Figure 8.3 and summarised in Table 8.3.

Single-season comparisons: differences between spring and autumn

The analysis showed that, in general, spring surveys showed more discrimination than autumn surveys (see Appendix tables 8.8 and 8.9). This was indicated by the generally higher F values in spring, compared to autumn (compare highlighted rows in Tables 8.8 and 8.9). For TAXA, TAXA.EQI, BMWP and BMWP.EQI, F values in spring were roughly double those in autumn. For example, the mean F value for BMWP, estimated using jackknife techniques, was 52.1 in autumn and 90.3 in spring (see Tables 8.8 and 8.9, column 2).

The difference between spring and autumn was significant for all indices with the exception of ASPT and ASPT.EQI. These results broadly parallel the results seen for this data set using a nested analysis.

Dual-sample comparisons: differences between spring and autumn

As with single samples, a comparison between spring and autumn data indicated that spring samples showed greater discrimination (see Appendix tables 8.10 and 8.11). Mean F values from jackknife analysis for TAXA, for example, were 73.6 in autumn, compared to 90.6 in spring. The trend was even more apparent with log transformed data. This trend for samples taken in spring to be more discriminatory was statistically significant for all biotic indices except untransformed BMWP.

Differences between single, dual and combined samples: the effect of survey strategy

A comparison of survey strategies (single, dual and combined samples) showed a clear trend in the data with the greatest discrimination in combined samples and the least discrimination using single samples (see Appendix tables 8.12, 8.13 and 8.14).

For example, for TAXA (untransformed data) mean F values estimated by jackknife analysis were 33.9, 44.6 and 110 for single, dual- and combined-season data, respectively (see column 1 in Appendix Tables 8.12, 8.13 and 8.14).

The jackknife F values for all water quality indices were statistically significantly different between the three data sets.

In addition the Jackknife Fs from combined-seasons data were higher than Jackknife Fs from autumn data alone, and broadly comparable with spring data alone.

Comparison of biotic indices

The relative discrimination of each biotic index in different seasons, and for different survey strategies, is shown in Figure 8.3. In the figure, the biotic index with the highest discrimination (highest Jackknife F value) is given on the left, and the index with the lowest discrimination on the right. Bars link all indices which were similar. Indices *not* connected by a bar were statistically *significantly different* in the Scheffé test ($p<0.05$).

The relative order of the biotic indices varied between different sampling strategies and different seasons. However, there was a distinct trend in the order in which the indices occurred.
Overall TAXA and BMWP usually gave better discrimination between sites than other indices, with TAXA the most consistent of the two. TAXA.EQI and BMWP.EQI were intermediate in their discriminatory ability, with BMWP.EQI usually the better of the two. ASPT and ASPT.EQI normally gave the poorest discrimination.

There was usually a difference between the results from the log transformed analysis and those from the raw analysis, but no trend was evident and the results are broadly comparable.

The discriminatory ability of the indices is summarised in Table 8.3 below. This places ability to discriminate into a 6 point scale (for the six indices TAXA, BMWP etc.), and notes the number of occurrences at a particular position. For example, BMWP was placed in the most discriminatory position by Scheffé test on 8 out of 14 occasions. Conversely, ASPT was placed in the *least* discriminatory position 7 out of 14 times.

Table 8.3 The ability of biotic indices to discriminate between sites: summary of Scheffé test results (see Figure 8.3)

Number of occurrences in position	1	2	3	4	5	6
	Most discrimination				Least discrimination	
TAXA	3	7	4	-	-	-
BMWP	8	2	2	2	-	-
ASPT	-	-	1	1	5	7
TAXA.EQI	-	4	-	5	2	3
BMWP.EQI	3	1	7	3	-	-
ASPT.EQI	-	-	-	3	7	4

Position 1 indicates the highest value of F.

8.6.3 Comparison of nested and non-nested analyses

In order to look at the robustness of the analysis, the results from the non-nested analysis in this chapter were compared with nested data analysed (using samples of different site numbers) in Chapter 7. The nested data shows similar relative discrimination for TAXA.EQI, BMWP.EQI and ASPT.EQI. However the positions of BMWP and TAXA in the nested analysis are variable, usually showing good discrimination in autumn and poor discrimination in spring.

Nested analysis also shows ASPT to have greater discrimination than the non-nested analysis suggests. This is because terms involving ASPT are more variable between samples compared to between person (because of the bias between 1st and 2nd samples) than terms involving TAXA and BMWP. However even in nested analyses ASPT is never the most discriminatory of the indices.

After considering the nested analysis, therefore, some caution should be placed on the interpretation of a strict order of discriminatory ability i.e. (TAXA, BMWP) > (TAXA.EQI, BMWP.EQI) > (ASPT, ASPT.EQI). However it does seem evident that ASPT, and particularly ASPT.EQI, are poorer than the other indices in their ability to discriminate between sites.

8.7 Overall conclusions and implications

The analysis showed that spring samples showed both less variation and more discrimination than autumn samples.

Samples *combined* from both spring and autumn data were less variable and also more discriminatory than other survey strategies (single and dual samples). Single samples showed most variation and least discrimination.

Thus a survey programme which uses two seasons of data is preferable to a dual-sample programme (i.e. two samples taken at the same site in one season). Single samples are the poorest option. However, if only one season's data can be used for water quality assessment, then spring is better than autumn. If spring data alone is used, then, from the results of this study, little discriminatory ability would be lost. This does not of course address the issue of changing water quality.

Results from the comparison of the biotic indices indicate that ASPT and ASPT EQIs are the least variable but also least discriminatory indices. TAXA, TAXA.EQI, ASPT and ASPT.EQI appear to be more discriminatory, but are also more variable.

A high ability of an index to discriminate between sites is a useful feature of that index; the index is, effectively, precise. That an index is precise, however, does not imply that it is accurate. The accuracy of a water quality index is its ability to measure water quality. It is quite possible that the least discriminatory of the indices in this study (ASPT and ASPT.EQI) are the most accurate indices in terms of measuring water quality, but it is not possible from this survey to come to any conclusions regarding this topic. It is, however, certainly erroneous to argue for the use of ASPT and ASPT.EQI purely on the grounds that they have low variability as judged by their coefficients of variation. In this study, in the Thames region, ASPT and ASPT.EQI have been shown to have less desirable statistical properties than the other four indices. Whether this pattern would be repeated in areas with more upland streams, and hence a higher possible range of ASPT values, it is not certain.

Key
A = ASPT
AE = ASPT.EQI
B = BMWP
BE = BMWP.EQI
T = TAXA
TE = TAXA.EQI

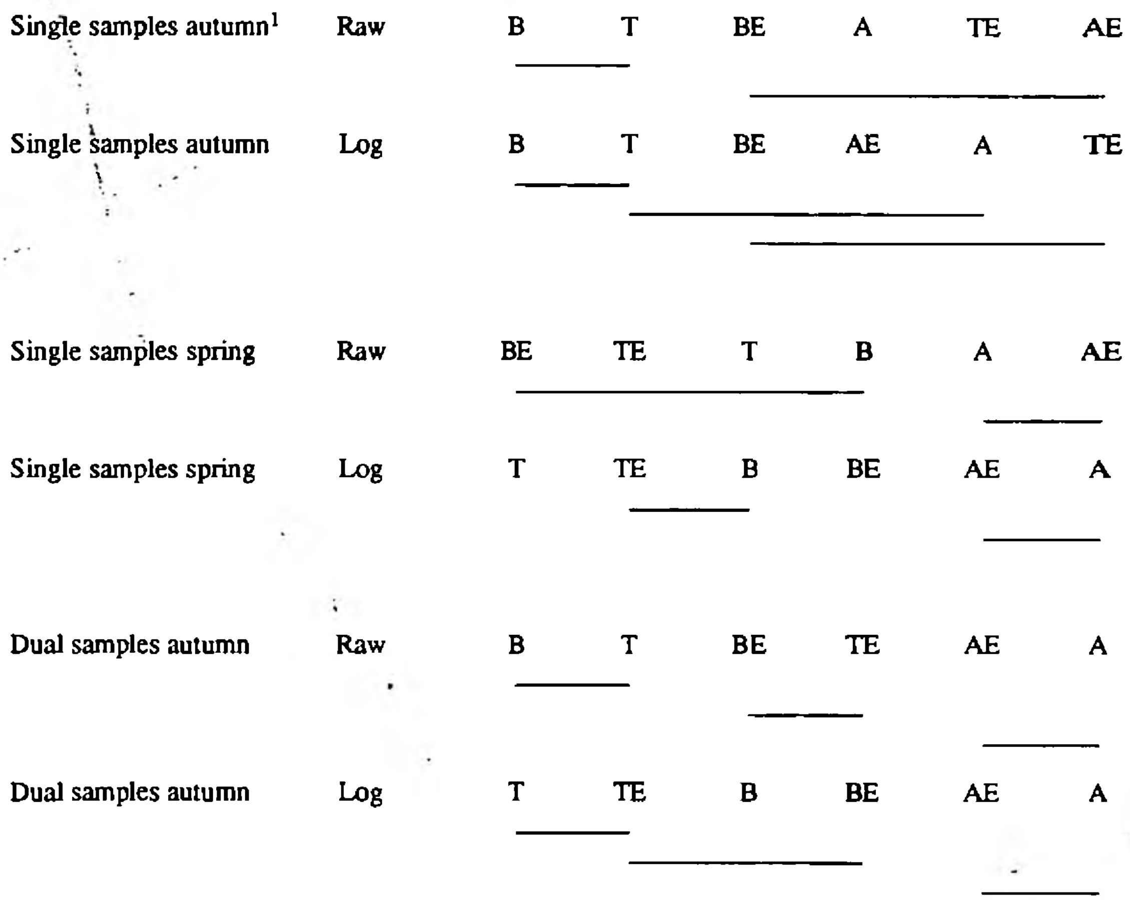


Figure 8.3 Comparison of the discrimination shown by biotic indices (using jackknife analysis)

[1] Note the biotic index with the highest discrimination (highest Jackknife F value) is given on the left. Bars link all indices which were similar. Indices not connected by a bar were statistically significantly different. For example in the first analysis, B and T were not statistically separable from each other, but B and T did have statistically higher discrimination than BE, A, TE and AE. BE, A, TE and AE were not statistically separable in terms of discrimination.

Key

A = ASPT
AE = ASPT.EQI
B = BMWP
BE = BMWP.EQI
T = TAXA
TE = TAXA.EQI

Dual samples spring	Raw	T	TE	BE	B	AE	A
Dual samples spring	Log	B	T	BE	TE	AE	A
Single samples spring or autumn	Raw	BE	B	T	TE	A	AE
Single samples spring or autumn	Log	B	T	A	BE	AE	TE
Dual samples Spring or autumn	Raw	B	T	BE	TE	AE	A
Dual samples spring or autumn	Log	B	BE	T	AE	A	TE
Combined samples spring and autumn.	Raw	BE	B	T	TE	AE	A
Combined samples spring and autumn.	Log	B	T	BE	AE	TE	A

Figure 8.3 Comparison of the discrimination shown by biotic indices (using jackknife analysis)

Table 8.4 Jackknife values of F (summary)

	Untransformed data						Log transformed data					
	TAXA (1)	BMWP (2)	ASPT (3)	TAXA EQI (4)	BMWP EQI (5)	ASPT EQI (6)	TAXA (7)	BMWP (8)	ASPT (9)	TAXA EQI (10)	BMWP EQI (11)	ASPT EQI (12)
Autumn single-samples												
Mean-jackknife F	52.08	52.09	44.19	43.53	47.02	42.96	43.95	47.37	39.72	35.97	41.37	40.54
Standard error of the mean	1.86	1.84	1.48	1.59	1.66	1.36	1.99	1.91	1.16	1.80	1.74	1.10
Spring single-samples												
Mean jackknife F	93.99	90.33	47.66	95.43	96.93	47.07	82.78	75.32	39.13	75.49	69.56	39.70
Standard error of the mean	5.67	7.13	2.25	5.08	5.96	2.16	2.05	2.22	1.86	2.12	2.14	1.79
Autumn dual-samples												
Mean F value	73.61	77.98	21.18	57.17	61.12	21.16	37.78	30.69	15.48	33.07	28.08	16.38
Standard error of the mean	2.51	2.39	0.680	2.14	2.13	0.655	2.91	1.84	0.503	2.59	1.60	0.445
Spring dual-samples												
Mean F value	90.56	72.89	48.48	85.88	76.33	50.63	95.28	102.03	48.08	77.72	87.39	53.65
Standard error of the mean	6.23	5.13	2.23	4.79	4.44	2.71	3.36	4.86	2.68	3.16	4.13	3.37
Spring or autumn single-samples												
Average jackknife F	39.73	42.13	36.22	38.11	47.08	35.09	33.28	35.98	32.73	28.53	32.60	32.22
Standard error of the mean	1.82	1.92	1.40	1.75	2.20	1.73	1.31	1.51	1.29	1.17	1.43	1.55
Spring or autumn dual-samples												
Mean F value	75.32	76.55	55.72	64.18	67.98	56.65	54.37	60.27	48.64	47.44	55.20	52.28
Standard error of the mean	2.86	2.34	1.73	2.57	2.34	1.93	2.20	2.40	1.44	2.04	2.32	1.61
Combined-season samples												
Mean jackknife F	109.68	124.90	89.88	101.36	128.24	91.37	78.71	85.28	66.58	68.49	78.08	68.73
Standard error of the mean	4.19	5.97	2.36	4.03	5.42	2.54	4.80	4.40	1.74	4.33	3.91	1.76

9. Summary of conclusions

9.1 The water quality of the sites in the study

This study was based on a stratified random selection of 12 river and stream sites representing the range of water qualities seen in the west area of EA Thames Region. As such, the results of this study, are only directly applicable to this area, and care must be exercised when drawing more general conclusions from the results. The 12 sites chosen were drawn from the four biological water quality bands of the 5M system (three sites each from bands A, B, C and D).

The results of the survey showed that, for some sites, water quality (assessed using the 5M system) appeared to have improved when compared to EA results for 1992/3. This was particularly evident for the sites with the poorest water quality. The reasons for this increase are not ascertainable from the present study. However some improvement might be expected by chance alone since, in the poorest quality sites, variation can *only* be expressed as improvement.

9.2 The importance of factors affecting the variability of water quality indices

9.2.1 Collection of invertebrate samples

The study was based on the variability of samples collected by four people. This was similar to the number of staff involved in routine biological survey work in the west area of Thames Region. All four samplers were experienced invertebrate biologists, but their amount of recent practice varied. One member of the team (R. Ashby-Crane) was a former NRA biologist whilst the other three had undertaken a variety of river survey work for EA contracts.

9.2.2 Within sampler variation

Individual sampler variability was investigated by examining the difference between duplicate samples taken consecutively by a person at each site. This sampling strategy also allowed investigation of an alternative sampling option, which is available to the EA but not currently used, i.e. collection of more than one sample on the same day (the so-called dual sampling strategy).

The results of the analysis showed that there was a significant overall trend (although it was individually significant for only R. Ashby-Crane) for the second sample collected on a visit to give higher scores than the first. This could have been a learning effect, but may also have been complicated by other psychological factors, e.g. a tendency to 'hurry through' the first sample or physical factors such as increased invertebrate drift after the first sample.

Between-sample bias does not have any significant implications for the EA's current monitoring programme which uses single samples from each site, in each season. However, should a dual sampling strategy be implemented by the EA, it would be advisable to monitor samples and samplers for bias. The samples of Biggs, Walker and Whitfield indicated that it should be possible to reduce this source of variability. The effectiveness of a dual sampling strategy is discussed further in section 9.6.

9.2.3 Differences between samplers

The analysis showed that there were statistically significant differences between the index results of different samplers. The most practised sampler (M. Whitfield) collected samples which gave significantly higher scores than D. Walker or J. Biggs. Those of R. Ashby-Crane were intermediate. M. Whitfield's samples gave scores which were, on average, 7% higher than other samplers. Conversely, J. Biggs (the least practised sampler) collected samples that gave significantly lower scores than his partner at any site (for example, up to 5% lower for BMWP.EQIs).

These differences between samplers can have a direct effect on the banding of sites. For example, taking the extremes of the study (i.e. the highest differences in bias seen between samplers) and applying this to the EQI bandings from Thames Regions' 1992 single-sample water quality data (with each of the most biased samplers taking half of the samples), 5% of BMWP.EQIs, 9% of TAXA.EQIs and 11% of ASPT.EQIs would be placed in a different band to that survey.

In practice, between sampler bias can be minimised in one of two ways:

(i) by estimating the degree of bias in an individual sampler's work and correcting to a 'true' value. Corrections of this sort could be made at a national or regional level.

(ii) by assigning samplers to sites randomly so that each person's biases were spread evenly throughout the database. Randomisation at a national level would not be practicable for the EA, but randomisation at a local level, at least between seasons, for combined-sample assessments, would seem feasible.

In practice EA biologists are generally aware of the potential for bias between samplers and attempt to correct it by informally comparing their results. However, in view of the inevitable differences between people it would also seem prudent to consider both regional randomisation and the more formal use of correction factors (periodically updated), to increase the reliability of biotic index results.

In terms of the variability of individual samplers, no sampler was found to be more variable than any other (note the distinction between variability and bias - some samplers collected samples that gave considerably higher/lower mean values but they were of similar variability). Thus, at least within this study, *differences* in the variability of samplers was not a significant effect.

9.2.4 The relative contribution of within- and between-sampler variation to variability

Unexpectedly, the analysis showed no difference between the overall variability of samples taken by one person and those taken by two or three people. However, this result was affected by the fact that a person's first sample generally contained more taxa than his/her second sample at a site. As a result of this bias the overall variation due to person and sampler is unlikely to have been underestimated in the study.

9.2.5 The relative contribution of season to variability

Variability due to systematic trends between season

Comparison of spring and autumn data across all sites showed that there was generally little difference between the biotic indices of *all* samples collected in autumn compared to *all* samples collected in spring. Overall this suggests that systematic variation between seasons did not contribute greatly to the amount of variation in the data set as a whole, and, in practical terms, there was no systematic tendency for indices to give higher water quality values in one season than another.

Variability due to non-systematic differences between seasons.

In contrast, most biotic indices did show a significant difference between their values at *any one* site in spring, and their values in autumn. In a sampling programme which collected samples in either spring *or* autumn, therefore, this non-systematic variation would lessen the ability to detect differences between water quality assessments at the sites.

Further work would be required to assess how much of the perceived seasonal changes in biotic index value at any site was due to an absolute water quality change (and in particular pollution), how much due to variation associated with sampling on another day (e.g. a day with poor weather), and how much due to other seasonally changing factors such as habitat availability, site homogeneity etc.

9.2.6 Variation between sites

As would be expected, the amount of variation in the analysis due to site is far greater than for any of the other effects (sample, person, season). For example, F values for log transformed indices in autumn, where the median value is about 37, suggest that, on average, 89% of variation in the whole data set is explained by site.

9.2.7 Conclusions and implications: the relative importance of factors affecting variability

Overall the analysis indicated the following relationship between factors causing variability at any site:

for combined-season data: site >> season > between samplers = within sampler

for single-season data: site >> between samplers = within sampler

9.3 Sampler variability when making RIVPACS assessments

Significant differences between the measurement of RIVPACS field variables (width, depth and substrate) made by different recorders occurred only for depth measurements. D.Walker recorded slightly greater (~3%) depths on average than his sampling partners and J.Biggs slightly less (~3%). This significant difference, however, was suggested only in nonparametric analyses and a 3% difference in depth on an average stream in this study corresponds to ~1.6 cm. Perhaps not surprisingly, then, there were no significant differences between samplers in the predicted RIVPACS variables (Pred. TAXA, Pred. BMWP and Pred. ASPT).

Coefficients of variation for width and depth were ~6% and ~8% respectively. The standard deviation of median particle size was ~0.22 ϕ units (it is not possible to calculate a meaningful coefficient of variation for median particle size).

RIVPACS predictions of TAXA, BMWP and ASPT were generally less variable than the observed values (or EQIs) of each index. Coefficients of variation were generally below 1% for predicted scores compared to 5% - 15% for observed values and EQIs.

Regression analysis showed that of the three field variables measured, variation in substrate assessments explained the greatest amount of variation in RIVPACS predictions, and thus had the greatest effect on the variability of predicted scores. IFE are currently working on the development of fixed predictions of RIVPACS variables so this source of variation may soon be eliminated. However, in the interim the results from this data set suggest that:

(i) the low variability of RIVPACS predictions should ensure that variation in field measurements is usually of relatively little practical significance.

(ii) most care in field measurements should be taken with substrate estimates; if the EA does not move to a policy of fixed RIVPACS variables, it would seem prudent to train operators in the consistent measurement of this variable.

9.4 Variability of indices: basic statistical relationships and the banding of EQIs

9.4.1 Changes in biotic index variability with increases in water quality

Estimates of TAXA and BMWP were significantly more variable at sites with high water quality. This reflected a basic statistical feature of the data; that the standard deviation of TAXA and BMWP, and their respective EQIs, increased with their mean value. In contrast, for ASPT and its EQI, there was a decrease in variability with mean (combined samples only). This finding, which reflects the nature of the indices (i.e. TAXA, TAXA.EQI, BMWP and BMWP.EQI have the properties of a sum whereas ASPT and ASPT.EQI have the properties of a mean), has implications for the development of banding systems, and is discussed further in Section 9.7.3.

9.4.2 Modelling variation in EQIs to predict the likelihood of a sample being in a particular EQI water quality band

At present, EA staff cannot predict the likelihood of any sample being correctly placed in a particular EQI water quality band. There are two ways in which such a prediction could be made.

The most reliable method (but also the most costly) would be for EA staff to collect more than one sample on each visit (as was done in this survey). This would enable basic statistics (mean, standard deviation, confidence limits) to be calculated for every sample, and, from this, the likelihood of samples being correctly placed in a particular water quality band could be assessed.

The second, more cost-effective, approach would be to model the variability of sites from a standard database of replicated samples. Data from the current study, was used to make a preliminary assessment of the viability of this second approach.

Modelling the likelihood of a site being correctly placed in a particular water quality band was a three stage process:

(i) modelling variation of standard deviations of EQIs using regression analysis
(ii) prediction of the standard deviations of EQIs using the regression equations
(iii) calculation of the probability of a sample being associated with a particular 5M band using standard deviations.

The derived estimates of variability were used to create a series of 'look-up' tables which give the likelihood of an individual sample being correctly associated with a particular water quality band.

9.4.3 Modelling the variability of an index which summarises the variability of three EQIs

As shown in Section 9.4.2 above, it is possible to predict the likelihood of a sample falling in its correct water quality band, *for individual EQIs*. Predicting the likelihood of sites being placed correctly within the *5M bands* is more problematic however because: (i) TAXA.EQI, BMWP.EQI and ASPT.EQI are interdependent variables, and (ii) the EQI banding system is categorical and not continuous. The conceptual framework for a computer model which can predict the likelihood of correct band placing has been developed for the report (see Chapter 6).

9.5 Comparison of the utility of biotic indices in terms of variability and discrimination

The utility of a biotic index for banding sites of different water quality depends on two factors: the variability of the index and, often forgotten, the discrimination of the index. Clearly the two are linked, since increased variability will reduce discrimination if other factors remain unchanged.

Of the indices, ASPT and ASPT.EQI were the least variable but also the least discriminatory. TAXA, TAXA.EQI, BMWP and BMWP.EQI were more variable, but also more discriminatory.

ASPT and ASPT.EQI are sometimes regarded as superior indices because of their lower variability. However, as noted above, in this data set, the low variability of ASPT and ASPT.EQI was countered by their poor discrimination, and overall the results indicate that for water quality banding, within the Thames region, ASPT and ASPT.EQI are statistically the *least* effective. An inherently poor statistical ability of an index to band sites can be compensated for by the structure of a banding system. In the 5M system, a large part of the range of BMWP.EQI and TAXA.EQI falls into a single band (band A). This reduces the apparent discrimination of these two indices, making ASPT.EQI appear to compare well with them when used solely within the 5M system.

Overall it is suggested that in further discussions of the design of new banding systems (and the choice of indices which those banding systems summarise) the EA should take an index's ability to discriminate into account.

9.6 Variability and discrimination of data using different sampling strategies (single samples, dual samples, combined samples)

9.6.1 TAXA, BMWP, ASPT and their respective EQIs

Across all the biotic indices there was a consistent, and usually significant, trend for combined-season samples to be both less variable and more discriminatory than single-season samples. Dual samples were intermediate for both parameters.

In terms of sampling strategy utility therefore: combined samples > dual samples > singles samples

9.6.2 5M bands

Similarly, using both the data from this study and the Thames data set as a whole, the likelihood of samples being assigned to the correct 5M band was greater for combined-season 5M bands than single-season.

9.6.3 Variability of the 5M band with water quality

The results of this study indicated that, using the 5M system, the water quality grading of sites varied depending on whether single- or combined-season data were used. In particular, *combined*-season data gave *lower* bandings than single-season samples in the 5M system. Thus at a site at which there was no change in water quality, combined-season samples would, on average, give lower water quality assessments than single-season samples. A bias of this sort is highly undesirable, especially where single- and combined-season data are likely to be compared. Its origin is likely to be a flaw in the design of 5M bands, which is based on setting band widths in relation to the variability of the RIVPACS data.

9.7 Practical implications of these analyses

9.7.1 Minimising sources of variability in the data set - practical implications

Sampler bias

In this survey there was a tendency for some samplers to record significantly higher (or lower) scores than others, as noted in section 9.2.3 above. The likelihood of a site being misclassified due to this bias could be reduced by (i) regional randomisation of samplers across seasons (combined samples only) (ii) investigation and use of a correction factor to equate the results of biologists with differing skills or experience

Seasonal variation

For most sites there was a significant, but non-systematic, difference between water quality values in consecutive seasons. If the results of single-season samples are to be widely used by the EA, further work would be advisable to assess how much of the perceived seasonal changes in biotic index values at any site was due to a real change in water quality and how much due to other potential effects, such as habitat availability or site homogeneity, or a simple effect of occasion (i.e. not a seasonal effect but due solely to a different day).

9.7.2 Sampling strategy (single samples vs. dual samples vs. combined samples) - practical implications

The utility of three different sampling strategies was assessed during this study (single samples, dual samples and combined samples). Standard RIVPACS assessment uses only single- and/or combined-season data. The viability of a dual sample (i.e. two samples taken on the same occasion) was assessed because:

(i) if the variability of water quality assessments was no greater using two samples collected on the same day than two samples in different seasons, there would be considerable savings in travel time and cost of the survey programme;

(ii) if more than one sample could be collected on the same day (rather than in different seasons) this would also make it possible to provide an estimate of the variability of the water quality assessment at a site. This would improve EA estimates of the likelihood of the site being correctly assigned to its water quality band.

The analyses undertaken here consistently showed that combined-season data was preferable in terms of both variability (low) and discrimination (high). In addition, combined samples were less likely to fall out of band in both the EQI and 5M systems, despite the correction for sampling variability inherent in the 5M banding system.

Dual samples consistently gave intermediate results in terms of variability. Thus the viability of using a dual sampling scheme depends on cost-benefit choices which weigh the gain in time/resources against a moderate increase in the probabilities of samples from a site falling out of band with no change in real water quality.

Preliminary results from this study suggest that a fourth water quality assessment strategy would also be worth assessing, namely the combined use of single samples from different seasons (i.e. comparative assessment of two/three *separate species lists* rather than one *combined* list from two (or three) seasons. Assessment of water quality could therefore be assessed on the basis of the mean EQIs of two samples (or mean or median of three samples) rather than the EQIs of combined samples.

