NRA

National Rivers Authority

NRA Thames Region Operational Investigation

No. 0I/T/001 (Draft)

Investigation into macroinvertebrate sampling variability and European methods of analysis

Pond Action
October 1994

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Authors J.Biggs
A.Corfield
D.Walker
M.Whitfield
P.Williams

Research Contractor:
Pond Action
c/o Oxford Brookes University
Gipsy Lane
Headington
Oxford
OX3 0BP

National River Authority Thames Region
Kings Meadow House
Kings Meadow Road
Reading
RG1 8DQ

Executive summary

1. Background

This report presents the results of an NRA Thames Region Operational Investigation undertaken by Pond Action. The study had two main objectives:

(i) to describe the effect of sampling variability on biological assessments of water quality made using the BMWP system and RIVPACS;

(ii) to make a preliminary comparison of three water quality banding systems used in the European Union as part of the preparation for harmonising of water quality monitoring in the EU.

2. The effect of sampling variability on water quality assessments made using the BMWP system and RIVPACS

The data set

The data set for the study consisted of macroinvertebrate samples collected from 12 randomly selected NRA (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 bio'ogists, in autumn 1993 and spring 1994.

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 NRA 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.

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).

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. 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 oft 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.

3. A preliminary comparison of three water quality banding systems used in the European Union

This section of the project investigated methods for harmonising biological water quality assessments across the European Union. The UK BMWP/RIVPACS system was compared with two other European indices: the French IBG system and the German Saprobien system.

The results from the preliminary analyses undertaken suggest that:

(i) the IBG and BMWP/RIVPACS systems produce biotic indices which are strongly and linearly correlated.

(ii) the Saprobien and EQI indices are not as similar as IBG and EQIs. However, the two sets of results are still strongly correlated and the relationship is relatively linear.

When sites were banded using their respective national systems, differences between band types became more apparent. The two main trends were:

(i) the 5M banding system showed a tendency to 'over-rate' sites, placing them into higher categories than the IBG and Saprobien banding systems. For example, samples graded 5M band A were spread over the top 3 of 5 IBG bands and the 2nd and 3rd GI bands, whilst about half of the samples placed in 5M band A were placed in Saprobien Class II-III, 'critically stressed'.

(ii) using the Saprobien system, Thames Region sites were also compressed into the centre of the Saprobien banding system. They were thus neither as good as the 'best' German sites, nor as bad as the worst that could be classified using this system.

Differences in the results given by the different systems could be due either to real differences in perceptions of water quality, or to the imperfect correspondence of the indices and their respective banding systems.

Contents

TABLES

FIGURES

BOXES

Investigation into macroinvertebrate sampling variability and European methods of analysis.

1. Introduction

This report describes the results of an Operational Investigation undertaken by Pond Action for NRA Thames Region between October 1993 and September 1994.

The project had two main objectives:

(i) to describe the effect of sampling variability on assessments of water quality made using the BMWP system and RIVPACS;

(ii) to make a preliminary comparison of three water quality banding systems used by Member States of the European Union, as part of studies of the potential for harmonising water quality monitoring in the EU.

These two major sections of the report are introduced separately below. The results of the sampling variability study are described in Chapters 4-8. The comparison of European water quality banding systems is described in Chapter 9 and 10.

1.2 The effect of sampling variability on water quality assessment: introduction

1.2.1 Sample variability and the BMWP/RIVPACS system

The BMWP scoring system is routinely used by the NRA, in conjunction with RIVPACS, for biological water quality assessment. Despite the extensive use of the system however, there is very little information about the effect of sampling variability on its application. Sampling variability influences the certainty with which a site can be assigned to a water quality class. Understanding sampling variability is, therefore, essential for the correct interpretation of biological monitoring survey results.

1.2.2 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 when the samples are collected and affects stage (iii), the calculation of scores and RIVPACS predictions to derive EQIs. 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 completely 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 practice and checking results, and can largely be eliminated. Field sampling variation cannot be eliminated and must be controlled by careful survey design, reduced by personnel training, and its effects on results understood and taken into account.

Laboratory variation has been the subject of extensive and detailed investigation by NRA and IFE, particularly in the course of the 1990 River Water Quality Survey. Sampling variability has not yet received the same level of investigation.

1.2.3 Specific objectives of the variability study

The specific objectives of the variability study were:

(i) to describe the sources of 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 NRA:

- single season samples - NRA routinely assesses the water quality of sites using single samples.
- combined season samples - NRA 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 - NRA does not, but could, adopt a policy of collecting more than one sample in the same season. In this study his 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 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 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.

1.3 Harmonisation of UK and European biological water quality assessment

1.3.1 Objectives of the study

The NRA is currently involved in discussions regarding the potential for harmonising water quality monitoring results throughout EU Member States.

In the second part of this study, a preparatory comparison of three representative European systems for biological assessment of water quality is made. These are the UK BMWP system, the French IBG system and the German Saprobien system.

The study was divided into two sections:

(i) a comparison of <u>EQI values</u> derived from the three systems (i.e. EQIs from the BMWP system, IBG and GI scores, saprobic index). This was undertaken to indicate how similar results were using the different indices, and whether it was possible to describe the statistical relationship between the indices

(ii) a comparison of the different <u>banding</u> systems (i.e. comparing the 5M system for UK data, with the 5 classes of the IBG system and the 7 classes of the Saprobien system). For example were the sites spread through out the bands in all systems, or were they consistently banded lower in some banding systems.

The comparison of indices used two different sets of data:

(i) data from the 12 sites investigated in this study. In order to compare the index results directly, additional specimen identification was required for the IBG and the Saprobien system. For the IBG analysis this required identification of <u>additional</u> taxa at <u>family</u> level not routinely identified in the UK. The Saprobien system required <u>species level</u> data and a subset of samples were therefore identified to species

(ii) data from 43 sites already collected by Pond Action for the National Rivers Authority Thames Region in the course of the South West Oxfordshire Reservoir Development Study (SWORDS). This information was not specifically collected or identified for the project, but included both family level and species level data.

The SWORDS data, therefore, provided an additional source of family level data, similar to that used by the NRA in routine monitoring in the UK and species level data, similar to that held by some NRA regions in the UK. It therefore allows assessment of the potential for harmonisation using <u>existing</u> UK data (and by implication, data from other European states) to calculate IBG scores and saprobic scores.

Table 1.1 Terminology used in this report

The following abbreviations and acronyms are used throughout this report.

ANOV	Analysis of Variance - a statistical technique for looking at variability in data sets
ASPT	Average Score Per Taxon
ASPT.EQI	Average Score Per Taxon Ecological Quality Index
BMWP system	Biological Monitoring Working Party system Ecological Quality Index
BMWP.EQI	Biological Monitoring Working Party score
BMWP	Biological Monitoring Working Party Environmental score
EQI	Ecological Quality Index. Observed/predicted BMWP, ASPT or TAXA. (BMWP.EQI, TAXA.EQI, ASPT.EQI)
5M	The 5M banding system
GI	The faunal indicator group of the IBG system
IBG	Indice Biologique Globale or IBG score
IBG system	Indice Biologique Globale system- the French system for assessing water quality using macroinvertebrates (including IBG score and GI)
Pred. ASPT	Predicted ASPT (as predicted by RIVPACS)
Pred. BMWP	Predicted BMWP (as predicted by RIVPACS)
Pred. TAXA	Predicted TAXA (as predicted by RIVPACS)
Saprobic index	The index of water quality produced using the German saprobien system
Saprobien system	The German system for assessing water quality using macroinvertebrates (using the saprobic index
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 Rationale of the sampling programme

The aim of the sampling programme, as outlined in Chapter 1, was:

(i) to describe the effect of sampling variability on assessments of water quality made using the BMWP system and RIVPACS;

(ii) to make a preliminary comparison of three water quality banding systems used by Member States of the European Union, as part of studies of the potential for harmonising water quality monitoring in the EU.

The same sampling programme was used to fulfil both of these objectives.

2.2 Sites surveyed

2.2.1 Site selection procedure

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 NRA Thames Region were obtained from the NRA 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 NRA 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 NRA's 1992 regional data set were in water quality band D. A further band D site was, therefore, selected by officers of the NRA, from the Thames West region. The locations at which NRA 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.

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

2.3.1 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, however the amount of sampling each surveyor currently routinely performs 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 NRA 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.

2.3.2 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 diagrammatic description of the design of the sampling programme is shown in Figure 2.2. A detailed diagrammatic description of the sampling programme is shown in Table 2.3. 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 NRA RIVPACS code (this refers to the NRA 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 NRA 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 the same stretch of the river.

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. Table 2.4 shows which spring samples were combined with the autumn samples at each site.

2.3.2 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 NRA standard practice for RIVPACS related work (as described in the explanatory video produced by the NRA for the 1990 River Quality Survey). Although each person collected two invertebrate samples at each site, it was not possible to make <u>two</u> 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 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.

Subsampling was undertaken where necessary, consistent with the numerical data required by the IBG and Saprobien systems. Up to 50 specimens of each immediately recognisable taxon were identified to species level.

Additional data on invertebrate abundance was gathered during laboratory sorting so that comparison could be made between RIVPACS and the IBG system and the Saprobien system.

2.3.3 Additional identification of taxa for the IBG and Saprobien systems

In addition to the level of identification required for the BMWP system, invertebrates from all samples were identified to the level required for the IBG system (this involved identification of additional <u>families</u>). For the Saprobien system additional identification to species level was required, and only one sample from each site in each season was analysed to this level (see Table 2.3).

Levels of identification required for both IBG and Saprobien System can be found in Tables 9.2 and 9.3.

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

Site	Location	NRA 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.
Dr 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.

Table 2.3 Sampling programme structure: autumn samples

Samples analysed for Saprobien system are shaded

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	

Table 2.3 Sampling programme structure: spring samples

Samples analysed for Saprobien system are shaded in Column 5

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	

Table 2.4 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

2.4 Calculation of biotic indices

2.4.1 The BMWP system

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

(i) number of taxa (TAXA), BMWP score and ASPT;

(ii) RIVPACS predicted scores for TAXA, BMWP and ASPT (abbreviated in the report to Pred. TAXA, Pred. BMWP and Pred. ASPT). This was undertaken by the NRA;

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

2.4.2 IBG and Saprobien systems

For comparisons between the UK water quality indices and the two other European systems (IBG and Saprobien), IBG and saprobic index were calculated. Approximate IBG and saprobic index were also calculated for the 12 sites in this study and also for a set of 43 sites in the NRA Thames Region South-West Oxfordshire Reservoir Development Study (SWORDS). The SWORDS data set consisted of 3-minute macroinvertebrate samples collected by Pond Action and identified mainly to species level. Approximate IBG, GI and Saprobic indices were calculated to investigate whether existing data held in the UK could be used in comparative studies of UK and other European water quality indices. Further information about IBG and Saprobic systems is given in Chapter 9.

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 (ANOV). A brief summary of these techniques is given in Box 1. Other statistical techniques, such as nonparametric analyses and tests within ANOVs 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.

Outlying values

Occasionally in data sets, one or more values does 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 2.5 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	CREN JB2A	CREN RA1A	CREN RA2A
	Number of individuals	Number of individuals	Number of individuals	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. In some cases, where the results of certain tests are of particular interest or importance, and the data appear to be far from normal, 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, 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). 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 (ANOVs) in this report.

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

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

Nested. In some of the ANOVs 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 ANOVs in this report, either as nested ANOVs, in which sampler is included as a term, or a non-nested ANOVs 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 ANOV 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 ANOVs with combined sample ANOVs, the single season ANOVs need to be performed without nesting, as this would alter the test statistics produced.

Interactions. In an ANOV, 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 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 ANOVs 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. $p< 5\times10^{-7}$).

3. The water quality at the 12 sites

3.1 Introduction

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 Table 3.1 (single-season data), Table 3.2 (combined-season data) and Table 3.3 (dual sample data), and described briefly below. RIVPACS environmental data (width, depth and substrate measured as phi) for all sites is given in Table 3.4.

IBG system indices (IBG, approximate IBG and GI) and Saprobien system indices (Saprobic score and approximate Saprobic score) are listed for all relevant sites in Table 3.5. IBG, GI and Saprobic score were calculated for single-season data only, following standard practice in continental Europe.

Results for actual and predicted TAXA, BMWP and ASPT, and for IBG and GI are illustrated graphically in Figures 3.1 to 3.11. Taxa lists for all samples are given in Appendix 1.

3.2 TAXA, BMWP and ASPT values at the 12 sites

3.2.1 Single season samples (see Table 3.1)

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 numbers 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 2.400 to 5.875 in the Crawters Brook and the River Coln, respectively (see Figure 3.3). ASPT values are quoted to three decimal places throughout the report to avoid rounding errors.

3.2.2 Combined sample biotic indices (see Table 3.2)

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 2.571 to 5.784 (see Figures 3.4, 3.5 and 3.6).

3.2.3 Dual sample biotic indices (see Table 3.3)

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 2.625 to 5.757.

3.2.4 Comparison of single, combined and dual season samples

Generally, combined-season samples had higher TAXA and BMWP scores than single-season samples. The average combined-season TAXA and BMWP scores for all samples were 22.7% and 27.2% higher, respectively, than for all single-season samples. ASPT was also higher in combined samples (by 4.5% 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, although on the River Coln an apparent under-prediction did occur.

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 four 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 (Moss et al, 1994);

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

(iv) The sites included in the RIVPACS database <u>were</u> 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 IBG and GI values at the 12 sites

3.3.1 Single-season samples

IBG values ranged from 3 (in the Crendon Stream, Crawters Brook and Wheatley Ditch) to 18 in the Coln. Sites surveyed, therefore, covered most of the range of the IBG index (0 = low quality, 20 = high quality) (see Table 3.5 and Figure 3.10). IBG indicates 'biogenic capacity' and is probably best seen as analogous to BMWP score. Further information about the IBG system is given in Box 9.1 (see Chapter 9).

Approximate IBGs for the 12 sites surveyed in this study ranged from 3 to 17.

The GI values for the sites were between 1 (the Wheatley Ditch) and 8 (River Coln), again covering most of the range of the GI score (1 = low quality, 10 = high quality). GI provides an indication of water quality and is analogous to ASPT. Values for GI were not approximated.

IBG and GI scores for combined or dual samples are not routinely used in France and were not calculated in this study.

3.4 Saprobic score values at the 12 sites

Saprobic scores ran from 1 (high quality) to 4 (low quality). Values for the sites varied from 1.94 in the River Coln to 3.18 in the Roundmoor Ditch (see Table 3.5).

3.5 Water quality indices for the additional sites derived from the SWORDS study

The results of the studies using approximated IBG and Saprobic scores from the SWORDS data are given in Chapters 9 and 10.

Table 3.1a Single-season (autumn) biotic indices for the 12 sites

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
Site	Sample	TAXA	BMWP	ASPT	Pred. TAXA	Pred. BMWP	Pred. ASPT	TAXA EQI	BMWP EQI	ASPT EQI	5M
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
Site	Sample	TAXA	BMWP	ASPT	Pred. TAXA	Pred. BMWP	Pred. ASPT	TAXA EQI	BMWP EQI	ASPT EQI	5M
River Coln	COLN DW1A	29	151	5.207	21.3	101.3	4.7	1.362	1.491	1.108	1
River Coln	CCLN 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
Site	Sample	TAXA	BMWP	ASPT	Pred. TAXA	Pred. BMWP	Pred. ASPT	TAXA EQI	BMWP EQI	ASPT EQI	5M
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
Site	Sample	TAXA	BMWP	ASPT	Pred. TAXA	Pred. BMWP	Pred. ASPT	TAXA EQI	BMWP EQI	ASPT EQI	5M
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
Site	Sample	TAXA	BMWP	ASPT	Pred. TAXA	Pred. BMWP	Pred. ASPT	TAXA EQI	BMWP EQI	ASPT EQI	5M
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
Site	Sample	TAXA	BMWP	ASPT	Pred. TAXA	Pred. BMWP	Pred. ASPT	TAXA EQI	BMWP EQI	ASPT EQI	5M
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

Table 3.1a Single-season (autumn) biotic indices for the 12 sites (continued)

Site	Sample	TAXA	BMWP	ASPT	Pred. TAXA	Pred. BMWP	Pred. ASPT	TAXA. EQI	BMWP EQI	ASPT EQI	5M
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

Site	Sample	TAXA	BMWP	ASPT	Pred. TAXA	Pred. BMWP	Pred. ASPT	TAXA. EQI	BMWP EQI	ASPT EQI	5M
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

Site	Sample	TAXA	BMWP	ASPT	Pred. TAXA	Pred. BMWP	Pred. ASPT	TAXA. EQI	BMWP EQI	ASPT EQI	5M
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

Site	Sample	TAXA	BMWP	ASPT	Pred. TAXA	Pred. BMWP	Pred. ASPT	TAXA. EQI	BMWP EQI	ASPT EQI	5M
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

Site	Sample	TAXA	BMWP	ASPT	Pred. TAXA	Pred. BMWP	Pred. ASPT	TAXA. EQI	BMWP EQI	ASPT EQI	5M
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

Table 3.1b Single-season (spring) biotic indices for the 12 sites

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
Site	Sample	TAXA	BMWP	ASPT	Pred. TAXA	Pred. BMWP	Pred. ASPT	TAXA EQI	BMWP EQI	ASPT EQI	5M
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
Site	Sample	TAXA	BMWP	ASPT	Pred. TAXA	Pred. BMWP	Pred. ASPT	TAXA EQI	BMWP EQI	ASPT EQI	5M
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
Site	Sample	TAXA	BMWP	ASPT	Pred. TAXA	Pred. BMWP	Pred. ASPT	TAXA EQI	BMWP EQI	ASPT EQI	5M
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
Site	Sample	TAXA	BMWP	ASPT	Pred. TAXA	Pred. BMWP	Pred. ASPT	TAXA EQI	BMWP EQI	ASPT EQI	5M
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
Site	Sample	TAXA	BMWP	ASPT	Pred. TAXA	Pred. BMWP	Pred. ASPT	TAXA EQI	BMWP EQI	ASPT EQI	5M
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
Site	Sample	TAXA	BMWP	ASPT	Pred. TAXA	Pred. BMWP	Pred. ASPT	TAXA EQI	BMWP EQI	ASPT EQI	5M
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