This approach has a number of advantages:

(i) the reliability and discrimination of this method may be similar (or better) than for combined samples;

(ii) it systematises the use of both season's data, highlighting where water quality changes between one sample and another. Sample pairs with high standard deviations could be highlighted as unusual, or investigated further.

(iii) the mean/median of EQIs would be more sensitive to changes seen between samples than a combined sample. Taking an extreme example, if a pollution caused a total loss of invertebrates from a site, this would halve the means of all three EQIs. In contrast the combined EQIs would decrease by only 19%, 23% and 5% for TAXA.EQI, BMWP.EQI and ASPT.EQI, respectively.

9.7.3 Implications of the results from this study for the development of banding systems

The existing limitations of the 5M system have been recognised by EA and IFE and a new banding system is currently being implemented. However, it is worth noting the implications of the work described here for the 5M system, and the development of other banding systems.

The existing band widths used for the 5M system were set in relation to the variability of RIVPACS data. Thus (a) there are different banding levels for one season, two season and three seasons data and (b) the band widths are related only to the variability of the relatively unpolluted RIVPACS data set. As a result, in the Thames Region: (i) Single-season samples were often put into a lower water quality band than combined-season samples from the same site; (ii) *very few* sites were placed in the lower bands. Indeed, with the single-season 5M system it is impossible for sites to be placed in band D on the basis of BMWP.EQI and TAXA.EQI.

Ideally, band cut levels and widths should be set by relating the three EQIs to chemical water quality at sites. If, however, biotic indices cannot be related to a more absolute scale of pollution (BOD, ammonia etc.) then it *is* rational to use the variability of data to set band widths, and cut levels. The significant point is that band widths should be set in relation to the variability o*f actual* data (of varying water quality), rather than RIVPACS data derived from relatively unpolluted sites alone.

Data from this study shows that estimates of TAXA and BMWP and their respective EQIs were significantly more variable at sites with high water quality. In contrast, for ASPT and its EQI, there was a decrease in variability with mean (combined samples only). This suggests that for TAXA and BMWP EQIs the bands should be narrower for lower quality sites. It should be recognised however, that this could lead to the downgrading of a significant proportion of sites, in terms of their biological quality.

At present the 5M banding system represents three different water quality assessment systems: one for single-season data, one for two-season data, and one for three-season data, with single-season data giving the highest water quality assessments. In order to ensure that biotic indices band single-season and combined-season samples from the same sites into the same water quality class it is recommended that band widths for all three strategies (one-, two- and three-season) should be the same. Thus, although, the *certainty* of a site being placed in any band will differ between single- and combined samples (single samples should be less confidently placed in bands than combined samples) its *class* should, on average, not change according to the number of sample seasons used.

This study suggests that utility of a water quality index for banding sites depends not only on the indices' variability but also on its ability to allow discrimination of sites. The six main biotic indices (TAXA, BMWP, ASPT and their respective EQIs) have inherent differences in their variability and ability to discriminate. It is therefore recommended that both parameters, rather than just variability (as is more usual), are considered when the utility of biotic indices is assessed.

9.8 Summary of recommendations for future work

Recommendations for additional work which would be beneficial to confirm, extend or develop the findings presented in this report are outlined below.

- Collection of further samples/sites to increase the size of the data set. This would be essential to increase the confidence limits for predictions which assess the probability of a sample falling out of EQI band.
- Extension of the survey across the UK to include sites with a wider range of water chemistry, pollutant types and macroinvertebrate community types.
- Comparison and correlation between biotic index scores and chemical water quality parameters.
- Further development of the model to predict the probability of a site classifying in its correct 5M band (or equivalent).
- Comparative assessment of a fourth sampling strategy: i.e. using the comparison between single samples from different two (or three) seasons as opposed to one *combined* list from two (or three) seasons.
- Further investigation of the reasons that index scores often change non-systematically between seasons (is this due to a real change in water quality to some form of seasonal change within the river?)
- Repeat visits to sites *within* a season, and 'duplicate' sampling of adjacent river reaches to extend our understanding of the causes of sample variation.

10. References

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Appendix table 2.1 Sampling programme structure: autumn samples

Site (1)	1992 5 M Band (2)	Season (3)	Sampler (4)	Sample order (5)	Sample name (6)	NRA RIVPACS code (7)
Bow Brook	A	Autumn	JB	1	BOWB JB1A	1930550
Bow Brook	A	Autumn	JB	2	BOWB JB2A	
Bow Brook	A	Autumn	DW	1	BOWB DW1A	1930551
Bow Brook	A	Autumn	DW	2	BOWB DW2A	
River Thames	A	Autumn	DW	1	THAM DW1A	1930552
River Thames	A	Autumn	DW	2	THAM DW2A	
River Thames	A	Autumn	RA	1	THAM RA1A	1930553
River Thames	A	Autumn	RA	2	THAM RA2A	
River Coln	A	Autumn	DW	1	COLN DW1A	1930554
River Coln	A	Autumn	DW	2	COLN DW2A	
River Coln	A	Autumn	MW	1	COLN MW1A	1930555
River Coln	A	Autumn	MW	2	COLN MW2A	
The Cut	B	Autumn	JB	1	CUT. JB1A	1930556
The Cut	B	Autumn	JB	2	CUT. JB2A	
The Cut	B	Autumn	RA	1	CUT. RA1A	1930557
The Cut	B	Autumn	RA	2	CUT. RA2A	
Lydiard Stream	B	Autumn	DW	1	LYDI DW1A	1930558
Lydiard Stream	B	Autumn	DW	2	LYDI DW2A	
Lydiard Stream	B	Autumn	MW	1	LYDI MW1A	1930559
Lydiard Stream	B	Autumn	MW	2	LYDI MW2A	
Halfacre Brook	B	Autumn	JB	1	HALF JB1A	1930560
Halfacre Brook	B	Autumn	JB	2	HALF JB2A	
Halfacre Brook	B	Autumn	RA	1	HALF RA1A	1930561
Halfacre Brook	B	Autumn	RA	2	HALF RA2A	
Roundmoor Ditch	C	Autumn	RA	1	ROUN RA1A	1930562
Roundmoor Ditch	C	Autumn	RA	2	ROUN RA2A	
Roundmoor Ditch	C	Autumn	MW	1	ROUN MW1A	1930563
Roundmoor Ditch	C	Autumn	MW	2	ROUN MW2A	
Summerstown Ditch	C	Autumn	MW	1	SUMM MW1A	1930564
Summerstown Ditch	C	Autumn	MW	2	SUMM MW2A	
Summerstown Ditch	C	Autumn	JB	1	SUMM JB1A	1930565
Summerstown Ditch	C	Autumn	JB	2	SUMM JB2A	
Crendon Stream	C	Autumn	JB	1	CREN JB1A	1930566
Crendon Stream	C	Autumn	JB	2	CREN JB2A	
Crendon Stream	C	Autumn	RA	1	CREN RA1A	1930567
Crendon Stream	C	Autumn	RA	2	CREN RA2A	
Wheatley Ditch	D	Autumn	DW	1	WHEA DW1A	1930568
Wheatley Ditch	D	Autumn	DW	2	WHEA DW2A	
Wheatley Ditch	D	Autumn	MW	1	WHEA MW1A	1930569
Wheatley Ditch	D	Autumn	MW	2	WHEA MW2A	
Crawters Brook	D	Autumn	MW	1	CRAW MW1A	1930570
Crawters Brook	D	Autumn	MW	2	CRAW MW2A	
Crawters Brook	D	Autumn	DW	1	CRAW DW1A	1930571
Crawters Brook	D	Autumn	DW	2	CRAW DW2A	
Catherine Bourne	D	Autumn	DW	1	CATH DW1A	1930572
Catherine Bourne	D	Autumn	DW	2	CATH DW2A	
Catherine Bourne	D	Autumn	JB	1	CATH JB1A	1930573
Catherine Bourne	D	Autumn	JB	2	CATH JB2A	

Appendix table 2.1 Sampling programme structure: spring samples

Site (1)	1993 5 M Band (2)	Season (3)	Sampler (4)	Sample order (5)	Sample name (6)	NRA RIVPACS code (7)
Bow Brook	A	Spring	JB	1	BOWB JB1S	1940179
Bow Brook	A	Spring	JB	2	BOWB JB2S	
Bow Brook	A	Spring	DW	1	BOWB DW1S	1940180
Bow Brook	A	Spring	DW	2	BOWB DW2S	
River Thames	A	Spring	RA	1	THAM RA1S	1940181
River Thames	A	Spring	RA	2	THAM RA2S	
River Thames	A	Spring	JB	1	THAM JB1S	1940182
River Thames	A	Spring	JB	2	THAM JB2S	
River Coln	A	Spring	JB	1	COLN JB1S	1940183
River Coln	A	Spring	JB	2	COLN JB2S	
River Coln	A	Spring	RA	1	COLN RA1S	1940184
River Coln	A	Spring	RA	2	COLN RA2S	
The Cut	B	Spring	MW	1	CUT. MW1S	1940186
The Cut	B	Spring	MW	2	CUT. MW2S	
The Cut	B	Spring	RA	1	CUT. RA1S	1940185
The Cut	B	Spring	RA	2	CUT. RA2S	
Lydiard Stream	B	Spring	JB	1	LYDI JB1S	1940188
Lydiard Stream	B	Spring	JB	2	LYDI JB2S	
Lydiard Stream	B	Spring	DW	1	LYDI DW1S	1940187
Lydiard Stream	B	Spring	DW	2	LYDI DW2S	
Halfacre Brook	B	Spring	JB	1	HALF JB1S	1940189
Halfacre Brook	B	Spring	JB	2	HALF JB2S	
Halfacre Brook	B	Spring	MW	1	HALF MW1S	1940190
Halfacre Brook	B	Spring	MW	2	HALF MW2S	
Roundmoor Ditch	C	Spring	MW	1	ROUN MW1S	1940192
Roundmoor Ditch	C	Spring	MW	2	ROUN MW2S	
Roundmoor Ditch	C	Spring	DW	1	ROUN DW1S	1940191
Roundmoor Ditch	C	Spring	DW	2	ROUN DW2S	
Summerstown Ditch	C	Spring	JB	1	SUMM JB1S	1940194
Summerstown Ditch	C	Spring	JB	2	SUMM JB2S	
Summerstown Ditch	C	Spring	DW	1	SUMM DW1S	1940193
Summerstown Ditch	C	Spring	DW	2	SUMM DW2S	
Crendon Stream	C	Spring	MW	1	CREN MW1S	1940196
Crendon Stream	C	Spring	MW	2	CREN MW2S	
Crendon Stream	C	Spring	JB	1	CREN JB1S	1940195
Crendon Stream	C	Spring	JB	2	CREN JB2S	
Wheatley Ditch	D	Spring	JB	1	WHEA JB1S	1940197
Wheatley Ditch	D	Spring	JB	2	WHEA JB2S	
Wheatley Ditch	D	Spring	MW	1	WHEA MW1S	1940198
Wheatley Ditch	D	Spring	MW	2	WHEA MW2S	
Crawters Brook	D	Spring	RA	1	CRAW RA1S	1940200
Crawters Brook	D	Spring	RA	2	CRAW RA2S	
Crawters Brook	D	Spring	MW	1	CRAW MW1S	1940199
Crawters Brook	D	Spring	MW	2	CRAW MW2S	
Catherine Bourne	D	Spring	MW	1	CATH MW1S	1940202
Catherine Bourne	D	Spring	MW	2	CATH MW2S	
Catherine Bourne	D	Spring	DW	1	CATH DW1S	1940201
Catherine Bourne	D	Spring	DW	2	CATH DW2S	

Appendix table 2.2 Combined sample pairings

Site	Autumn sample	Spring sample paired with autumn sample to give combined season sample
Bow Brook	BOWB JB1A	BOWB DW2S
Bow Brook	BOWB JB2A	BOWB DW1S
Bow Brook	BOWB DW1A	BOWB JB1S
Bow Brook	BOWB DW2A	BOWB JB2S
River Thames	THAM DW1A	THAM RA2S
River Thames	THAM DW2A	THAM JB2S
River Thames	THAM RA1A	THAM RA1S
River Thames	THAM RA2A	THAM JB1S
River Coln	COLN DW1A	COLN JB1S
River Coln	COLN DW2A	COLN JB2S
River Coln	COLN MW1A	COLN RA2S
River Coln	COLN MW2A	COLN RA1S
The Cut	CUT. JB1A	CUT. RA2S
The Cut	CUT. JB2A	CUT. RA1S
The Cut	CUT. RA1A	CUT. MW1S
The Cut	CUT. RA2A	CUT. MW2S
Lydiard Stream	LYDI DW1A	LYDI DW2S
Lydiard Stream	LYDI DW2A	LYDI JB2S
Lydiard Stream	LYDI MW1A	LYDI DW1S
Lydiard Stream	LYDI MW2A	LYDI JB1S
Halfacre Brook	HALF JB1A	HALF JB2S
Halfacre Brook	HALF JB2A	HALF MW1S
Halfacre Brook	HALF RA1A	HALF MW2S
Halfacre Brook	HALF RA2A	HALF JB1S
Roundmoor Ditch	ROUN RA1A	ROUN DW2S
Roundmoor Ditch	ROUN RA2A	ROUN MW2S
Roundmoor Ditch	ROUN MW1A	ROUN MW1S
Roundmoor Ditch	ROUN MW2A	ROUN DW1S
Summerstown Ditch	SUMM MW1A	SUMM DW1S
Summerstown Ditch	SUMM MW2A	SUMM JB2S
Summerstown Ditch	SUMM JB1A	SUMM DW2S
Summerstown Ditch	SUMM JB2A	SUMM JB1S
Crendon Stream	CREN JB1A	CREN MW2S
Crendon Stream	CREN JB2A	CREN MW1S
Crendon Stream	CREN RA1A	CREN JB2S
Crendon Stream	CREN RA2A	CREN JB1S
Wheatley Ditch	WHEA DW1A	WHEA JB1S
Wheatley Ditch	WHEA DW2A	WHEA MW2S
Wheatley Ditch	WHEA MW1A	WHEA JB2S
Wheatley Ditch	WHEA MW2A	WHEA MW1S
Crawters Brook	CRAW MW1A	CRAW RA2S
Crawters Brook	CRAW MW2A	CRAW MW1S
Crawters Brook	CRAW DW1A	CRAW MW2S
Crawters Brook	CRAW DW2A	CRAW RA1S
Catherine Bourne	CATH DW1A	CATH DW1S
Catherine Bourne	CATH DW2A	CATH MW1S
Catherine Bourne	CATH JB1A	CATH MW2S
Catherine Bourne	CATH JB2A	CATH DW2S

Appendix table 2.3 Taxa recorded for assessment of TAXA, BMWP and ASPT, and example calculation.

SITE: Catherine BourneAutumn 1993: JB sample 1

Ten points

Siphlonuridae	
Heptageniidae	
Leptophlebiidae	
Ephemerellidae	
Potamanthidae	
Ephemeridae	
Taeniopterygidae	
Leuctridae	
Capniidae	
Perlodidae	
Perlidae	
Chloroperlidae	
Aphelocheiridae	
Phryganeidae	
Molannidae	
Beraeidae	
Odontoceridae	
Leptoceridae	
Goeridae	
Lepidostomatidae	
Brachycentridae	
Sericostomatidae	
No. Taxa scoring 10 points	0

Eight points

Astacidae	
Lestidae	
Agriidae	
Gomphidae	
Cordulegasteridae	
Aeshnidae	
Corduliidae	
Libellulidae	
Psychomyiidae & Ecnomidae	
Philopotamidae	
No. Taxa scoring 8 points	0

Seven points

Caenidae	
Nemouridae	
Rhyacophilidae & Glossosomatidae	
Polycentropodidae	
Limnephilidae	present
No. of taxa scoring 7 points	1

Six points

Neritidae	
Viviparidae	
Ancylidae & Acroloxidae	
Hudroptilidae	
Unionidae	
Corophiidae	
Gammaridae	present
Platycnemididae	
Coenagrionidae	
No. of taxa scoring 6 pints	1

Five points

Mesoveliidae	
Hydrometridae	
Gerridae	
Nepidae	
Naucoridae	
Notonectidae	
Pleidae	
Corixidae	present
Haliplidae	present
Hygrobiidae	
Dytiscidae &Noteridae	present
Gyrinidae	
Hydrophilidae &Hydraenidae	
Clambidae	
Scirtidae	
Dryopidae	
Elmidae	
Chrysomelidae	
Curculionidae	
Hydropsychidae	
Tipulidae	
Simuliidae	present
Planariidae &Dugesiidae	
Dendrocoelidae	
No. of taxa scoring 5 points	4

Four points

Baetidae	
Sialidae	present
Piscicolidae	
No. of taxa scoring 4 points	1

Three points

Valvatidae	
Hydrobiidae	present
Lymnaeidae	present
Physidae	
Planorbidae	
Sphaeriidae	
Glossiphoniidae	present
Hirudidae	
Erpobdellidae	present
Asellidae	present
No. of taxa scoring 3 points	5

Two points

Chironomidae	present
No. of taxa scoring 2 points	1

One point

Oligochaeta	present
No. of taxa scoring 1 point	1

Total taxa TAXA	14
BMWP score	55
ASPT	3.93

Appendix table 3.1 **Macroinvertebrates recorded in Environment Agency variability study**

Site	Bow Brook							
Season	Autumn				Spring			
Sampler	JB		DW		JB		DW	
Sample	1	2	1	2	1	2	1	2
Planariidae & Dugesiidae	-	-	-	-	-	-	-	-
Dendrocoelidae	-	2	-	1	-	-	-	-
Neritidae	-	-	-	-	-	-	-	-
Valvatidae	-	112	8	12	-	14	14	1
Hydrobiidae	1	11	1	4	-	-	2	1
Bithyniidae	6	5	4	3	-	2	6	1
Physidae	2	4	-	1	-	-	-	-
Lymnaeidae	-	10	1	-	1	1	-	1
Planorbidae	196	588	197	358	34	25	145	5
Ancylidae & Acroloxidae	1	2	-	14	1	1	1	1
Unionidae	5	3	1	-	-	4	2	1
Sphaeriidae	16	1	16	4	-	4	3	2
Oligochaeta	144	40	80	40	240	35	196	240
Piscicolidae	1	-	-	-	-	-	2	-
Glossiphoniidae	-	-	2	4	1	3	7	3
Erpobdellidae	2	5	7	3	4	6	4	1
Asellidae	176	368	192	504	58	34	300	11
Corophiidae	-	-	-	-	-	-	-	-
Gammaridae and Crangonyctidae	54	500	141	38	79	87	393	37
Baetidae	1	4	1	1	4	8	16	-
Heptageniidae	-	-	-	-	-	-	-	-
Leptophlebiidae	-	-	-	-	-	4	2	-
Ephemeridae	9	15	4	5	4	6	8	8
Ephemerellidae	-	-	-	-	-	-	-	-
Caenidae	-	32	-	64	3	20	97	3
Nemouridae	-	-	-	-	1	-	-	-
Platycnemididae	1	1	-	-	5	-	-	-
Coenagriidae	24	5	29	15	15	2	6	6
Calopterygidae								
Gomphidae	-	-	-	-	-	-	-	-
Hydrometridae	-	-	-	-	-	-	-	-
Gerridae	-	-	-	-	-	-	-	-
Nepidae	-	-	-	-	-	1	-	-
Notonectidae	1	1	1	4	-	-	-	-
Corixidae	13	47	15	81	2	6	6	9
Haliplidae	-	1	1	-	3	-	2	-
Dytiscidae & Noteridae	2	9	4	17	8	3	6	1
Gyrinidae	-	-	-	-	-	-	-	-
Hydrophilidae and Hydraenidae	1	-	-	-	1	-	10	1
Elmidae	-	2	-	-	1	8	56	5
Helodidae	-	-	-	-	-	-	-	-
Dryopidae	-	-	-	-	-	-	-	-
Curculionidae	-	-	-	-	-	-	-	-
Sialidae	144	181	145	71	68	142	67	63
Rhyacophilidae & Glossosomatidae	-	-	-	-	-	-	-	-
Hydroptilidae	-	-	-	-	-	1	-	-
Psychomyiidae	-	-	-	-	1	-	-	-
Polycentropodidae	-	-	-		-	-	-	-
Hydropsychidae	-	-	-	-	-	4	1	1
Phryganeidae	-	-	-	1	-	1	-	-
Brachycentridae	-	-	-	-	-	-	-	-
Limnephilidae	-	-	-	1	1	21	5	2
Goeridae	-	-	-	-	-	-	-	-
Beraeidae	-	-	-	-	-	-	-	-
Sericostomatidae	-	-	-	-	-	-	-	-
Molannidae	-	-	-	-	-	-	-	-
Leptoceridae	-	8	-	2	5	1	9	3
Chironomidae	497	430	352	124	492	241	1028	449
Tipulidae	-	2	-	-	-	-	5	-
Simuliidae	-	-	-	-	1	-	-	1

Appendix table 3.1 **Macroinvertebrates recorded in Environment Agency variability study (continued)**

Site	River Thames							
Season	Autumn				Spring			
Sampler	DW		RA		RA		JB	
Sample	1	2	1	2	1	2	1	2
Planariidae & Dugesiidae	-	1	-	-	1	1	1	2
Dendrocoelidae	-	-	-	-	-	2	-	1
Neritidae	1	2	1	-	1	12	3	2
Valvatidae	5	52	4	48	64	32	40	176
Hydrobiidae	-	2	2	32	5	3	4	36
Bithyniidae	3	48	11	32	4	52	8	116
Physidae	5	16	-	4	-	8	4	3
Lymnaeidae	4	14	5	3	1	4	2	4
Planorbidae	13	42	22	35	2	1	3	5
Ancylidae & Acroloxidae	-	-	-	-	-	-	-	-
Unionidae	-	-	1	2	2	1	1	-
Sphaeriidae	7	76	3	28	2	9	4	24
Oligochaeta	13	3	9	9	85	11	45	20
Piscicolidae	-	2	-	-	-	-	-	-
Glossiphoniidae	1	9	-	4	3	5	4	10
Erpobdellidae	-	1	2	12	2	3	1	1
Asellidae	362	224	1001	252	460	80	308	242
Corophiidae	5	1	-	4	24	2	24	3
Gammaridae and Crangonyctidae	296	140	190	68	50	52	175	52
Baetidae	1	-	-	-	-	-	-	-
Heptageniidae	-	-	-	-	-	-	1	-
Leptophlebiidae	-	-	-	-	-	-	-	-
Ephemeridae	5	2	3	4	-	7	3	1
Ephemerellidae	-	-	-	-	-	-	-	-
Caenidae	4	5	2	6	12	-	20	1
Nemouridae	-	-	-	-	-	-	-	-
Platycnemididae	-	-	-	-	-	-	-	-
Coenagriidae	1	1	-	4	1	-	-	-
Calopterygidae								
Gomphidae	-	-	-	2	-	-	-	-
Hydrometridae	-	1	-	-	-	-	-	-
Gerridae	-	-	-	-	-	-	-	-
Nepidae	-	-	-	-	-	-	-	-
Notonectidae	-	-	-	-	-	-	-	-
Corixidae		-	-	1	1	-	2	1
Haliplidae	-	-	-	-	-	-	1	1
Dytiscidae & Noteridae	-	1	1	1	-	-	3	-
Gyrinidae	-	1	2	1	-	-	-	-
Hydrophilidae and Hydraenidae	-	-	2	-	-	-	1	1
Elmidae	-	1	-	-	-	-	2	2
Helodidae	-	-	-	-	-	-	-	-
Dryopidae	-	-	-	1	-	-	-	-
Curculionidae	1	-	-	-	-	-	-	-
Sialidae	4	3	14	6	-	13	4	1
Rhyacophilidae & Glossosomatidae	-	-	-	-	-	-	-	-
Hydroptilidae	-	-	-	-	-	-	2	-
Psychomyiidae	-	1	-	1	-	1	1	2
Polycentropodidae	1	4	-	5	1	1	3	1
Hydropsychidae	-	1	-	-	-	-	-	-
Phryganeidae	-	-	-	-	-	-	-	-
Brachycentridae	-	-	-	-	-	-	-	-
Limnephilidae	3		-	3	17	7	10	10
Goeridae	-	-	-	-	-	-	-	-
Beraeidae	-	-	-	-	-	-	-	-
Sericostomatidae	-	-	-	-	-	-	-	-
Molannidae	-	-	1	5	-	-	3	-
Leptoceridae	5	13	4	4	13	4	46	4
Chironomidae	78	94	240	243	110	220	152	28
Tipulidae	2	11	17	3	1	3	1	-
Simuliidae	-	-	-	-	-	1	2	1

Appendix table 3.1 **Macroinvertebrates recorded in Environment Agency variability study (continued)**

Site	River Coln							
Season	Autumn				Spring			
Sampler	DW		MW		JB		RA	
Sample	1	2	1	2	1	2	1	2
Planariidae & Dugesiidae	1	1	-	-	-	1	-	-
Dendrocoelidae	-	-	-	-	-	-	-	-
Neritidae	-	-	-	-	-	-	-	-
Valvatidae	3	5	16	5	3	12	1	1
Hydrobiidae	144	53	32	40	19	144	8	368
Bithyniidae	-	-	-	-	-	-	-	-
Physidae	-	-	2	-	-	2	1	4
Lymnaeidae	-	1	2	6	-	-	-	2
Planorbidae	3	2	44	6	6	3	1	2
Ancylidae & Acroloxidae	29	28	32	6	20	8	5	6
Unionidae	-	-	-	-	-	-	-	-
Sphaeriidae	32	15	12	2		18	-	4
Oligochaeta	300	40	100	44	4222	11	2009	11
Piscicolidae	4	1	6	1	3	3	5	3
Glossiphoniidae	280	20	39	6	50	44	16	52
Erpobdellidae	1	1	-	-	2	-	-	1
Asellidae	-	-	-	1	-	-	1	1
Corophiidae	-	-	-	-	-	-	-	-
Gammaridae and Crangonyctidae	8640	2000	2912	3100	2572	2752	2091	3088
Baetidae	30	32	312	92	228	152	360	256
Heptageniidae	-	-	-	-	1	1	1	1
Leptophlebiidae	1	2	4	2	4	-	-	-
Ephemeridae	31	34	68	46	86	88	35	96
Ephemerellidae	-	1	-	-		-	8	-
Caenidae	5	1	1	7	-	3	12	-
Nemouridae	-	1	-	-	8	5	76	4
Platycnemididae	-	-	-	-	-	-	-	-
Coenagriidae	-	-	-	1	-	-	-	-
Calopterygidae								
Gomphidae	-	-	-	-	-	-	-	-
Hydrometridae	-	-	1	-	-	-	-	-
Gerridae	-	-	-	-	-	-	-	-
Nepidae	-	-	-	-	-	-	-	-
Notonectidae	-	-	-	1	-	-	-	-
Corixidae	6	1	1	4	1	1	1	-
Haliplidae	2	3	3	2	-	1	2	-
Dytiscidae & Noteridae	12	4	13	5	1	-	1	-
Gyrinidae	3	1	-	-	20	1	-	1
Hydrophilidae and Hydraenidae	2	-	3	2	-	1	-	1
Elmidae	337	14	23	108	212	368	102	256
Helodidae	-	-	-	-	-	-	-	-
Dryopidae	-	1	-	-	12	2	14	6
Curculionidae	-	-	-	-	-	-	-	-
Sialidae	1	-	-	-	-	-	-	-
Rhyacophilidae & Glossosomatidae	456	32	5	5	336	294	108	492
Hydroptilidae	-	1	-	-	48	-	-	3
Psychomyiidae	-	-	-	-	-	-	-	-
Polycentropodidae	-	-	-	-	-	-	-	1
Hydropsychidae	33	23	16	7	92	8	44	13
Phryganeidae	-	-	-	-	-	-	-	-
Brachycentridae	-	1	-	-	8	2	-	16
Limnephilidae	8	5	118	25	401	77	526	266
Goeridae	1124	168	96	45	240	696	328	752
Beraeidae	-	-	2	-	-	-	-	-
Sericostomatidae	5	8	1	-	48			
Molannidae	-	-	-	-	-	-	-	-
Leptoceridae	-	-	-	-	16	1	-	2
Chironomidae	10	1	6	28	40	10	32	15
Tipulidae	2	6	2	1	5	3	-	1
Simuliidae	-	4	10	1	1005	1	324	1