Table 3.1b Single-season (spring) biotic indices for the 12 sites (continued)

Site	Sample	TAXA	BMWP	ASPT	Pred. TAXA	Pred. BMWP	Pred. ASPT	TAXA EQI	BMWP EQI	ASPT EQI	5M
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
Site	Sample	TAXA	BMWP	ASPT	Pred. TAXA	Pred. BMWP	Pred. ASPT	TAXA EQI	BMWP EQI	ASPT EQI	5M
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
Site	Sample	TAXA	BMWP	ASPT	Pred. TAXA	Pred. BMWP	Pred. ASPT	TAXA EQI	BMWP EQI	ASPT EQI	5M
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
Site	Sample	TAXA	BMWP	ASPT	Pred. TAXA	Pred. BMWP	Pred. ASPT	TAXA EQI	BMWP EQI	ASPT EQI	5M
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
Site	Sample	TAXA	BMWP	ASPT	Pred. TAXA	Pred. BMWP	Pred. ASPT	TAXA EQI	BMWP EQI	ASPT EQI	5M
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

Table 3.2 Combined-season biotic indices for the 12 sites

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

Table 3.3 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

Table 3.4 RIVPACS field measurements for the 12 sites

Site	Autumn sample	Width (m)	Depth (cm)	PHI	Spring sample	Width (m)	Depth (cm)	PHI
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

Table 3.4 RIVPACS field measurements for the 12 sites (continued)

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

Table 3.5 IBG and Saprobien system data for the 12 sites: autumn						
Sample	IBG	GI	Approximate IBG	Saprobic score (*S*)	Dispersion value (*SM*)	Abundance value (*A*)
BOWB JB1A	13	6	12			
BOWB JB2A	14	6	14	2.26	0.09	61
BOWB DW1A	12	6	12			
BOWB DW2A	14	6	13			
THAM DW1A	13	6	12			
THAM DW2A	13	4	12	2.20	0.05	58
THAM RA1A	12	6	12			
THAM RA2A	15	6	14			
COLN DW1A	16	7	15			
COLN DW2A	18	7	16			
COLN MW1A	17	7	15			
COLN MW2A	15	7	15	1.95	0.08	58
CUT. JB1A	9	3	8			
CUT. JB2A	8	3	8			
CUT. RA1A	10	3	9			
CUT. RA2A	10	3	9	2.48	0.1	52
LYDI DW1A	9	3	9	2.32	0.13	54
LYDI DW2A	9	3	9			
LYDI MW1A	10	3	9			
LYDI MW2A	11	4	8			
HALF JB1A	4	2	4			
HALF JB2A	5	2	4			
HALF RA1A	5	2	5	2.36	0.22	27
HALF RA2A	5	2	5			
ROUN RA1A	5	2	4			
ROUN RA2A	7	2	5	3.00	0.24	29
ROUN MW1A	7	2	6			
ROUN MW2A	7	2	6			
SUMM MW1A	6	2	5			
SUMM MW2A	5	2	5			
SUMM JB1A	4	2	4			
SUMM JB2A	5	2	5	3.08	0.17	22
CREN JB1A	3	2	3			
CREN JB2A	3	2	3			
CREN RA1A	3	2	3			
CREN RA2A	6	2	5	2.43	0.19	14
WHEA DW1A	4	2	4			
WHEA DW2A	4	1	3	2.90	0.19	21
WHEA MW1A	4	2	4			
WHEA MW2A	3	1	3			
CRAW MW1A	4	2	4			
CRAW MW2A	4	2	4			
CRAW DW1A	4	2	4			
CRAW DW2A	4	2	4	2.72	0.12	20
CATH DW1A	6	2	6			
CATH DW2A	6	2	6			
CATH JB1A	7	2	6	2.87	0.19	38
CATH JB2A	6	2	6			

Table 3.5 IBG and Saprobien system data for the 12 sites: spring (continued)

Sample	IBG	GI	Approximate IBG	Saprobic score (S)	Dispersion value (SM)	Abundance value (A)
BOWB JB1S	13	6	13			
BOWB JB2S	15	7	15	2.37	0.1	50
BOWB DW1S	16	7	14			
BOWB DW2S	14	6	13			
THAM RA1S	11	4	10			
THAM RA2S	13	6	13			
THAM JB1S	16	6	15	2.33	0.09	60
THAM JB2S	12	4	12			
COLN JB1S	17	8	17	1.95	0.1	82
COLN JB2S	17	8	16			
COLN RA1S	15	7	15			
COLN RA2S	18	8	17			
CUT. MW1S	6	2	6	2.64	0.14	34
CUT. MW2S	7	2	6			
CUT. RA1S	6	2	5			
CUT. RA2S	8	3	7			
LYDI JB1S	11	3	10	2.35	0.1	68
LYDI JB2S	11	4	11			
LYDI DW1S	11	3	10			
LYDI DW2S	10	3	10			
HALF JB1S	5	2	5			
HALF JB2S	10	6	6			
HALF MW1S	6	2	6			
HALF MW2S	6	2	6	2.65	0.27	20
ROUN MW1S	6	2	5	3.06	0.27	26
ROUN MW2S	4	2	4			
ROUN DW1S	5	2	4			
ROUN DW2S	4	2	4			
SUMM JB1S	5	2	5			
SUMM JB2S	4	2	4	3.01	0.2	16
SUMM DW1S	4	2	4			
SUMM DW2S	5	2	4			
CREN MW1S	3	2	3			
CREN MW2S	4	2	4	2.91	0.24	21
CREN JB1S	4	2	3			
CREN JB2S	3	2	3			
WHEA JB1S	3	2	3			
WHEA JB2S	4	2	3			
WHEA MW1S	3	1	3			
WHEA MW2S	4	2	4	2.84	0.19	21
CRAW RA1S	3	2	3			
CRAW RA2S	4	2	4			
CRAW MW1S	4	2	4	3.05	0.17	25
CRAW MW2S	4	2	4			
CATH MW1S	11	6	10			
CATH MW2S	10	6	10			
CATH DW1S	11	6	10	2.64	0.18	32
CATH DW2S	10	6	9			

3.6 Effect of sample combination on 5M banding

3.6.1 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 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 III development work.

3.6.2 Results of this study compared with NRA 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 NRA staff. Overall, three sites moved clearly into higher bands, and one site moved into a lower band. Specifically, the following changes occurred between 1992 NRA data and the combined data of this study:

(i) Band A: all sites banded A by NRA 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 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 biotic index scores than was typical for NRA 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.

Comparisons with the results of French and German water quality bands are described in Chapter 9.

3.7 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 III development work.

IBG and GI index values for the 12 sites encompassed most of the range of variation available in these indices. The range of variation in the Saprobic score was less.

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

The greatest movement in site banding between NRA 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 NRA Thames Region staff.

Table 3.6 Effect of season and sample combinations on 5M banding

	Data used for banding				
Site	NRA 1992 combined-seasons	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

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

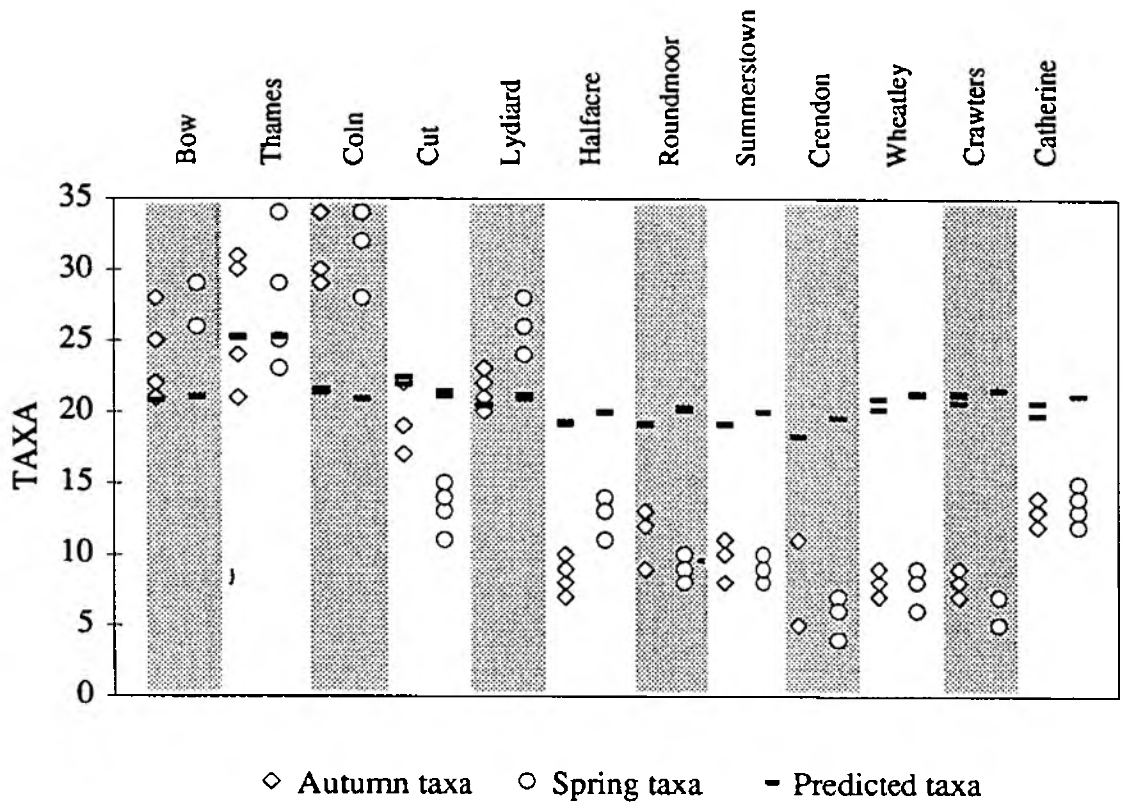


Figure 3.2 **Water quality indicies for the 12 sites in this study: BMWP, autumn and spring single samples, and single season RIVPACS predictions**

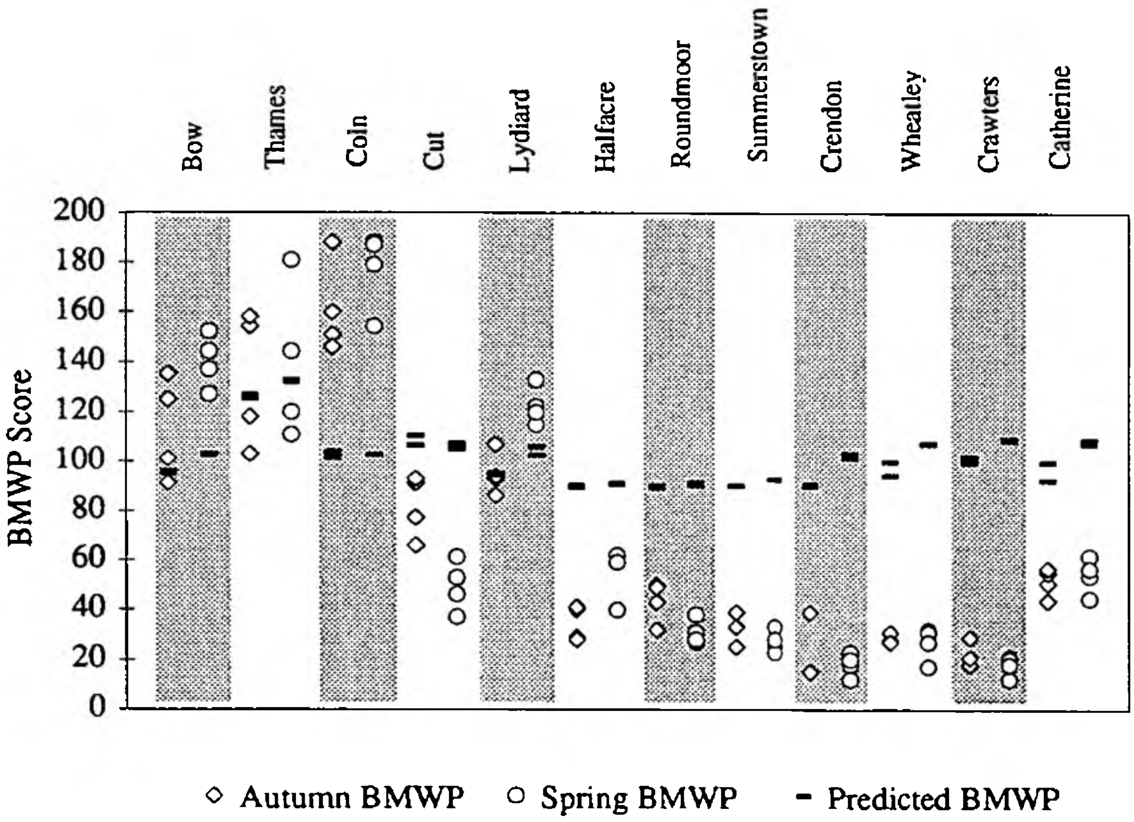


Figure 3.3 **Water quality indicies for the 12 sites in this study: ASPT, autumn and spring single samples, and single season RIVPACS predictions**

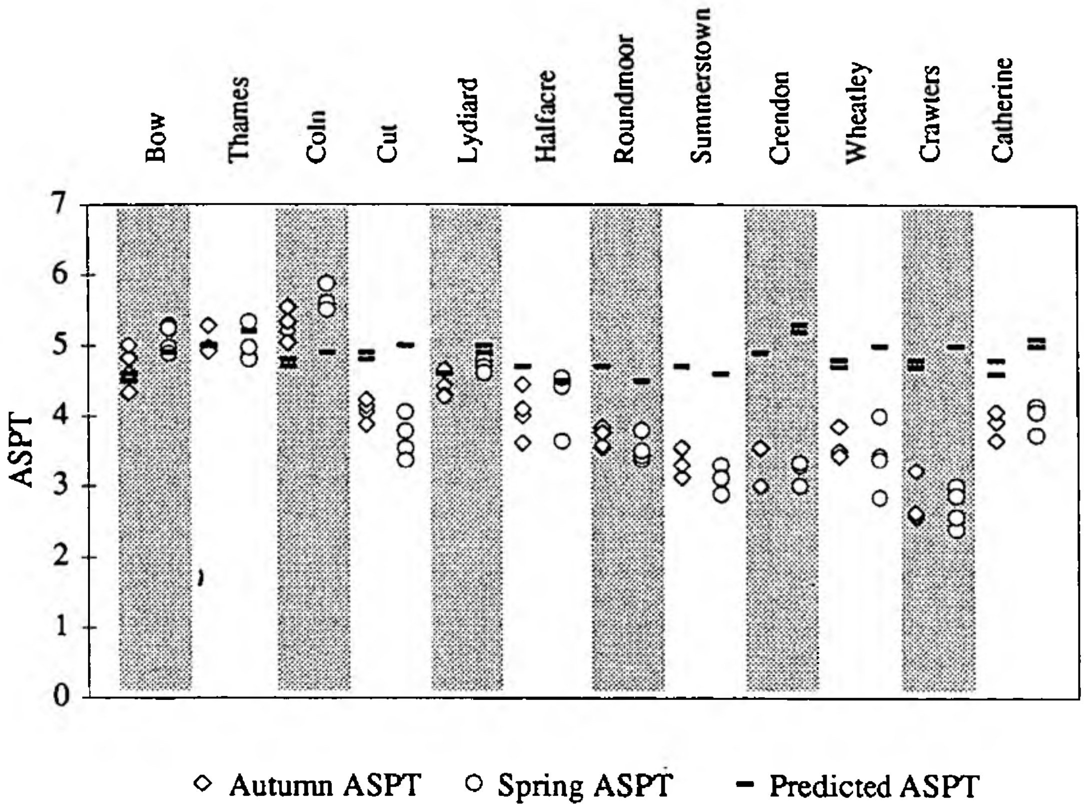


Figure 3.4 **Water quality indicies for the 12 sites in this study: TAXA, autumn and spring samples combined, and combined season RIVPACS predictions**