Appendix table 3.1 Macroinvertebrates recorded in Environment Agency variability study (continued)

<table>
<tr><th>Site</th><th colspan="8">The Cut</th></tr>
<tr><th>Season</th><th colspan="4">Autumn</th><th colspan="4">Spring</th></tr>
<tr><th>Sampler</th><th colspan="2">JB</th><th colspan="2">RA</th><th colspan="2">MW</th><th colspan="2">RA</th></tr>
<tr><th>Sample</th><th>1</th><th>2</th><th>1</th><th>2</th><th>1</th><th>2</th><th>1</th><th>2</th></tr>
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<tr><td>Dendrocoelidae</td><td>1</td><td>-</td><td>2</td><td>1</td><td>-</td><td>-</td><td>3</td><td>-</td></tr>
<tr><td>Neritidae</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Valvatidae</td><td>-</td><td>-</td><td>1</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Hydrobiidae</td><td>-</td><td>-</td><td>12</td><td>-</td><td>1</td><td>2</td><td>-</td><td>-</td></tr>
<tr><td>Bithyniidae</td><td>1</td><td>2</td><td>7</td><td>2</td><td>-</td><td>1</td><td>-</td><td>1</td></tr>
<tr><td>Physidae</td><td>168</td><td>144</td><td>76</td><td>160</td><td>32</td><td>4</td><td>6</td><td>1</td></tr>
<tr><td>Lymnaeidae</td><td>9</td><td>7</td><td>17</td><td>12</td><td>5</td><td>1</td><td>1</td><td>5</td></tr>
<tr><td>Planorbidae</td><td>13</td><td>13</td><td>36</td><td>23</td><td>2</td><td>4</td><td>1</td><td>-</td></tr>
<tr><td>Ancylidae & Acroloxidae</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
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<tr><td>Oligochaeta</td><td>7</td><td>20</td><td>20</td><td>41</td><td>32</td><td>500</td><td>200</td><td>48</td></tr>
<tr><td>Piscicolidae</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Glossiphoniidae</td><td>8</td><td>32</td><td>23</td><td>87</td><td>3</td><td>8</td><td>20</td><td>23</td></tr>
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<tr><td>Corophiidae</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
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<tr><td>Caenidae</td><td>-</td><td>-</td><td>1</td><td>1</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Nemouridae</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
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<tr><td>Coenagriidae</td><td>20</td><td>12</td><td>21</td><td>5</td><td>5</td><td>9</td><td>-</td><td>3</td></tr>
<tr><td>Calopterygidae</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td>Gerridae</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Nepidae</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Notonectidae</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Corixidae</td><td>-</td><td>-</td><td>-</td><td>-</td><td>1</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Haliplidae</td><td>-</td><td>7</td><td>2</td><td>1</td><td>-</td><td>-</td><td>-</td><td>1</td></tr>
<tr><td>Dytiscidae & Noteridae</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Gyrinidae</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Hydrophilidae and Hydraenidae</td><td>-</td><td>-</td><td>-</td><td>1</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Elmidae</td><td>1</td><td>-</td><td>-</td><td>1</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Helodidae</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Dryopidae</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
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<tr><td>Sialidae</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Rhyacophilidae & Glossosomatidae</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
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<tr><td>Psychomyiidae</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Polycentropodidae</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
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<tr><td>Brachycentridae</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
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<tr><td>Goeridae</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Beraeidae</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Sericostomatidae</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Molannidae</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Leptoceridae</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Chironomidae</td><td>4</td><td>5</td><td>4</td><td>11</td><td>48</td><td>200</td><td>30</td><td>24</td></tr>
<tr><td>Tipulidae</td><td>1</td><td>-</td><td>1</td><td>6</td><td>-</td><td>-</td><td>-</td><td>2</td></tr>
<tr><td>Simuliidae</td><td>1</td><td>-</td><td>1</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
</table>

Appendix table 3.1 **Macroinvertebrates recorded in Environment Agency variability study (continued)**

Site	Lydiard Brook							
Season	Autumn				Spring			
Sampler	DW		MW		JB		DW	
Sample	1	2	1	2	1	2	1	2
Planariidae & Dugesiidae	-	-	-	-	-	-	-	-
Dendrocoelidae	-	-	-	-	-	-	-	-
Neritidae	-	-	-	-	-	-	-	-
Valvatidae	-	-	3	-	1	-	-	2
Hydrobiidae	2106	292	1000	152	172	904	204	144
Bithyniidae	-	-	3	-	-	-	-	-
Physidae	-	-	-	-	-	-	-	-
Lymnaeidae	10	10	32	32	3	3	13	8
Planorbidae	512	53	211	33	49	5	52	9
Ancylidae & Acroloxidae	1	1	4	16	-	1	-	-
Unionidae	18	44	9	5	7	22	13	13
Sphaeriidae	6000	5120	3886	896	2117	2416	1862	2464
Oligochaeta	508	1	100	32	304	76	13	668
Piscicolidae	-	-	-	-	-	-	-	-
Glossiphoniidae	6	17	2	4	19	4	18	8
Erpobdellidae	-	4	2	1	12	6	9	1
Asellidae	6	1	9	2	27	16	20	24
Corophiidae	-	-	-	-	-	-	-	-
Gammaridae and Crangonyctidae	214	16	21	6	74	102	81	184
Baetidae	-	-	-	-	6	17	8	16
Heptageniidae	-	-	-	-	-	-	-	-
Leptophlebiidae	-	-	-	-	-	-	-	-
Ephemeridae	-	-	-	-	-	1	-	-
Ephemerellidae	-	-	-	-	-	-	-	-
Caenidae	-	-	-	1	3	-	1	8
Nemouridae	-	-	-	-	-	-	-	-
Platycnemididae	-	-	-	-	-	-	-	-
Coenagriidae	-	-	-	1	2	-	1	2
Calopterygidae								
Gomphidae	-	-	-	-	-	-	-	-
Hydrometridae	1	-	-	-	-	-	-	-
Gerridae	-	1	-	-	-	-	-	-
Nepidae	-	-	-	-	-	-	-	-
Notonectidae	-	-	-	-	-	-	-	-
Corixidae	1	-	6	-	34	13	15	34
Haliplidae	2	-	3	3	7	6	4	6
Dytiscidae & Noteridae	-	1	-	3	8	6	3	3
Gyrinidae	-	-	-	-	-	-	-	-
Hydrophilidae and Hydraenidae	-	-	-	1	3	-	2	-
Elmidae	133	9	12	26	11	48	23	240
Helodidae	-		-	-	-	-	-	-
Dryopidae	-	-	-	-	-	-	-	-
Curculionidae	-	-	-	-	-	-	-	-
Sialidae	11	12	5	14	52	12	11	13
Rhyacophilidae & Glossosomatidae	-	-	-	-	-	-	-	-
Hydroptilidae	-	-	-	-	-	-	-	-
Psychomyiidae	-	-	-	2	1	-	-	-
Polycentropodidae	-	-	-	-	-	-	-	-
Hydropsychidae	380	80	21	-	200	30	174	53
Phryganeidae	-	-	-	-	-	-	-	-
Brachycentridae	-	-	-	-	-	-	-	-
Limnephilidae	2	3	5	4	108	94	150	38
Goeridae	-	-	-	-	-	-	-	-
Beraeidae	-	-	-	-	-	-	-	-
Sericostomatidae	-	-	-	-	-	-	-	-
Molannidae	-	-	-	-	-	-	-	-
Leptoceridae	-	-	-	-	1	8	1	1
Chironomidae	54	29	72	36	510	104	456	540
Tipulidae	2	-	2	-	4	2	3	5
Simuliidae	1	5	1	2	1	-	1	-

Appendix table 3.1 **Macroinvertebrates recorded in Environment Agency variability study (continued)**

Site	Halfacre Brook							
Season	Autumn				Spring			
Sampler	JB		RA		JB		MW	
Sample	1	2	1	2	1	2	1	2
Planariidae & Dugesiidae	-	-	-	-	-	-	-	-
Dendrocoelidae	-	-	-	-	-	-	-	-
Neritidae	-	-	-	-	-	-	-	-
Valvatidae	-	-	-	9	6	20	12	3
Hydrobiidae	-	-	-	-	-	-	-	-
Bithyniidae	-	-	-	-	-	-	-	-
Physidae	-	-	-	-	-	-	-	-
Lymnaeidae	3	-	-	5	1	-	1	-
Planorbidae	-	-	-	-	-	-	-	-
Ancylidae & Acroloxidae	-	-	-	-	-	-	-	-
Unionidae	-	-	-	-	-	-	-	-
Sphaeriidae	-	-	-	-	-	-	-	-
Oligochaeta	4	1	12	1	49	50	50	15
Piscicolidae	-	-	-	-	1	1	2	2
Glossiphoniidae	1	-	3	2	1	3	2	-
Erpobdellidae	-	-	-	-	-	-	-	1
Asellidae	8	8	4	6	35	50	35	30
Corophiidae	-	-	-	-	-	-	-	-
Gammaridae and Crangonyctidae	504	208	105	348	100	120	104	150
Baetidae	-	-	-	-	-	-	-	-
Heptageniidae	-	-	-	-	-	-	-	-
Leptophlebiidae	-	-	-	-	-	-	-	-
Ephemeridae	-	-	5	1	-	2	1	1
Ephemerellidae	-	-	-	-	-	-	-	-
Caenidae	-	-	-	-	-	-	-	-
Nemouridae	-	-	-	-	-	-	-	-
Platycnemididae	-	-	-	-	-	-	-	-
Coenagriidae	3	22	7	14	4	5	4	4
Calopterygidae								
Gomphidae	-	-	-	-	-	-	-	-
Hydrometridae	-	-	-	-	-	-	-	-
Gerridae	-	-	-	-	-	-	-	-
Nepidae	-	-	-	-	-	-	-	-
Notonectidae	-	-	-	-	-	-	-	-
Corixidae	-	-	-	-	-	-	-	-
Haliplidae	-	-	-	-	-	-	-	-
Dytiscidae & Noteridae	3	1	3	-	-	4	1	4
Gyrinidae	-	-	-	-	-	-	-	-
Hydrophilidae and Hydraenidae	-	3	-	-	4	1	6	2
Elmidae	-	-	-	-	-	-	-	-
Helodidae	-	-	-	-	-	-	-	-
Dryopidae	-	-	-	-	-	-	-	-
Curculionidae	-	-	-	-	-	-	-	-
Sialidae	-	-	3	4	1	8	2	2
Rhyacophilidae & Glossosomatidae	-	-	-	-	-	-	-	-
Hydroptilidae	-	-	-	-	-	-	-	-
Psychomyiidae	-	-	-	-	-	-	-	-
Polycentropodidae	-	-	-	-	-	-	-	-
Hydropsychidae	-	-	-	-	-	-	-	-
Phryganeidae	-	-	-	-	-	-	-	-
Brachycentridae	-	-	-	-	-	-	-	-
Limnephilidae	-	-	-	-	-	2	4	5
Goeridae	-	-	-	-	-	-	-	-
Beraeidae	-	-	-	-	-	-	-	-
Sericostomatidae	-	-	-	-	-	-	-	-
Molannidae	-	-	-	-	-	-	-	-
Leptoceridae	-	-	-	-	-	-	-	-
Chironomidae	232	224	282	532	1075	1050	1100	450
Tipulidae	-	-	-	-	-	-	-	-
Simuliidae	-	-	-	-	-	-	-	-

Appendix table 3.1 **Macroinvertebrates recorded in Environment Agency variability study (continued)**

Site	Roundmoor Ditch							
Season	Autumn				Spring			
Sampler	RA		MW		MW		DW	
Sample	1	2	1	2	1	2	1	2
Planariidae & Dugesiidae	-	-	-	-	-	-	1	1
Dendrocoelidae	-	-	-	-	-	-	-	-
Neritidae	-	-	-	-	-	-	-	-
Valvatidae	176	64	7	40	236	192	2	4
Hydrobiidae	-	-	-	-	-	-	-	-
Bithyniidae	-	-	-	-	-	-	-	-
Physidae	-	-	-	-	-	-	-	-
Lymnaeidae	-	2	1	1	-	-	1	-
Planorbidae	576	324	205	1276	288	528	78	168
Ancylidae & Acroloxidae	-	-	-	-	-	-	-	-
Unionidae	-	-	-	-	-	-	-	-
Sphaeriidae	-	-	-	-	-	-	-	-
Oligochaeta	40	38	96	40	28	160	13	64
Piscicolidae	-	-	-	-	-	-	-	-
Glossiphoniidae	26	6	4	8	40	5	8	24
Erpobdellidae	-	-	-	-	-	-	-	-
Asellidae	-	-	-	-	-	-	-	-
Corophiidae	-	-	-	-	-	-	-	-
Gammaridae and Crangonyctidae	-	-	-	-	-	-	-	-
Baetidae	-	1	1	2	-	-	-	-
Heptageniidae	-	-	-	-	-	-	-	-
Leptophlebiidae	-	-	-	-	-	-	-	-
Ephemeridae	-	-	-	-	-	-	-	-
Ephemerellidae	-	-	-	-	-	-	-	-
Caenidae	-	-	-	-	-	-	-	-
Nemouridae	-	-	-	-	-	-	-	-
Platycnemididae	-	-	-	-	-	-	-	-
Coenagriidae	-	-	2	2	1	-	1	2
Calopterygidae								
Gomphidae	-	-	-	-	-	-	-	-
Hydrometridae	-	-	-	-	-	-	-	-
Gerridae	-	-	-	-	-	-	-	-
Nepidae	-	1	-	-	-	-	-	-
Notonectidae	-	1	-	-	-	-	-	-
Corixidae	1	-	1	-	1	1	-	-
Haliplidae	-	-	-	-	-	-	-	-
Dytiscidae & Noteridae	6	9	17	6	3	3	2	1
Gyrinidae	-	-	-	-	-	-	-	-
Hydrophilidae and Hydraenidae	1	3	6	1	2	-	-	-
Elmidae	-	-	-	-	-	-	-	-
Helodidae	-	-	1	-	-	-	-	-
Dryopidae	-	-	-	-	-	-	-	-
Curculionidae	-	-	-	1	-	-	-	-
Sialidae	-	1	-	1	-	-	-	-
Rhyacophilidae & Glossosomatidae	-	-	-	-	-	-	-	-
Hydroptilidae	-	-	-	-	-	-	-	-
Psychomyiidae	-	-	-	-	-	-	-	-
Polycentropodidae	-	-	-	-	-	-	-	-
Hydropsychidae	-	-	-	-	-	-	-	-
Phryganeidae	-	-	-	-	-	-	-	-
Brachycentridae	-	-	-	-	-	-	-	-
Limnephilidae	-	-	-	-	-	-	-	-
Goeridae	-	-	-	-	-	-	-	-
Beraeidae	-	-	-	-	-	-	-	-
Sericostomatidae	-	-	-	-	-	-	-	-
Molannidae	-	-	-	-	-	-	-	-
Leptoceridae	-	-	-	-	-	-	-	-
Chironomidae	3458	576	850	1481	2001	2000	1001	1236
Tipulidae	-	-	-	4	1	-	-	-
Simuliidae	-	-	-	-	-	1	-	-

Appendix table 3.1 **Macroinvertebrates recorded in Environment Agency variability study (continued)**

Site	Summerstown Ditch							
Season	Autumn				Spring			
Sampler	MW		JB		JB		DW	
Sample	1	2	1	2	1	2	1	2
Planariidae & Dugesiidae	-	-	-	-	-	-	-	-
Dendrocoelidae	-	-	-	-	-	-	-	-
Neritidae	-	-	-	-	-	-	-	-
Valvatidae	-	-	-	-	-	-	-	-
Hydrobiidae	-	-	-	-	-	-	-	-
Bithyniidae	-	-	-	-	-	-	-	-
Physidae	7	3	2	3	1	-	3	1
Lymnaeidae	1	2	-	-	10	5	3	3
Planorbidae	11	42	11	2	4	8	4	12
Ancylidae & Acroloxidae	-	-	-	-	-	-	-	-
Unionidae	-	-	-	-	-	-	-	-
Sphaeriidae	-	-	-	-	-	-	-	-
Oligochaeta	18	2	1	87	120	10	105	50
Piscicolidae	-	-	-	-	-	-	-	-
Glossiphoniidae	1	2	1	3	1	3	1	2
Erpobdellidae	-	-	-	1	-	-	-	-
Asellidae	576	124	20	560	37	58	75	55
Corophiidae	-	-	-	-	-	-	-	-
Gammaridae and Crangonyctidae	1	3	-	-	-	-	-	-
Baetidae	-	-	-	-	-	-	-	-
Heptageniidae	-	-	-	-	-	-	-	-
Leptophlebiidae	-	-	-	-	-	-	-	-
Ephemeridae	-	-	-	-	-	-	-	-
Ephemerellidae	-	-	-	-	-	-	-	-
Caenidae	-	-	-	-	-	-	-	-
Nemouridae	-	-	-	-	-	-	-	-
Platycnemididae	-	-	-	-	-	-	-	-
Coenagriidae	-	-	-	-	-	-	-	-
Calopterygidae								
Gomphidae	-	-	-	-	-	-	-	-
Hydrometridae	-	-	-	-	-	-	-	-
Gerridae	-	-	-	-	-	-	-	-
Nepidae	-	-	-	-	-	-	-	-
Notonectidae	-	-	-	-	-	-	-	-
Corixidae	-	-	-	-	-	-	-	-
Haliplidae	-	1	-	1	-	-	-	-
Dytiscidae & Noteridae	147	16	39	81	2	2	6	3
Gyrinidae	-	-	-	-	-	-	-	-
Hydrophilidae and Hydraenidae	4	3	2	3	3	2	-	6
Elmidae	-	-	-	-	-	-	-	-
Helodidae	-	-	-	-	-	-	-	-
Dryopidae	-	-	-	-	-	-	-	-
Curculionidae	-	-	-	-	-	-	-	-
Sialidae	-	-	-	-	-	-	-	-
Rhyacophilidae & Glossosomatidae	-	-	-	-	-	-	-	-
Hydroptilidae	-	-	-	-	-	-	-	-
Psychomyiidae	-	-	-	-	-	-	-	-
Polycentropodidae	-	-	-	-	-	-	-	-
Hydropsychidae	-	-	-	-	-	-	-	-
Phryganeidae	-	-	-	-	-	-	-	-
Brachycentridae	-	-	-	-	-	-	-	-
Limnephilidae	-	-	-	-	-	-	-	-
Goeridae	-	-	-	-	-	-	-	-
Beraeidae	-	-	-	-	-	-	-	-
Sericostomatidae	-	-	-	-	-	-	-	-
Molannidae	-	-	-	-	-	-	-	-
Leptoceridae	-	-	-	-	-	-	-	-
Chironomidae	17349	50001	3500	21746	12000	10000	10000	11160
Tipulidae	1	-	-	-	1	-	-	-
Simuliidae	-	-	-	-	-	-	-	-

Appendix table 3.1 **Macroinvertebrates recorded in Environment Agency variability study (continued)**

Site	Crendon Stream							
Season	Autumn				Spring			
Sampler	JB		RA		MW		JB	
Sample	1	2	1	2	1	2	1	2
Planariidae & Dugesiidae	-	-	-	-	-	-	-	-
Dendrocoelidae	-	-	-	-	-	-	-	-
Neritidae	-	-	-	-	-	-	-	-
Valvatidae	-	-	-	-	-	-	-	-
Hydrobiidae	-	1	-	1	1	1	1	-
Bithyniidae	-	-	-	-	-	-	-	-
Physidae	-	-	-	-	-	-	-	-
Lymnaeidae	-	-	-	1	1	1	-	-
Planorbidae	-	-	-	-	-	-	-	-
Ancylidae & Acroloxidae	-	-	-	-	-	-	-	-
Unionidae	-	-	-	-	-	-	-	-
Sphaeriidae	-	-	-	-	-	-	-	-
Oligochaeta	6	12	61	52	41	192	1215	1
Piscicolidae	-	-	-	-	-	-	-	-
Glossiphoniidae	-	1	-	1	-	-	-	-
Erpobdellidae	3	-	1	1	-	-	-	-
Asellidae	2	-	5	5	24	17	56	5
Corophiidae	-	-	-	-	-	-	-	-
Gammaridae and Crangonyctidae	31	62	44	86	223	36	30	82
Baetidae	-	-	-	-	-	-	-	-
Heptageniidae	-	-	-	-	-	-	-	-
Leptophlebiidae	-	-	-	-	-	-	-	-
Ephemeridae	-	-	-	-	-	-	-	-
Ephemerellidae	-	-	-	-	-	-	-	-
Caenidae	-	-	-	-	-	-	-	-
Nemouridae	-	-	-	-	-	-	-	-
Platycnemididae	-	-	-	-	-	-	-	-
Coenagriidae	-	-	-	-	-	-	-	-
Calopterygidae								
Gomphidae	-	-	-	-	-	-	-	-
Hydrometridae	-	-	-	2	-	-	-	-
Gerridae	-	-	-	-	-	-	-	-
Nepidae	-	-	-	-	-	-	-	-
Notonectidae	-	-	-	-	-	-	-	-
Corixidae	-	-	-	-	-	-	-	-
Haliplidae	-	-	-	-	-	-	-	-
Dytiscidae & Noteridae	-	-	-	-	-	-	-	-
Gyrinidae	-	-	-	-	-	-	-	-
Hydrophilidae and Hydraenidae	-	-	-	2	-	-	-	-
Elmidae	-	-	-	-	-	-	-	-
Helodidae	-	-	-	-	-	-	-	-
Dryopidae	-	-	-	-	-	-	-	-
Curculionidae	-	-	-	-	-	-	-	-
Sialidae	-	-	-	-	-	-	-	-
Rhyacophilidae & Glossosomatidae	-	-	-	-	-	-	-	-
Hydroptilidae	-	-	-	-	-	-	-	-
Psychomyiidae	-	-	-	-	-	-	-	-
Polycentropodidae	-	-	-	-	-	-	-	-
Hydropsychidae	-	-	-	-	-	-	-	-
Phryganeidae	-	-	-	-	-	-	-	-
Brachycentridae	-	-	-	-	-	-	-	-
Limnephilidae	-	-	-	-	-	-	-	-
Goeridae	-	-	-	-	-	-	-	-
Beraeidae	-	-	-	-	-	-	-	-
Sericostomatidae	-	-	-	-	-	-	-	-
Molannidae	-	-	-	-	-	-	-	-
Leptoceridae	-	-	-	-	-	-	-	-
Chironomidae	5	1	4	18	46	78	39	103
Tipulidae	-	-	-	2	-	1	3	-
Simuliidae	-	-	-	-	-	-	-	-

Appendix table 3.1 **Macroinvertebrates recorded in Environment Agency variability study (continued)**

Site	Wheatley Ditch							
Season	Autumn				Spring			
Sampler	DW		MW		JB		MW	
Sample	1	2	1	2	1	2	1	2
Planariidae & Dugesiidae	-	-	-	-	-	-	-	-
Dendrocoelidae	-	-	-	-	-	-	-	-
Neritidae	-	-	-	-	-	-	-	-
Valvatidae	-	-	-	-	-	-	-	-
Hydrobiidae	-	-	-	-	-	-	-	-
Bithyniidae	-	-	-	-	-	-	-	-
Physidae	2	-	5	-	-	-	-	-
Lymnaeidae	6	2	6	-	3	2	1	7
Planorbidae	-	-	-	-	-	-	-	-
Ancylidae & Acroloxidae	-	-	-	-	-	-	-	-
Unionidae	-	-	-	-	-	-	-	-
Sphaeriidae	-	-	-	-	-	-	-	-
Oligochaeta	1	5	5	6	5	25	20	48
Piscicolidae	-	-	-	-	-	-	-	-
Glossiphoniidae	-	-	-	-	1	-	2	2
Erpobdellidae	-	1	1	-	-	-	1	1
Asellidae	500	570	452	580	612	750	1120	490
Corophiidae	-	-	-	-	-	-	-	-
Gammaridae and Crangonyctidae	2	3	1	1	-	1	1	1
Baetidae	-	-	-	-	-	-	-	-
Heptageniidae	-	-	-	-	-	-	-	-
Leptophlebiidae	-	-	-	-	-	-	-	-
Ephemeridae	-	-	-	-	-	-	-	-
Ephemerellidae	-	-	-	-	-	-	-	-
Caenidae	-	-	-	-	-	-	-	-
Nemouridae	-	-	-	-	-	-	-	-
Platycnemididae	-	-	-	-	-	-	-	-
Coenagriidae	-	-	-	-	-	-	-	1
Calopterygidae								
Gomphidae	-	-	-	-	-	-	-	-
Hydrometridae	-	-	-	-	-	-	-	-
Gerridae	-	-	-	-	-	-	-	-
Nepidae	-	2	-	-	-	-	-	-
Notonectidae	-	-	-	-	-	-	-	-
Corixidae	-	-	-	-	-	-	-	-
Haliplidae	-	-	-	-	-	-	-	-
Dytiscidae & Noteridae	1	11	3	9	-	-	2	-
Gyrinidae	-	-	-	-	-	-	-	-
Hydrophilidae and Hydraenidae	-	-	-	2	-	2	-	-
Elmidae	-	-	-	-	-	-	-	-
Helodidae	-	-	-	-	-	-	-	-
Dryopidae	-	-	-	-	-	-	-	-
Curculionidae	-	-	-	-	-	-	-	-
Sialidae	-	-	-	-	-	-	-	-
Rhyacophilidae & Glossosomatidae	-	-	-	-	-	-	-	-
Hydroptilidae	-	-	-	-	-	-	-	-
Psychomyiidae	-	-	-	-	-	-	-	-
Polycentropodidae	-	-	-	-	-	-	-	-
Hydropsychidae	-	-	-	-	-	-	-	-
Phryganeidae	-	-	-	-	-	-	-	-
Brachycentridae	-	-	-	-	-	-	-	-
Limnephilidae	-	-	-	-	-	1	-	-
Goeridae	-	-	-	-	-	-	-	-
Beraeidae	-	-	-	-	-	-	-	-
Sericostomatidae	-	-	-	-	-	-	-	-
Molannidae	-	-	-	-	-	-	-	-
Leptoceridae	-	-	-	-	-	-	-	-
Chironomidae	1000	1250	1000	1030	152	78	310	133
Tipulidae	-	-	-	-	-	-	-	-
Simuliidae	-	-	-	-	-	-	-	-

Appendix table 3.1 **Macroinvertebrates recorded in Environment Agency variability study (continued)**

Site	Crawters Brook							
Season	Autumn				Spring			
Sampler	MW		DW		RA		MW	
Sample	1	2	1	2	1	2	1	2
Planariidae & Dugesiidae	-	-	-	-	-	-	-	-
Dendrocoelidae	-	-	-	-	-	-	-	-
Neritidae	-	-	-	-	-	-	-	-
Valvatidae	-	-	-	-	-	-	-	-
Hydrobiidae	17	15	1	18	-	-	-	1
Bithyniidae	-	-	-	-	-	-	-	-
Physidae	2880	5000	6692	3521	250	128	918	871
Lymnaeidae	576	54	260	52	5	21	20	12
Planorbidae	-	-	-	-	-	-	-	-
Ancylidae & Acroloxidae	-	-	-	-	-	-	-	-
Unionidae	-	-	-	-	-	-	-	-
Sphaeriidae	-	-	-	-	-	-	-	-
Oligochaeta	12827	18000	24698	6000	2001	4640	3184	1005
Piscicolidae	-	-	-	-	-	-	-	-
Glossiphoniidae	-	-	-	1	-	-	-	-
Erpobdellidae	3	4	5	4	-	5	2	1
Asellidae	832	450	68	463	431	512	864	562
Corophiidae	-	-	-	-	-	-	-	-
Gammaridae and Crangonyctidae	-	1	-	-	-	1	-	-
Baetidae	-	-	-	-	-	-	-	-
Heptageniidae	-	-	-	-	-	-	-	-
Leptophlebiidae	-	-	-	-	-	-	-	-
Ephemeridae	-	-	-	-	-	-	-	-
Ephemerellidae	-	-	-	-	-	-	-	-
Caenidae	-	-	-	-	-	-	-	-
Nemouridae	-	-	-	-	-	-	-	-
Platycnemididae	-	-	-	-	-	-	-	-
Coenagriidae	-	-	-	-	-	-	-	-
Calopterygidae								
Gomphidae	-	-	-	-	-	-	-	-
Hydrometridae	-	-	-	-	-	-	-	-
Gerridae	-	-	-	-	-	-	-	-
Nepidae	-	-	-	-	-	-	-	-
Notonectidae	-	-	-	-	-	-	-	-
Corixidae	-	-	-	-	-	-	-	-
Haliplidae	-	-	-	-	-	-	-	-
Dytiscidae & Noteridae	-	-	-	-	-	-	-	-
Gyrinidae	-	-	-	-	-	-	-	-
Hydrophilidae and Hydraenidae	-	-	-	-	-	-	-	-
Elmidae	-	-	-	-	-	-	-	-
Helodidae	-	-	-	-	-	-	-	-
Dryopidae	-	-	-	-	-	-	-	-
Curculionidae	-	-	-	-	-	-	-	-
Sialidae	-	-	-	-	-	-	-	-
Rhyacophilidae & Glossosomatidae	-	-	-	-	-	-	-	-
Hydroptilidae	-	-	-	-	-	-	-	-
Psychomyiidae	-	-	-	-	-	-	-	-
Polycentropodidae	-	-	-	-	-	-	-	-
Hydropsychidae	-	-	-	-	-	-	-	-
Phryganeidae	-	-	-	-	-	-	-	-
Brachycentridae	-	-	-	-	-	-	-	-
Limnephilidae	-	-	-	-	-	-	-	-
Goeridae	-	-	-	-	-	-	-	-
Beraeidae	-	-	-	-	-	-	-	-
Sericostomatidae	-	-	-	-	-	-	-	-
Molannidae	-	-	-	-	-	-	-	-
Leptoceridae	-	-	-	-	-	-	-	-
Chironomidae	5	8	6	6	50	196	80	100
Tipulidae	-	1	-	-	-	-	19	-
Simuliidae	-	-	-	-	-	-	-	-

Appendix table 3.1 **Macroinvertebrates recorded in Environment Agency variability study (continued)**

Site	Catherine Bourne							
Season	Autumn				Spring			
Sampler	DW		JB		MW		DW	
Sample	1	2	1	2	1	2	1	2
Planariidae & Dugesiidae	-	-	-	-	-	-	1	-
Dendrocoelidae	-	-	-	-	-	-	-	-
Neritidae	-	-	-	-	-	-	-	-
Valvatidae	-	-	-	-	-	-	-	-
Hydrobiidae	720	28	1472	61	32	60	240	50
Bithyniidae	-	-	-	-	-	-	-	-
Physidae	-	-	-	-	-	-	-	-
Lymnaeidae	-	-	1	-	1	-	1	7
Planorbidae	-	-	-	-	-	-	-	-
Ancylidae & Acroloxidae	-	-	-	-	-	-	-	-
Unionidae	-	-	-	-	-	-	-	-
Sphaeriidae	-	-	-	-	-	-	-	-
Oligochaeta	300	300	848	300	32	84	270	95
Piscicolidae	-	-	-	-	-	-	-	-
Glossiphoniidae	13	44	9	36	1	3	5	4
Erpobdellidae	6	17	4	3	9	13	36	3
Asellidae	384	944	432	435	92	70	480	120
Corophiidae	-	-	-	-	-	-	-	-
Gammaridae and Crangonyctidae	52	352	28	30	32	30	112	50
Baetidae	1	2	-	-	1	-	2	1
Heptageniidae	-	-	-	-	-	-	-	-
Leptophlebiidae	-	-	-	-	-	-	-	-
Ephemeridae	-	-	-	-	-	-	-	-
Ephemerellidae	-	-	-	-	-	-	-	-
Caenidae	-	-	-	-	-	-	-	-
Nemouridae	-	-	-	-	13	34	124	84
Platycnemididae	-	-	-	-	-	-	-	-
Coenagriidae	-	-	-	-	-	-	-	-
Calopterygidae								
Gomphidae	-	-	-	-	-	-	-	-
Hydrometridae	-	-	-	-	-	-	-	-
Gerridae	-	-	-	-	-	-	-	-
Nepidae	-	-	-	-	-	-	-	-
Notonectidae	-	-	-	-	-	-	-	-
Corixidae	1	-	1	-	1	1	-	-
Haliplidae	-	3	4	1	-	1	-	-
Dytiscidae & Noteridae	9	21	7	17	1	-	2	2
Gyrinidae	-	-	-	-	-	-	-	-
Hydrophilidae and Hydraenidae	-	-	-	1	-	-	-	-
Elmidae	-	-	-	-	-	-	-	-
Helodidae	-	1	-	1	-	-	-	-
Dryopidae	-	-	-	-	-	-	-	-
Curculionidae	-	-	-	-	-	-	-	-
Sialidae	3	1	2	14	-	1	-	-
Rhyacophilidae & Glossosomatidae	-	-	-	-	-	-	-	-
Hydroptilidae	-	-	-	-	-	-	-	-
Psychomyiidae	-	-	-	-	-	-	-	-
Polycentropodidae	-	-	-	-	-	-	-	-
Hydropsychidae	-	-	-	-	-	-	-	-
Phryganeidae	-	-	-	-	-	-	-	-
Brachycentridae	-	-	-	-	-	-	-	-
Limnephilidae	-	4	1	1	2	2	5	-
Goeridae	-	-	-	-	-	-	-	-
Beraeidae	-	-	-	-	-	-	-	-
Sericostomatidae	-	-	-	-	-	-	-	-
Molannidae	-	-	-	-	-	-	-	-
Leptoceridae	-	-	-	-	-	-	-	-
Chironomidae	574	268	960	275	332	889	1696	995
Tipulidae	-	-	-	-	5	-	-	-
Simuliidae	2	-	5	1	17	36	53	50

Appendix table 3.2a Single-season (autumn) BMWP/RIVPACS, biotic indices for the 12 sites in this survey

Site	Sample name	TAXA	BMWP	ASPT	Pred. TAXA	Pred. BMWP	Pred. ASPT	TAXA EQI	BMWP EQI	ASPT EQI	5M
Bow Brook	BOWB JB1A	22	101	4.591	20.8	95.1	4.5	1.058	1.062	1.020	1
Bow Brook	BOWB JB2A	28	135	4.821	20.8	95.1	4.5	1.346	1.420	1.071	1
Bow Brook	BOWB DW1A	21	91	4.333	20.8	95.8	4.6	1.010	0.950	0.942	1
Bow Brook	BOWB DW2A	25	125	5.000	20.8	95.8	4.6	1.202	1.305	1.087	1
River Thames	THAM DW1A	24	118	4.917	25.3	126.6	5.0	0.949	0.932	0.983	1
River Thames	THAM DW2A	31	154	4.968	25.3	126.6	5.0	1.225	1.216	0.994	1
River Thames	THAM RA1A	21	103	4.905	25.1	125.2	5.0	0.837	0.823	0.981	1
River Thames	THAM RA2A	30	158	5.267	25.1	125.2	5.0	1.195	1.262	1.053	1
River Coln	COLN DW1A	29	151	5.207	21.3	101.3	4.7	1.362	1.491	1.108	1
River Coln	COLN DW2A	34	188	5.529	21.3	101.3	4.7	1.596	1.856	1.176	1
River Coln	COLN MW1A	30	160	5.333	21.6	103.9	4.8	1.389	1.540	1.111	1
River Coln	COLN MW2A	29	146	5.034	21.6	103.9	4.8	1.343	1.405	1.049	1
The Cut	CUT. JB1A	19	77	4.053	22.4	110.5	4.9	0.848	0.697	0.827	2
The Cut	CUT. JB2A	17	66	3.882	22.4	110.5	4.9	0.759	0.597	0.792	2
The Cut	CUT. RA1A	22	91	4.136	21.9	106.5	4.8	1.005	0.854	0.862	1
The Cut	CUT. RA2A	22	93	4.227	21.9	106.5	4.8	1.005	0.873	0.881	1
Lydiard Stream	LYDI DW1A	21	93	4.429	20.4	94.6	4.6	1.029	0.983	0.963	1
Lydiard Stream	LYDI DW2A	20	86	4.300	20.4	94.6	4.6	0.980	0.909	0.935	1
Lydiard Stream	LYDI MW1A	22	94	4.273	20.5	95.1	4.6	1.073	0.988	0.929	1
Lydiard Stream	LYDI MW2A	23	107	4.652	20.5	95.1	4.6	1.122	1.125	1.011	1
Halfacre Brook	HALF JB1A	8	29	3.625	19.1	89.5	4.7	0.419	0.324	0.771	2
Halfacre Brook	HALF JB2A	7	28	4.000	19.1	89.5	4.7	0.366	0.313	0.851	2
Halfacre Brook	HALF RA1A	9	40	4.444	19.3	90.3	4.7	0.466	0.443	0.946	2
Halfacre Brook	HALF RA2A	10	41	4.100	19.3	90.3	4.7	0.518	0.454	0.872	2
Roundmoor Ditch	ROUN RA1A	9	32	3.556	19.1	89.5	4.7	0.471	0.358	0.757	2
Roundmoor Ditch	ROUN RA2A	12	43	3.583	19.1	89.5	4.7	0.628	0.480	0.762	2
Roundmoor Ditch	ROUN MW1A	13	50	3.846	19.2	90.2	4.7	0.677	0.554	0.818	2
Roundmoor Ditch	ROUN MW2A	13	49	3.769	19.2	90.2	4.7	0.677	0.543	0.802	2
Summerstown Ditch	SUMM MW1A	11	39	3.545	19.1	90.2	4.7	0.576	0.432	0.754	2
Summerstown Ditch	SUMM MW2A	11	39	3.545	19.1	90.2	4.7	0.576	0.432	0.754	2
Summerstown Ditch	SUMM JB1A	8	25	3.125	19.2	90.2	4.7	0.417	0.277	0.665	3
Summerstown Ditch	SUMM JB2A	10	33	3.300	19.2	90.2	4.7	0.521	0.366	0.702	2
Crendon Stream	CREN JB1A	5	15	3.000	18.3	90.3	4.9	0.273	0.166	0.612	3
Crendon Stream	CREN JB2A	5	15	3.000	18.3	90.3	4.9	0.273	0.166	0.612	3
Crendon Stream	CREN RA1A	5	15	3.000	18.3	90.7	4.9	0.273	0.165	0.612	3
Crendon Stream	CREN RA2A	11	39	3.545	18.3	90.7	4.9	0.601	0.430	0.723	2
Wheatley Ditch	WHEA DW1A	8	28	3.500	20.9	100.0	4.8	0.383	0.280	0.729	2
Wheatley Ditch	WHEA DW2A	8	28	3.500	20.9	100.0	4.8	0.383	0.280	0.729	2
Wheatley Ditch	WHEA MW1A	9	31	3.444	20.2	94.4	4.7	0.446	0.328	0.733	2
Wheatley Ditch	WHEA MW2A	7	27	3.857	20.2	94.4	4.7	0.347	0.286	0.821	2
Crawters Brook	CRAW MW1A	7	18	2.571	21.2	102.2	4.8	0.330	0.176	0.536	3
Crawters Brook	CRAW MW2A	9	29	3.222	21.2	102.2	4.8	0.425	0.284	0.671	3
Crawters Brook	CRAW DW1A	7	18	2.571	21.3	101.4	4.7	0.329	0.178	0.547	3
Crawters Brook	CRAW DW2A	8	21	2.625	20.7	99.8	4.8	0.386	0.210	0.547	3
Catherine Bourne	CATH DW1A	12	44	3.667	19.8	92.5	4.6	0.606	0.476	0.797	2
Catherine Bourne	CATH DW2A	13	51	3.923	19.8	92.5	4.6	0.657	0.551	0.853	2
Catherine Bourne	CATH JB1A	14	55	3.929	20.7	99.8	4.8	0.676	0.551	0.819	2
Catherine Bourne	CATH JB2A	14	57	4.071	20.7	99.8	4.8	0.676	0.571	0.848	1

Appendix table 3.2b Single-season (spring) BMWP/RIVPACS biotic indices for the 12 sites in this survey

Site	Sample	TAXA	BMWP	ASPT	Pred. TAXA	Pred. BMWP	Pred. ASPT	TAXA. EQI	BMWP EQI	ASPT EQI	5M
Bow Brook	BOWB JB1S	26	137	5.269	21.0	102.8	4.9	1.238	1.333	1.075	1
Bow Brook	BOWB JB2S	29	152	5.241	21.0	102.8	4.9	1.381	1.479	1.070	1
Bow Brook	BOWB DW1S	29	144	4.966	21.1	102.9	4.9	1.374	1.399	1.013	1
Bow Brook	BOWB DW2S	26	127	4.885	21.1	102.9	4.9	1.232	1.234	0.997	1
River Thames	THAM RA1S	23	111	4.826	25.3	132.6	5.2	0.909	0.837	0.928	1
River Thames	THAM RA2S	25	120	4.800	25.3	132.6	5.2	0.988	0.905	0.923	1
River Thames	THAM JB1S	34	181	5.324	25.2	131.8	5.2	1.349	1.373	1.024	1
River Thames	THAM JB2S	29	144	4.966	25.2	131.8	5.2	1.151	1.093	0.955	1
River Coln	COLN JB1S	32	188	5.875	20.9	102.7	4.9	1.531	1.831	1.199	1
River Coln	COLN JB2S	32	179	5.594	20.9	102.7	4.9	1.531	1.743	1.142	1
River Coln	COLN RA1S	28	154	5.500	20.9	102.7	4.9	1.340	1.500	1.122	1
River Coln	COLN RA2S	34	187	5.500	20.9	102.7	4.9	1.627	1.821	1.122	1
The Cut	CUT. MW1S	13	46	3.538	21.1	105.2	5.0	0.616	0.437	0.708	2
The Cut	CUT. MW2S	15	61	4.067	21.1	105.2	5.0	0.711	0.580	0.813	2
The Cut	CUT. RA1S	11	37	3.364	21.4	107.4	5.0	0.514	0.345	0.673	3
The Cut	CUT. RA2S	14	53	3.786	21.4	107.4	5.0	0.654	0.493	0.757	2
Lydiard Stream	LYDI JB1S	28	133	4.750	21.2	106.0	5.0	1.321	1.255	0.950	1
Lydiard Stream	LYDI JB2S	24	115	4.792	21.2	106.0	5.0	1.132	1.085	0.958	1
Lydiard Stream	LYDI DW1S	26	122	4.692	20.9	102.6	4.9	1.244	1.189	0.958	1
Lydiard Stream	LYDI DW2S	26	120	4.615	20.9	102.6	4.9	1.244	1.170	0.942	1
Halfacre Brook	HALF JB1S	11	40	3.636	19.9	91.0	4.5	0.553	0.440	0.808	2
Halfacre Brook	HALF JB2S	13	59	4.538	19.9	91.0	4.5	0.653	0.648	1.008	1
Halfacre Brook	HALF MW1S	14	62	4.429	20.0	90.8	4.5	0.700	0.683	0.984	1
Halfacre Brook	HALF MW2S	13	59	4.538	20.0	90.8	4.5	0.650	0.650	1.008	1
Roundmoor Ditch	ROUN MW1S	10	38	3.800	20.3	91.4	4.5	0.493	0.416	0.844	2
Roundmoor Ditch	ROUN MW2S	8	27	3.375	20.3	91.4	4.5	0.394	0.295	0.750	2
Roundmoor Ditch	ROUN DW1S	9	31	3.444	20.1	90.4	4.5	0.448	0.343	0.765	2
Roundmoor Ditch	ROUN DW2S	8	28	3.500	20.1	90.4	4.5	0.398	0.310	0.778	2
Summerstown Ditch	SUMM JB1S	10	33	3.300	20.0	92.8	4.6	0.500	0.356	0.717	3
Summerstown Ditch	SUMM JB2S	8	25	3.125	20.0	92.8	4.6	0.400	0.269	0.679	3
Summerstown Ditch	SUMM DW1S	8	23	2.875	20.0	92.7	4.6	0.400	0.248	0.625	3
Summerstown Ditch	SUMM DW2S	9	28	3.111	20.0	92.7	4.6	0.450	0.302	0.676	3
Crendon Stream	CREN MW1S	6	18	3.000	19.6	101.6	5.2	0.306	0.177	0.577	3
Crendon Stream	CREN MW2S	7	23	3.286	19.6	101.6	5.2	0.357	0.226	0.632	3
Crendon Stream	CREN JB1S	6	20	3.333	19.6	103.5	5.3	0.306	0.193	0.629	3
Crendon Stream	CREN JB2S	4	12	3.000	19.6	103.5	5.3	0.204	0.116	0.566	3
Wheatley Ditch	WHEA JB1S	6	17	2.833	21.2	107.4	5.0	0.283	0.158	0.567	3
Wheatley Ditch	WHEA JB2S	8	32	4.000	21.2	107.4	5.0	0.377	0.298	0.800	2
Wheatley Ditch	WHEA MW1S	9	31	3.444	21.3	107.6	5.0	0.423	0.288	0.689	3
Wheatley Ditch	WHEA MW2S	8	27	3.375	21.3	107.6	5.0	0.376	0.251	0.675	2
Crawters Brook	CRAW RA1S	5	12	2.400	21.5	108.7	5.0	0.233	0.110	0.480	4
Crawters Brook	CRAW RA2S	7	21	3.000	21.5	108.7	5.0	0.326	0.193	0.600	3
Crawters Brook	CRAW MW1S	7	20	2.857	21.6	109.3	5.0	0.324	0.183	0.571	3
Crawters Brook	CRAW MW2S	7	18	2.571	21.6	109.3	5.0	0.324	0.165	0.514	4
Catherine Bourne	CATH MW1S	15	62	4.133	21.2	107.3	5.0	0.708	0.578	0.827	2
Catherine Bourne	CATH MW2S	13	54	4.154	21.2	107.3	5.0	0.613	0.503	0.831	2
Catherine Bourne	CATH DW1S	14	57	4.071	21.2	109.1	5.1	0.660	0.522	0.798	2
Catherine Bourne	CATH DW2S	12	45	3.750	21.2	109.1	5.1	0.566	0.412	0.735	2

Appendix table 3.3 Combined-season BMWP/RIVPACS biotic indices for the 12 sites in this survey

Autumn sample	Spring sample	TAXA	BMWP	ASPT	Pred. TAXA	Pred. BMWP	Pred. ASPT	TAXA EQI	BMWP EQI	ASPT EQI	5M
BOWB JB1A	BOWB DW2S	31	149	4.806	25.9	128.1	4.9	1.197	1.163	0.981	1
BOWB JB2A	BOWB DW1S	35	174	4.971	25.9	128.1	4.9	1.351	1.358	1.014	1
BOWB DW1A	BOWB JB1S	31	157	5.065	25.9	128.0	4.9	1.197	1.227	1.034	1
BOWB DW2A	BOWB JB2S	32	165	5.156	25.9	128.0	4.9	1.236	1.289	1.052	1
THAM DW1A	THAM RA2S	30	150	5.000	30.9	164.4	5.3	0.971	0.912	0.943	1
THAM DW2A	THAM JB2S	36	179	4.972	30.9	164.7	5.3	1.165	1.087	0.938	1
THAM RA1A	THAM RA1S	29	150	5.172	30.9	164.2	5.3	0.939	0.914	0.976	1
THAM RA2A	THAM JB1S	38	205	5.395	31.0	165.0	5.3	1.226	1.242	1.018	1
COLN DW1A	COLN JB1S	37	214	5.784	26.0	129.0	5.0	1.423	1.659	1.157	1
COLN DW2A	COLN JB2S	38	216	5.684	26.0	129.0	5.0	1.462	1.674	1.137	1
COLN MW1A	COLN RA2S	41	234	5.707	25.9	128.9	5.0	1.583	1.815	1.141	1
COLN MW2A	COLN RA1S	35	191	5.457	25.9	128.9	5.0	1.351	1.482	1.091	1
CUT. JB1A	CUT. RA2S	20	82	4.100	27.1	140.3	5.2	0.738	0.584	0.788	2
CUT. JB2A	CUT. RA1S	18	71	3.944	27.1	140.3	5.2	0.664	0.506	0.758	3
CUT. RA1A	CUT. MW1S	23	96	4.174	26.7	136.2	5.1	0.861	0.705	0.818	2
CUT. RA2A	CUT. MW2S	23	100	4.348	26.7	136.2	5.1	0.861	0.734	0.853	2
LYDI DW1A	LYDI DW2S	29	136	4.690	25.8	128.2	5.0	1.124	1.061	0.938	1
LYDI DW2A	LYDI JB2S	26	125	4.808	25.8	129.0	5.0	1.008	0.969	0.962	1
LYDI MW1A	LYDI DW1S	28	131	4.679	25.6	127.1	4.9	1.094	1.031	0.955	1
LYDI MW2A	LYDI JB1S	29	139	4.793	25.9	129.4	5.0	1.120	1.074	0.959	1
HALF JB1A	HALF JB2S	14	62	4.429	24.1	115.4	4.8	0.581	0.537	0.923	2
HALF JB2A	HALF MW1S	14	62	4.429	24.1	115.4	4.8	0.581	0.537	0.923	2
HALF RA1A	HALF MW2S	14	62	4.429	24.1	115.2	4.8	0.581	0.538	0.923	2
HALF RA2A	HALF JB1S	12	50	4.167	24.0	114.9	4.8	0.500	0.435	0.868	2
ROUN RA1A	ROUN DW2S	11	43	3.909	23.9	113.8	4.7	0.460	0.378	0.832	3
ROUN RA2A	ROUN MW2S	14	53	3.786	23.9	113.4	4.7	0.586	0.467	0.806	2
ROUN MW1A	ROUN MW1S	14	55	3.929	24.1	114.8	4.7	0.581	0.479	0.836	2
ROUN MW2A	ROUN DW1S	14	54	3.857	24.0	113.8	4.7	0.583	0.475	0.821	2
SUMM MW1A	SUMM DW1S	11	39	3.545	24.1	116.0	4.8	0.456	0.336	0.739	3
SUMM MW2A	SUMM JB2S	11	39	3.545	24.0	115.9	4.8	0.458	0.336	0.739	3
SUMM JB1A	SUMM DW2S	9	28	3.111	24.0	115.2	4.8	0.375	0.243	0.648	3
SUMM JB2A	SUMM JB1S	12	41	3.417	24.1	116.5	4.8	0.498	0.352	0.712	3
CREN JB1A	CREN MW2S	8	26	3.250	23.8	127.7	5.3	0.336	0.204	0.613	4
CREN JB2A	CREN MW1S	7	21	3.000	23.8	127.7	5.3	0.294	0.164	0.566	4
CREN RA1A	CREN JB2S	5	15	3.000	23.9	129.0	5.4	0.209	0.116	0.556	4
CREN RA2A	CREN JB1S	11	39	3.545	23.9	129.0	5.4	0.460	0.302	0.656	3
WHEA DW1A	WHEA JB1S	9	31	3.444	26.2	134.5	5.1	0.344	0.230	0.675	3
WHEA DW2A	WHEA MW2S	10	37	3.700	26.3	134.2	5.1	0.380	0.276	0.725	3
WHEA MW1A	WHEA JB2S	11	43	3.909	25.9	131.1	5.0	0.425	0.328	0.782	3
WHEA MW2A	WHEA MW1S	10	36	3.600	25.7	129.8	5.0	0.389	0.277	0.720	3
CRAW MW1A	CRAW RA2S	8	24	3.000	26.5	135.4	5.1	0.302	0.177	0.588	4
CRAW MW2A	CRAW MW1S	9	29	3.222	26.6	136.7	5.1	0.338	0.212	0.632	4
CRAW DW1A	CRAW MW2S	7	18	2.571	26.6	135.8	5.1	0.263	0.133	0.504	4
CRAW DW2A	CRAW RA1S	8	21	2.625	26.6	135.8	5.1	0.301	0.155	0.515	4
CATH DW1A	CATH DW1S	16	66	4.125	25.8	132.5	5.1	0.620	0.498	0.809	2
CATH DW2A	CATH MW1S	18	76	4.222	25.6	131.1	5.1	0.703	0.580	0.828	2
CATH JB1A	CATH MW2S	15	62	4.133	26.6	135.8	5.1	0.564	0.457	0.810	2
CATH JB2A	CATH DW2S	17	71	4.176	26.3	137.7	5.2	0.646	0.516	0.803	2