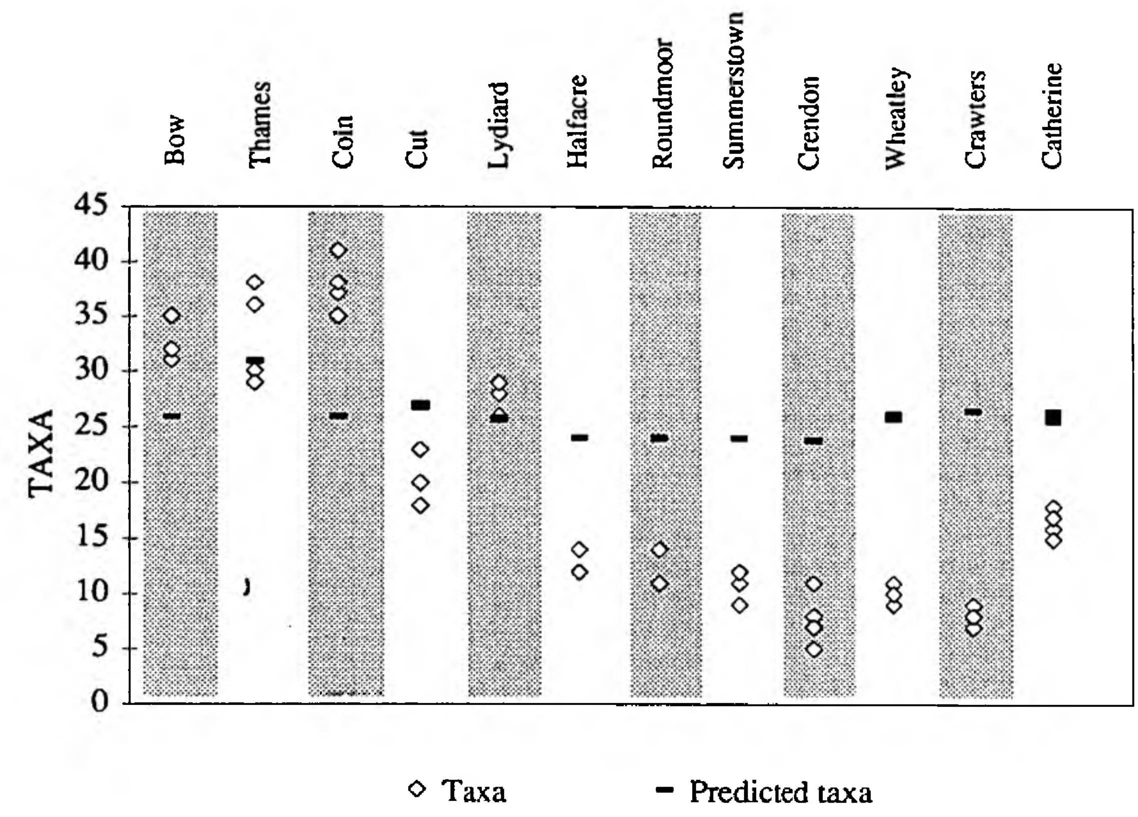


Figure 3.5 **Water quality indicies for the 12 sites in this study: BMWP, autumn and spring samples combined, and combined season RIVPACS predictions**

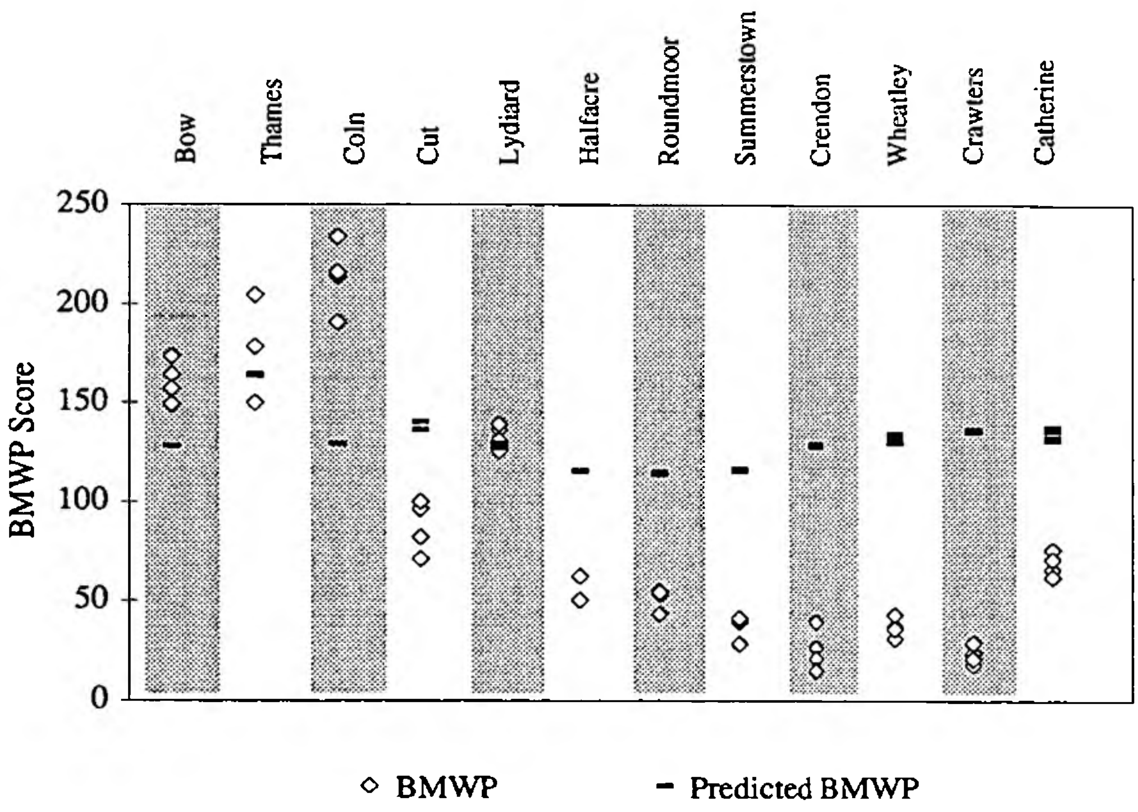


Figure 3.6 **Water quality indicies for the 12 sites in this study: ASPT, autumn and spring samples combined, and combined season RIVPACS predictions**

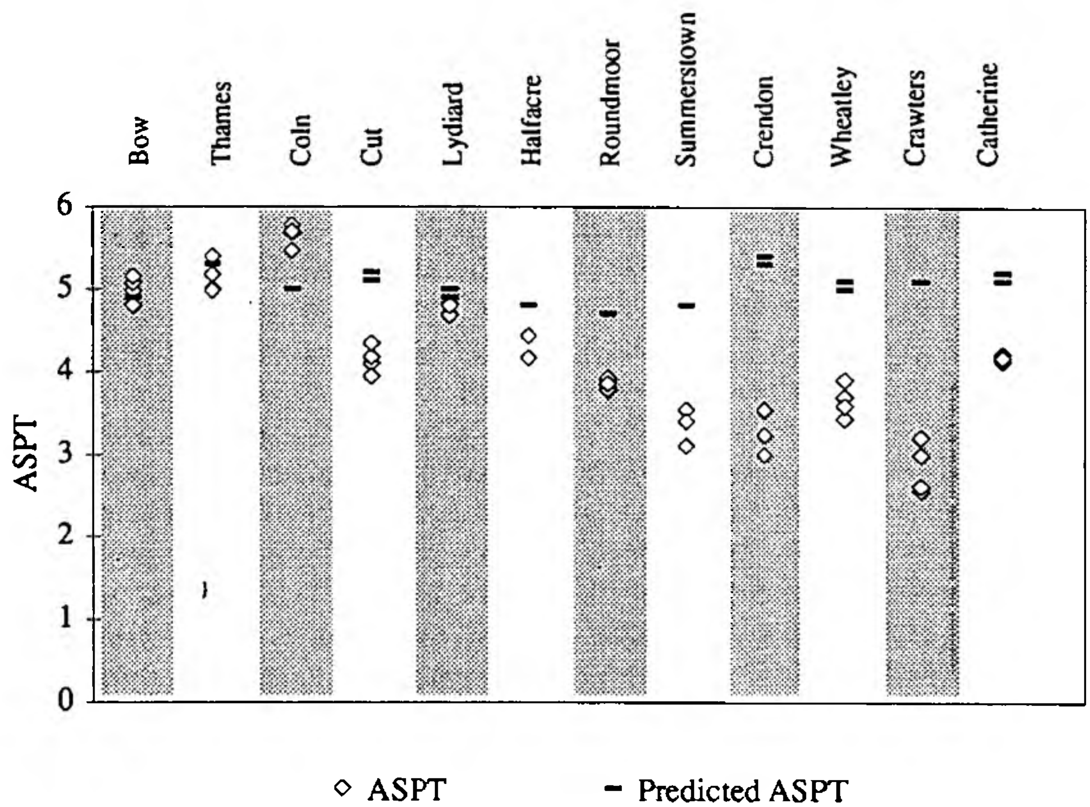


Figure 3.7 **Water quality indicies for the 12 sites in this study: TAXA, autumn and spring dual samples, and RIVPACS predictions.**

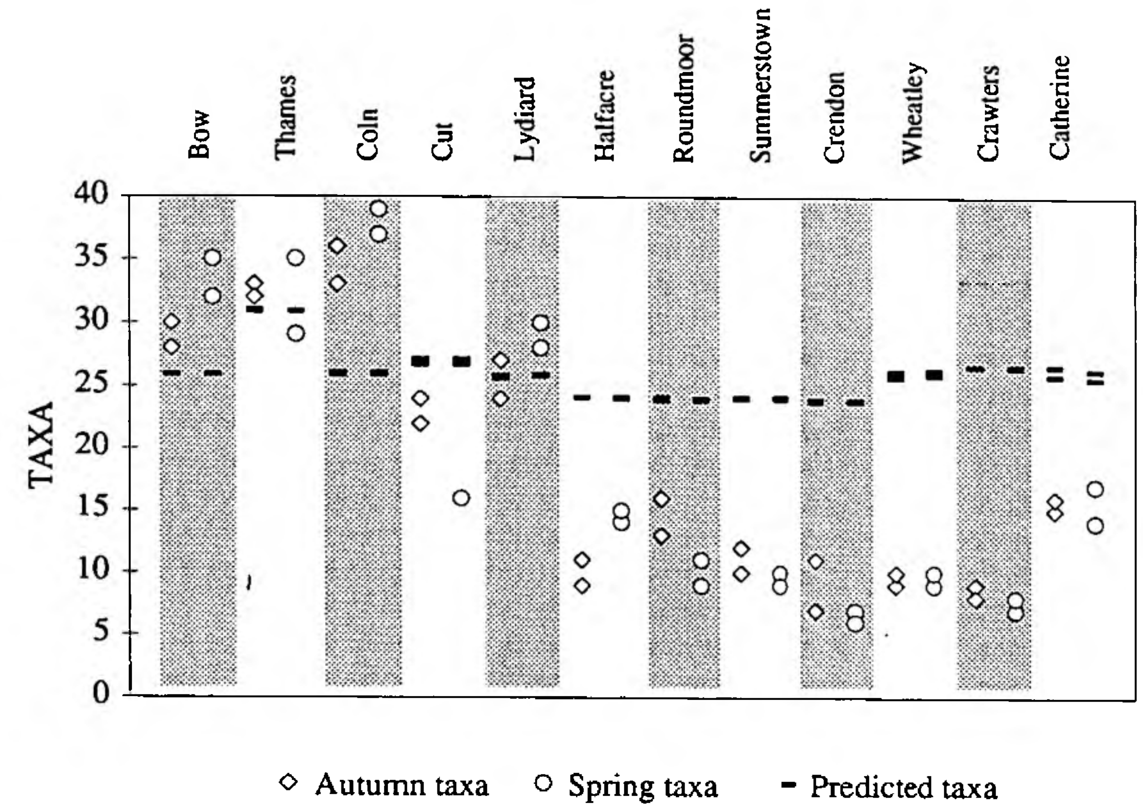


Figure 3.8 **Water quality indicies for the 12 sites in this study: BMWP, autumn and spring dual samples, and RIVPACS predictions.**

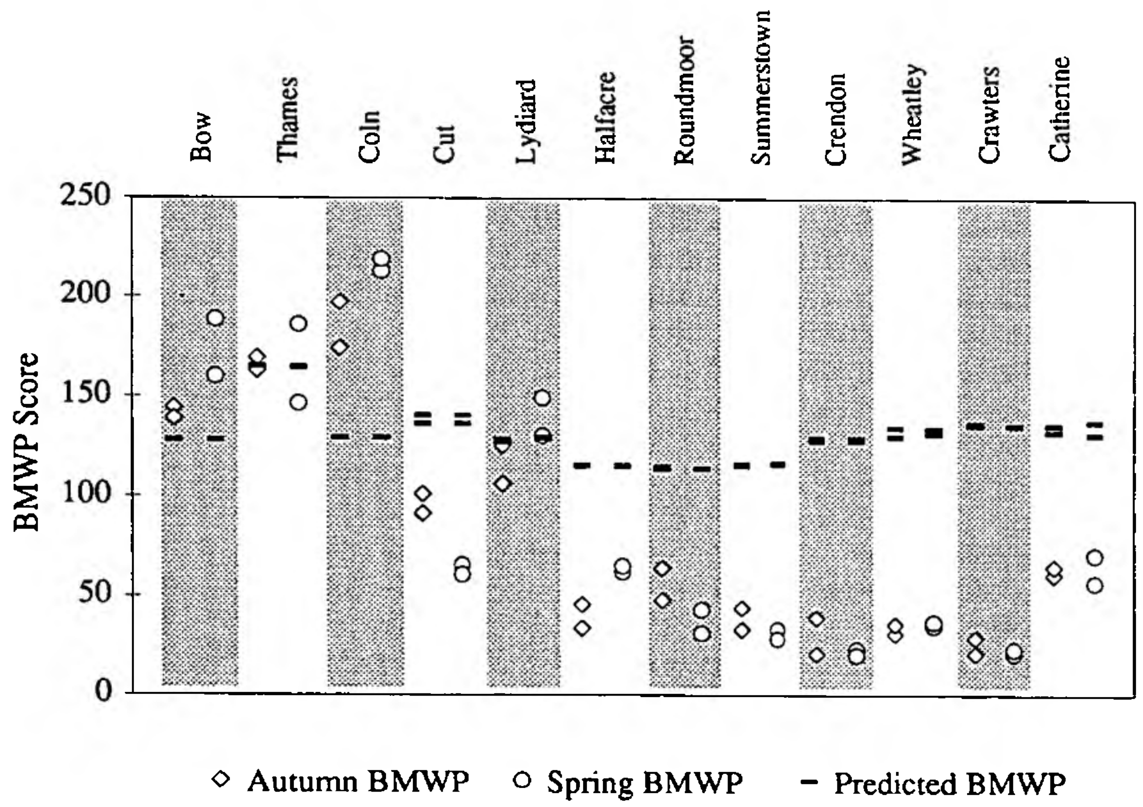


Figure 3.9 **Water quality indicies for the 12 sites in this study: ASPT, autumn and spring dual samples, and RIVPACS predictions.**

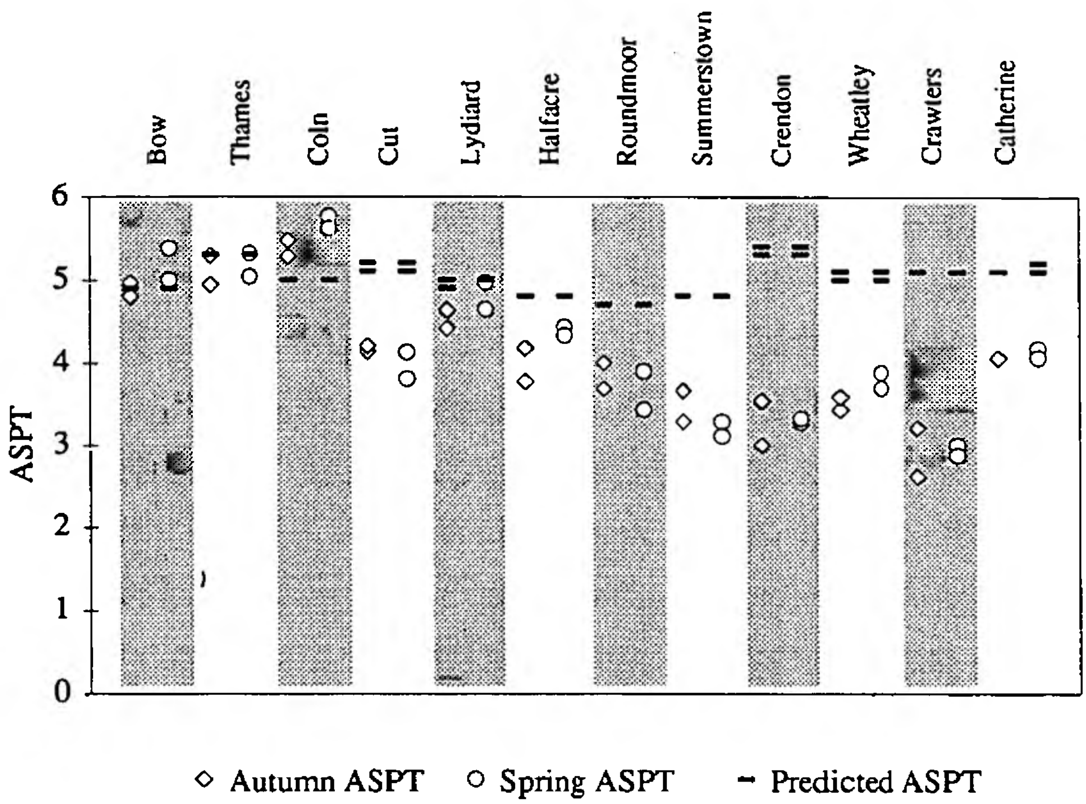
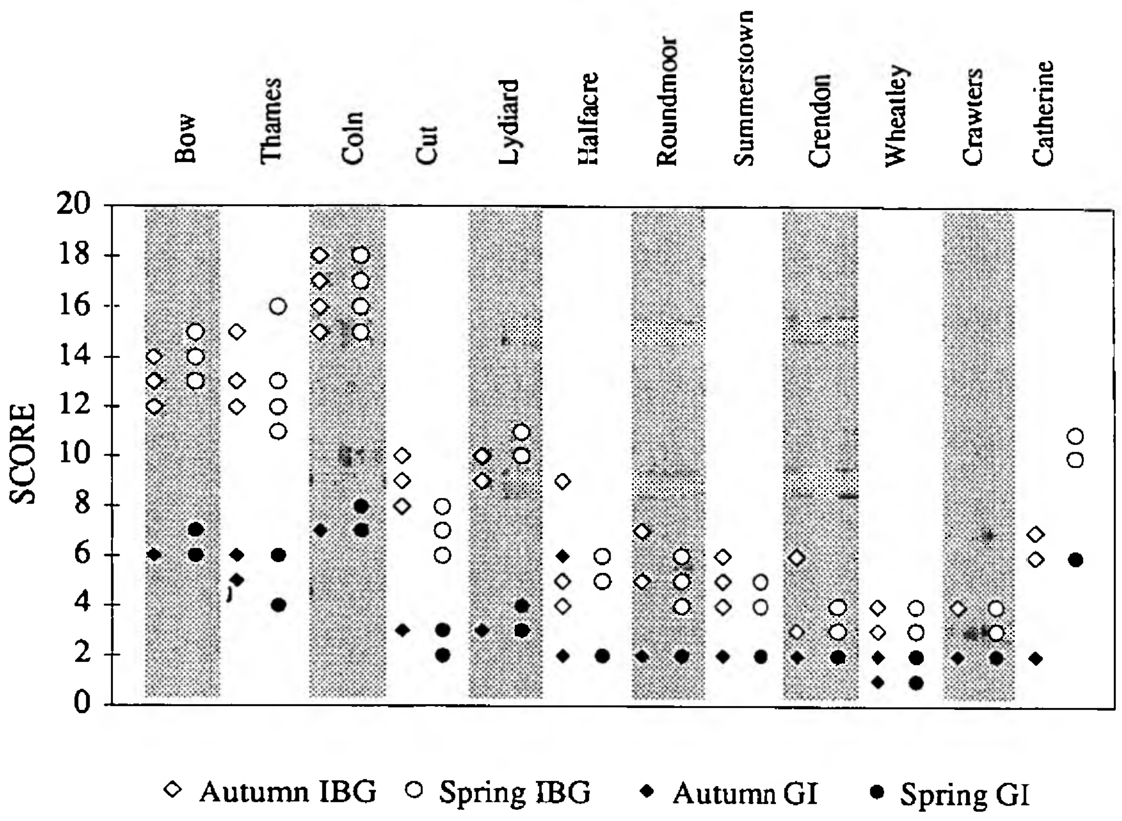


Figure 3.10 **Water quality indicies for the 12 sites in this study: IBG and GI autumn and spring single samples.**



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, ASPT and IBG scores);

(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 NRA 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 NRA.

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 first invertebrate sample taken by each person (Sample 1) to the biotic index of the second sample (Sample 2).

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

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 NRA practice. During this study samplers were randomised so that any differences in sampler variability were controlled. However, the NRA 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, ASPT, and IBG. 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 (see Table 3.1 for example). 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 was used to assess whether there were any significant biases (deviations from 1). The Student t-test result is shown in row 5 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 ANOV. The significance of this test is given in the first cell of row 6 in the tables in Table 4.1. An estimate of which, if any, samplers differed significantly from the others was made using a Scheffé test, shown in row 6 of the tables (where significant differences occur).

Scheffé tests assess the differences between means within ANOVs (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.

4.2.1 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% and 8% higher or lower 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 $p<0.0281$, 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 (see Table 2.4 for discussion of this sample). Nevertheless, even, analysing the results using the non-parametric Mann-Whitney-U test (which uses ranked data and will not be as affected by this extreme value) gives $p<0.0005$ for TAXA and $p<0.0001$ 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.

4.2.3 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 ($p<0.0124$).

4.2.4 IBG

The IBG results showed no significant bias for a higher second sample for all surveyors combined. No individual sampler alone showed significant bias, although RAC's results were rather high (25% difference between first and second samples). ANOV suggested there was a bias between surveyors overall, but there were no significant differences between individual pairs.

4.2.5 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 NRA (single samples in one, two or three seasons), and so the variations seen in this study are probably greater than those normally seen in NRA 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; it is possible that any variation shown by RAC normally is in some way absorbed into this bias.

Lacking a concrete theory of why the bias between RAC's samples occurred, 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.

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	4.01				
	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 1	16.32	16.13	15.81	15.68	18.03
(4)	Average TAXA for Sample 2	15.18	15.37	15.69	15.82	13.47
(5)	One sample Student t-test	p<.0363	ns	ns	ns	p<.0209
(6)	ANOV/Scheffé Test	p<0.0019	RAC>DW,JB&MW			

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 1	74.21	72.55	72.18	71.00	82.60
(4)	Average BMWP for Sample 2	65.57	67.22	67.59	68.77	57.17
(5)	One sample t-test	p<.0115	ns	ns	ns	p<.0281
(6)	ANOV/Scheffé Test	P<.022	RAC>DW,JB&MW			

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 1	4.09	4.06	4.09	4.07	4.13
(4)	Average ASPT for Sample 2	3.93	3.96	3.93	3.94	3.89
(5)	One sample t-test	p<.0124	ns	ns	ns	ns
(6)	ANOV/Scheffé Test	ns				

Row	IBG	All samplers	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
(1)	Mean IBG for all samples	8.07				
	Upper confidence limit	1.11	1.08	1.09	1.09	1.43
(2)	**Mean bias**	**1.04**	**1.01**	**0.99**	**0.98**	**1.21**
	Lower confidence limit	0.98	0.94	0.90	0.87	0.98
(3)	Average IBG for Sample 1	8.24	8.10	8.10	8.00	8.83
(4)	Average IBG for Sample 2	7.91	8.04	7.05	8.14	7.31
(5)	One sample t-test	ns	ns	ns	ns	ns
(6)	ANOV/Scheffé Test	p<.0312				

4.3 Bias between different samplers

4.3.1 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 NRA 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 to gain a greater understanding of biases within the NRA 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.

4.3.2 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, 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.

ANOVs showed that MW recorded significantly higher TAXA and BMWP values than JB and higher ASPT values than DW and JB (see row 5 in each subsection of Table 4.3(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 4.3a):

(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.

4.3.3 Effects of between-sampler bias on IBG values

There was no obvious bias in IBG values between samplers (see Table 4.2 (a)).

4.3.4 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' predictions were 0.5% above average.

4.3.5 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.

4.3.6 Effects of between-sampler bias on width, depth and phi measurements for RIVPACS (see Table 4.2d)

This analysis deals with the field-measured RIVPACS variables, width, depth and substrate composition (as phi). Phi is an index of substrate composition, a low phi indicating a greater proportion of finer substrate. Note that, as phi ranges about zero the values used are estimate for sampler **minus** average estimate for site.

None of the estimates of RIVPACS field data varied significantly between recorders. Translated into the hypothetical average site for the study, 7m wide and 55cm deep, estimates of the width would vary by 23cm and for depth by 5 cm. Average phi's would vary over 0.75 units.

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

	Person collecting samples			
TAXA	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
Upper confidence limit **Mean bias** Lower confidence limit	1.001 **0.983** 0.966	1.011 **0.960** 0.910	1.082 **1.057** 1.032	1.082 **1.002** 0.922
Mean TAXA	15.487	15.124	16.644	15.785
One group t	ns	ns	P<.0007	ns
ANOV	p<.0019	MW>JB		

	Person collecting samples			
BMWP	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
Upper confidence limit **Mean bias** Lower confidence limit	0.987 **0.963** 0.939	1.023 **0.957** 0.892	1.104 **1.075** 1.047	1.109 **1.007** 0.906
Mean BMWP	67.298	66.897	75.148	70.382
One group t	P,.011	ns	P<.0002	ns
ANOV	P<0.0155	MW>JB		

	Person collecting samples			
ASPT	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
Upper confidence limit **Mean bias** Lower confidence limit	0.990 **0.980** 0.970	1.014 **0.996** 0.978	1.033 **1.021** 1.009	1.025 **1.002** 0.980
Mean ASPT	3.930	3.995	4.093	4.019
One group t	p<.0027	ns	p<.0052	ns
ANOV	P<0.0072	MW>JB&DW		

	Person collecting samples			
IBG	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
Upper confidence limit **Mean bias** Lower confidence limit	1.013 **0.994** 0.976	1.003 **0.959** 0.914	1.051 **1.024** 0.996	1.103 **1.040** 0.977
Mean IBG	8.208	7.740	8.265	8.394
One group t	ns	ns	ns	ns
ANOV	ns			

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

	Person collecting samples			
Pred. TAXA	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
Upper confidence limit	1.003	1.006	1.004	1.003
Mean bias	**0.998**	**1.002**	**1.000**	**0.999**
Lower confidence limit	0.993	0.998	0.997	0.996
Mean TAXA	20.831	20.918	20.879	20.861
One group t	ns	ns	ns	ns
ANOV	ns			

	Person collecting samples			
Pred. BMWP	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
Upper confidence limit	1.006	1.011	1.004	1.004
Mean bias	**0.997**	**1.005**	**0.998**	**0.999**
Lower confidence limit	0.988	0.999	0.993	0.993
Mean BMWP	101.051	101.859	101.192	101.241
One group t	ns	ns	ns	ns
ANOV	ns			

	Person collecting samples			
Pred. ASPT	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
Upper confidence limit	1.004	1.007	1.002	1.001
Mean bias	**0.999**	**1.003**	**0.999**	**0.999**
Lower confidence limit	0.993	0.999	0.996	0.997
Mean ASPT	4.820	4.840	4.821	4.821
One group t	ns	ns	ns	ns
ANOV	ns			

Table 4.2 (c) Biases between personnel: EQIs

	Person collecting samples			
TAXA EQI	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
Upper confidence limit	1.002	1.008	1.082	1.083
Mean bias	**0.985**	**0.958**	**1.057**	**1.003**
Lower confidence limit	0.969	0.908	1.031	0.922
Mean TAXA.EQI	0.731	0.711	0.784	0.744
One group t	ns	ns	p<.0008	ns
ANOV	p<.018	MW>JB&DW		

	Person collecting samples			
BMWP EQI	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
Upper confidence limit	0.990	1.017	1.107	1.111
Mean bias	**0.966**	**0.952**	**1.077**	**1.008**
Lower confidence limit	0.942	0.888	1.047	0.906
Mean BMWP.EQI	0.652	0.643	0.727	0.681
One group t	p<.0173	ns	p<.0003	ns
ANOV	P<.0122	MW>JB&DW		

	Person collecting samples			
ASPT EQI	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
Upper confidence limit	0.993	1.011	1.035	1.027
Mean bias	**0.981**	**0.993**	**1.022**	**1.003**
Lower confidence limit	0.970	0.976	1.009	0.980
Mean ASPT.EQI	0.817	0.827	0.850	0.835
One group t	p<.0101	ns	p<.0051	ns
ANOV	p<.0072	MW>JB&DW		

Table 4.2 (d) Biases between personnel: RIVPACS variables

	Person collecting samples			
WIDTH (m)	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
Upper confidence limit	1.035	1.041	1.032	1.007
Mean bias	**1.005**	**1.012**	**0.995**	**0.981**
Lower confidence limit	0.976	0.984	0.958	0.954
Mean Width	7.412	7.463	7.338	7.230
One group t	ns	ns	ns	ns
ANOV	ns			

	Person collecting samples			
DEPTH (cm)	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
Upper confidence limit	1.053	1.016	1.021	1.136
Mean bias	**1.028**	**0.969**	**0.961**	**1.066**
Lower confidence limit	1.003	0.923	0.902	0.996
Mean Depth	56.316	53.109	52.674	58.399
One group t	ns	ns	ns	ns
ANOV	p<.049	No individual contrasts significant		

	Person collecting samples			
PHI	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
Upper confidence limit	0.792	0.555	0.749	0.818
Mean bias	**-0.072**	**-0.105**	**0.121**	**0.084**
Lower confidence limit	-0.936	-0.766	-0.506	-0.649
Mean Phi	-0.241	-0.353	0.407	0.284
One group t	Not applicable			
ANOV	ns			

4.4 Variability of different personnel

4.4.1 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.

4.4.2 Results

Individual samplers had standard deviations that were between 77% and 119% of the total standard deviations for the sites (see Table 4.3). Despite this, ANOVs showed that none of the samplers was significantly more variable than any other.

This result is of interest as it mig'ht 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 RACs data.

4.5 Conclusions

4.5.1 Sources of variation due to personnel differences

This section analysed 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 4.3);

(ii) How much variation there is in each persons observations (variability - section 4.4).

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.

4.5.2 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

Mean IBG	All	Dave Walker	Jeremy Biggs	Mericia Whitfield	Richard Ashby-Crane
Upper confidence limit	1.025	1.011	1.098	1.172	1.520
Standard deviation	**0.855**	**0.659**	**0.805**	**0.836**	**1.135**
Total Standard Deviation					
Lower confidence limit	0.685	0.308	0.573	0.500	0.750

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. (The procedure used for collecting the RIVPACS environmental data is given in Section 2.3.2.)

5.1.2 RIVPACS predictions

Measured values for width, depth and substrate composition (measured as phi) were passed to NRA Thames Region staff to make RIVPACS predictions for TAXA, BMWP and ASPT values. Two types of taxa list were predicted:

(i) single-season taxa lists

(ii) combined-season taxa lists (from an autumn and a spring sample). 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.

A summary of the predicted biotic indices produced from each of these taxa lists is given in Table 5.2 (a and b).

An attempt was also made to produce a RIVPACS predicted taxa list for dual samples (combining two samples taken on the same day by the same person) (see below and Table 5.3(c)).

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. To obtain a predicted score for dual samples, therefore, an alternative approach to obtaining taxon frequencies, using the combined probabilities of individual taxon occurrences for a single season was tested. Since the probability of a taxon occurring in two samples is the product of its probabilities in one sample, this method seemed theoretically sound, and consistent with the underlying approach of RIVPACS. The method used is illustrated in Table 5.1 where a simple worked example, with three taxa, is given. These calculations were performed for all 48 dual samples. As this method was untried, the results of these calculations were compared with the results of the single- and combined-season calculations.

The comparison of dual-sample predictions with single- and combined-sample results showed some inconsistencies. For example, whereas observed TAXA, BMWP and ASPT for dual samples have values intermediate between single- and combined-sample values, the predicted results were consistently higher than both, and the EQIs consequently lower (see Table 5.2).

It was concluded that this method of estimating a predicted score for dual-sample data was not sufficiently consistent for its use to be justified, and the method was rejected. For the purposes of these analyses, combined-season predictions were therefore 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.

Table 5.1	Trial method for predicting RIVPACS values for dual-sample data

Taxon	Probability of occurrence in a single sample (p)	Expected probability of occurrence in any two samples = $1-(1-p)^2$	BMWP rating	Probabilistic score for taxon (single sample)	Probabilistic score for taxon (two samples)
Chironomidae	0.9	0.99	1	0.9	0.99
Dytiscidae	0.5	0.75	5	2.5	3.75
Leuctridae	0.05	0.0975	10	0.5	0.975
		Predicted TAXA		1.45	1.84
		Predicted BMWP		3.9	5.72
		Predicted ASPT		2.69	3.11

Table 5.2	Observed TAXA, BMWP and ASPT, predicted TAXA, BMWP and ASPT and TAXA.EQI, BMWP.EQI AND ASPT.EQI for three combinations of samples

(a) Single-season data

	TAXA	BMWP	ASPT	Pred. TAXA	Pred. BMWP	Pred. ASPT	TAXA EQI	BMWP EQI	ASPT EQI
Upper confidence limit	17.5	80.2	4.2	21.2	104	4.9			
Mean	**15.8**	**69.9**	**4.0**	**20.9**	**101**	**4.8**	**0.75**	**0.69**	**0.83**
Lower confidence limit	14.0	59.6	3.8	20.4	98	4.8			

(b) Combined-season data

	TAXA	BMWP	ASPT	Pred. TAXA	Pred. BMWP	Pred. ASPT	TAXA EQI	BMWP EQI	ASPT EQI
Upper confidence limit	22.3	107	4.4	26.4	134	5.1			
Mean	**19.3**	**89**	**4.2**	**25.8**	**130**	**5.0**	**0.75**	**0.68**	**0.83**
Lower confidence limit	16.3	71	3.9	25.3	127	5.0			

(c) Dual-sample data (Pred. TAXA, Pred. BMWP and Pred. ASPT calculated using method outlined in Table 5.1)

	TAXA	BMWP	ASPT	Pred. TAXA	Pred. BMWP	Pred. ASPT	TAXA EQI	BMWP EQI	ASPT EQI
Upper confidence limit	21.4	102	4.4	28.7	149	5.2			
Mean	**18.5**	**84**	**4.1**	**28.1**	**144**	**5.1**	**0.66**	**0.58**	**0.81**
Lower confidence limit	15.6	67	3.9	27.5	140	5.1			

5.2 Results: Variation of RIVPACS predictions.

5.2.1 Data analysed

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 Tables 5.3.

5.2.2 Variation in RIVPACS predictions

Comparing the mean variation of autumn, spring and combined samples, Table 5.3 shows that variation was greatest in RIVPACS predictions for autumn samples. Spring-sample predictions showed least variation. Variations in combined-sample 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 samples, respectively.

There was a consistent trend for predicted BMWP scores 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 (see summary in Table 5.3b).

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). At some sites there was no variability in RIVPACS predictions (see for example Bow Brook, autumn predicted TAXA).