Appendix table 3.4 Dual-sample biotic indices for the 12 sites

Dual Sample	TAXA	BMWP	ASPT	Pred. TAXA	Pred. BMWP	Pred. ASPT	TAXA EQI	BMWP EQI	ASPT EQI	5M
BOWB JB.A	30	144	4.800	25.9	128.1	4.9	1.158	1.124	0.980	1
BOWB DW.A	28	139	4.964	25.9	128.0	4.9	1.081	1.086	1.013	1
THAM DW.A	33	163	4.939	30.9	164.7	5.3	1.068	0.990	0.932	1
THAM RA.A	32	169	5.281	31.0	165.0	5.3	1.032	1.024	0.996	1
COLN DW.A	36	197	5.472	26.0	129.0	5.0	1.385	1.527	1.094	1
COLN MW.A	33	174	5.273	25.9	128.9	5.0	1.274	1.350	1.055	1
CUT. JB.A	22	91	4.136	27.1	140.3	5.2	0.812	0.649	0.795	2
CUT. RA.A	24	101	4.208	26.7	136.2	5.1	0.899	0.742	0.825	2
LYDI DW.A	24	106	4.417	25.8	128.2	5.0	0.930	0.827	0.883	1
LYDI MW.A	27	125	4.630	25.6	127.1	4.9	1.055	0.983	0.945	1
HALF JB.A	9	34	3.778	24.1	115.4	4.8	0.373	0.295	0.787	3
HALF RA.A	11	46	4.182	24.1	115.2	4.8	0.456	0.399	0.871	3
ROUN RA.A	13	48	3.692	23.9	113.4	4.7	0.544	0.423	0.786	2
ROUN MW.A	16	64	4.000	24.1	114.8	4.7	0.664	0.557	0.851	2
SUMM MW.A	12	44	3.667	24.1	116.0	4.8	0.498	0.379	0.764	3
SUMM JB.A	10	33	3.300	24.0	115.2	4.8	0.417	0.286	0.688	3
CREN JB.A	7	21	3.000	23.8	127.7	5.3	0.294	0.164	0.566	4
CREN RA.A	11	39	3.545	23.9	129.0	5.4	0.460	0.302	0.656	3
WHEA DW.A	9	31	3.444	26.2	134.5	5.1	0.344	0.230	0.675	3
WHEA MW.A	10	36	3.600	25.7	129.8	5.0	0.389	0.277	0.720	3
CRAW MW.A	9	29	3.222	26.6	136.7	5.1	0.338	0.212	0.632	4
CRAW DW.A	8	21	2.625	26.6	135.8	5.1	0.301	0.155	0.515	4
CATH DW.A	15	61	4.067	25.8	132.5	5.1	0.581	0.460	0.797	2
CATH JB.A	16	65	4.063	26.6	135.8	5.1	0.602	0.479	0.797	2
BOWB JB.S	35	188	5.371	25.9	128.1	4.9	1.351	1.468	1.096	1
BOWB DW.S	32	160	5.000	25.9	128.0	4.9	1.236	1.250	1.020	1
THAM RA.S	29	146	5.034	30.9	164.4	5.3	0.939	0.888	0.950	1
THAM JB.S	35	186	5.314	30.9	164.2	5.3	1.133	1.133	1.003	1
COLN JB.S	37	213	5.757	26.0	129.0	5.0	1.423	1.651	1.151	1
COLN RA.S	39	219	5.615	25.9	128.9	5.0	1.506	1.699	1.123	1
CUT. MW.S	16	66	4.125	27.1	140.3	5.2	0.590	0.470	0.793	2
CUT. RA.S	16	61	3.813	26.7	136.2	5.1	0.599	0.448	0.748	3
LYDI JB.S	30	149	4.967	25.8	129.0	5.0	1.163	1.155	0.993	1
LYDI DW.S	28	130	4.643	25.9	129.4	5.0	1.081	1.005	0.929	1
HALF JB.S	14	62	4.429	24.1	115.4	4.8	0.581	0.537	0.923	2
HALF MW.S	15	65	4.333	24.0	114.9	4.8	0.625	0.566	0.903	2
ROUN MW.S	11	43	3.909	23.9	113.8	4.7	0.460	0.378	0.832	3
ROUN DW.S	9	31	3.444	24.0	113.8	4.7	0.375	0.272	0.733	3
SUMM JB.S	10	33	3.300	24.0	115.9	4.8	0.417	0.285	0.688	3
SUMM DW.S	9	28	3.111	24.1	116.5	4.8	0.373	0.240	0.648	3
CREN MW.S	7	23	3.286	23.8	127.7	5.3	0.294	0.180	0.620	4
CREN JB.S	6	20	3.333	23.9	129.0	5.4	0.251	0.155	0.617	4
WHEA JB.S	9	35	3.889	26.3	134.2	5.1	0.342	0.261	0.763	3
WHEA MW.S	10	37	3.700	25.9	131.1	5.0	0.386	0.282	0.740	3
CRAW RA.S	7	21	3.000	26.5	135.4	5.1	0.264	0.155	0.588	4
CRAW MW.S	8	23	2.875	26.6	135.8	5.1	0.301	0.169	0.564	4
CATH MW.S	17	71	4.176	25.6	131.1	5.1	0.664	0.542	0.819	2
CATH DW.S	14	57	4.071	26.3	137.7	5.2	0.532	0.414	0.783	2

Appendix table 3.5 RIVPACS field measurements for the 12 sites

Site	Autumn sample	Width (m)	Depth (cm)	MPS	Spring sample	Width (m)	Depth (cm)	MPS
Bow Brook	BOWB JB1A	5.30	81.33	7.00	BOWB JB1S	5.05	95.56	4.59
Bow Brook	BOWB JB2A	5.30	81.33	7.00	BOWB JB2S	5.05	95.56	4.59
Bow Brook	BOWB DW1A	4.70	93.33	5.86	BOWB DW1S	4.98	103.75	4.48
Bow Brook	BOWB DW2A	4.70	93.33	5.86	BOWB DW2S	4.98	103.75	4.48
River Thames	THAM DW1A	50.00	250.00	0.09	THAM RA1S	50.00	250.00	0.09
River Thames	THAM DW2A	50.00	250.00	0.09	THAM RA2S	50.00	250.00	0.09
River Thames	THAM RA1A	50.00	250.00	0.09	THAM JB1S	50.00	250.00	0.09
River Thames	THAM RA2A	50.00	250.00	0.09	THAM JB2S	50.00	250.00	0.09
River Coln	COLN DW1A	4.60	16.89	-1.56	COLN JB1S	6.92	47.22	-2.05
River Coln	COLN DW2A	4.60	16.89	-1.56	COLN JB2S	6.92	47.22	-2.05
River Coln	COLN MW1A	4.80	15.00	-1.90	COLN RA1S	6.30	48.00	-0.90
River Coln	COLN MW2A	4.80	15.00	-1.90	COLN RA2S	6.30	48.00	-0.90
The Cut	CUT. JB1A	8.50	17.56	-3.29	CUT. MW1S	10.33	19.56	1.55
The Cut	CUT. JB2A	8.50	17.56	-3.29	CUT. MW2S	10.33	19.56	1.55
The Cut	CUT. RA1A	8.83	17.56	-0.96	CUT. RA1S	11.17	34.44	0.09
The Cut	CUT. RA2A	8.83	17.56	-0.96	CUT. RA2S	11.17	34.44	0.09
Lydiard Stream	LYDI DW1A	2.27	43.89	2.98	LYDI JB1S	2.10	32.13	4.33
Lydiard Stream	LYDI DW2A	2.27	43.89	2.98	LYDI JB2S	2.10	32.13	4.33
Lydiard Stream	LYDI MW1A	2.17	43.33	2.55	LYDI DW1S	1.88	34.67	2.04
Lydiard Stream	LYDI MW2A	2.17	43.33	2.55	LYDI DW2S	1.88	34.67	2.04
Halfacre Brook	HALF JB1A	1.65	34.17	8.00	HALF JB1S	4.47	39.44	8.00
Halfacre Brook	HALF JB2A	1.65	34.17	8.00	HALF JB2S	4.47	39.44	8.00
Halfacre Brook	HALF RA1A	1.60	53.00	8.00	HALF MW1S	5.60	42.50	8.00
Halfacre Brook	HALF RA2A	1.60	53.00	8.00	HALF MW2S	5.60	42.50	8.00
Roundmoor Ditch	ROUN RA1A	5.00	70.00	8.00	ROUN MW1S	1.58	28.00	8.00
Roundmoor Ditch	ROUN RA2A	5.00	70.00	8.00	ROUN MW2S	1.58	28.00	8.00
Roundmoor Ditch	ROUN MW1A	5.20	73.00	8.00	ROUN DW1S	1.70	27.50	7.70
Roundmoor Ditch	ROUN MW2A	5.20	73.00	8.00	ROUN DW2S	1.70	27.50	7.70
Summerstown Ditch	SUMM MW1A	2.15	35.00	8.00	SUMM JB1S	1.93	24.17	8.00
Summerstown Ditch	SUMM MW2A	2.15	35.00	8.00	SUMM JB2S	1.93	24.17	8.00
Summerstown Ditch	SUMM JB1A	1.85	52.50	8.00	SUMM DW1S	1.80	25.00	8.00
Summerstown Ditch	SUMM JB2A	1.85	52.50	8.00	SUMM DW2S	1.80	25.00	8.00
Crendon Stream	CREN JB1A	1.13	14.67	3.01	CREN MW1S	1.02	14.33	2.53
Crendon Stream	CREN JB2A	1.13	14.67	3.01	CREN MW2S	1.02	14.33	2.53
Crendon Stream	CREN RA1A	0.98	16.00	2.89	CREN JB1S	1.15	13.67	2.79
Crendon Stream	CREN RA2A	0.98	16.00	2.89	CREN JB2S	1.15	13.67	2.79
Wheatley Ditch	WHEA DW1A	1.03	27.89	2.74	WHEA JB1S	1.27	32.78	4.59
Wheatley Ditch	WHEA DW2A	1.03	27.89	2.74	WHEA JB2S	1.27	32.78	4.59
Wheatley Ditch	WHEA MW1A	1.07	30.56	5.68	WHEA MW1S	1.15	41.67	3.88
Wheatley Ditch	WHEA MW2A	1.07	30.56	5.68	WHEA MW2S	1.15	41.67	3.88
Crawters Brook	CRAW MW1A	2.24	30.83	2.18	CRAW RA1S	2.27	36.67	2.90
Crawters Brook	CRAW MW2A	2.24	30.83	2.18	CRAW RA2S	2.27	36.67	2.90
Crawters Brook	CRAW DW1A	2.90	31.78	3.49	CRAW MW1S	2.67	31.78	4.03
Crawters Brook	CRAW DW2A	2.90	31.78	3.49	CRAW MW2S	2.67	31.78	4.03
Catherine Bourne	CATH DW1A	2.35	11.00	0.74	CATH MW1S	2.84	16.07	-0.18
Catherine Bourne	CATH DW2A	2.35	11.00	0.74	CATH MW2S	2.84	16.07	-0.18
Catherine Bourne	CATH JB1A	2.27	10.67	-1.90	CATH DW1S	3.15	20.83	1.03
Catherine Bourne	CATH JB2A	2.27	10.67	-1.90	CATH DW2S	3.15	20.83	1.03

MPS = Median particle size in ϕ units

Appendix table 3.6 Effect of season and sample combinations on 5M banding

Site	NRA 1992 combined-seasons	Data used for banding: Autumn single sample	Spring single sample	Combined-seasons	Dual sample
Bow Brook	1	1	1	1	1
		1	1	1	1
		1	1	1	1
		1	1	1	1
River Thames	1	1	1	1	1
		1	1	1	1
		1	1	1	1
		1	1	1	1
River Coln	1	1	1	1	1
		1	1	1	1
		1	1	1	1
		1	1	1	1
The Cut	2	2	2	2	2
		2	2	3	2
		1	3	2	2
		1	2	2	3
Lydiard Stream	2	1	1	1	1
		1	1	1	1
		1	1	1	1
		1	1	1	1
Halfacre Brook	2	2	2	2	3
		2	1	2	3
		2	1	2	2
		2	1	2	2
Roundmoor Ditch	3	2	2	3	2
		2	2	2	2
		2	2	2	3
		2	2	2	3
Summerstown Ditch	3	2	3	3	3
		2	3	3	3
		3	3	3	3
		2	3	3	3
Crendon Stream	3	3	3	4	4
		3	3	4	3
		3	3	4	4
		2	3	3	4
Wheatley Ditch	4	2	3	3	3
		2	2	3	3
		2	3	3	3
		2	2	3	3
Crawters Brook	4	3	4	4	4
		3	3	4	4
		3	3	4	4
		3	4	4	4
Catherine Bourne	4	2	2	2	2
		2	2	2	2
		2	2	2	2
		1	2	2	2

Appendix table 5.1a Variability of RIVPACS predictions and field data (measured as standard deviation and coefficient of variation): single season

Autumn samples	Predicted TAXA		Predicted BMWP		Predicted ASPT		WIDTH (m)		DEPTH (cm)		PHI
	STDEV	CV%	STDEV	CV%	STDEV	CV%	STDEV	CV%	STDEV	CV%	STDEV
Bow Brook	0.000	0.0	0.404	0.4	0.058	1.3	0.346	6.9	6.928	7.9	0.658
River Thames	0.115	0.5	0.808	0.6	0.000	0.0	0.000	0.0	0.000	0.0	0.000
River Coln	0.173	0.8	1.501	1.5	0.058	1.2	0.115	2.5	1.091	6.8	0.195
The Cut	0.289	1.3	2.309	2.1	0.058	1.2	0.192	2.2	0.000	0.0	1.342
Lydiard Stream	0.058	0.3	0.289	0.3	0.000	0.0	0.058	2.6	0.321	0.7	0.247
Halfacre Brook	0.115	0.6	0.462	0.5	0.000	0.0	0.029	1.8	10.873	24.9	0.000
Roundmoor Ditch	0.058	0.3	0.404	0.4	0.000	0.0	0.115	2.3	1.732	2.4	0.000
Summerstown Ditch	0.058	0.3	0.000	0.0	0.000	0.0	0.173	8.7	10.104	23.1	0.000
Crendon Stream	0.000	0.0	0.231	0.3	0.000	0.0	0.085	8.0	0.768	5.0	0.072
Wheatley Ditch	0.404	2.0	3.233	3.3	0.058	1.2	0.019	1.8	1.540	5.3	1.697
Crawters Brook	0.271	1.3	1.131	1.1	0.050	1.0	0.382	14.9	0.545	1.7	0.758
Catherine Bourne	0.520	2.6	4.215	4.4	0.115	2.5	0.048	2.1	0.192	1.8	1.524
Mean	0.172	0.82	1.249	1.25	1.250	0.70	0.130	4.48	2.841	6.65	0.541
Standard error of the mean	0.048	0.23	0.386	0.40	0.395	0.23	0.036	1.24	1.165	2.46	0.187
Spring samples	**Predicted TAXA**		**Predicted BMWP**		**Predicted ASPT**		**WIDTH (m)**		**DEPTH (cm)**		**PHI**
	STDEV	CV%	STDEV	CV%	STDEV	CV%	STDEV	CV%	STDEV	CV%	STDEV
Bow Brook	0.058	0.3	0.058	0.1	0.000	0.0	0.043	0.9	4.731	4.7	0.065
River Thames	0.058	0.2	0.462	0.3	0.000	0.0	0.000	0.0	0.000	0.0	0.000
River Coln	0.000	0.0	0.000	0.0	0.000	0.0	0.356	5.4	0.449	0.9	0.663
The Cut	0.173	0.8	1.270	1.2	0.000	0.0	0.481	4.5	8.596	31.8	0.844
Lydiard Stream	0.173	0.8	1.963	1.9	0.058	1.2	0.125	6.3	1.463	4.4	1.321
Halfacre Brook	0.058	0.3	0.115	0.1	0.000	0.0	0.654	13.0	1.764	4.3	0.000
Roundmoor Ditch	0.115	0.6	0.577	0.6	0.000	0.0	0.067	4.1	0.289	1.0	0.173
Summerstown Ditch	0.000	0.0	0.058	0.1	0.000	0.0	0.072	3.9	0.481	2.0	0.000
Crendon Stream	0.000	0.0	1.097	1.1	0.058	1.1	0.077	7.1	0.385	2.7	0.152
Wheatley Ditch	0.058	0.3	0.115	0.1	0.000	0.0	0.067	5.6	5.132	13.8	0.411
Crawters Brook	0.058	0.3	0.346	0.3	0.000	0.0	0.231	9.4	2.823	8.2	0.650
Catherine Bourne	0.000	0.0	1.039	1.0	0.058	1.1	0.179	6.0	2.752	14.9	0.693
Mean	0.063	0.30	0.592	0.56	0.564	0.28	0.196	5.50	2.405	7.41	0.414
Standard error of the mean	0.018	0.09	0.179	0.17	0.172	0.15	0.058	1.00	0.752	2.62	0.122
Autumn and spring summary	**Predicted TAXA**		**Predicted BMWP**		**Predicted ASPT**		**WIDTH (m)**		**DEPTH (cm)**		**PHI**
	STDEV	CV%	STDEV	CV%	STDEV	CV%	STDEV	CV%	STDEV	CV%	STDEV
Mean	0.117	0.56	0.920	0.91	0.907	0.49	0.163	4.99	2.623	7.03	0.478
Standard error of the mean	0.027	0.13	0.219	0.22	0.223	0.14	0.034	0.79	0.679	1.76	0.110

Appendix table 5.1b Variability of RIVPACS predictions and field data (measured as standard deviation and coefficient of variation): combined-seasons

Combined-seasons	Predicted TAXA		Predicted BMWP		Predicted ASPT		WIDTH (m)		DEPTH (cm)		PHI
	STDEV	CV%	STDEV	CV%	STDEV	CV%	STDEV	CV%	STDEV	CV%	STDEV
Bow Brook	0.000	0.0	0.058	0.0	0.000	0.0	0.2	3.0	1.1	1.2	0.3
River Thames	0.050	0.2	0.350	0.2	0.000	0.0	0.0	0.0	0.0	0.0	0.0
River Coln	0.058	0.2	0.058	0.0	0.000	0.0	0.1	2.1	0.3	1.0	0.2
The Cut	0.231	0.9	2.367	1.7	0.058	1.1	0.1	1.5	4.3	19.3	1.1
Lydiard Stream	0.126	0.5	1.014	0.8	0.050	1.0	0.1	3.3	0.7	1.9	0.7
Halfacre Brook	0.050	0.2	0.236	0.2	0.000	0.0	0.3	9.8	5.5	13.0	0.0
Roundmoor Ditch	0.096	0.4	0.597	0.5	0.000	0.0	0.1	2.0	0.9	1.8	0.1
Summerstown Ditch	0.058	0.2	0.535	0.5	0.000	0.0	0.1	4.9	5.1	14.8	0.0
Crendon Stream	0.058	0.2	0.751	0.6	0.058	1.1	0.0	0.4	0.2	1.3	0.0
Wheatley Ditch	0.275	1.1	2.317	1.7	0.058	1.1	0.0	3.1	2.7	8.1	0.9
Crawters Brook	0.050	0.2	0.550	0.4	0.000	0.0	0.2	8.9	1.4	4.4	0.5
Catherine Bourne	0.457	1.8	3.016	2.2	0.050	1.0	0.1	3.5	1.4	9.4	0.8
Mean	0.126	0.49	0.987	0.75	0.023	0.44	0.111	3.54	1.966	6.35	0.386
Standard error of the mean	0.038	0.15	0.290	0.21	0.008	0.159	0.027	0.88	0.523	1.57	0.114

Appendix table 5.2 Factors affecting variability in RIVPACS predictions

(1)	**Standard deviation of single-season predicted TAXA (SDSPT)**		
STEP	Variable included	R^2 adjusted	F for inclusion
1	Standard deviation of phi [1](SD PHI)	50.3%	24.3
2	Coefficient of variation of width (CVW)	60.3%	18.5
Regression	SDSPT = .094 + 0.176 SD PHI - .010 CVW		
(2)	**Standard deviation of single-season predicted BMWP (SDSPB)**		
STEP	Variable included	R^2 adjusted	F for inclusion
1	Standard deviation of phi (SD PHI)	62.8%	39.8
2	Coefficient of variation of width (CVW)	69.9%	27.7
Regression	SDSPB = .606 + 1.603 SD PHI - .071 CVW		
(3)	**Standard deviation of single-season predicted ASPT (SDSPA)**		
STEP	Variable included	R^2 adjusted	F for inclusion
1	Standard deviation of phi (SD PHI)	47.3%	21.6
2	No other variable included		
Regression	SDSPA = .00368 + 0.0440 SD PHI		
(4)	**Coefficient of variation of single-season predicted TAXA (CVSPT)**		
STEP	Variable included	R^2 adjusted	F for inclusion
1	Standard deviation of phi (SD PHI)	49.1%	23.2
2	Coefficient of variation of width (CVW)	58.0%	16.9
Regression	CVSPT = 0.439 + 0.851 SD PHI - .048 CVW		
(5)	**Coefficient of variation of single-season predicted BMWP (CVSPB)**		
STEP	Variable included	R^2 adjusted	F for inclusion
1	Standard deviation of phi (SD PHI)	60.3%	36.0
2	Standard deviation of width (SD W)	67.1%	24.5
Regression	CVSPB = 0.476 + 1.672 SD PHI - 1.874 SDW		
(6)	**Coefficient of variation of single-season predicted ASPT (CVSPA)**		
STEP	Variable included	R^2 adjusted	F for inclusion
1	Standard deviation of phi (SD PHI)	47.3%	21.6
2	No other variables included		
Regression	CVSPA = 0.070 + 0.929 SD PHI		

[1] Phi = median substrate size in ϕ units

Appendix table 5.2 Factors affecting variability in RIVPACS predictions[2] (continued)

(7) Standard deviation of combined-season predicted TAXA (SDCPT)

STEP	Variable included	R^2 adjusted	F for inclusion
1	Standard deviation of phi (SD PHI)	50.8%	12.4
2	No other variables included	p=<0.006	
Regression	SDCPT = 0.30 + 0.248 SD PHI		

(8) Standard deviation of combined-season predicted BMWP (SDCPB)

STEP	Variable included	R^2 adjusted	F for inclusion
1	Standard deviation of phi (SD PHI)	65.9%	22.2
2	No other variables included		
Regression	SDCPB = 0.174 + 2.107 SD PHI		

(9) Standard deviation of combined-season predicted ASPT (SDCPA)

STEP	Variable included	R^2 adjusted	F for inclusion
1	Standard deviation of phi (SD PHI)	43.5%	9.47
2	No other variables included	p=<0.012	
Regression	SDCPA = 0.0035 + 0.050 SD PHI		

(10) Coefficient of variation of combined-season predicted TAXA (CVCPT)

STEP	Variable included	R^2 adjusted	F for inclusion
1	Standard deviation of phi (SD PHI)	49.0%	11.6
2	No other variables included	p=<.0068	
Regression	CVCPT = 0.126 + 0.930 SD PHI		

(11) Coefficient of variation of combined-season predicted BMWP (CVCPB)

STEP	Variable included	R^2 adjusted	F for inclusion
1	Standard deviation of phi (SD PHI)	63.8%	20.4
2	No other variables included		
Regression	CVCPB = 0.157 + 1.532 SD PHI		

(12) Coefficient of variation of combined-season predicted ASPT (CVCPA)

STEP	Variable included	R^2 adjusted	F for inclusion
1	Standard deviation of phi (SD PHI)	45.7%	10.3
2	No other variables included	p=<.0094	
Regression	CVCPA = 0.0618 + 0.989 SD PHI		

[2] The tables show the R^2 adjusted term which estimates the amount of variation explained by the included variable in step 1 or both included variables where there is a second step. Variables not included did not add significant predictive power to the regression equation. The F to enter for the analysis was 4 and the F values for inclusion of variables are also shown. The number of values used with single-season data was 24 and the number for combined-season data was 12. The F values are not, therefore, directly comparable between single- and combined-season analyses. Where the probability of inclusion drops below the P=<0.001 level this is also shown.

Appendix 6.1. Variability of TAXA.EQI (single season)

% probability of inclusion in 5M bands

TAXA.EQI	TAXA=5		TAXA=8		TAXA=10		TAXA=12		TAXA=14		TAXA=16		TAXA=18		TAXA=20	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1.00																
0.99																
0.98																
0.97																
0.96																
0.95																
0.94																
0.93																
0.92																
0.91															100	0
0.90															99	1
0.89													100	0	99	1
0.88											100	0	99	1	99	1
0.87											99	1	99	1	99	1
0.86									100	0	99	1	99	1	98	2
0.85							100	0	99	1	99	1	98	2	98	2
0.84					100	0	99	1	99	1	99	2	98	2	97	3
0.83			100	0	99	1	99	1	99	1	98	2	97	3	96	4
0.82			99	1	99	1	99	1	98	2	97	3	96	4	95	5
0.81	100	0	99	1	99	1	98	2	97	3	96	4	95	5	94	6
0.80	99	1	99	1	98	2	97	3	96	4	95	5	94	6	93	7
0.79	99	1	98	2	97	3	96	4	95	5	94	6	92	8	91	9
0.78	98	2	97	3	96	4	95	5	93	7	92	8	90	10	89	11
0.77	97	3	95	5	94	6	93	7	91	9	90	10	88	12	87	13
0.76	95	5	94	6	92	8	91	9	89	11	87	13	86	14	84	16
0.75	93	7	91	9	90	10	88	12	86	14	85	15	83	17	81	19
0.74	91	9	88	12	86	14	85	15	83	17	82	18	80	20	78	22
0.73	87	13	85	15	83	17	81	19	79	21	78	22	76	24	75	25
0.72	83	17	80	20	79	21	77	23	75	25	74	26	73	27	71	29
0.71	77	23	75	25	74	26	72	28	71	29	70	31	68	32	67	33
0.70	71	29	70	31	68	32	67	33	66	34	65	35	64	36	63	37
0.69	65	35	63	37	63	37	61	39	61	39	60	40	59	41	59	41
0.68	58	42	57	43	56	44	56	44	56	44	55	45	55	45	54	46
0.67	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50

Appendix 6.1. Variability of TAXA.EQI (single season) (continued)

% probability of inclusion in 5M bands

TAXA.EQI	TAXA=22		TAXA=24		TAXA=26		TAXA=28		TAXA=30	
	A	B	A	B	A	B	A	B	A	B
1.00									100	0
0.99									99	1
0.98							100	0	99	1
0.97							99	1	99	1
0.96					100	0	99	1	99	1
0.95					99	1	99	1	99	1
0.94			100	0	99	1	99	1	98	2
0.93			99	1	99	1	99	1	98	2
0.92	100	0	99	1	99	1	98	2	98	3
0.91	99	1	99	1	98	2	98	2	97	3
0.90	99	1	99	1	98	2	97	3	96	4
0.89	99	1	98	2	98	2	97	3	96	4
0.88	99	1	98	2	97	3	96	4	95	5
0.87	98	2	97	3	96	4	95	5	94	6
0.86	98	2	97	3	96	4	95	5	93	7
0.85	97	3	96	4	95	5	93	7	92	8
0.84	96	4	95	5	94	6	92	8	91	9
0.83	95	5	94	6	93	7	91	9	89	11
0.82	94	6	93	7	91	9	90	10	88	12
0.81	93	7	91	9	90	10	88	12	86	14
0.80	91	9	90	10	88	12	86	14	85	15
0.79	89	11	88	12	86	14	84	16	83	17
0.78	87	13	86	14	84	16	82	18	81	19
0.77	85	15	83	17	82	18	80	20	78	22
0.76	82	18	81	19	79	21	78	22	76	24
0.75	80	20	78	22	76	24	75	25	74	26
0.74	77	23	75	25	74	26	72	28	71	29
0.73	73	27	72	28	71	29	69	31	68	32
0.72	70	30	68	32	67	33	66	34	65	35
0.71	66	34	65	35	64	36	63	37	61	39
0.70	62	38	61	39	61	39	60	40	58	41
0.69	58	42	58	42	57	43	57	43	56	44
0.68	54	46	54	46	54	57	53	47	52	48
0.67	50	50	50	50	50	50	50	50	50	50

Appendix 6.1 Variability of TAXA.EQI (single season)
(continued)