Table 5.3a 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	0.495	0.5	0.071	1.6	0.424	8.5	8.485	9.7	0.806
River Thames	0.141	0.6	0.990	0.8	0.000	0.0	0.000	0.0	0.000	0.0	0.000
River Coln	0.212	1.0	1.838	1.8	0.071	1.5	0.141	3.0	1.336	8.4	0.239
The Cut	0.354	1.6	2.828	2.6	0.071	1.5	0.236	2.7	0.000	0.0	1.644
Lydiard Stream	0.071	0.3	0.354	0.4	0.000	0.0	0.071	3.2	0.393	0.9	0.302
Halfacre Brook	0.141	0.7	0.566	0.6	0.000	0.0	0.035	2.2	13.31	30.6	0.000
Roundmoor Ditch	0.071	0.4	0.495	0.6	0.000	0.0	0.141	2.8	2.121	3.0	0.000
Summerstown Ditch	0.071	0.4	0.000	0.0	0.000	0.0	0.212	10.6	12.374	28.3	0.000
Crendon Stream	0.000	0.0	0.283	0.3	0.000	0.0	0.104	9.8	0.940	6.1	0.088
Wheatley Ditch	0.495	2.4	3.960	4.1	0.071	1.5	0.024	2.2	1.886	6.5	2.079
Crawters Brook	0.071	0.3	0.566	0.6	0.071	1.5	0.468	18.2	0.668	2.1	0.928
Catherine Bourne	0.636	3.1	5.162	5.4	0.141	3.0	0.059	2.6	0.236	2.2	1.867
Upper confidence limit	0.303	1.46	2.402	2.43	0.068	1.44	0.246	8.45	6.275	14.05	1.111
Mean	0.189	0.90	1.461	1.46	0.041	0.87	0.160	5.48	3.480	8.14	0.663
Lower confidence limit	0.074	0.34	0.521	0.50	0.015	0.31	0.073	2.51	0.684	2.23	0.214
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	0.071	0.3	0.071	0.1	0.000	0.0	0.053	1.1	5.794	5.8	0.080
River Thames	0.071	0.3	0.566	0.4	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	0.436	6.6	0.550	1.2	0.811
The Cut	0.212	1.0	1.556	1.5	0.000	0.0	0.589	5.5	10.528	39.0	1.034
Lydiard Stream	0.212	1.0	2.404	2.3	0.071	1.4	0.153	7.7	1.791	5.4	1.618
Halfacre Brook	0.071	0.4	0.141	0.2	0.000	0.0	0.801	15.9	2.161	5.3	0.000
Roundmoor Ditch	0.141	0.7	0.707	0.8	0.000	0.0	0.082	5.0	0.354	1.3	0.212
Summerstown Ditch	0.000	0.0	0.071	0.1	0.000	0.0	0.088	4.7	0.589	2.4	0.000
Crendon Stream	0.000	0.0	1.344	1.3	0.071	1.3	0.094	8.7	0.471	3.4	0.186
Wheatley Ditch	0.071	0.3	0.141	0.1	0.000	0.0	0.082	6.8	6.285	16.9	0.504
Crawters Brook	0.071	0.3	0.424	0.4	0.000	0.0	0.283	11.5	3.457	10.1	0.795
Catherine Bourne	0.000	0.0	1.273	1.2	0.071	1.4	0.219	7.3	3.371	18.3	0.849
Upper confidence limit	0.120	0.57	1.155	1.10	0.036	0.70	0.380	9.14	4.751	15.37	0.800
Mean	0.077	0.36	0.725	0.69	0.018	0.35	0.240	6.74	2.946	9.07	0.507
Lower confidence limit	0.033	0.15	0.294	0.28	0.000	-0.01	0.100	4.34	1.141	2.77	0.214

Table 5.3b	**Variability of RIVPACS predictions and field data: summary of single-season data (spring and autumn)**										
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
Upper confidence limit	0.197	0.94	1.621	1.61	0.046	0.96	0.282	8.00	4.844	12.84	0.849
Mean	0.133	0.63	1.093	1.08	0.029	0.61	0.200	6.11	3.213	8.61	0.585
Lower confidence limit	0.068	0.32	0.565	0.54	0.013	0.27	0.118	4.23	1.582	4.38	0.321

Table 5.3c	**Variability of RIVPACS predictions and field data (measured as standard deviation and coefficient of variation): combined-seasons**										
Combined 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	0.058	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
Upper confidence limit	0.200	0.77	1.556	1.17	0.039	0.75	0.164	5.26	3.069	10.01	0.610
Mean	0.126	0.49	0.987	0.75	0.023	0.44	0.111	3.54	1.966	6.35	0.386
Lower confidence limit	0.051	0.20	0.419	0.33	0.007	0.13	0.058	1.82	0.863	2.69	0.162

5.2.3 Factors affecting variation in RIVPACS predictions

Stepwise regression was used to investigate which of the physical parameters (width, depth, substrate) had the greatest effect on 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 phi 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. Statistically significant results from these analyses are shown in Table 5.4.[1]

The results of the regression analysis indicated that the main factor correlated with variation in RIVPACS predictions was substrate composition (measured as phi). The amount of variation in predicted values explained by this single variable was high, ranging from 43.5% (see regression 9 in Table 5.3) to 65.9% (see regression 8, Table 5.3). 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 currently inherent within the RIVPACS method itself.

The results suggest that estimation of phi (and to a much lesser extent width) is the most critical factor in producing consistent estimates of predicted TAXA, BMWP and ASPT.

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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 5.4	Factors affecting variability in RIVPACS predictions[2]

(1)	Standard deviation of single-season predicted TAXA (SDSPT)		
STEP	Variable included	R^2 adjusted	F for inclusion
1	Standard deviation of phi (SD PHI)	50.3%	24.3
2	Coefficient of deviation of width (CVW)	60.3%	18.5
Regression equation	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 deviation of width (CVW)	69.9%	27.7
Regression equation	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 equation	SDSPA = .00368 + 0.0440 SD PHI		

(4)	Coefficient of deviation 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 deviation of width (CVW)	58.0%	16.9
Regression equation	CVSPT = 0.439 + 0.851 SD PHI - .048 CVW		

(5)	Coefficient of deviation 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 equation	CVSPB = 0.476 + 1.672 SD PHI - 1.874 SDW		

(6)	Coefficient of deviation 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 equation	CVSPA = 0.070 + 0.929 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.

Table 5.4	Factors affecting variability in RIVPACS predictions[3]

(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 equation	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 equation	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 equation	SDCPA = 0.0035 + 0.050 SD PHI		

(10)	Coefficient of deviation 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 equation	CVCPT = 0.126 + 0.930 SD PHI		

(11)	Coefficient of deviation 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 equation	CVCPB = 0.157 + 1.532 SD PHI		

(12)	Coefficient of deviation 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 equation	CVCPA = 0.0618 + 0.989 SD PHI		

3 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.

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 ANOV were used to estimate this ability to discriminate.

F values estimate 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. This analysis, therefore, assessed the ability of the three RIVPACS predicted indices to discriminate between sites. It also considered the discriminatory power of the width, depth and phi measurements. Further discussion of the significance of discrimination is given in the conclusions (Chapter 11).

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

ANOVs were first performed using all single-season predictions and physical parameters (two factor, 12 x 2 ANOVs), with site and season as factors. Table 5.5 gives the F values from these analyses. In most cases F values were highly significant at the $p=<0.05$ level. Where they were not they are indicated (ns).

Table 5.5 F values from 2 factor (site and season) ANOVs

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 <u>may</u> 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 5.5 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 5.5).

All parameters except phi 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 samples, to discriminate between sites, three separate ANOVs were run for autumn, spring and combined-season data (summarised in Table 5.6). 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.

Table 5.6 F values for ANOVs 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 Phi) explained most variation in RIVPACS predictions. There was very little variation in width or depth measurements.

Estimation of phi (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 variability of the EQIs of single samples;

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

(iv) to demonstrate the application of this system, using the NRA Thames Region biological monitoring data for 1992;

(v) 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 seven biotic indices considered in detail in this study (TAXA, BMWP, ASPT, TAXA.EQI, BMWP.EQI, ASPT.EQI and IBG). 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 seven 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, ASPT and IBG

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.

Single-season data

Single-season data showed significant correlations between the mean value of an index and its standard deviation for TAXA ($p<0.0026$), BMWP ($p<0.0002$) and IBG ($p<0.0288$). 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 but there was no significant correlation between IBG mean and standard deviation.

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, ASPT and IBG

Single-season data

Single-season values for all biotic indices (TAXA, BMWP, ASPT, IBG) 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, ASPT and IBG ($p<0.025$, $p<0.026$, and $p<0.013$ 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
IBG	0.0288	*0.0130*	ns	*0.0133*	Not applicable	
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 NRA 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). This suggests that it is some element of the richness of the fauna, rather than water or ecological quality, which may be affecting variability.

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:

$$\text{Log standard deviation TAXA.EQI} = 0.0152\ \text{TAXA} - 1.350 \qquad \text{(Equation 6.1)}$$

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:

$$\text{Log standard deviation TAXA.EQI} = 0.0114\ \text{TAXA} - 1.417 \qquad \text{(Equation 6.2)}$$

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:

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

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:

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

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:

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

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

TAXA.EQI. Single-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	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

	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	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.

	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	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	0 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	0 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*	*0 25.2*	*ns*	*45.4*	*0.010*
Log coefficient of variation	*30.4*	*0.037*	*27.2*	*0.047*	*40.7*	*0.016*	*0 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 Appendix 2). 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 Appendix 2. A small extract of the Appendix 2 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 Appendix 2)

Appendix 2 contains 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 2) 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 single-season samples in the 5M system.

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 Appendix 2, columns of bands which have zero probability (in practice less than 0.5%) have been omitted.

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 = $10^{(0.0152\ TAXA\ -1.350)}$	
(ii) Standard deviation BMWP.EQI = $10^{(0.00378\ BMWP\ -1.335)}$	
(iii) Standard deviation ASPT.EQI = 0.0483	

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

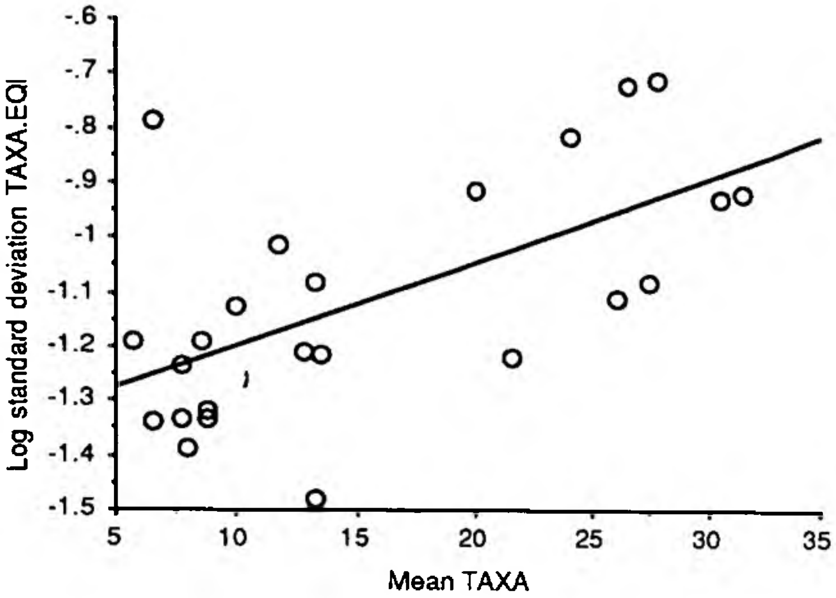


Figure 6.2 Regression of log standard deviation TAXA.EQI against mean TAXA: combined-season data

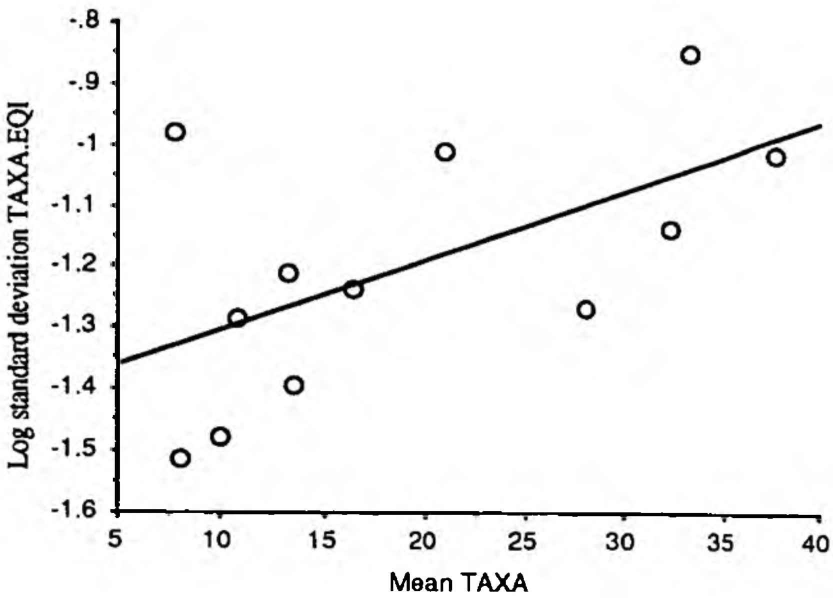


Figure 6.3 Regression of standard deviation BMWP.EQI (untransformed) against mean BMWP: single-season data

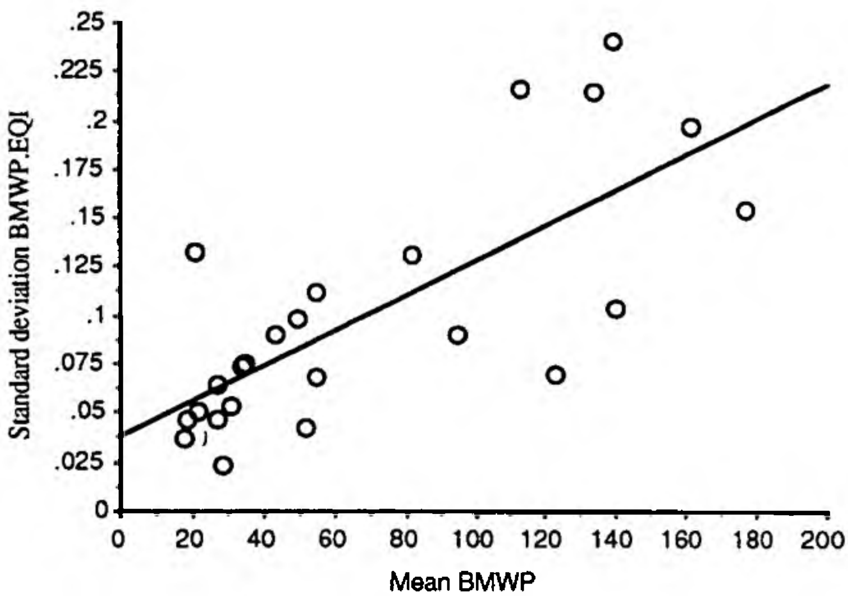


Figure 6.4 Regression of log standard deviation BMWP.EQI against mean BMWP: single-season data

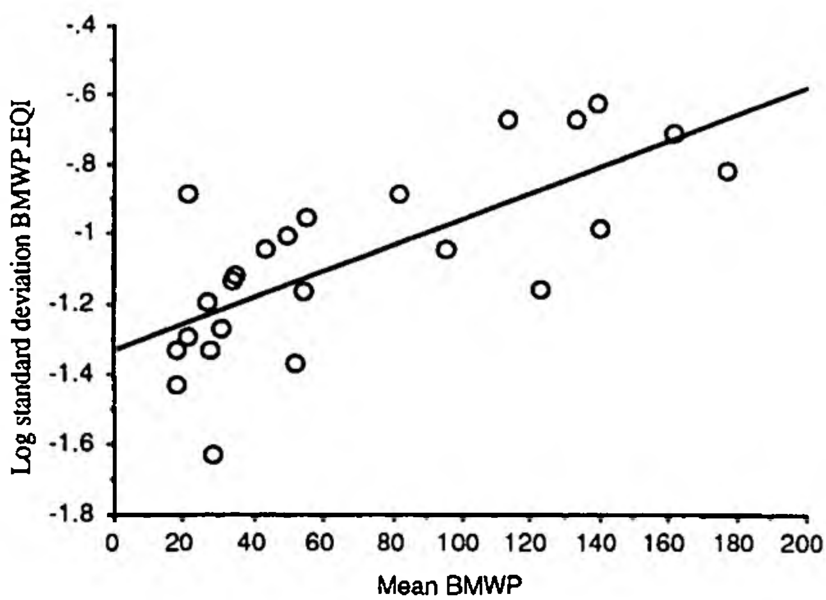


Figure 6.5 Regression of standard deviation BMWP.EQI (untransformed) against mean BMWP: combined-season data

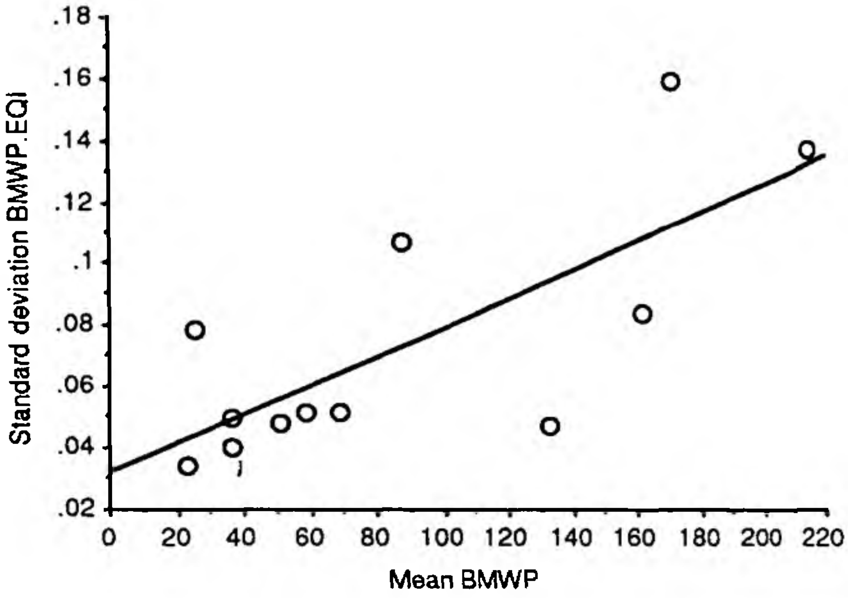
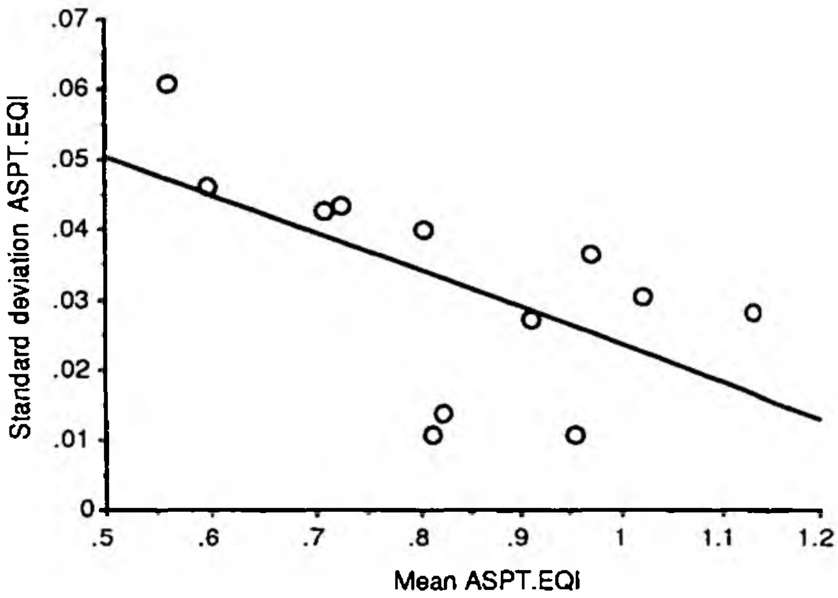


Figure 6.6 Regression of log coefficient of variation ASPT.EQI against mean ASPT.EQI: combined-season data



6.6 Estimated variability of NRA 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 NRA 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 band 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 NRA, 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 in total (four in autumn, four in spring) 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 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 seen, for example, in Table 5.2 (a) and (b) (Chapter 5) where average EQIs for the whole data-set in this study are shown for single- and combined-seasons. As can be seen there was little difference between single- and combined-season samples[1]. 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.