% probability of inclusion in 5M bands

	TAXA=5				TAXA=8				TAXA=10				TAXA=12			
TAXA.EQI	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
0.67	50	50	0	0	50	50	0	0	50	50	0	0	50	50	0	0
0.66	42	58	0	0	43	57	0	0	44	56	0	0	44	56	0	0
0.65	35	65	0	0	37	63	0	0	37	63	0	0	39	61	0	0
0.64	29	71	0	0	31	70	0	0	32	68	0	0	33	67	0	0
0.63	23	77	0	0	25	75	0	0	26	74	0	0	28	72	0	0
0.62	17	83	0	0	20	80	0	0	21	79	0	0	23	77	0	0
0.61	13	87	0	0	15	85	0	0	17	83	0	0	19	81	0	0
0.60	9	91	0	0	12	88	0	0	14	86	0	0	15	85	0	0
0.59	7	93	0	0	9	91	0	0	10	90	0	0	12	88	0	0
0.58	5	95	0	0	6	94	0	0	8	92	0	0	9	91	0	0
0.57	3	97	0	0	5	95	0	0	6	94	0	0	7	93	0	0
0.56	2	98	0	0	3	97	0	0	4	96	0	0	5	95	0	0
0.55	1	99	0	0	2	98	0	0	3	97	0	0	4	96	0	0
0.54	1	99	0	0	1	99	0	0	2	98	0	0	3	97	0	0
0.53	0	100	0	0	1	99	0	0	1	99	0	0	2	98	0	0
0.52	0	100	0	0	1	99	0	0	1	99	0	0	1	98	0	0
0.51	0	100	0	0	0	99	0	0	1	99	0	0	1	98	1	0
0.50	0	100	0	0	0	99	0	0	0	99	1	0	1	98	1	0
0.49	0	100	0	0	0	99	1	0	0	99	1	0	0	98	1	0
0.48	0	100	0	0	0	99	1	0	0	99	1	0	0	98	2	0
0.47	0	99	1	0	0	99	1	0	0	98	2	0	0	97	3	0
0.46	0	99	1	0	0	98	2	0	0	97	3	0	0	96	4	0
0.45	0	98	2	0	0	97	3	0	0	96	4	0	0	95	5	0
0.44	0	97	3	0	0	95	5	0	0	94	6	0	0	93	7	0
0.43	0	95	5	0	0	94	6	0	0	92	8	0	0	91	9	0
0.42	0	93	7	0	0	91	9	0	0	90	10	0	0	88	12	0
0.41	0	91	9	0	0	88	12	0	0	86	14	0	0	85	15	0
0.40	0	87	13	0	0	85	15	0	0	83	17	0	0	81	19	0
0.39	0	83	17	0	0	80	20	0	0	79	21	0	0	77	23	0
0.38	0	77	23	0	0	75	25	0	0	74	26	0	0	72	28	0
0.37	0	71	29	0	0	70	31	0	0	68	32	0	0	67	33	0
0.36	0	65	35	0	0	63	37	0	0	63	37	0	0	61	39	0
0.35	0	58	42	0	0	57	43	0	0	56	44	0	0	56	44	0
0.34	0	50	50	0	0	50	50	0	0	50	50	0	0	50	50	0
0.33	0	42	58	0	0	43	57	0	0	44	56	0	0	44	56	0
0.32	0	35	65	0	0	37	63	0	0	37	63	0	0	39	61	0
0.31	0	29	71	0	0	31	70	0	0	32	68	0	0	33	67	0
0.30	0	23	77	0	0	25	75	0	0	26	74	0	0	28	72	0
0.29	0	17	83	0	0	20	80	0	0	21	79	0	0	23	77	0
0.28	0	13	87	0	0	15	85	0	0	17	83	0	0	19	81	0
0.27	0	9	91	0	0	12	88	0	0	14	86	0	0	15	85	0
0.26	0	7	93	0	0	9	91	0	0	10	90	0	0	12	88	0
0.25	0	5	95	0	0	6	94	0	0	8	92	0	0	9	91	0
0.24	0	3	97	0	0	5	95	0	0	6	94	0	0	7	93	0
0.23	0	2	98	0	0	3	97	0	0	4	96	0	0	5	95	0
0.22	0	1	99	0	0	2	98	0	0	3	97	0	0	4	96	0
0.21	0	1	99	0	0	1	99	0	0	2	98	0	0	3	97	0
0.20	0	0	100	0	0	1	99	0	0	1	99	0	0	2	98	0
0.19	0	0	100	0	0	1	99	0	0	1	99	0	0	1	98	0
0.18	0	0	100	0	0	0	99	0	0	1	99	0	0	1	98	1
0.17	0	0	100	0	0	0	99	0	0	0	99	1	0	1	98	1
0.16	0	0	100	0	0	0	99	1	0	0	99	1	0	0	98	1
0.15	0	0	100	0	0	0	99	1	0	0	99	1	0	0	98	2
0.14	0	0	99	1	0	0	99	1	0	0	98	2	0	0	97	3
0.13	0	0	99	1	0	0	98	2	0	0	97	3	0	0	96	4
0.12	0	0	98	2	0	0	97	3	0	0	96	4	0	0	95	5
0.11	0	0	97	3	0	0	95	5	0	0	94	6	0	0	93	7
0.10	0	0	95	5	0	0	94	6	0	0	92	8	0	0	91	9
0.09	0	0	93	7	0	0	91	9	0	0	90	10	0	0	88	12
0.08	0	0	91	9	0	0	88	12	0	0	86	14	0	0	85	15
0.07	0	0	87	13	0	0	85	15	0	0	83	17	0	0	81	19

Appendix 6.1 Variability of TAXA.EQI (single season) (continued)

% probability of inclusion in 5M bands

	TAXA=14				TAXA=16				TAXA=18			
TAXA.EQI	A	B	C	D	A	B	C	D	A	B	C	D
0.67	50	50	0	0	50	50	0	0	50	50	0	0
0.66	44	56	0	0	45	55	0	0	45	55	0	0
0.65	39	61	0	0	40	60	0	0	41	59	0	0
0.64	34	66	0	0	35	65	0	0	36	64	0	0
0.63	29	71	0	0	31	70	0	0	32	68	0	0
0.62	25	75	0	0	26	74	0	0	27	73	0	0
0.61	21	79	0	0	22	78	0	0	24	76	0	0
0.60	17	83	0	0	18	82	0	0	20	80	0	0
0.59	14	86	0	0	15	85	0	0	17	83	0	0
0.58	11	89	0	0	13	87	0	0	14	86	0	0
0.57	9	91	0	0	10	90	0	0	12	88	0	0
0.56	7	93	0	0	8	92	0	0	10	90	0	0
0.55	5	95	0	0	6	93	0	0	8	92	1	0
0.54	4	96	0	0	5	95	1	0	6	93	1	0
0.53	3	97	0	0	4	96	1	0	5	94	1	0
0.52	2	97	1	0	3	96	1	0	4	95	2	0
0.51	1	98	1	0	2	96	2	0	3	95	2	0
0.50	1	98	1	0	2	96	2	0	2	95	3	0
0.49	1	97	2	0	1	96	3	0	2	95	4	0
0.48	0	97	3	0	1	96	4	0	1	94	5	0
0.47	0	96	4	0	1	95	5	0	1	93	6	0
0.46	0	95	5	0	0	93	6	0	1	92	8	0
0.45	0	93	7	0	0	92	8	0	0	90	10	0
0.44	0	91	9	0	0	90	10	0	0	88	12	0
0.43	0	89	11	0	0	87	13	0	0	86	14	0
0.42	0	86	14	0	0	85	15	0	0	83	17	0
0.41	0	83	17	0	0	82	18	0	0	80	20	0
0.40	0	79	21	0	0	78	22	0	0	76	24	0
0.39	0	75	25	0	0	74	26	0	0	73	27	0
0.38	0	71	29	0	0	70	31	0	0	68	32	0
0.37	0	66	34	0	0	65	35	0	0	64	36	0
0.36	0	61	39	0	0	60	40	0	0	59	41	0
0.35	0	56	44	0	0	55	45	0	0	55	45	0
0.34	0	50	50	0	0	50	50	0	0	50	50	0
0.33	0	44	56	0	0	45	55	0	0	45	55	0
0.32	0	39	61	0	0	40	60	0	0	41	59	0
0.31	0	34	66	0	0	35	65	0	0	36	64	0
0.30	0	29	71	0	0	31	70	0	0	32	68	0
0.29	0	25	75	0	0	26	74	0	0	27	73	0
0.28	0	21	79	0	0	22	78	0	0	24	76	0
0.27	0	17	83	0	0	18	82	0	0	20	80	0
0.26	0	14	86	0	0	15	85	0	0	17	83	0
0.25	0	11	89	0	0	13	87	0	0	14	86	0
0.24	0	9	91	0	0	10	90	0	0	12	88	0
0.23	0	7	93	0	0	8	92	0	0	10	90	0
0.22	0	5	95	0	0	6	93	0	0	8	92	1
0.21	0	4	96	0	0	5	95	1	0	6	93	1
0.20	0	3	97	0	0	4	96	1	0	5	94	1
0.19	0	2	97	1	0	3	96	1	0	4	95	2
0.18	0	1	98	1	0	2	96	2	0	3	95	2
0.17	0	1	98	1	0	2	96	2	0	2	95	3
0.16	0	1	97	2	0	1	96	3	0	2	95	4
0.15	0	0	97	3	0	1	96	4	0	1	94	5
0.14	0	0	96	4	0	1	95	5	0	1	93	6
0.13	0	0	95	5	0	0	93	6	0	1	92	8
0.12	0	0	93	7	0	0	92	8	0	0	90	10
0.11	0	0	91	9	0	0	90	10	0	0	88	12
0.10	0	0	89	11	0	0	87	13	0	0	86	14
0.09	0	0	86	14	0	0	85	15	0	0	83	17
0.08	0	0	83	17	0	0	82	18	0	0	80	20
0.07	0	0	79	21	0	0	78	22	0	0	76	24

Appendix 6.2 Variability of TAXA.EQI (combined season)

% probability of inclusion in 5M bands

TAXA.EQI	TAXA=15		TAXA=20		TAXA=25		TAXA=30		TAXA=35			TAXA=40		
	A	B	A	B	A	B	A	B	A	B	C	A	B	C
1.06												100	0	0
1.05												99	1	0
1.04												99	1	0
1.03												99	1	0
1.02									100	0	0	99	1	0
1.01									99	1	0	99	1	0
1.00									99	1	0	98	2	0
0.99							100	0	99	1	0	98	2	0
0.98							99	1	99	1	0	97	3	0
0.97					100	0	99	1	98	2	0	97	3	0
0.96					99	1	99	1	98	2	0	96	4	0
0.95					99	1	98	2	97	3	0	95	5	0
0.94			100	0	99	1	98	2	96	4	0	94	6	0
0.93			99	1	99	2	97	3	95	5	0	93	7	0
0.92	100	0	99	1	98	2	96	4	94	6	0	91	9	0
0.91	99	1	98	2	97	3	95	5	93	7	0	90	10	0
0.90	99	1	98	2	96	4	94	6	91	9	0	88	12	0
0.89	98	2	97	3	95	5	92	8	89	11	0	86	14	0
0.88	97	3	96	4	93	7	90	10	87	13	0	84	16	0
0.87	96	4	94	6	91	9	88	12	85	15	0	82	18	0
0.86	94	6	92	8	89	11	86	14	83	17	0	79	20	0
0.85	92	8	89	11	86	14	83	17	80	20	0	77	23	0
0.84	89	11	86	14	83	17	80	20	77	23	0	74	26	0
0.83	86	14	82	18	79	21	76	24	74	26	0	71	29	0
0.82	81	19	78	22	75	25	72	28	70	30	0	68	32	1
0.81	76	24	73	27	71	29	68	32	66	33	0	64	35	1
0.80	70	30	68	32	66	34	64	36	62	37	0	61	38	1
0.79	64	36	62	38	61	39	59	40	58	41	0	57	42	1
0.78	57	43	56	44	56	44	55	45	54	45	1	54	45	1
0.77	50	50	50	50	50	50	50	50	50	49	1	50	48	2

Appendix 6.2 Variability of TAXA.EQI (combined season) (continued)
% probability of inclusion in 5M bands

TAXA.EQI	TAXA=5 A	TAXA=5 B	TAXA=5 C	TAXA=5 D	TAXA=10 A	TAXA=10 B	TAXA=10 C	TAXA=10 D	TAXA=15 A	TAXA=15 B	TAXA=15 C	TAXA=15 D	TAXA=20 A	TAXA=20 B	TAXA=20 C	TAXA=20 D
0.77	50	50	0	0	50	50	0	0	50	50	0	0	50	50	0	0
0.76	41	59	0	0	42	58	0	0	43	57	0	0	44	56	0	0
0.75	32	68	0	0	34	66	0	0	36	64	0	0	38	62	0	0
0.74	25	75	0	0	27	73	0	0	30	70	0	0	32	68	0	0
0.73	18	82	0	0	21	79	0	0	24	76	0	0	27	73	0	0
0.72	13	87	0	0	16	84	0	0	19	81	0	0	22	78	0	0
0.71	9	91	0	0	11	89	0	0	14	85	0	0	18	82	0	0
0.70	5	95	0	0	8	92	0	0	11	89	0	0	14	85	1	0
0.69	3	97	0	0	5	95	0	0	8	92	0	0	11	88	1	0
0.68	2	98	0	0	4	96	0	0	6	94	1	0	8	90	2	0
0.67	1	99	0	0	2	97	0	0	4	95	1	0	6	92	2	0
0.66	1	99	0	0	1	98	1	0	3	96	2	0	4	92	3	0
0.65	0	99	1	0	1	98	1	0	2	96	3	0	3	92	4	0
0.64	0	99	1	0	0	97	2	0	1	95	4	0	2	92	6	0
0.63	0	98	2	0	0	96	4	0	1	94	6	0	2	90	8	0
0.62	0	97	3	0	0	95	5	0	0	92	8	0	1	88	11	0
0.61	0	95	5	0	0	92	8	0	0	89	11	0	1	85	14	0
0.60	0	91	9	0	0	89	11	0	0	85	14	0	0	82	18	0
0.59	0	87	13	0	0	84	16	0	0	81	19	0	0	78	22	0
0.58	0	82	18	0	0	79	21	0	0	76	24	0	0	73	27	0
0.57	0	75	25	0	0	73	27	0	0	70	30	0	0	68	32	0
0.56	0	68	32	0	0	66	34	0	0	41	59	0	0	62	38	0
0.55	0	59	41	0	0	58	42	0	0	45	55	0	0	56	44	0
0.54	0	50	50	0	0	50	50	0	0	50	50	0	0	50	50	0
0.53	0	41	59	0	0	42	58	0	0	43	57	0	0	44	56	0
0.52	0	32	68	0	0	34	66	0	0	36	64	0	0	38	62	0
0.51	0	25	75	0	0	27	73	0	0	30	70	0	0	32	68	0
0.50	0	18	82	0	0	21	79	0	0	24	76	0	0	27	73	0
0.49	0	13	87	0	0	16	84	0	0	19	81	0	0	22	78	0
0.48	0	9	91	0	0	11	89	0	0	14	85	0	0	18	82	0
0.47	0	5	95	0	0	8	92	0	0	11	89	0	0	14	85	1
0.46	0	3	97	0	0	5	95	0	0	8	92	0	0	11	88	1
0.45	0	2	98	0	0	4	96	0	0	5	94	1	0	8	90	2
0.44	0	1	99	0	0	2	97	0	0	4	95	1	0	7	92	3
0.43	0	1	99	0	0	1	98	1	0	3	96	2	0	4	92	4
0.42	0	0	99	1	0	1	98	1	0	1	96	3	0	3	92	5
0.41	0	0	99	1	0	0	97	2	0	1	95	4	0	2	92	6
0.40	0	0	98	2	0	0	96	4	0	1	94	5	0	2	90	8
0.39	0	0	97	3	0	0	95	5	0	0	92	8	0	1	88	12
0.38	0	0	95	5	0	0	92	8	0	0	89	11	0	1	85	14
0.37	0	0	91	9	0	0	89	11	0	0	85	15	0	0	82	18
0.36	0	0	87	13	0	0	84	16	0	0	81	19	0	0	78	22
0.35	0	0	82	18	0	0	79	21	0	0	76	24	0	0	73	27
0.34	0	0	75	25	0	0	73	27	0	0	70	30	0	0	68	32
0.33	0	0	68	32	0	0	66	34	0	0	64	36	0	0	62	38
0.32	0	0	59	41	0	0	58	42	0	0	57	43	0	0	56	44
0.31	0	0	50	50	0	0	50	50	0	0	50	50	0	0	50	50
0.30	0	0	41	59	0	0	42	58	0	0	43	57				
0.29	0	0	32	68	0	0	34	66	0	0	36	64				
0.28	0	0	25	75	0	0	27	73	0	0	30	70				
0.27	0	0	18	82	0	0	21	79	0	0	24	76				
0.26	0	0	13	87	0	0	16	84	0	0	19	81				
0.25	0	0	9	91	0	0	11	89	0	0	14	86				
0.24	0	0	5	95	0	0	8	92	0	0	11	89				
0.23	0	0	3	97	0	0	5	95	0	0	8	92				
0.22	0	0	2	98	0	0	4	96	0	0	6	94				
0.21	0	0	1	99	0	0	2	98	0	0	4	96				

Appendix 6.2 Variability of TAXA.EQI (combined season)
(continued)

% probability of inclusion in 5M bands

	TAXA=25			
TAXA.EQI	A	B	C	D
0.77	50	50	0	0
0.76	45	55	0	0
0.75	40	61	0	0
0.74	34	66	0	0
0.73	30	71	1	0
0.72	25	75	1	0
0.71	21	78	1	0
0.70	18	81	2	0
0.69	14	84	2	0
0.68	12	86	3	0
0.67	9	87	4	0
0.66	7	88	6	0
0.65	6	88	7	0
0.64	4	87	9	0
0.63	3	86	12	0
0.62	2	84	14	0
0.61	2	81	18	0
0.60	1	78	21	0
0.59	1	75	25	0
0.58	1	71	30	0
0.57	0	66	34	0
0.56	0	61	40	0
0.55	0	55	45	0
0.54	0	50	50	0
0.53	0	44	55	0
0.52	0	39	60	0
0.51	0	34	66	0
0.50	0	29	70	1
0.49	0	25	74	1
0.48	0	21	78	1
0.47	0	17	81	2
0.46	0	14	84	2
0.45	0	11	86	3
0.44	0	9	87	4
0.43	0	7	88	5
0.42	0	5	88	7
0.41	0	4	87	9
0.40	0	3	86	11
0.39	0	2	84	14
0.38	0	2	81	17
0.37	0	1	78	21
0.36	0	1	74	25
0.35	0	1	70	29
0.34	0	0	66	34
0.33	0	0	60	39
0.32	0	0	55	44
0.31	0	0	50	50

Appendix 6.3 Variability of BMWP.EQI (single season)

% probability of inclusion in 5M bands

BMWP.EQI	BMWP = 40		BMWP = 50		BMWP = 60		BMWP = 70		BMWP = 80		BMWP = 90		BMWP = 100		BMWP = 110	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1.11	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
1.10	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
1.09	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
1.08	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
1.07	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
1.06	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
1.05	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
1.04	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
1.03	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
1.02	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
1.01	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
1.00	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
0.99	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
0.98	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
0.97	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
0.96	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
0.95	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
0.94	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
0.93	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	1
0.92	100	0	100	0	100	0	100	0	100	0	100	0	100	0	99	1
0.91	100	0	100	0	100	0	100	0	100	0	100	0	100	0	99	1
0.90	100	0	100	0	100	0	100	0	100	0	100	0	100	1	99	1
0.89	100	0	100	0	100	0	100	0	100	0	100	0	99	1	99	1
0.88	100	0	100	0	100	0	100	0	100	0	100	1	99	1	99	2
0.87	100	0	100	0	100	0	100	0	100	0	99	1	99	1	98	2
0.86	100	0	100	0	100	0	100	0	100	1	99	1	99	2	98	2
0.85	100	0	100	0	100	0	100	0	99	1	99	1	98	2	97	3
0.84	100	0	100	0	100	0	100	1	99	1	99	2	98	2	97	3
0.83	100	0	100	0	100	0	99	1	99	1	98	2	97	3	96	4
0.82	100	0	100	0	100	1	99	1	99	2	98	2	97	4	95	5
0.81	100	0	100	0	99	1	99	1	98	2	97	3	96	4	94	6
0.80	100	0	99	1	99	1	98	2	97	3	96	4	95	5	93	7
0.79	100	1	99	1	99	2	98	2	97	3	95	5	94	6	92	8
0.78	99	1	99	1	98	2	97	3	96	4	94	6	93	7	91	9
0.77	99	1	98	2	97	3	96	4	95	5	93	7	91	9	89	11
0.76	98	2	98	3	96	4	95	5	94	7	92	8	90	10	88	12
0.75	98	2	97	3	95	5	94	6	92	8	90	10	88	12	86	14
0.74	97	3	95	5	94	6	92	8	90	10	88	12	86	14	84	16
0.73	95	5	94	6	92	8	90	10	88	12	86	14	84	16	82	18
0.72	94	6	92	8	90	10	88	12	86	14	84	16	82	18	80	20
0.71	92	9	90	10	88	13	86	15	83	17	81	19	79	21	77	23
0.70	89	11	87	13	85	15	83	17	81	20	79	22	76	24	75	26
0.69	86	14	84	16	82	18	79	21	77	23	76	25	74	26	72	28
0.68	82	18	80	20	78	22	76	24	74	26	72	28	71	30	69	31
0.67	78	22	76	24	74	26	72	28	71	30	69	31	67	33	66	34
0.66	73	27	71	29	70	31	68	32	67	33	66	35	64	36	63	37
0.65	68	32	66	34	65	35	64	36	63	38	62	38	61	39	60	40
0.64	62	38	61	39	60	40	60	41	59	41	58	42	57	43	57	43
0.63	56	44	56	44	55	45	55	45	54	46	54	46	54	46	53	47
0.62	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50

Appendix 6.3 Variability of BMWP.EQI (single season)
(continued)
% probability of inclusion in 5M bands

BMWP.EQI	BMWP = 120		BMWP = 130		BMWP = 140			BMWP = 150			BMWP = 160		
	A	B	A	B	A	B	C	A	B	C	A	B	C
1.11	100	0	100	0	100	0	0	100	0	0	100	0	0
1.1	100	0	100	0	100	0	0	100	0	0	100	1	0
1.09	100	0	100	0	100	0	0	100	0	0	99	1	0
1.08	100	0	100	0	100	0	0	100	0	0	99	1	0
1.07	100	0	100	0	100	0	0	100	0	0	99	1	0
1.06	100	0	100	0	100	0	0	100	1	0	99	1	0
1.05	100	0	100	0	100	0	0	99	1	0	99	1	0
1.04	100	0	100	0	100	0	0	99	1	0	99	1	0
1.03	100	0	100	0	100	0	0	99	1	0	99	1	0
1.02	100	0	100	0	100	1	0	99	1	0	98	2	0
1.01	100	0	100	0	99	1	0	99	1	0	98	2	0
1	100	0	100	0	99	1	0	99	1	0	98	2	0
0.99	100	0	100	1	99	1	0	99	2	0	98	2	0
0.98	100	0	99	1	99	1	0	98	2	0	97	3	0
0.97	100	0	99	1	99	1	0	98	2	0	97	3	0
0.96	100	1	99	1	99	2	0	98	2	0	97	3	0
0.95	99	1	99	1	98	2	0	97	3	0	96	4	0
0.94	99	1	99	1	98	2	0	97	3	0	96	4	0
0.93	99	1	99	2	98	2	0	97	3	0	95	5	0
0.92	99	1	98	2	97	3	0	96	4	0	95	5	0
0.91	99	1	98	2	97	3	0	96	5	0	94	6	0
0.9	98	2	97	3	96	4	0	95	5	0	93	7	0
0.89	98	2	97	3	96	4	0	94	6	0	93	7	0
0.88	98	2	97	4	95	5	0	94	6	0	92	8	0
0.87	97	3	96	4	95	6	0	93	7	0	91	9	0
0.86	97	3	95	5	94	6	0	92	8	0	90	10	0
0.85	96	4	95	6	93	7	0	91	9	0	89	11	0
0.84	95	5	94	6	92	8	0	90	10	0	88	12	0
0.83	95	6	93	7	91	9	0	89	11	0	87	13	0
0.82	94	6	92	8	90	10	0	88	12	0	86	14	0
0.81	93	7	91	9	89	11	0	87	13	0	85	15	0
0.8	92	9	90	10	88	13	0	86	15	0	83	17	0
0.79	90	10	88	12	86	14	0	84	16	0	82	18	0
0.78	89	11	87	13	85	15	0	83	17	0	81	19	0
0.77	87	13	85	15	83	17	0	81	19	0	79	21	0
0.76	86	14	84	16	82	18	0	79	21	0	77	22	0
0.75	84	16	82	18	80	20	0	78	22	0	76	24	0
0.74	82	18	80	20	78	22	0	76	24	0	74	26	0
0.73	80	20	78	22	76	24	0	74	26	0	72	27	0
0.72	78	22	76	24	74	26	0	72	28	0	71	29	1
0.71	75	25	74	26	72	28	0	70	30	0	68	31	1
0.7	73	27	71	29	70	30	0	68	32	0	67	33	1
0.69	70	30	69	31	67	32	0	66	34	0	65	34	1
0.68	68	32	66	34	65	35	0	64	36	1	63	37	1
0.67	65	35	64	36	63	37	0	61	38	1	61	38	1
0.66	62	38	61	39	60	39	0	59	40	1	58	41	1
0.65	59	41	58	42	58	42	0	57	42	1	56	42	1
0.64	56	44	56	44	55	44	1	55	44	1	54	44	2
0.63	53	47	53	47	52	47	1	52	47	1	52	46	2
0.62	50	50	50	50	50	49	1	50	49	1	50	48	2

Appendix 6.3 Variability of BMWP.EQI (single season) (continued)