[1] Note that the dual samples EQIs shown in Table 5.2 are not the same as those for single and combined seasons because no RIVPACS based method exists for calculating the predicted scores of dual season samples.

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**						
		% of sites with 0,1,2,3 or 4 samples falling outside the mode band.					
Mode 5M band of site	No. of samples falling outside 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**				
		% of sites with 0,1, or 2 samples falling outside the mode band.			
Mode 5M band of site	No. of samples falling outside mode band	0	1	2	Total number of sites
A		100	0	0	4
B		50	50	0	4
C		100	0	0	2
D		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**				
	% of samples in combined-season 5M band.				
Single-sample 5M band	Band A	Band B	Band C	Band D	No. 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

This chapter develops a mathematical model 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

Problems associated with describing the variability of banding systems

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 NRA. Although the 5M system has now been 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 Chapter 6)	Standard deviation
TAXA.EQI	0.601	Log standard deviation TAXA.EQI = 0.0114 TAXA -1.417	0.0656
BMWP.EQI	0.430	Need to fill in from new equations	0.0649
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 is 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.[2] This is shown by the diagonal line of densely shaded cells. As one moves further away from the central diagonal, the occurrence of 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.

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2 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.

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

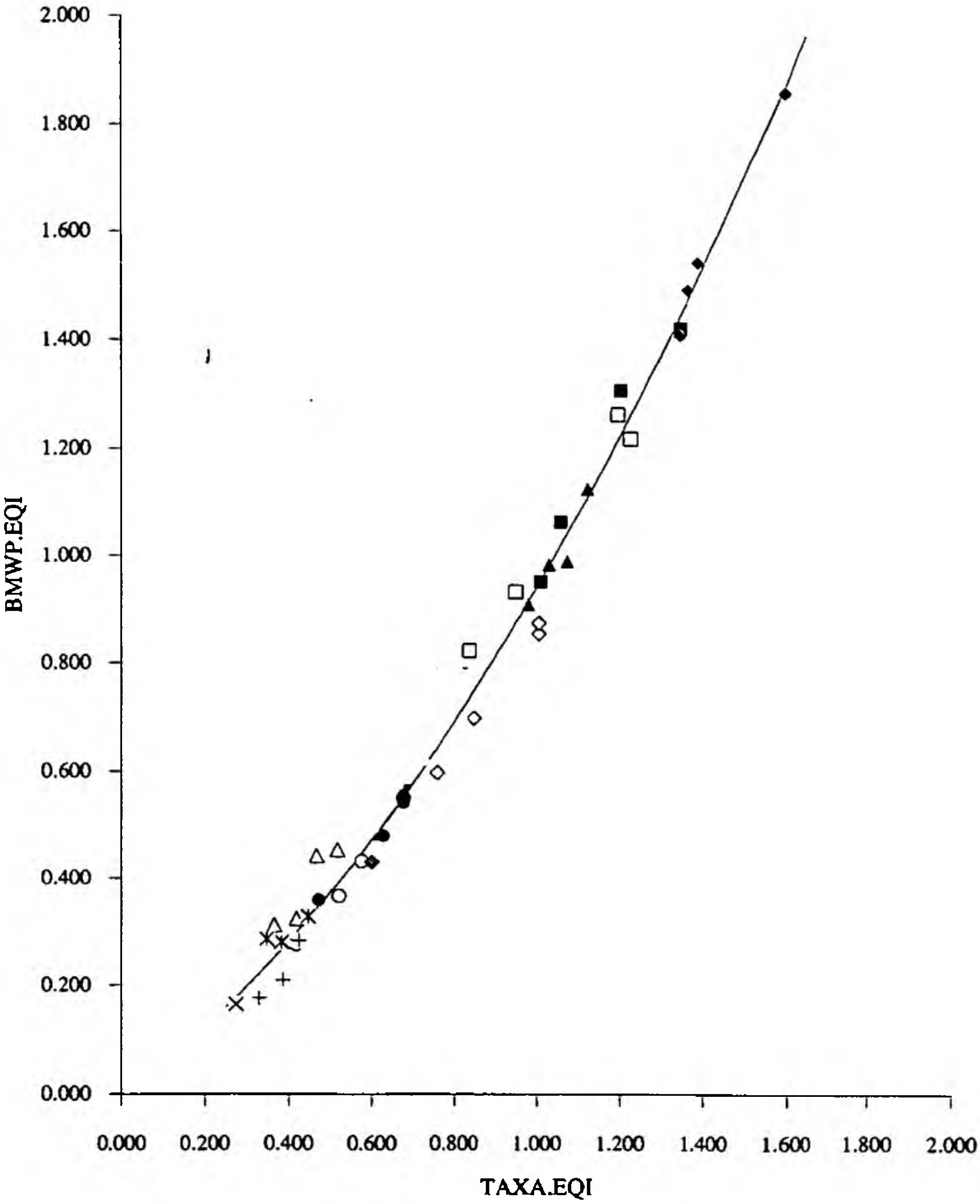


Figure 6.8. TAXA.EQI variation

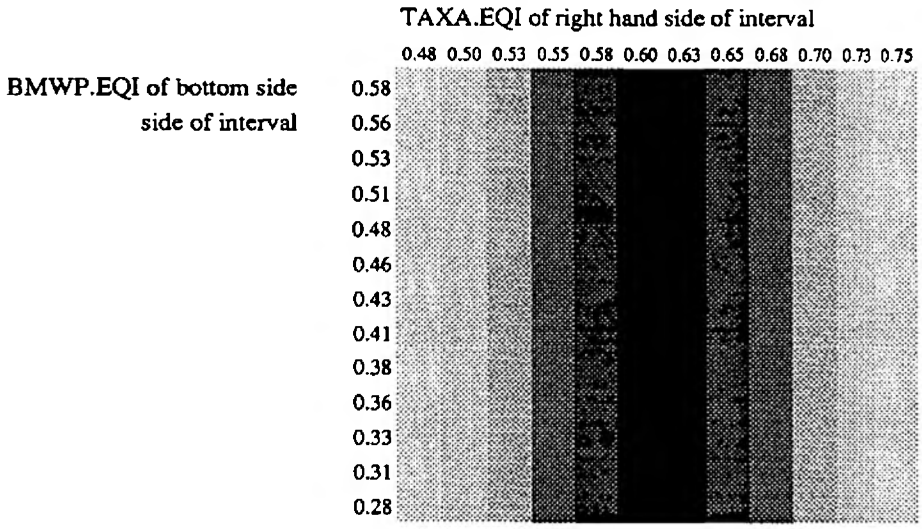


Figure 6.9 BMWP.EQI variation

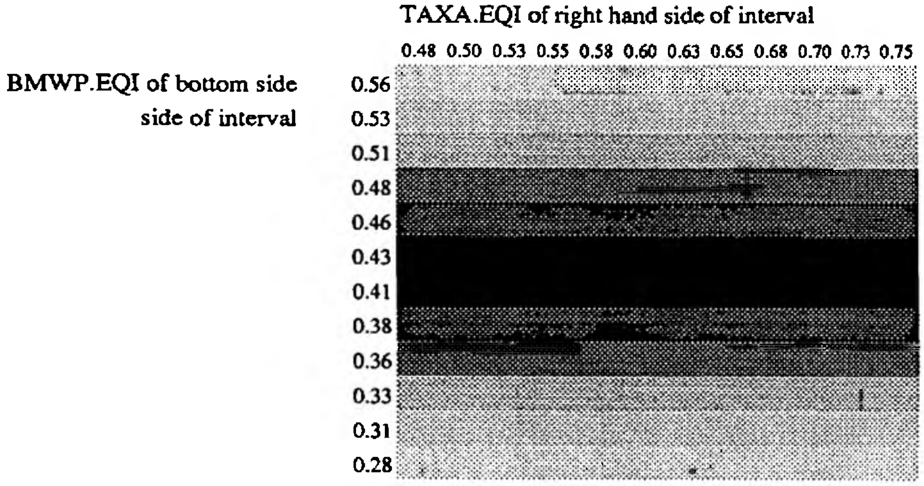


Figure 6.10 BMWP.EQI & TAXA.EQI variation

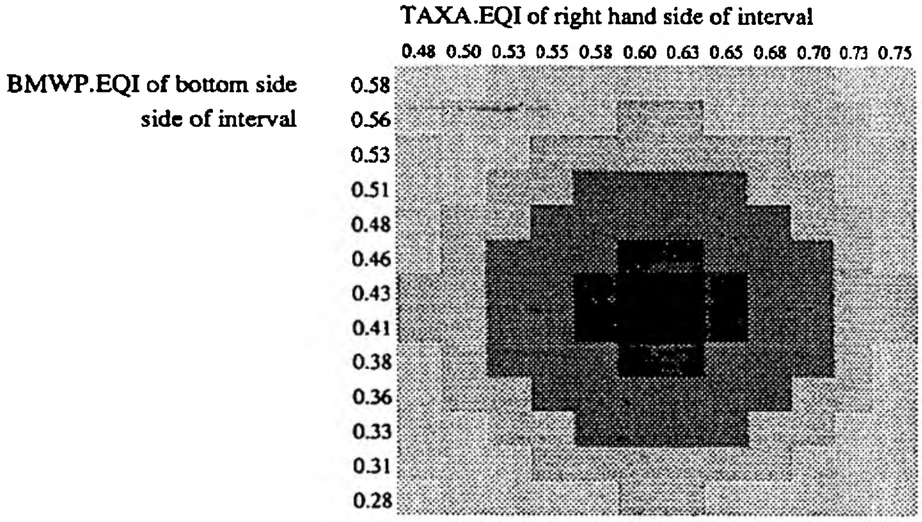


Figure 6.11 Diagrammatic representation of the inter-related variation of TAXA.EQI and BMWP.EQI

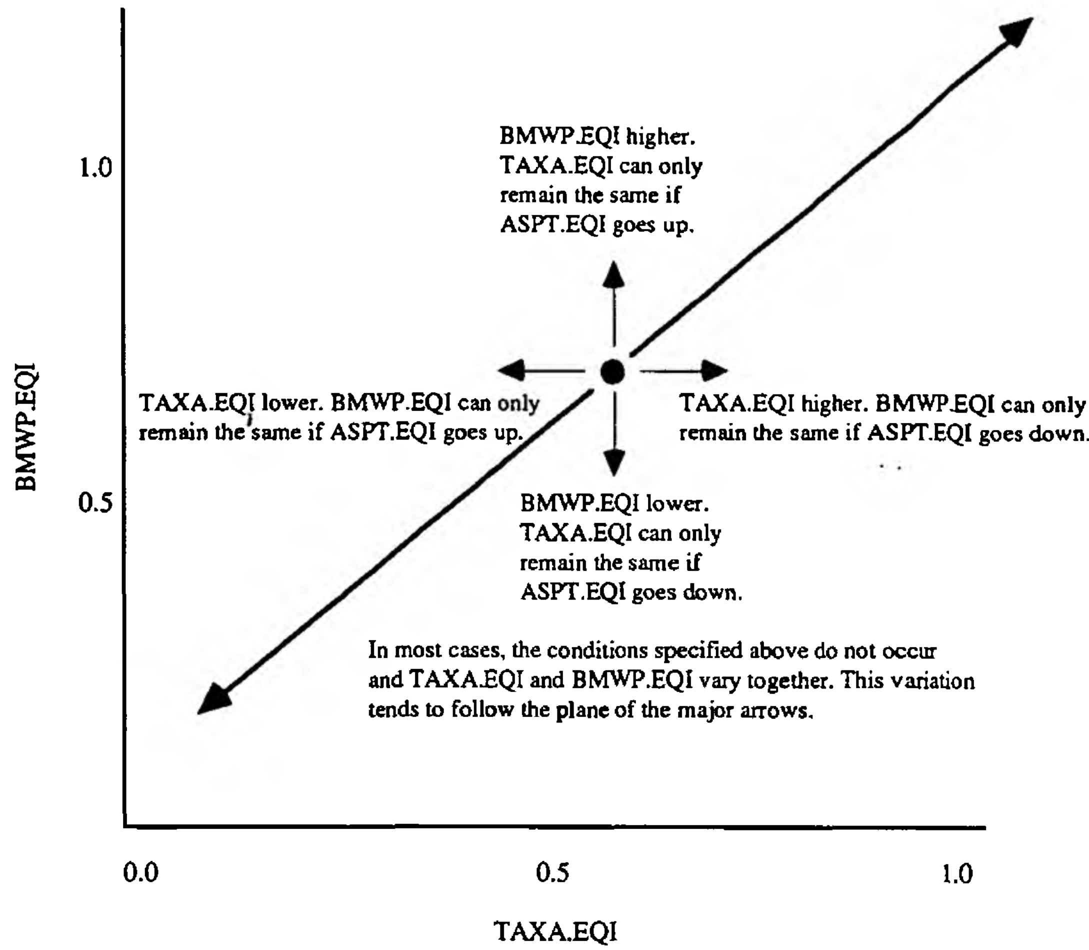


Figure 6.12. ASPT.EQI variation

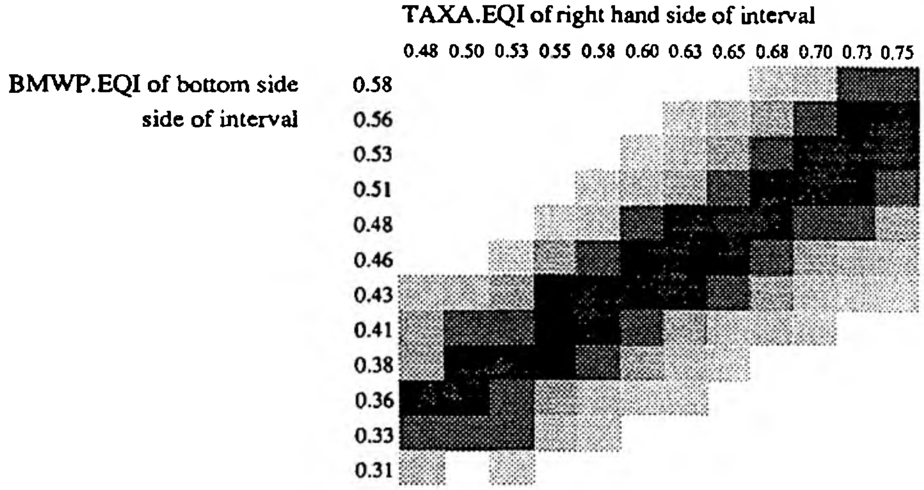


Figure 6.13 BMWP.EQI, TAXA.EQI & ASPT.EQI variation

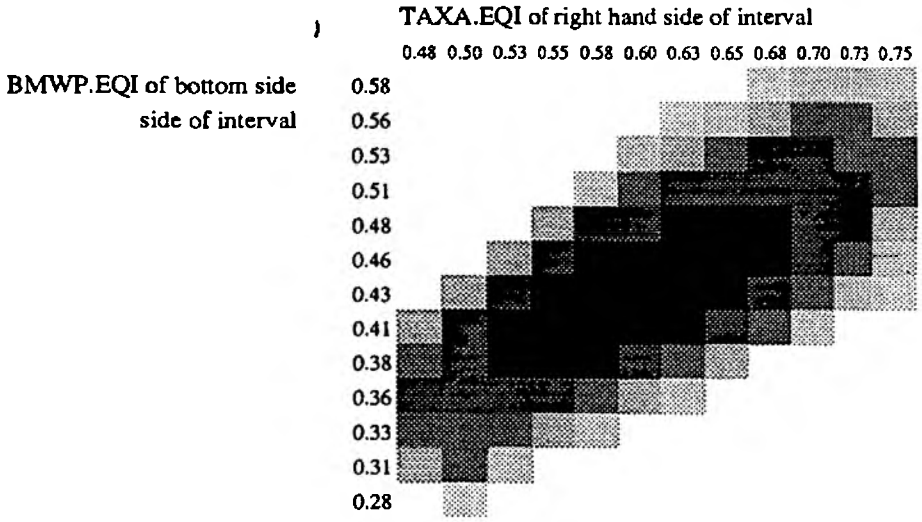
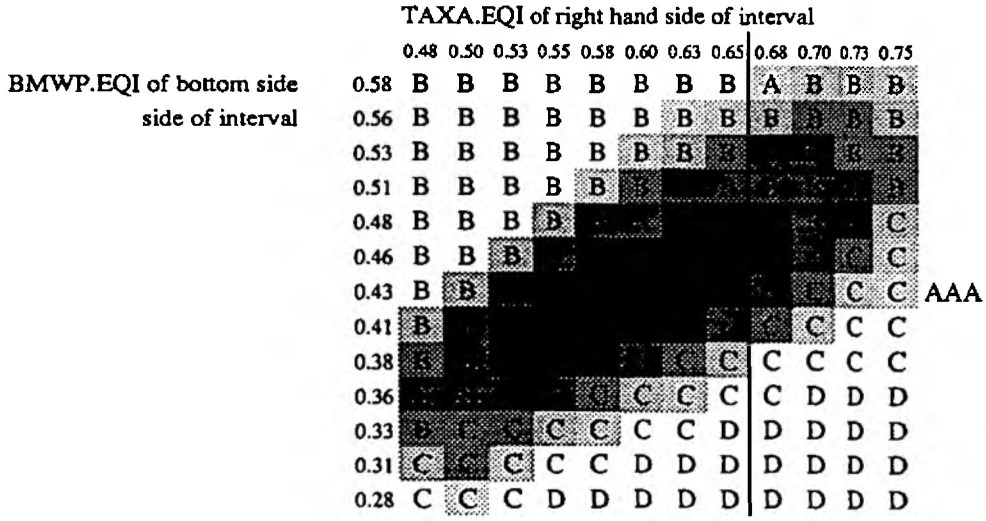


Figure 6.14 5M Band probabilities



Vertical line shows TAXA.EQI A/B boundary

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

7.1 Introduction

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

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 are higher 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. The analyses investigated variation in terms of TAXA, BMWP, ASPT, IBG, TAXA.EQI, BMWP.EQI, and ASPT.EQI. Analyses used both untransformed and log transformed data. ANOV tables for these analyses are presented in Appendix 3.

7.3 Results

Results of the ANOVs are shown in Tables 7.1, 7.2 and 7.3. 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. The results show that the F values for all three analyses (autumn, spring, both seasons), and all seven indices, gave values varying 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 suggest, 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 spring (see Column 3, Table 7.1). 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 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 a 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 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. 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 ANOVs (using non-nested data) it is also worth nothing that the current analysis (using nested ANOVs) generally showed the following F value (discrimination) relationship between the indices: BMWP, BMWP.EQI & TAXA > ASPT and ASPT.EQI.

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 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)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	F value	probability level	F value	probability level	F value	probability level	F value	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
IBG	0.7345	0.791293	0.1084	0.744791	6.5750	0.000061	179.4469	<0.0000001
TAXA.EOI	1.1877	0.299133	0.0365	0.850175	3.8408	0.002829	110.6343	<0.0000001
BMWP.EOI	1.1715	0.312937	0.0033	0.954714	2.9872	0.012088	116.9457	<0.0000001
ASPT.EOI	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 IBG	0.8785	0.626103	0.3829	0.541906	4.6425	0.000814	114.8510	<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 ANOV 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)	(2)	(3)	(4)
	F	p-level	F	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
IBG	1.03448	0.451071	58.75758	<0.0000001
TAXA.EOI	1.0075	0.4718	43.48418	<0.0000001
BMWP.EQI	0.87524	0.581072	50.86769	<0.0000001
ASPT.EOI	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 IBG	1.27006	0.29702	32.03460	0.000001
Log TAXA.EQI	1.21225	0.330261	31.15038	<0.0000001
Log BMWP.EQI	1.40611	0.229912	32.95475	<0.0000001
Log ASPT.EOI	1.40594	0.229986	32.75241	<0.0000001

The ANOV 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)	(2)	(3)	(4)
	F	p-level	F	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
IBG	0.4182	0.941129	182.3676	<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 IBG	0.3568	0.966813	191.2065	<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 ANOV 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

Chapter 7 described the relative importance of sampler and season on the variability of water quality values of a site. In the assessment, general trends were identified across all biotic indices. This chapter assesses in more detail the differences in the variability of different biotic 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 NRA. 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 which biotic indices were most 'useful' for measuring water quality

(ii) to identify which sampling strategy provided the most 'useful' data (e.g. single- season, combined-season or dual samples)

The usefulness 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. The first two of these are absolute and relative measures of variability. The third was used to describe the ability of an index or combination of samples to discriminate between sites of different water quality. 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 ANOV 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.

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

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 Tables 8.2 and 8.3, Column 3). These standard deviations were about 19% and 17% of the mean, respectively, measured as coefficients of variation (see Column 10 in Tables 8.2 and 8.3).

For ASPT and ASPT EQI standard deviations and coefficients of variation were virtually the same in autumn and spring (see Columns 4, 7, 11 and 14 in Tables 8.2 and 8.3). The mean standard deviation for ASPT in autumn was 0.22, compared to 0.24 in spring. These value represented 5.8% and 6.4% of the mean, respectively.

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. A 'useful' index would ideally 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. A 'useful' index would ideally 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 there 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. A 'useful' index would 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.

8.2.2 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 Table 8.2, Columns 2, 5, 9 and 12). BMWP and BMWP.EQI had average standard deviations of 11.18 and 0.111, respectively. These values represented about 19% of the mean (see Table 8.2, Columns 3, 6, 10 and 13). 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 ANOV showed that these differences were significant for BMWP and BMWP.EQI compared to TAXA and TAXA, which were again significantly different to ASPT an ASPT.EQI.

Spring

In spring there was no significant difference between IBG, TAXA and BMWP (and their respective EQIs), but these indices did have significantly higher variability than ASPT and ASPT EQI (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, TAXA EQI and IBG 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.

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

Key

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

Autumn single-season data	B	BE	TE	T	I	A	AE
Spring single-season data	B	BE	T	TE	I	AE	A

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.

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.

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

Standard deviation and coefficient of variation

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 Tables 8.4 and 8.5, columns 2 and 9).

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

Standard deviation and coefficient of variation

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, TAXA.EQI and IBG. 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 pairwise in the following pairs:

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

The three combinations of samples that were compared are shown in Table 8.6, 8.7 and 8.8. 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, except IBG, was lower using dual samples rather than single-samples (see Tables 8.6 and 8.7). 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 Tables 8.6 and 8.7. columns 5 and 12).

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 IBG and 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 Tables 8.6 and 8.8, columns 3 and 10). The standard deviation and CV of all the single samples is much higher than in spring or autumn alone (Tables 8.2, 8.3 compared to 8.6). 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
	IBG
Most variable	BMWP and BMWP.EQI

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

Figure 8.2 Comparison of sampling strategies

Key

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

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

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 no to the level of combined samples.

It should also be noted that during this survey, samplers were randomly assigned to sites in both seasons. Current practice in NRA (Thames Region) is 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 seven indices. The indices are arranged in order of increasing variability:

Least variable	ASPT and ASPT.EQI
	IBG or TAXA / TAXA.EQI
Most variable	BMWP and BMWP.EQI

IBG was usually intermediate between BMWP and TAXA. 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 Autumn single samples: standard deviations and coefficients of variation of indices

	Standard Deviation (SD)							Coefficient of variation (CV)						
SITE	IBG (1)	TAXA (2)	BMWP (3)	ASPT (4)	TAXA EQI (5)	BMWP EQI (6)	ASPT EQI (7)	IBG (8)	TAXA (9)	BMWP (10)	ASPT (11)	TAXA EQI (12)	BMWP EQI (13)	ASPT EQI (14)
Bow Brook	0.96	3.16	20.46	0.29	0.152	0.216	0.065	7.2	13.2	18.1	6.2	13.2	18.2	6.3
River Thames	1.26	4.80	27.02	0.17	0.189	0.214	0.034	9.5	18.1	20.3	3.4	18.0	20.3	3.4
River Coln	1.29	2.38	18.75	0.21	0.118	0.197	0.052	7.8	7.8	11.6	4.0	8.3	12.5	4.7
The Cut	0.96	2.45	12.69	0.15	0.122	0.132	0.039	10.4	12.2	15.5	3.6	13.5	17.4	4.6
Lydiard Stream	0.50	1.29	8.76	0.17	0.060	0.090	0.038	5.4	6.0	9.2	3.9	5.8	9.0	3.9
Halfacre Brook	2.22	1.29	6.95	0.34	0.065	0.075	0.072	38.6	15.2	20.2	8.3	14.7	19.7	8.3
Roundmoor Ditch	1.00	1.89	8.27	0.14	0.098	0.090	0.030	15.4	16.1	19.0	3.8	15.9	18.7	3.8
Summerstown Ditch	0.82	1.41	6.63	0.20	0.075	0.074	0.044	16.3	14.1	19.5	6.1	14.4	19.5	6.1
Crendon Stream	1.50	3.00	12.00	0.27	0.164	0.132	0.056	40.0	46.2	57.1	8.7	46.2	56.9	8.7
Wheatley Ditch	0.50	0.82	1.73	0.19	0.041	0.023	0.045	13.3	10.2	6.1	5.3	10.6	8.0	6.0
Crawters Brook	0.00	0.96	5.20	0.32	0.047	0.050	0.064	0.0	12.4	24.2	11.6	12.7	23.8	11.2
Catherine Bourne	0.50	0.96	5.74	0.17	0.033	0.042	0.026	8.0	7.2	11.1	4.3	5.1	7.8	3.2
Upper confidence limit	1.33	2.79	15.89	0.26	0.130	0.154	0.056	22.3	21.6	27.6	7.4	21.6	27.6	7.4
Mean	0.96	2.03	11.18	0.22	0.097	0.111	0.047	14.3	14.9	19.3	5.8	14.8	19.3	5.9
Lower confidence limit	0.59	1.28	6.47	0.18	0.064	0.069	0.038	6.3	8.2	11.0	4.1	8.1	11.1	4.3

Table 8.3 Spring single samples: standard deviations and coefficients of variation of indices

	Standard Deviation (SD)							Coefficient of variation (CV)						
SITE	IBG (1)	TAXA (2)	BMWP (3)	ASPT (4)	TAXA EQI (5)	BMWP EQI (6)	ASPT EQI (7)	IBG (8)	TAXA (9)	BMWP (10)	ASPT (11)	TAXA EQI (12)	BMWP EQI (13)	ASPT EQI (14)
Bow Brook	0.96	1.73	10.61	0.19	0.082	0.104	0.039	6.7	6.3	7.6	3.8	6.3	7.6	3.8
River Thames	2.16	4.86	31.27	0.24	0.195	0.240	0.046	16.6	17.5	22.5	4.8	17.7	22.8	4.8
River Coln	1.29	2.52	15.85	0.18	0.120	0.154	0.036	7.8	8.0	9.0	3.2	8.0	9.0	3.2
The Cut	0.96	1.71	10.21	0.31	0.083	0.099	0.061	14.2	12.9	20.7	8.3	13.3	21.3	8.3
Lydiard Stream	0.50	1.63	7.59	0.08	0.078	0.070	0.008	4.7	6.3	6.2	1.6	6.3	6.0	0.8
Halfacre Brook	0.50	1.26	10.10	0.44	0.062	0.112	0.097	8.7	9.9	18.4	10.2	9.7	18.4	10.2
Roundmoor Ditch	0.96	0.96	4.97	0.19	0.047	0.054	0.042	20.2	10.9	16.0	5.3	10.8	15.7	5.3
Summerstown Ditch	0.58	0.96	4.35	0.17	0.048	0.047	0.038	12.8	10.9	16.0	5.6	10.9	15.9	5.6
Crendon Stream	0.58	1.26	4.65	0.18	0.064	0.046	0.034	16.5	21.9	25.5	5.7	21.9	26.0	5.7
Wheatley Ditch	0.50	1.26	6.85	0.48	0.059	0.064	0.095	15.4	16.2	25.6	14.0	16.1	25.6	14.0
Crawters Brook	0.50	1.00	4.03	0.27	0.046	0.037	0.054	13.3	15.4	22.7	10.0	15.3	22.7	10.0
Catherine Bourne	0.58	1.29	7.14	0.19	0.061	0.069	0.044	5.5	9.6	13.1	4.7	9.6	13.6	5.5
Upper confidence limit	1.15	2.39	14.62	0.32	0.11	0.13	0.07	15.10	15.19	21.26	8.67	15.20	21.46	8.72
Mean	0.84	1.70	9.80	0.24	0.08	0.09	0.05	11.87	12.15	16.93	6.43	12.14	17.05	6.44
Lower confidence limit	0.52	1.01	4.99	0.17	0.05	0.05	0.03	8.63	9.11	12.60	4.20	9.09	12.64	4.15

Table 8.4 Dual autumn samples: standard deviations and coefficients of variation of indices

	Standard deviation						Coefficient of variation (CV)					
SITE	TAXA (2)	BMWP (3)	ASPT (4)	TAXA EQI (5)	BMWP EQI (6)	ASPT EQI (7)	TAXA (9)	BMWP (10)	ASPT (11)	TAXA EQI (12)	BMWP EQI (13)	ASPT EQI (14)
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
Upper confidence limit	1.92	10.90	0.28	0.08	0.09	0.06	15.03	21.84	8.06	14.97	21.78	8.06
Mean	1.47	8.07	0.20	0.06	0.06	0.04	10.09	14.54	5.33	10.05	14.62	5.57
Lower confidence limit	1.03	5.24	0.12	0.04	0.04	0.03	5.15	7.25	2.61	5.14	7.46	3.08

Table 8.5 Dual spring samples: standard deviations and coefficients of variation of indices

	Standard deviation						Coefficient of variation (CV)					
SITE	TAXA (2)	BMWP (3)	ASPT (4)	TAXA EQI (5)	BMWP EQI (6)	ASPT EQI (7)	TAXA (9)	BMWP (10)	ASPT (11)	TAXA EQI (12)	BMWP EQI (13)	ASPT EQI (14)
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
Upper confidence limit	2.06	13.59	0.21	0.08	0.10	0.04	10.80	13.90	5.15	11.30	14.51	4.98
Mean	1.36	8.19	0.16	0.05	0.06	0.03	8.01	9.93	3.75	8.46	10.30	3.57
Lower confidence limit	0.65	2.79	0.10	0.03	0.03	0.02	5.21	5.96	2.34	5.63	6.09	2.17

Table 8.6 Single-sample (spring or autumn): standard deviations and coefficients of variation of indices

	Standard Deviation (SD)							Coefficient of variation (CV)						
SITE	IBG (1)	TAXA (2)	BMWP (3)	ASPT (4)	TAXA EQI (5)	BMWP EQI (6)	ASPT EQI (7)	IBG (8)	TAXA (9)	BMWP (10)	ASPT (11)	TAXA EQI (12)	BMWP EQI (13)	ASPT EQI (14)
Bow Brook	0.58	1.89	11.63	0.174	0.084	0.072	0.032	4.0	6.8	8.4	3.5	6.3	5.2	3.0
River Thames	1.73	5.85	34.86	0.227	0.231	0.259	0.042	12.8	21.1	25.0	4.5	21.0	24.0	4.3
River Coln	1.41	2.36	20.84	0.345	0.127	0.216	0.067	8.3	7.3	11.8	6.3	8.4	12.5	5.9
The Cut	2.06	5.12	26.21	0.410	0.222	0.242	0.098	26.6	31.5	41.4	10.8	29.8	41.1	12.7
Lydiard Stream	0.96	3.30	20.14	0.224	0.138	0.139	0.015	9.3	13.6	18.2	4.9	11.8	12.6	1.6
Halfacre Brook	2.06	2.63	14.84	0.443	0.122	0.161	0.112	33.0	24.5	31.7	10.3	22.3	31.2	12.0
Roundmoor Ditch	1.41	2.22	9.25	0.167	0.127	0.104	0.038	23.6	20.6	23.3	4.5	23.2	23.6	4.7
Summerstown Ditch	0.96	1.50	7.39	0.283	0.089	0.086	0.054	20.2	16.2	24.6	8.8	18.7	26.1	7.8
Crendon Stream	1.26	2.63	10.37	0.224	0.149	0.120	0.050	29.6	36.3	42.8	6.8	38.6	47.2	7.8
Wheatley Ditch	0.82	1.26	6.08	0.308	0.067	0.072	0.077	20.4	16.2	23.6	9.4	18.0	28.1	11.5
Crawters Brook	0.00	0.50	1.41	0.201	0.030	0.015	0.029	0.0	6.9	7.1	7.3	8.8	7.8	5.1
Catherine Bourne	2.38	0.96	5.80	0.213	0.035	0.032	0.016	28.0	7.2	11.1	5.4	5.4	6.2	2.0
Upper confidence limit	1.73	3.54	20.25	0.326	0.159	0.177	0.072	24.6	23.6	30.0	8.4	24.1	30.8	9.0
Mean	1.30	2.52	14.07	0.268	0.118	0.126	0.053	18.0	17.4	22.4	6.9	17.7	22.1	6.5
Lower confidence limit	0.88	1.50	7.88	0.211	0.078	0.076	0.033	11.3	11.1	14.8	5.3	11.3	13.4	4.1

Table 8.7 Dual-sample data: standard deviations and coefficients of variation of indices

	Standard deviation						Coefficient of variation (CV)					
SITE	TAXA (1)	BMWP (2)	ASPT (3)	TAXA EQI (4)	BMWP EQI (5)	ASPT EQI (6)	TAXA (7)	BMWP (9)	ASPT (10)	TAXA EQI (11)	BMWP EQI (12)	ASPT EQI (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
Upper confidence limit	2.87	16.96	0.247	0.111	0.131	0.049	18.9	23.8	6.5	19.0	23.7	6.4
Mean	2.21	12.66	0.210	0.086	0.098	0.042	13.9	18.1	5.3	14.0	18.2	5.2
Lower confidence limit	1.55	8.35	0.173	0.061	0.066	0.034	8.9	12.3	4.0	9.1	12.7	4.1

Table 8.8 Combined-season data: standard deviations and coefficients of variation of indices