% probability of inclusion in 5M bands

	BMWP = 0			BMWP = 10			BMWP = 20			BMWP = 30			BMWP = 40		
BMWP.EQI	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
0.62	50	50	0	50	50	0	50	50	0	50	50	0	50	50	0
0.61	41	59	0	42	58	0	43	57	0	43	57	0	44	56	0
0.60	33	67	0	35	66	0	36	64	0	37	63	0	38	62	0
0.59	26	74	0	28	72	0	29	71	0	31	69	0	32	68	0
0.58	19	81	0	22	79	0	23	77	0	25	75	0	27	73	0
0.57	14	86	0	16	84	0	18	82	0	20	80	0	22	78	0
0.56	10	90	0	12	88	0	14	86	0	16	84	0	18	82	0
0.55	7	94	0	8	92	0	10	90	0	12	88	0	14	86	0
0.54	4	96	0	6	94	0	7	93	0	9	91	0	11	89	0
0.53	3	97	0	4	96	0	5	95	0	7	93	0	9	92	0
0.52	2	99	0	2	98	0	3	97	0	5	95	0	6	94	0
0.51	1	99	0	2	99	0	2	98	0	3	97	0	5	95	0
0.50	1	100	0	1	99	0	2	99	0	2	98	0	3	97	0
0.49	0	100	0	1	100	0	1	99	0	2	99	0	2	98	0
0.48	0	100	0	0	100	0	1	100	0	1	99	0	2	98	0
0.47	0	100	0	0	100	0	0	100	0	1	99	0	1	99	0
0.46	0	100	0	0	100	0	0	100	0	0	100	0	1	99	0
0.45	0	100	0	0	100	0	0	100	0	0	100	0	1	100	0
0.44	0	100	0	0	100	0	0	100	0	0	100	0	0	100	0
0.43	0	100	0	0	100	0	0	100	0	0	100	0	0	100	0
0.42	0	100	0	0	100	0	0	100	0	0	100	0	0	100	0
0.41	0	100	0	0	100	0	0	100	0	0	100	0	0	100	1
0.40	0	100	0	0	100	0	0	100	0	0	100	0	0	99	1
0.39	0	100	0	0	100	0	0	100	0	0	99	1	0	99	1
0.38	0	100	0	0	100	0	0	100	1	0	99	1	0	98	2
0.37	0	100	0	0	100	1	0	99	1	0	99	2	0	98	2
0.36	0	100	1	0	99	1	0	99	2	0	98	2	0	97	3
0.35	0	99	1	0	99	2	0	98	2	0	97	3	0	95	5
0.34	0	99	2	0	98	2	0	97	3	0	95	5	0	94	6
0.33	0	97	3	0	96	4	0	95	5	0	93	7	0	92	9
0.32	0	96	4	0	94	6	0	93	7	0	91	9	0	89	11
0.31	0	94	7	0	92	8	0	90	10	0	88	12	0	86	14
0.30	0	90	10	0	88	12	0	86	14	0	84	16	0	82	18
0.29	0	86	14	0	84	16	0	82	18	0	80	20	0	78	22
0.28	0	81	19	0	79	22	0	77	23	0	75	25	0	73	27
0.27	0	74	26	0	72	28	0	71	29	0	69	31	0	68	32
0.26	0	67	33	0	66	35	0	64	36	0	63	37	0	62	38
0.25	0	59	41	0	58	42	0	57	43	0	57	43	0	56	44
0.24	0	50	50	0	50	50	0	50	50	0	50	50	0	50	50
0.23	0	41	59	0	42	58	0	43	57	0	43	57	0	44	56
0.22	0	33	67	0	35	66	0	36	64	0	37	63	0	38	62
0.21	0	26	74	0	28	72	0	29	71	0	31	69	0	32	68
0.20	0	19	81	0	22	79	0	23	77	0	25	75	0	27	73
0.19	0	14	86	0	16	84	0	18	82	0	20	80	0	22	78
0.18	0	10	90	0	12	88	0	14	86	0	16	84	0	18	82
0.17	0	7	94	0	8	92	0	10	90	0	12	88	0	14	86
0.16	0	4	96	0	6	94	0	7	93	0	9	91	0	11	89
0.15	0	3	97	0	4	96	0	5	95	0	7	93	0	9	92
0.14	0	2	98	0	2	97	0	3	97	0	5	95	0	6	94
0.13	0	1	99	0	2	99	0	2	98	0	3	97	0	5	95
0.12	0	1	99	0	1	99	0	2	99	0	2	98	0	3	97
0.11	0	0	100	0	1	100	0	1	99	0	2	99	0	2	98
0.10	0	0	100	0	0	100	0	1	99	0	1	99	0	2	98
0.09	0	0	100	0	0	100	0	0	100	0	1	99	0	1	99
0.08	0	0	100	0	0	100	0	0	100	0	0	100	0	1	99
0.07	0	0	100	0	0	100	0	0	100	0	0	100	0	1	100
0.06	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100
0.05	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100
0.04	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100
0.03	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100
0.02	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100
0.01	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100
0.00	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100

Appendix 6.3 Variability of BMWP.EQI (single season)

(continued)

% probability of inclusion in 5M bands

	BMWP = 50			BMWP = 60			BMWP = 70			BMWP = 80			BMWP = 90			BMWP = 100		
BMWP.EQI	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
0.62	50	50	0	50	50	0	50	50	0	50	50	0	50	50	0	50	50	0
0.61	44	56	0	45	55	0	45	55	0	46	54	0	46	54	0	46	54	0
0.60	39	61	0	40	60	0	41	60	0	41	59	0	42	58	0	43	57	0
0.59	34	66	0	35	65	0	36	64	0	38	63	0	38	62	0	39	61	0
0.58	29	71	0	31	70	0	32	68	0	33	67	0	35	66	0	36	64	0
0.57	24	76	0	26	74	0	28	72	0	30	71	0	31	69	0	33	67	0
0.56	20	80	0	22	78	0	24	76	0	26	74	0	28	72	0	30	70	0
0.55	16	84	0	18	82	0	21	79	0	23	77	0	25	75	0	26	73	0
0.54	13	87	0	15	85	0	17	83	0	20	81	0	22	78	0	24	76	0
0.53	10	90	0	13	88	0	15	86	0	17	83	0	19	81	0	21	79	0
0.52	8	92	0	10	90	0	12	88	0	14	86	0	16	84	0	18	81	1
0.51	6	94	0	8	92	0	10	90	0	12	88	0	14	86	0	16	83	1
0.50	5	95	0	6	94	0	8	92	0	10	90	0	12	88	1	14	85	1
0.49	3	97	0	5	95	0	6	94	0	8	92	0	10	89	1	12	87	1
0.48	3	98	0	4	96	0	5	95	0	7	93	1	8	91	1	10	88	2
0.47	2	98	0	3	97	0	4	96	0	5	94	1	7	92	1	9	89	2
0.46	1	99	0	2	98	0	3	97	1	4	95	1	6	93	2	7	90	2
0.45	1	99	0	2	98	0	2	97	1	3	96	1	5	94	2	6	91	3
0.44	1	99	0	1	99	1	2	97	1	3	96	2	4	94	2	5	91	4
0.43	0	99	0	1	99	1	1	97	1	2	96	2	3	94	3	4	92	4
0.42	0	99	1	1	99	1	1	97	2	2	96	3	2	94	4	4	91	5
0.41	0	99	1	0	98	2	1	97	2	1	96	3	2	94	5	3	91	6
0.40	0	99	1	0	98	2	1	97	3	1	95	4	2	93	6	2	90	7
0.39	0	98	2	0	97	3	0	96	4	1	94	5	1	92	7	2	89	9
0.38	0	98	3	0	96	4	0	95	5	1	93	7	1	91	8	2	88	10
0.37	0	97	3	0	95	5	0	94	6	0	92	8	1	89	10	1	87	12
0.36	0	95	5	0	94	6	0	92	8	0	90	10	1	88	12	1	85	14
0.35	0	94	6	0	92	8	0	90	10	0	88	12	0	86	14	1	83	16
0.34	0	92	8	0	90	10	0	88	12	0	86	14	0	84	16	1	81	18
0.33	0	90	10	0	88	13	0	86	15	0	83	17	0	81	19	0	79	21
0.32	0	87	13	0	85	15	0	83	17	0	81	20	0	78	22	0	76	24
0.31	0	84	16	0	82	18	0	79	21	0	77	23	0	75	24	0	73	27
0.30	0	80	20	0	78	22	0	76	24	0	74	26	0	72	28	0	70	29
0.29	0	76	24	0	74	26	0	72	28	0	71	30	0	69	31	0	67	33
0.28	0	71	29	0	70	31	0	68	32	0	67	33	0	66	34	0	64	36
0.27	0	66	34	0	65	35	0	64	36	0	63	37	0	62	38	0	61	39
0.26	0	61	39	0	60	40	0	60	40	0	59	41	0	58	42	0	57	43
0.25	0	56	44	0	55	45	0	55	45	0	54	45	0	54	45	0	54	46
0.24	0	50	50	0	50	50	0	50	50	0	50	50	0	50	50	0	50	50
0.23	0	44	56	0	45	55	0	45	55	0	46	54	0	46	54	0	46	54
0.22	0	39	61	0	40	60	0	41	60	0	41	59	0	42	58	0	43	57
0.21	0	34	66	0	35	65	0	36	64	0	38	63	0	38	62	0	39	61
0.20	0	29	71	0	31	70	0	32	68	0	33	67	0	35	66	0	36	64
0.19	0	24	76	0	26	74	0	28	72	0	30	71	0	31	69	0	33	67
0.18	0	20	80	0	22	78	0	24	76	0	26	74	0	28	72	0	30	71
0.17	0	16	84	0	18	82	0	21	79	0	23	77	0	25	76	0	26	74
0.16	0	13	87	0	15	85	0	17	83	0	20	81	0	22	79	0	24	76
0.15	0	10	90	0	13	88	0	15	86	0	17	83	0	19	81	0	21	79
0.14	0	8	92	0	10	90	0	12	88	0	14	86	0	16	84	0	18	82
0.13	0	6	94	0	8	92	0	10	90	0	12	88	0	14	86	0	16	84
0.12	0	5	95	0	6	94	0	8	92	0	10	90	0	12	88	0	14	86
0.11	0	3	97	0	5	95	0	6	94	0	8	92	0	10	90	0	12	88
0.10	0	3	98	0	4	96	0	5	95	0	7	93	0	8	92	0	10	90
0.09	0	2	98	0	3	97	0	4	96	0	5	95	0	7	93	0	9	91
0.08	0	1	99	0	2	98	0	3	97	0	4	96	0	6	94	0	7	93
0.07	0	1	99	0	2	99	0	2	98	0	3	97	0	5	95	0	6	94
0.06	0	1	99	0	1	99	0	2	98	0	3	97	0	4	96	0	5	95
0.05	0	0	100	0	1	99	0	1	99	0	2	98	0	3	97	0	4	96
0.04	0	0	100	0	1	100	0	1	99	0	2	99	0	2	98	0	4	97
0.03	0	0	100	0	0	100	0	1	99	0	1	99	0	2	98	0	3	97
0.02	0	0	100	0	0	100	0	1	100	0	1	99	0	2	99	0	2	98
0.01	0	0	100	0	0	100	0	0	100	0	1	99	0	1	99	0	2	98
0.00	0	0	100	0	0	100	0	0	100	0	1	100	0	1	99	0	2	99

Appendix 6.4 Variability of BMWP.EQI (combined season)

% probability of inclusion in 5M bands

BMWP.EQI	BMWP=70		BMWP=80		BMWP=90		BMWP=100		BMWP=110		BMWP=120		BMWP=130		BMWP=140	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1.07																
1.06																
1.05																
1.04																
1.03																
1.02																
1.01																
1.00																
0.99																
0.98															100	0
0.97															99	1
0.96													100	0	99	1
0.95											100	0	99	1	99	1
0.94									100	0	99	1	99	1	99	1
0.93							100	0	99	1	99	1	99	1	98	2
0.92					100	0	99	1	99	1	99	1	98	2	98	2
0.91					99	1	99	1	99	1	98	2	98	2	97	3
0.90			100	0	99	1	99	1	98	2	98	2	97	3	97	3
0.89	100	0	99	1	99	1	98	2	98	2	97	3	97	3	96	4
0.88	99	1	99	1	98	2	98	2	97	3	96	4	96	4	95	5
0.87	99	1	98	2	98	2	97	3	96	4	96	4	95	5	94	6
0.86	98	2	98	2	97	3	96	4	95	5	94	6	93	7	92	8
0.85	98	2	97	3	96	4	95	5	94	6	93	7	92	8	91	9
0.84	97	3	96	4	95	5	94	6	92	8	91	9	90	10	89	11
0.83	96	4	94	6	93	7	92	8	90	10	89	11	88	12	87	13
0.82	94	6	93	7	91	9	90	10	88	12	87	13	86	14	85	15
0.81	92	8	90	10	89	11	87	13	86	14	85	15	83	17	82	18
0.80	89	11	87	13	86	14	84	16	83	17	82	18	81	19	79	21
0.79	86	14	84	16	83	17	81	19	80	20	79	21	77	23	76	24
0.78	82	18	81	19	79	21	78	22	76	24	75	25	74	26	73	27
0.77	78	22	76	24	75	25	74	26	73	27	72	28	71	29	70	31
0.76	73	27	72	28	71	29	70	31	68	32	67	33	67	33	66	34
0.75	68	32	67	33	66	34	65	35	64	36	63	37	63	37	62	38
0.74	62	38	61	39	61	39	60	40	59	41	59	41	58	42	58	42
0.73	56	44	56	44	55	45	55	45	55	45	54	46	54	46	54	46
0.72	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50

Appendix 6.4 Variability of BMWP.EQI (combined season)
(continued)

% probability of inclusion in 5M bands

BMWP.EQI	BMWP=150		BMWP=160		BMWP=170			BMWP=180			BMWP=190			BMWP=200			BMWP=220		
	A	B	A	B	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
1.07																	100	0	0
1.06																	99	1	0
1.05														100	0	0	99	1	0
1.04											100	0	0	99	1	0	99	1	0
1.03								100	0	0	99	1	0	99	1	0	99	1	0
1.02								99	1	0	99	1	0	99	1	0	99	1	0
1.01					100	0	0	99	1	0	99	1	0	99	1	0	98	2	0
1.00			100	0	99	1	0	99	1	0	99	1	0	99	1	0	98	2	0
0.99	100	0	99	1	99	1	0	99	1	0	99	1	0	98	2	0	98	2	0
0.98	99	1	99	1	99	1	0	99	1	0	98	2	0	98	2	0	97	3	0
0.97	99	1	99	1	99	1	0	98	2	0	98	2	0	98	2	0	97	3	0
0.96	99	1	99	1	98	2	0	98	2	0	98	2	0	97	3	0	96	4	0
0.95	99	1	98	2	98	2	0	98	2	0	97	3	0	97	3	0	96	4	0
0.94	98	2	98	2	98	3	0	97	3	0	96	4	0	96	4	0	95	5	0
0.93	98	2	98	3	97	3	0	96	4	0	96	4	0	95	5	0	94	6	0
0.92	97	3	97	3	96	4	0	96	4	0	95	5	0	94	6	0	93	7	0
0.91	97	3	96	4	96	4	0	95	5	0	94	6	0	93	7	0	92	8	0
0.90	96	4	95	5	95	5	0	94	6	0	93	7	0	92	8	0	91	9	0
0.89	95	5	94	6	94	6	0	93	7	0	92	8	0	91	9	0	89	11	0
0.88	94	6	93	7	92	8	0	91	9	0	91	9	0	90	10	0	88	12	0
0.87	93	7	92	8	91	9	0	90	10	0	89	11	0	88	12	0	87	13	0
0.86	91	9	90	10	89	11	0	88	12	0	87	13	0	87	13	0	85	15	0
0.85	90	10	89	11	88	12	0	87	13	0	86	14	0	85	15	0	83	17	0
0.84	88	12	87	13	86	14	0	85	15	0	84	16	0	83	17	0	81	19	0
0.83	86	14	85	15	84	16	0	83	17	0	82	18	0	81	19	0	79	21	0
0.82	83	17	82	18	81	19	0	81	19	0	79	21	0	79	21	0	77	23	0
0.81	81	19	80	20	79	21	0	78	22	0	77	23	0	76	24	0	75	25	0
0.80	78	22	77	23	76	24	0	75	24	0	75	25	0	74	26	0	72	27	0
0.79	75	25	74	26	73	27	0	73	27	0	72	28	0	71	29	0	70	30	0
0.78	72	28	71	29	71	29	0	70	30	0	69	31	0	68	31	0	67	32	1
0.77	69	31	68	32	67	32	0	67	33	0	66	34	0	66	34	0	64	35	1
0.76	65	35	64	35	64	36	0	63	36	0	63	37	0	63	37	1	61	38	1
0.75	61	38	61	39	61	39	0	60	39	0	60	40	1	59	40	1	59	40	1
0.74	58	42	58	42	57	42	0	57	43	1	56	43	1	56	43	1	56	43	1
0.73	54	46	54	46	54	46	0	54	46	1	53	46	1	53	46	1	53	46	2
0.72	50	50	50	50	50	49	1	50	49	1	50	49	1	50	49	1	50	48	2

Appendix 6.4 Variability of BMWP.EQI (combined season)

% probability of inclusion in 5M bands

BMWP.EQI	BMWP=20		BMWP=30		BMWP=40		BMWP=50		BMWP=60		BMWP=70		BMWP=80		BMWP=90	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
0.72	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
0.71	41	59	0	41	59	0	42	58	0	43	57	0	43	57	0	44
0.70	32	68	0	33	67	0	35	65	0	36	64	0	37	63	0	38
0.69	23	77	0	26	74	0	28	72	0	29	71	0	31	69	0	32
0.68	17	83	0	19	81	0	21	79	0	24	76	0	25	75	0	27
0.67	11	89	0	14	86	0	16	84	0	18	82	0	20	80	0	22
0.66	7	93	0	10	90	0	12	88	0	14	86	0	16	84	0	18
0.65	4	96	0	6	94	0	8	92	0	10	90	0	12	88	0	14
0.64	3	97	0	4	96	0	6	94	0	7	93	0	9	91	0	11
0.63	1	99	0	3	98	0	4	96	0	5	95	0	7	93	0	8
0.62	1	99	0	2	99	0	2	98	0	4	96	0	5	95	0	6
0.61	0	100	0	1	99	0	2	99	0	2	98	0	3	96	0	4
0.60	0	100	0	0	100	0	1	99	0	2	98	0	2	97	0	3
0.59	0	100	0	0	100	0	1	99	0	1	99	0	2	98	1	2
0.58	0	100	0	0	100	0	0	99	0	1	99	1	1	98	1	2
0.57	0	100	0	0	100	0	0	99	1	0	99	1	1	98	2	1
0.56	0	100	0	0	100	0	0	99	1	0	98	2	0	97	2	1
0.55	0	100	0	0	99	1	0	99	2	0	98	2	0	96	3	0
0.54	0	99	1	0	99	2	0	98	2	0	96	4	0	95	5	0
0.53	0	99	1	0	98	3	0	96	4	0	95	5	0	93	7	0
0.52	0	97	3	0	96	4	0	94	6	0	93	7	0	91	9	0
0.51	0	96	4	0	94	6	0	92	8	0	90	10	0	88	12	0
0.50	0	93	7	0	90	10	0	88	12	0	86	14	0	84	16	0
0.49	0	89	11	0	86	14	0	84	16	0	82	18	0	80	20	0
0.48	0	83	17	0	81	19	0	79	21	0	76	24	0	75	25	0
0.47	0	77	23	0	74	26	0	72	28	0	71	29	0	69	31	0
0.46	0	68	32	0	67	33	0	65	35	0	64	36	0	63	37	0
0.45	0	59	41	0	59	41	0	58	42	0	57	43	0	57	43	0
0.44	0	50	50	0	50	50	0	50	50	0	50	50	0	50	50	0
0.43	41	59	0	41	59	0	42	58	0	43	57	0	43	57	0	44
0.42	32	68	0	33	67	0	35	65	0	36	64	0	37	63	0	38
0.41	23	77	0	26	74	0	28	72	0	29	71	0	31	69	0	32
0.40	17	83	0	19	81	0	21	79	0	24	76	0	25	75	0	27
0.39	11	89	0	14	86	0	16	84	0	18	82	0	20	80	0	22
0.38	7	93	0	10	90	0	12	88	0	14	85	0	16	84	0	18
0.37	4	96	0	6	94	0	8	92	0	10	90	0	12	88	0	14
0.36	3	97	0	4	96	0	6	94	0	7	93	0	9	91	0	11
0.35	1	99	0	3	98	0	4	96	0	5	95	0	7	93	0	8
0.34	1	99	0	2	99	0	2	98	0	4	96	0	5	95	0	6
0.33	0	100	0	1	99	0	2	99	0	2	98	0	3	96	0	4
0.32	0	100	0	0	100	0	1	99	0	2	98	0	2	97	0	3
0.31	0	100	0	0	100	0	1	99	0	1	99	0	2	98	1	2
0.30	0	100	0	0	100	0	0	99	0	1	99	1	1	98	1	2
0.29	0	100	0	0	100	0	0	99	1	0	99	1	1	98	2	1
0.28	0	100	0	0	100	0	0	99	1	0	98	2	0	97	2	1
0.27	0	100	0	0	99	1	0	99	2	0	98	2	0	96	3	0
0.26	0	99	1	0	99	2	0	98	2	0	96	4	0	95	5	0
0.25	0	99	1	0	98	3	0	96	4	0	95	5	0	93	7	0
0.24	0	97	3	0	96	4	0	94	6	0	93	7	0	91	9	0
0.23	0	96	4	0	94	6	0	92	8	0	90	10	0	88	12	0
0.22	0	93	7	0	90	10	0	88	12	0	86	14	0	84	16	0
0.21	0	89	11	0	86	14	0	84	16	0	82	18	0	80	20	0
0.20	0	83	17	0	81	19	0	79	21	0	76	24	0	75	25	0

Appendix 6.4 Variability of BMWP.EQI (combined season)

% probability of inclusion in 5M bands

BMWP.EQI	BMWP=100		BMWP=110		BMWP=120		BMWP=130		BMWP=140	
	A	B	A	B	A	B	A	B	A	B
0.72	50	50	50	50	50	50	50	50	50	50
0.71	56	0	44	56	0	45	55	0	45	55
0.70	62	0	39	61	0	39	61	0	40	60
0.69	68	0	33	67	0	34	66	0	35	65
0.68	73	0	28	72	0	29	71	0	31	69
0.67	78	0	24	76	0	25	75	0	26	73
0.66	82	0	19	81	0	21	79	0	22	77
0.65	86	0	16	84	0	17	82	0	19	81
0.64	89	0	13	87	0	14	86	0	16	84
0.63	92	0	10	90	0	11	88	1	13	86
0.62	94	0	7	92	0	9	90	1	10	89
0.61	95	0	6	94	1	7	92	1	8	90
0.60	96	1	4	95	1	5	93	2	6	91
0.59	97	1	3	95	2	4	94	2	5	92
0.58	97	2	2	96	2	3	94	3	4	92
0.57	97	2	2	95	3	2	94	4	3	92
0.56	96	3	1	95	4	2	93	5	2	91
0.55	95	4	1	94	6	1	92	7	2	90
0.54	94	6	0	92	7	1	90	9	1	89
0.53	92	8	0	90	10	1	88	11	1	86
0.52	89	11	0	87	13	0	86	14	1	84
0.51	86	14	0	84	16	0	82	17	0	81
0.50	82	18	0	81	19	0	79	21	0	77
0.49	78	22	0	76	24	0	75	25	0	73
0.48	73	27	0	72	28	0	71	29	0	69
0.47	68	32	0	67	33	0	66	34	0	65
0.46	62	38	0	61	39	0	61	39	0	60
0.45	56	44	0	56	44	0	55	45	0	55
0.44	50	50	0	50	50	0	50	50	0	50
0.43	56	0	44	56	0	45	55	0	45	55
0.42	62	0	39	61	0	39	61	0	40	60
0.41	68	0	33	67	0	34	66	0	35	65
0.40	73	0	28	72	0	29	71	0	31	69
0.39	78	0	24	76	0	25	75	0	26	73
0.38	82	0	19	81	0	21	79	0	22	77
0.37	86	0	16	84	0	17	82	0	19	81
0.36	89	0	13	87	0	14	86	0	16	84
0.35	92	0	10	90	0	11	88	1	13	86
0.34	94	0	7	92	0	9	90	1	10	89
0.33	95	0	6	94	1	7	92	1	8	90
0.32	96	1	4	95	1	5	93	2	6	91
0.31	97	1	3	95	2	4	94	2	5	92
0.30	97	2	2	96	2	3	94	3	4	92
0.29	97	2	2	95	3	2	94	4	3	92
0.28	96	3	1	95	4	2	93	5	2	91
0.27	95	4	1	94	6	1	92	7	2	90
0.26	94	6	0	92	7	1	90	9	1	89
0.25	92	8	0	90	10	1	88	11	1	86
0.24	89	11	0	87	13	0	86	14	1	84
0.23	86	14	0	84	16	0	82	17	0	81
0.22	82	18	0	81	19	0	79	21	0	77
0.21	78	22	0	76	24	0	75	25	0	73
0.20	73	27	0	72	28	0	71	29	0	69

Appendix 6.5 Variability of ASPT.EQI.

% probability of inclusion in 5M bands

	Single season				Combined season			
ASPTEQI	A	B	C	D	A	B	C	D
0.97	100	0	0	0	100	0	0	0
0.96	99	1	0	0	100	0	0	0
0.95	99	1	0	0	100	0	0	0
0.94	98	2	0	0	99	1	0	0
0.93	97	3	0	0	97	3	0	0
0.92	95	5	0	0	92	8	0	0
0.91	93	7	0	0	85	15	0	0
0.90	89	11	0	0	76	25	0	0
0.89	85	15	0	0	63	37	0	0
0.88	80	20	0	0	50	50	0	0
0.87	73	27	0	0	37	63	0	0
0.86	66	34	0	0	26	74	0	0
0.85	58	42	0	0	17	82	0	0
0.84	50	50	0	0	11	89	1	0
0.83	42	58	0	0	6	92	2	0
0.82	34	66	0	0	4	93	4	0
0.81	27	73	0	0	2	91	7	0
0.80	20	79	1	0	1	87	12	0
0.79	15	84	1	0	1	80	20	0
0.78	11	87	2	0	0	71	29	0
0.77	7	90	3	0	0	61	39	0
0.76	5	90	5	0	0	50	50	0
0.75	3	90	7	0	0	39	61	0
0.74	2	87	11	0	0	30	70	0
0.73	1	84	15	0	0	22	78	1
0.72	1	79	20	0	0	15	83	2
0.71	0	73	27	0	0	10	86	4
0.70	0	66	34	0	0	7	87	7
0.69	0	58	42	0	0	4	85	11
0.68	0	50	50	0	0	3	81	16
0.67	0	42	58	0	0	2	75	24
0.66	0	34	66	0	0	1	68	32
0.65	0	27	73	0	0	1	59	41
0.64	0	20	79	1	0	0	50	50
0.63	0	15	84	1	0	0	41	59
0.62	0	11	87	2	0	0	33	67
0.61	0	7	90	3	0	0	25	75
0.60	0	5	90	5	0	0	19	81
0.59	0	3	90	7	0	0	14	86
0.58	0	2	87	11	0	0	10	90
0.57	0	1	84	15	0	0	7	93
0.56	0	1	79	20	0	0	5	96
0.55	0	0	73	27	0	0	3	97
0.54	0	0	66	34	0	0	2	98
0.53	0	0	58	42	0	0	1	99
0.52	0	0	50	50	0	0	1	99
0.51	0	0	42	58	0	0	1	100
0.50	0	0	34	66	0	0	0	100
0.49	0	0	27	73	0	0	0	100
0.48	0	0	20	80	0	0	0	100
0.47	0	0	15	85	0	0	0	100
0.46	0	0	11	89	0	0	0	100
0.45	0	0	7	93	0	0	0	100
0.44	0	0	5	95	0	0	0	100
0.43	0	0	3	97	0	0	0	100
0.42	0	0	2	98	0	0	0	100
0.41	0	0	1	99	0	0	0	100
0.40	0	0	1	99	0	0	0	100
0.39	0	0	0	100	0	0	0	100

Appendix table 8.1 Autumn single-samples: standard deviations and coefficients of variation of indices

SITE	Standard Deviation (SD) TAXA (1)	BMWP (2)	ASPT (3)	TAXA EQI (4)	BMWP EQI (5)	ASPT EQI (6)	Coefficient of variation (CV) TAXA (7)	BMWP (8)	ASPT (9)	TAXA EQI (10)	BMWP EQI (11)	ASPT EQI (12)
Bow Brook	3.16	20.46	0.29	0.152	0.216	0.065	13.2	18.1	6.2	13.2	18.2	6.3
River Thames	4.80	27.02	0.17	0.189	0.214	0.034	18.1	20.3	3.4	18.0	20.3	3.4
River Coln	2.38	18.75	0.21	0.118	0.197	0.052	7.8	11.6	4.0	8.3	12.5	4.7
The Cut	2.45	12.69	0.15	0.122	0.132	0.039	12.2	15.5	3.6	13.5	17.4	4.6
Lydiard Stream	1.29	8.76	0.17	0.060	0.090	0.038	6.0	9.2	3.9	5.8	9.0	3.9
Halfacre Brook	1.29	6.95	0.34	0.065	0.075	0.072	15.2	20.2	8.3	14.7	19.7	8.3
Roundmoor Ditch	1.89	8.27	0.14	0.098	0.090	0.030	16.1	19.0	3.8	15.9	18.7	3.8
Summerstown Ditch	1.41	6.63	0.20	0.075	0.074	0.044	14.1	19.5	6.1	14.4	19.5	6.1
Crendon Stream	3.00	12.00	0.27	0.164	0.132	0.056	46.2	57.1	8.7	46.2	56.9	8.7
Wheatley Ditch	0.82	1.73	0.19	0.041	0.023	0.045	10.2	6.1	5.3	10.6	8.0	6.0
Crawters Brook	0.96	5.20	0.32	0.047	0.050	0.064	12.4	24.2	11.6	12.7	23.8	11.2
Catherine Bourne	0.96	5.74	0.17	0.033	0.042	0.026	7.2	11.1	4.3	5.1	7.8	3.2
Mean	2.03	11.18	0.22	0.097	0.111	0.047	14.89	19.33	5.77	14.87	19.32	5.85
Standard error of the mean	0.342	2.14	0.020	0.015	0.019	0.004	3.04	3.77	0.741	3.07	3.75	0.712

Appendix table 8.2 Spring single-samples: standard deviations and coefficients of variation of indices

SITE	Standard Deviation (SD) TAXA (1)	BMWP (2)	ASPT (3)	TAXA EQI (4)	BMWP EQI (5)	ASPT EQI (6)	Coefficient of variation (CV) TAXA (7)	BMWP (8)	ASPT (9)	TAXA EQI (10)	BMWP EQI (11)	ASPT EQI (12)
Bow Brook	1.73	10.61	0.19	0.082	0.104	0.039	6.3	7.6	3.8	6.3	7.6	3.8
River Thames	4.86	31.27	0.24	0.195	0.240	0.046	17.5	22.5	4.8	17.7	22.8	4.8
River Coln	2.52	15.85	0.18	0.120	0.154	0.036	8.0	9.0	3.2	8.0	9.0	3.2
The Cut	1.71	10.21	0.31	0.083	0.099	0.061	12.9	20.7	8.3	13.3	21.3	8.3
Lydiard Stream	1.63	7.59	0.08	0.078	0.070	0.008	6.3	6.2	1.6	6.3	6.0	0.8
Halfacre Brook	1.26	10.10	0.44	0.062	0.112	0.097	9.9	18.4	10.2	9.7	18.4	10.2
Roundmoor Ditch	0.96	4.97	0.19	0.047	0.054	0.042	10.9	16.0	5.3	10.8	15.7	5.3
Summerstown Ditch	0.96	4.35	0.17	0.048	0.047	0.038	10.9	16.0	5.6	10.9	15.9	5.6
Crendon Stream	1.26	4.65	0.18	0.064	0.046	0.034	21.9	25.5	5.7	21.9	26.0	5.7
Wheatley Ditch	1.26	6.85	0.48	0.059	0.064	0.095	16.2	25.6	14.0	16.1	25.6	14.0
Crawters Brook	1.00	4.03	0.27	0.046	0.037	0.054	15.4	22.7	10.0	15.3	22.7	10.0
Catherine Bourne	1.29	7.14	0.19	0.061	0.069	0.044	9.6	13.1	4.7	9.6	13.6	5.5
Mean	1.70	9.80	0.243	0.079	0.091	0.050	12.15	16.93	6.43	12.14	17.05	6.44
Standard error of the mean	0.314	2.19	0.034	0.012	0.017	0.007	1.38	1.97	1.02	1.39	2.00	1.04

Appendix table 8.3 Autumn dual-samples: standard deviations and coefficients of variation of indices

SITE	Standard deviation						Coefficient of variation (CV)					
	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Bow Brook	1.41	3.5	0.12	0.055	0.027	0.024	4.9	2.5	2.4	4.9	2.4	2.4
River Thames	0.71	4.2	0.24	0.025	0.024	0.046	2.2	2.6	4.7	2.4	2.4	4.7
River Coln	2.12	16.3	0.14	0.078	0.125	0.028	6.1	8.8	2.6	5.9	8.7	2.6
The Cut	1.41	7.1	0.05	0.062	0.066	0.021	6.1	7.4	1.2	7.2	9.5	2.6
Lydiard Stream	2.12	13.4	0.15	0.088	0.111	0.043	8.3	11.6	3.3	8.9	12.2	4.8
Halfacre Brook	1.41	8.5	0.29	0.059	0.074	0.060	14.1	21.2	7.2	14.1	21.3	7.2
Roundmoor Ditch	2.12	11.3	0.22	0.085	0.095	0.046	14.6	20.2	5.7	14.0	19.4	5.7
Summerstown Ditch	1.41	7.8	0.26	0.057	0.066	0.054	12.9	20.2	7.4	12.6	19.7	7.4
Crendon Stream	2.83	12.7	0.39	0.117	0.097	0.064	31.4	42.4	11.8	31.1	41.8	10.5
Wheatley Ditch	0.71	3.5	0.11	0.032	0.033	0.032	7.4	10.6	3.1	8.8	13.1	4.5
Crawters Brook	0.71	5.7	0.42	0.027	0.041	0.083	8.3	22.6	14.4	8.3	22.2	14.4
Catherine Bourne	0.71	2.8	0.00	0.014	0.013	0.001	4.6	4.5	0.1	2.4	2.8	0.1
Mean	1.47	8.07	0.199	0.058	0.064	0.042	10.09	14.54	5.33	10.05	14.62	5.57
Standard error of the mean	0.203	1.29	0.037	0.009	0.011	0.006	2.24	3..31	1.24	2.23	3.25	1.13

Appendix table 8.4 Spring dual-samples: standard deviations and coefficients of variation of indices

SITE	Standard deviation						Coefficient of variation (CV)					
	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Bow Brook	2.12	19.8	0.26	0.082	0.154	0.054	6.3	11.4	5.1	6.3	11.3	5.1
River Thames	4.24	28.3	0.20	0.137	0.173	0.037	13.3	17.0	3.8	13.3	17.1	3.8
River Coln	1.41	4.2	0.10	0.058	0.034	0.020	3.7	2.0	1.8	4.0	2.0	1.8
The Cut	0.00	3.5	0.22	0.006	0.016	0.032	0.0	5.6	5.6	1.1	3.5	4.2
Lydiard Stream	1.41	13.4	0.23	0.058	0.106	0.046	4.9	9.6	4.8	5.1	9.8	4.8
Halfacre Brook	0.71	2.1	0.07	0.031	0.020	0.014	4.9	3.3	1.5	5.2	3.6	1.5
Roundmoor Ditch	1.41	8.5	0.33	0.060	0.075	0.070	14.1	22.9	8.9	14.4	22.9	8.9
Summerstown Ditch	0.71	3.5	0.13	0.031	0.031	0.028	7.4	11.6	4.2	7.7	12.0	4.2
Crendon Stream	0.71	2.1	0.03	0.030	0.018	0.002	10.9	9.9	1.0	11.2	10.6	0.3
Wheatley Ditch	0.71	1.4	0.13	0.031	0.015	0.016	7.4	3.9	3.5	8.5	5.6	2.1
Crawters Brook	0.71	1.4	0.09	0.026	0.010	0.017	9.4	6.4	3.0	9.2	6.2	3.0
Catherine Bourne	2.12	9.9	0.07	0.093	0.090	0.025	13.7	15.5	1.8	15.6	18.9	3.2
Mean	1.36	8.19	0.155	0.054	0.062	0.030	8.01	9.93	3.75	8.46	10.30	3.57
Standard error of the mean	0.319	2.46	0.026	0.010	0.017	0.006	1.27	1.80	0.639	1.29	1.91	0.639

Appendix table 8.5 Spring or autumn single-samples: standard deviations and coefficients of variation of indices

	Standard Deviation (SD)						Coefficient of variation (CV)					
SITE	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Bow Brook	1.89	11.63	0.174	0.084	0.072	0.032	6.8	8.4	3.5	6.3	5.2	3.0
River Thames	5.85	34.86	0.227	0.231	0.259	0.042	21.1	25.0	4.5	21.0	24.0	4.3
River Coln	2.36	20.84	0.345	0.127	0.216	0.067	7.3	11.8	6.3	8.4	12.5	5.9
The Cut	5.12	26.21	0.410	0.222	0.242	0.098	31.5	41.4	10.8	29.8	41.1	12.7
Lydiard Stream	3.30	20.14	0.224	0.138	0.139	0.015	13.6	18.2	4.9	11.8	12.6	1.6
Halfacre Brook	2.63	14.84	0.443	0.122	0.161	0.112	24.5	31.7	10.3	22.3	31.2	12.0
Roundmoor Ditch	2.22	9.25	0.167	0.127	0.104	0.038	20.6	23.3	4.5	23.2	23.6	4.7
Summerstown Ditch	1.50	7.39	0.283	0.089	0.086	0.054	16.2	24.6	8.8	18.7	26.1	7.8
Crendon Stream	2.63	10.37	0.224	0.149	0.120	0.050	36.3	42.8	6.8	38.6	47.2	7.8
Wheatley Ditch	1.26	6.08	0.308	0.067	0.072	0.077	16.2	23.6	9.4	18.0	28.1	11.5
Crawters Brook	0.50	1.41	0.201	0.030	0.015	0.029	6.9	7.1	7.3	8.8	7.8	5.1
Catherine Bourne	0.96	5.80	0.213	0.035	0.032	0.016	7.2	11.1	5.4	5.4	6.2	2.0
Mean	2.52	14.07	0.268	0.118	0.126	0.053	17.35	22.42	6.88	17.69	22.13	6.53
Standard error of the mean	0.462	2.81	0.026	0.018	0.023	0.009	2.86	3.44	0.710	2.92	3.95	1.12

Appendix table 8.6 Spring or autumn dual-samples: standard deviations and coefficients of variation of indices

	Standard deviation						Coefficient of variation (CV)					
SITE	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Bow Brook	2.99	22.07	0.241	0.115	0.172	0.049	9.6	14.0	4.8	9.6	14.0	4.8
River Thames	2.50	16.51	0.184	0.081	0.101	0.035	7.8	9.9	3.6	7.8	10.0	3.6
River Coln	2.50	20.11	0.207	0.096	0.156	0.041	6.9	10.0	3.7	6.9	10.0	3.7
The Cut	4.12	19.31	0.176	0.155	0.142	0.032	21.1	24.2	4.3	21.3	24.6	4.0
Lydiard Stream	2.50	17.67	0.227	0.096	0.134	0.045	9.2	13.9	4.9	9.1	13.5	4.8
Halfacre Brook	2.75	14.48	0.287	0.115	0.126	0.060	22.5	28.0	6.9	22.6	28.1	6.9
Roundmoor Ditch	2.99	13.67	0.248	0.123	0.118	0.053	24.4	29.4	6.6	24.1	29.0	6.6
Summerstown Ditch	1.26	6.76	0.233	0.052	0.058	0.048	12.3	19.6	7.0	12.2	19.6	7.0
Crendon Stream	2.22	8.92	0.224	0.093	0.069	0.037	28.6	34.6	6.8	28.5	34.3	6.0
Wheatley Ditch	0.58	2.63	0.186	0.026	0.023	0.037	6.1	7.6	5.1	7.1	8.9	5.1
Crawters Brook	0.82	3.79	0.249	0.030	0.027	0.049	10.2	16.1	8.5	10.1	15.7	8.5
Catherine Bourne	1.29	5.97	0.055	0.055	0.053	0.015	8.3	9.4	1.3	9.2	11.2	1.9
Mean	2.21	12.66	0.210	0.086	0.098	0.042	13.92	18.06	5.29	14.04	18.24	5.24
Standard error of the mean	0.298	1.96	0.017	0.011	0.015	0.003	2.28	2.60	0.568	2.24	2.51	0.530

Appendix table 8.7 Combined-season samples: standard deviations and coefficients of variation of indices

SITE	Standard Deviation (SD)						Coefficient of variation (CV)					
	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Bow Brook	1.89	10.72	0.15	0.073	0.084	0.031	5.9	6.6	3.0	5.9	6.6	3.0
River Thames	4.43	26.47	0.19	0.142	0.159	0.037	13.3	15.5	3.8	13.2	15.3	3.8
River Coln	2.50	17.63	0.14	0.097	0.137	0.028	6.6	8.2	2.5	6.7	8.2	2.5
The Cut	2.45	13.30	0.17	0.097	0.106	0.040	11.7	15.2	4.1	12.5	16.8	5.0
Lydiard Stream	1.41	6.13	0.07	0.054	0.047	0.011	5.1	4.6	1.4	5.0	4.5	1.1
Halfacre Brook	1.00	6.00	0.13	0.040	0.051	0.027	7.4	10.2	3.0	7.2	10.0	3.0
Roundmoor Ditch	1.50	5.56	0.06	0.062	0.048	0.014	11.3	10.8	1.6	11.1	10.7	1.6
Summerstown Ditch	1.26	5.91	0.20	0.052	0.050	0.043	11.7	16.1	6.0	11.6	15.7	6.0
Crendon Stream	2.50	10.21	0.26	0.105	0.079	0.046	32.3	40.4	8.1	32.2	40.2	7.8
Wheatley Ditch	0.82	4.92	0.19	0.033	0.040	0.044	8.2	13.4	5.3	8.7	14.3	6.0
Crawters Brook	0.82	4.69	0.31	0.031	0.034	0.061	10.2	20.4	10.9	10.2	20.1	10.9
Catherine Bourne	1.29	6.08	0.04	0.058	0.051	0.011	7.8	8.8	1.1	9.1	10.0	1.3
Mean	1.82	9.80	0.159	0.070	0.074	0.033	10.95	1420	4.23	11.10	14.37	4.34
Standard error of the mean	0.297	1.90	0.023	0.010	0.012	0.004	2.08	2.72	0.847	2.06	2.69	0.850

Appendix table 8.8 Jacknife values of F: autumn single-samples

	Untransformed data						Log transformed data					
	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Bow Brook	55.5	59.4	47.1	45.5	53.6	44.2	41.1	45.1	40.1	32.9	38.4	39.5
River Thames	67.1	65.1	38.3	54.2	57.3	40.7	41.6	43.4	34.5	36.3	40.6	37.9
River Coln	39.3	39.0	34.2	31.5	34.2	34.5	34.9	37.3	31.8	27.8	32.1	33.4
The Cut	55.8	56.0	46.0	47.5	51.4	45.7	43.5	47.8	41.1	36.2	42.8	42.9
Lydiard Stream	50.9	52.5	45.3	41.6	46.6	43.2	41.0	44.9	39.9	32.8	38.4	39.9
Halfacre Brook	49.5	50.7	54.4	41.9	46.5	53.2	43.3	49.1	47.3	35.5	43.1	48.1
Roundmoor Ditch	53.9	52.5	45.2	45.4	48.2	44.1	47.5	50.7	40.9	38.9	44.3	41.9
Summerstown Ditch	51.2	50.6	44.6	43.8	46.3	43.5	45.1	49.2	41.0	37.3	43.4	42.3
Crendon Stream	53.2	50.5	44.1	47.6	46.5	40.6	63.6	65.0	40.9	53.4	57.0	40.0
Wheatley Ditch	48.2	48.6	45.8	40.0	43.9	45.1	40.8	44.0	41.6	32.6	38.2	43.2
Crawters Brook	48.1	47.8	38.8	39.5	42.5	36.6	40.8	43.6	35.7	32.1	36.4	35.6
Catherine Bourne	52.3	52.4	46.5	43.8	47.2	44.1	44.2	48.3	41.8	35.8	41.7	41.8
Mean jacknife F	52.08	52.09	44.19	43.53	47.02	42.96	43.95	47.37	39.72	35.97	41.37	40.54
Standard error of the mean	1.86	1.84	1.48	1.59	1.66	1.36	1.99	1.91	1.16	1.80	1.74	1.10

Appendix table 8.9 Jacknife values of F: spring single-samples

	Untransformed data						Log transformed data					
	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Bow Brook	84.0	79.6	43.0	84.2	86.6	42.6	72.9	66.0	34.8	65.4	60.2	35.5
River Thames	154	166	45.5	147	156	47.2	82.7	73.4	36.1	80.3	72.1	38.6
River Coln	78.0	66.6	34.5	76.6	69.4	34.4	69.0	60.8	29.9	61.1	54.9	30.7
The Cut	97.7	91.1	52.7	102	102	51.3	90.5	84.1	43.2	82.9	78.0	43.6
Lydiard Stream	86.8	82.8	45.2	88.0	90.6	44.8	74.7	68.3	36.7	67.2	62.7	37.5
Halfacre Brook	94.6	91.7	60.7	98.2	105	60.3	87.3	83.4	46.8	79.4	76.6	45.5
Roundmoor Ditch	89.1	83.9	48.1	92.0	94.1	48.8	83.7	76.7	39.8	76.6	71.8	41.3
Summerstown Ditch	89.1	82.8	44.3	92.3	92.4	45.9	83.7	75.1	36.7	76.9	70.5	39.4
Crendon Stream	85.1	80.5	45.0	88.9	88.7	41.6	91.0	76.7	37.3	84.5	70.6	35.3
Wheatley Ditch	88.8	84.0	62.0	91.0	92.4	59.0	88.7	87.1	54.0	79.6	79.0	54.0
Crawters Brook	85.5	86.1	41.3	86.9	87.4	39.5	82.4	73.3	33.9	72.9	65.2	33.4
Catherine Bourne	95.2	88.9	49.6	98.0	98.5	49.4	86.8	78.9	40.4	79.1	73.1	41.6
Mean jacknife F	93.99	90.33	47.66	95.43	96.93	47.07	82.78	75.32	39.13	75.49	69.56	39.70
Standard error of the mean	5.67	7.13	2.25	5.08	5.96	2.16	2.05	2.22	1.86	2.12	2.14	1.79

Appendix table 8.10 Jacknife values of F: autumn dual-samples

Site	Untransformed data						Log transformed data					
	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Bow Brook	69.9	70.9	19.4	52.3	53.4	18.8	32.8	26.7	14.0	28.2	24.1	14.5
River Thames	59.9	62.7	19.2	52.3	56.5	21.0	30.7	25.2	13.5	28.8	24.9	15.6
River Coln	63.4	71.9	15.7	44.3	48.6	15.7	30.1	24.3	12.0	25.5	21.6	12.9
The Cut	77.2	82.0	21.3	60.7	65.7	21.6	35.8	29.7	15.4	31.8	27.7	16.6
Lydiard Stream	81.8	92.4	21.3	63.0	72.2	22.0	35.4	29.3	15.2	30.7	26.7	16.4
Halfacre Brook	72.8	79.7	24.2	57.1	64.1	24.6	37.6	32.3	17.1	33.4	30.2	18.1
Roundmoor Ditch	84.6	87.9	22.7	66.1	70.7	23.2	41.1	33.4	16.3	35.8	30.5	17.4
Summerstown Ditch	74.1	78.4	22.1	58.1	62.6	23.1	38.0	31.7	16.2	33.6	29.5	17.8
Crendon Stream	89.6	85.6	24.3	71.5	65.5	20.6	68.2	48.9	18.1	60.0	43.5	16.4
Wheatley Ditch	68.6	73.5	20.4	52.9	57.5	20.7	34.1	28.3	14.9	29.6	26.0	16.1
Crawters Brook	67.2	72.7	22.3	50.9	55.8	21.4	32.6	28.2	17.5	27.3	24.6	18.3
Catherine Bourne	74.2	78.0	21.2	56.8	60.8	21.2	37.0	30.3	15.5	32.1	27.7	16.4
Mean F value	73.61	77.98	21.18	57.17	61.12	21.16	37.78	30.69	15.48	33.07	28.08	16.38
Standard error of the mean	2.51	2.39	0.680	2.14	2.13	0.655	2.91	1.84	0.503	2.59	1.60	0.445

Appendix table 8.11 Jacknife values of F: spring dual-samples

Site	Untransformed data						Log transformed data					
	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Bow Brook	83.8	78.8	51.3	78.9	85.4	52.3	84.3	94.0	47.2	67.1	78.4	51.7
River Thames	154.4	123.1	47.1	129.3	112.8	51.9	100.7	107.3	44.8	85.0	95.8	53.1
River Coln	66.4	46.3	35.2	61.1	45.3	36.5	76.8	79.4	36.7	60.9	66.4	41.0
The Cut	88.1	70.9	55.1	84.6	74.6	53.3	95.4	103.4	55.2	77.8	87.4	57.4
Lydiard Stream	85.8	75.3	53.3	82.1	81.2	55.5	87.9	97.9	50.1	70.7	82.9	56.1
Halfacre Brook	88.7	70.5	48.7	86.3	75.5	50.0	97.7	102.2	47.7	79.7	87.3	52.2
Roundmoor Ditch	88.7	70.6	65.1	87.6	77.6	74.3	114.0	144.5	72.4	92.7	121.0	86.0
Summerstown Ditch	84.3	66.9	44.4	82.0	71.9	48.3	95.0	102.0	44.6	78.2	88.8	52.7
Crendon Stream	80.0	65.0	43.6	77.5	68.9	42.8	87.7	89.6	42.9	72.2	76.1	44.1
Wheatley Ditch	84.3	67.4	49.7	81.0	71.4	50.0	95.0	97.7	49.8	77.4	83.6	53.3
Crawters Brook	81.5	65.0	39.3	77.5	68.5	40.3	90.9	87.2	37.1	70.6	72.0	40.6
Catherine Bourne	100.7	74.9	49.0	102.7	82.8	52.4	117.9	119.1	48.4	100.3	109.0	55.6
Mean F value	90.56	72.89	48.48	85.88	76.33	50.63	95.28	102.03	48.08	77.72	87.39	53.65
Standard error of the mean	6.23	5.13	2.23	4.79	4.44	2.71	3.36	4.86	2.68	3.16	4.13	3.37

Appendix table 8.12 Jacknife values of F: spring or autumn single-samples

Site	Untransformed data						Log transformed data					
Site	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Bow Brook	34.6	37.2	32.5	32.0	38.9	30.1	28.6	30.9	29.1	23.9	27.2	27.8
River Thames	49.7	55.3	33.4	47.3	59.8	34.0	31.7	33.5	29.6	28.9	32.2	30.6
River Coln	29.3	30.4	29.3	27.1	33.7	27.8	26.2	28.1	26.5	21.9	25.0	26.0
The Cut	52.8	52.4	43.8	49.5	60.4	44.3	42.5	46.9	39.8	35.2	42.0	41.4
Lydiard Stream	40.8	45.3	37.0	37.8	47.6	33.7	31.3	34.4	32.6	26.1	30.1	30.6
Halfacre Brook	40.9	43.9	45.3	39.8	51.6	47.6	37.5	41.9	39.5	31.5	37.8	40.2
Roundmoor Ditch	40.0	41.5	36.8	40.1	47.8	36.0	36.1	38.2	33.5	32.0	34.9	33.1
Summerstown Ditch	38.1	40.1	36.0	37.5	45.9	34.9	33.4	36.4	33.7	29.4	33.8	33.0
Crendon Stream	38.4	40.0	35.5	38.8	46.0	33.0	37.5	39.3	32.8	33.5	36.4	30.9
Wheatley Ditch	36.8	39.4	37.3	35.3	44.3	37.3	31.7	35.5	35.6	27.0	32.9	37.2
Crawters Brook	35.9	38.2	29.6	34.2	42.4	27.3	29.3	30.1	25.6	24.4	26.2	23.5
Catherine Bourne	39.5	41.9	38.1	37.9	46.6	35.1	33.6	36.6	34.4	28.6	32.7	32.3
Average jacknife F	39.73	42.13	36.22	38.11	47.08	35.09	33.28	35.98	32.73	28.53	32.60	32.22
Standard error of the mean	1.82	1.92	1.40	1.75	2.20	1.73	1.31	1.51	1.29	1.17	1.43	1.55

Appendix table 8.13 Jacknife values of F: spring or autumn dual-samples

Site	Untransformed data						Log transformed data					
Site	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Bow Brook	73.7	83.0	55.0	60.6	71.3	54.2	48.2	54.2	46.0	41.2	48.7	48.4
River Thames	68.7	71.9	50.7	63.1	68.7	55.6	47.0	52.2	43.5	43.7	51.2	50.2
River Coln	59.2	60.3	43.0	46.8	48.4	43.6	43.7	48.1	38.5	36.9	42.8	41.8
The Cut	99.4	90.9	59.3	82.9	79.4	59.5	63.4	68.6	51.6	55.5	63.1	55.1
Lydiard Stream	77.1	84.2	59.2	64.4	73.4	59.9	51.0	57.9	49.7	43.8	52.4	53.3
Halfacre Brook	81.6	82.0	65.7	71.5	75.6	67.3	65.2	73.9	56.2	57.4	68.3	60.0
Roundmoor Ditch	83.4	80.4	61.6	73.0	73.9	64.9	66.6	73.0	54.6	58.3	67.3	59.8
Summerstown Ditch	72.4	73.5	56.1	62.4	66.2	59.7	53.7	60.7	50.3	47.4	56.7	56.8
Crendon Stream	72.7	72.6	54.9	62.9	64.2	50.6	59.1	63.9	49.4	52.3	57.5	47.5
Wheatley Ditch	70.3	72.4	57.7	59.5	64.1	58.4	50.6	57.1	51.0	43.7	52.0	55.0
Crawters Brook	68.6	70.1	49.0	57.5	61.6	48.7	48.3	52.2	43.7	40.4	45.8	46.3
Catherine Bourne	76.7	77.3	56.4	65.6	68.9	57.4	55.6	61.4	49.2	48.7	56.6	53.1
Mean F value	75.32	76.55	55.72	64.18	67.98	56.65	54.37	60.27	48.64	47.44	55.20	52.28
Standard error of the mean	2.86	2.34	1.73	2.57	2.34	1.93	2.20	2.40	1.44	2.04	2.32	1.61

Appendix table 8.14 Jacknife values of F: combined-season samples

	Untransformed data						Log transformed data					
	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Bow Brook	101	117	87.2	90.3	119	86.6	68.1	74.9	62.4	58.1	67.6	63.4
River Thames	147	183	87.8	132	174	95.4	72.4	77.8	61.7	66.8	75.9	67.7
River Coln	88.5	96.8	66.4	77.2	94.9	68.2	62.9	67.4	51.7	53.1	60.3	54.1
The Cut	124	139	97.7	117	147	102	81.6	89.9	70.4	71.8	84.1	74.9
Lydiard Stream	107	121	87.6	97.0	124	88.2	71.8	78.5	63.9	61.7	71.4	65.7
Halfacre Brook	108	124	94.3	102	131	94.2	78.4	86.9	68.1	68.5	79.8	69.3
Roundmoor Ditch	111	122	90.2	105	129	93.0	81.7	86.4	66.8	71.3	79.9	69.6
Summerstown Ditch	106	119	93.1	99.4	126	98.7	78.3	86.6	70.1	68.7	80.4	74.6
Crendon Stream	110	120	95.1	106	125	86.4	128	129	72.0	112	115	66.3
Wheatley Ditch	103	118	96.7	94.4	122	99.4	73.6	83.2	71.2	63.3	76.1	75.5
Crawters Brook	98.7	113	91.4	90.0	116	91.5	68.2	76.5	73.7	56.7	67.0	74.3
Catherine Bourne	112	126	91.0	106	131	92.8	79.5	86.2	67.0	69.9	79.5	69.4
Mean jacknife F	109.68	124.90	89.88	101.36	128.24	91.37	78.71	85.28	66.58	68.49	78.08	68.73
Standard error of the mean	4.19	5.97	2.36	4.03	5.42	2.54	4.80	4.40	1.74	4.33	3.91	1.76