	Standard Deviation (SD)							Coefficient of variation (CV)						
SITE	IBG (1)	TAXA (2)	BMWP (3)	ASPT (4)	TAXA EQI (5)	BMWP EQI (6)	ASPT EQI (7)	IBG (8)	TAXA (9)	BMWP (10)	ASPT (11)	TAXA EQI (12)	BMWP EQI (13)	ASPT EQI (14)
Bow Brook	1.41	1.89	10.72	0.15	0.073	0.084	0.031	8.8	5.9	6.6	3.0	5.9	6.6	3.0
River Thames	1.29	4.43	26.47	0.19	0.142	0.159	0.037	8.3	13.3	15.5	3.8	13.2	15.3	3.8
River Coln	1.41	2.50	17.63	0.14	0.097	0.137	0.028	7.4	6.6	8.2	2.5	6.7	8.2	2.5
The Cut	0.82	2.45	13.30	0.17	0.097	0.106	0.040	8.2	11.7	15.2	4.1	12.5	16.8	5.0
Lydiard Stream	0.50	1.41	6.13	0.07	0.054	0.047	0.011	4.1	5.1	4.6	1.4	5.0	4.5	1.1
Halfacre Brook	2.06	1.00	6.00	0.13	0.040	0.051	0.027	25.0	7.4	10.2	3.0	7.2	10.0	3.0
Roundmoor Ditch	0.82	1.50	5.56	0.06	0.062	0.048	0.014	11.7	11.3	10.8	1.6	11.1	10.7	1.6
Summerstown Ditch	0.58	1.26	5.91	0.20	0.052	0.050	0.043	10.5	11.7	16.1	6.0	11.6	15.7	6.0
Crendon Stream	1.26	2.50	10.21	0.26	0.105	0.079	0.046	29.6	32.3	40.4	8.1	32.2	40.2	7.8
Wheatley Ditch	0.96	0.82	4.92	0.19	0.033	0.040	0.044	20.2	8.2	13.4	5.3	8.7	14.3	6.0
Crawters Brook	0.50	0.82	4.69	0.31	0.031	0.034	0.061	11.8	10.2	20.4	10.9	10.2	20.1	10.9
Catherine Bourne	0.50	1.29	6.08	0.04	0:058	0.051	0.011	4.4	7.8	8.8	1.1	9.1	10.0	1.3
Upper confidence limit	1.32	2.48	13.99	0.21	0.09	0.10	0.04	17.65	15.53	20.18	6.09	15.64	20.28	6.20
Mean	1.01	1.82	9.80	0.16	0.07	0.07	0.03	12.50	10.95	14.20	4.23	11.10	14.37	4.34
Lower confidence limit	0.70	1.17	5.62	0.11	0.05	0.05	0.02	7.35	6.37	8.22	2.37	6.57	8.46	2.47

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 ANOVs. In order to make the ANOVs comparable (i.e. the same number of samples in each data set), ANOVs 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 ANOVs which do not use nested values, this variability remains.

To investigate the robustness of the non-nested ANOV results in this chapter, the results are compared with similar analyses in Chapter 7 which were carried out using nested analysis of samples.

Jacknife techniques

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

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

8.6.2 Results

Jacknife values for F are given in Tables 8.10 to 8.16 together with their means and upper and lower 5% confidence limits. Results of the Wilcoxon test are cited in the text and results from the Scheffé test in Figures 8.3 and 8.4.

Single-season comparisons: differences between spring and autumn

The analysis showed that, in general, spring surveys showed more discrimination than autumn surveys (see Tables 8.10 and 8.11). This was indicated by the generally higher F values in spring, compared to autumn (compare highlighted rows in Tables 8.10 and 8.11). For TAXA, TAXA.EQI, BMWP, BMWP.EQI and IBG, F values in spring were roughly double those in autumn. For example, the mean F value for BMWP, estimated using jacknife techniques, was 52.1 in autumn and 90.3 in spring (see Tables 8.10 and 8.11, column 3).

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 Tables 8.13 and 8.14). Mean F values from jacknife 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 Tables 8.12, 8.13 and 8.14).

For example, for TAXA (untransformed data) mean F values estimated by jacknife analysis were 33.9, 44.6 and 110 for single, dual- and combined-season data, respectively (see column 2 in Tables 8.12, 8.13 and 8.14).

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

In addition the Jacknife Fs from combined-seasons data were higher than Jacknife 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 Jacknife 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.

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 (see Table 8.9).

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 8.9 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 Sheffé test on 8 out of 14 occasions. Conversely, ASPT was placed in the least discriminatory position 7 out of 14 times.

Figure 8.3 The ability of biotic indices to discriminate between sites: summary of Sheffé test results (see Table 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 <u>combined</u> 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.

Comparison of the biotic indices results suggests 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.

Table 8.10 Jacknife values of F for autumn season data

	Autumn season samples (untransformed)							Autumn season samples (log transformed)						
	IBG (1)	TAXA (2)	BMWP (3)	ASPT (4)	TAXA EQI (5)	BMWP EQI (6)	ASPT EQI (7)	IBG (8)	TAXA (9)	BMWP (10)	ASPT (11)	TAXA EQI (12)	BMWP EQI (13)	ASPT EQI (14)
Bow Brook	55.2	55.5	59.4	47.1	45.5	53.6	44.2	32.7	41.1	45.1	40.1	32.9	38.4	39.5
River Thames	58.0	67.1	65.1	38.3	54.2	57.3	40.7	33.1	41.6	43.4	34.5	36.3	40.6	37.9
River Coln	41.9	39.3	39	34.2	31.5	34.2	34.5	28.3	34.9	37.3	31.8	27.8	32.1	33.4
The Cut	64.1	55.8	56	46	47.5	51.4	45.7	37.8	43.5	47.8	41.1	36.2	42.8	42.9
Lydiard Stream	61.1	50.9	52.5	45.3	41.6	46.6	43.2	36.9	41	44.9	39.9	32.8	38.4	39.9
Halfacre Brook	88.6	49.5	50.7	54.4	41.9	46.5	53.2	55.6	43.3	49.1	47.3	35.5	43.1	48.1
Roundmoor Ditch	64.2	53.9	52.5	45.2	45.4	48.2	44.1	40.8	47.5	50.7	40.9	38.9	44.3	41.9
Summerstown Ditch	60.3	51.2	50.6	44.6	43.8	46.3	43.5	39.0	45.1	49.2	41	37.3	43.4	42.3
Crendon Stream	64.5	53.2	50.5	44.1	47.6	46.5	40.6	47.4	63.6	65	40.9	53.4	57	40
Wheatley Ditch	55.5	48.2	48.6	45.8	40	43.9	45.1	34.2	40.8	44	41.6	32.6	38.2	43.2
Crawters Brook	55.2	48.1	47.8	38.8	39.5	42.5	36.6	33.4	40.8	43.6	35.7	32.1	36.4	35.6
Catherine Bourne	60.6	52.3	52.4	46.5	43.8	47.2	44.1	38.0	44.2	48.3	41.8	35.8	41.7	41.8
F value	60.1							37.3						
Upper confidence limit	66.8	56.2	56.1	47.5	47	50.7	46	42.3	48.3	51.6	42.3	39.9	45.2	43
Mean jacknife F	60.8	52.1	52.1	44.2	43.5	47	43	38.1	44	47.4	39.7	36	41.4	40.5
Lower confidence limit	54.7	48	48	40.9	40	43.4	40	34.0	39.6	43.2	37.2	32	37.5	38.1

Table 8.11 Jacknife values of F for spring season data

	Spring season samples (untransformed)							Spring season samples (log transformed)						
	IBG	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI	IBG	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI
Bow Brook	86.2	84	79.6	43	84.2	86.6	42.6	76.3	72.9	66	34.8	65.4	60.2	35.5
River Thames	146.9	154	166	45.5	147	156	47.2	89.8	82.7	73.4	36.1	80.3	72.1	38.6
River Coln	76.4	78	66.6	34.5	76.6	69.4	34.4	71.0	69	60.8	29.9	61.1	54.9	30.7
The Cut	103.1	97.7	91.1	52.7	102	102	51.3	97.2	90.5	84.1	43.2	82.9	78	43.6
Lydiard Stream	94.5	86.8	82.8	45.2	88	90.6	44.8	83.6	74.7	68.3	36.7	67.2	62.7	37.5
Halfacre Brook	95.2	94.6	91.7	60.7	98.2	105	60.3	90.6	87.3	83.4	46.8	79.4	76.6	45.5
Roundmoor Ditch	98.7	89.1	83.9	48.1	92	94.1	48.8	104.7	83.7	76.7	39.8	76.6	71.8	41.3
Summerstown Ditch	92.6	89.1	82.8	44.3	92.3	92.4	45.9	90.7	83.7	75.1	36.7	76.9	70.5	39.4
Crendon Stream	88.9	85.1	80.5	45	88.9	88.7	41.6	88.5	91	76.7	37.3	84.5	70.6	35.3
Wheatley Ditch	87.2	88.8	84	62	91	92.4	59	82.0	88.7	87.1	54	79.6	79	54
Crawters Brook	89.2	85.5	86.1	41.3	86.9	87.4	39.5	87.5	82.4	73.3	33.9	72.9	65.2	33.4
Catherine Bourne	95.8	95.2	88.9	49.6	98	98.5	49.4	84.5	86.8	78.9	40.4	79.1	73.1	41.6
F	94.6							86.8						
Upper confidence limit	106.0	107	106	52.6	106	110	51.8	92.2	87.3	80.2	43.2	80.2	74.3	43.6
Mean jacknife F	96.2	94	90.3	47.7	95.3	96.9	47.1	87.2	82.8	75.3	39.1	75.5	69.6	39.7
Lower confidence limit	86.4	81.5	74.7	42.7	84.3	83.8	42.3	82.2	78.3	70.4	35.1	70.8	64.8	35.8

Table 8.12 Jacknife values of F for dual autumn season data

Site	Dual-sample autumn data (untransformed) TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI	Dual-sample autumn data (log transformed) TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI
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
F	73.2	77.7	21.1	56.8	61.0	21.1	36.4	29.9	15.3	31.8	27.5	16.3
Upper confidence	79.1	83.2	22.7	61.9	65.6	22.6	44.2	34.7	16.6	38.8	31.6	17.4
Mean F value	73.6	78.0	21.2	57.2	61.1	21.2	37.8	30.7	15.5	33.1	28.1	16.4
Lower confidence	68.1	72.7	19.7	52.4	56.6	19.7	31.4	26.7	14.4	27.4	24.6	15.4

Table 8.13 Jacknife values of F for dual spring season data

Site	Dual-sample spring data (untransformed) TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI	Dual-sample spring data (log transformed) TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI
	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI
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
F	87.8	70.5	48.0	84.4	74.8	49.9	94.6	100.6	47.3	77.1	86.1	52.5
Upper confidence	104.3	84.2	53.4	96.4	86.1	56.6	102.7	112.7	54.0	84.7	97.1	61.1
Mean F value	90.6	72.9	48.5	85.9	76.3	50.6	95.2	102.0	48.1	77.7	87.4	53.6
Lower confidence	76.9	61.6	43.6	75.3	66.6	44.7	87.8	91.3	42.2	70.8	77.6	46.2

Table 8.14 Jacknife estimates of F-values: single-sample data (spring or autumn)

Site	Single sample spring or autumn (untransformed)							Single sample spring or autumn (log transformed)						
Site	IBG	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI	IBG	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI
Bow Brook	31.37	34.6	37.2	32.5	32.0	38.9	30.1	20.9	28.6	30.9	29.1	23.9	27.2	27.8
River Thames	37.5	49.7	55.3	33.4	47.3	59.8	34.0	22.4	31.7	33.5	29.6	28.9	32.2	30.6
River Coln	26.1	29.3	30.4	29.3	27.1	33.7	27.8	19.0	26.2	28.1	26.5	21.9	25.0	26.0
The Cut	49.4	52.8	52.4	43.8	49.5	60.4	44.3	29.1	42.5	46.9	39.8	35.2	42.0	41.4
Lydiard Stream	38.7	40.8	45.3	37.0	37.8	47.6	33.7	24.6	31.3	34.4	32.6	26.1	30.1	30.6
Halfacre Brook	44.5	40.9	43.9	45.3	39.8	51.6	47.6	31.3	37.5	41.9	39.5	31.5	37.8	40.2
Roundmoor Ditch	40.0	40.0	41.5	36.8	40.1	47.8	36.0	28.5	36.1	38.2	33.5	32.0	34.9	33.1
Summerstown Ditch	36.8	38.1	40.1	36.0	37.5	45.9	34.9	25.2	33.4	36.4	33.7	29.4	33.8	33.0
Crendon Stream	37.0	38.4	40.0	35.5	38.8	46.0	33.0	26.2	37.5	39.3	32.8	33.5	36.4	30.9
Wheatley Ditch	35.2	36.8	39.4	37.3	35.3	44.3	37.3	23.7	31.7	35.5	35.6	27.0	32.9	37.2
Crawters Brook	34.3	35.9	38.2	29.6	34.2	42.4	27.3	21.9	29.3	30.1	25.6	24.4	26.2	23.5
Catherine Bourne	43.8	39.5	41.9	38.1	37.9	46.6	35.1	29.7	33.6	36.6	34.4	28.6	32.7	32.3
F	37.6	39.2	41.7	36.0	37.7	46.7	34.6	25.0	33.0	35.6	32.5	28.3	32.3	31.8
Upper confidence limit	41.9	43.7	46.4	39.3	42.0	51.9	38.9	27.4	36.2	39.3	35.6	31.1	35.8	35.6
Average jackknife F	38.0	39.7	42.1	36.2	38.1	47.1	35.1	25.2	33.3	36.0	32.7	28.5	32.6	32.2
Lower confidence limit	34.5	35.7	37.9	33.1	34.2	42.2	31.3	23.0	30.4	32.7	29.9	25.9	29.4	28.8

Table 8.15 Jacknife estimates of F-values: dual-sample data (spring or autumn)

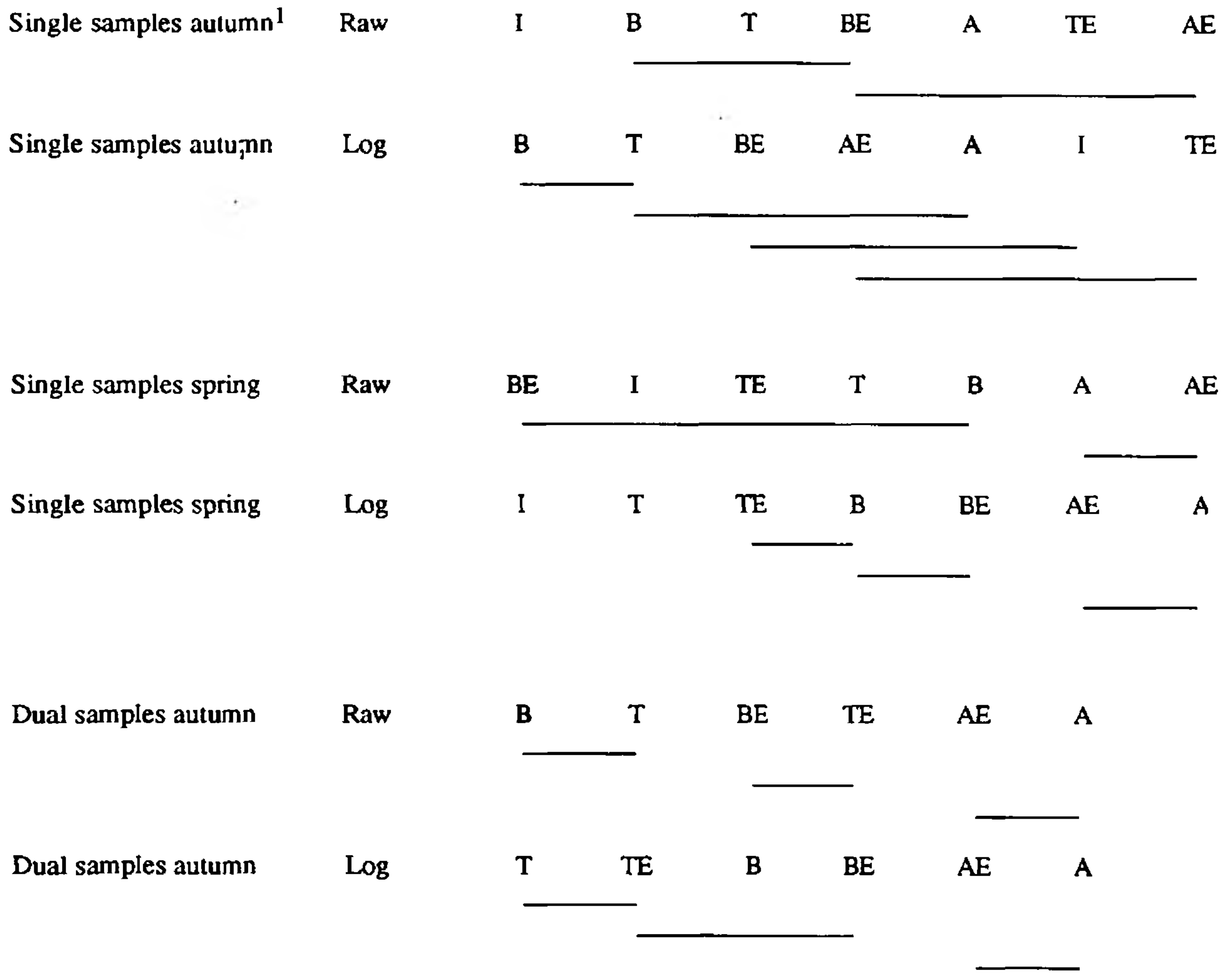
Site	Dual-sample spring or autumn (untransformed)							Dual-sample spring or autumn (log transformed)						
Site	IBG	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI	IBG	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI
Bow Brook	40.2	73.7	83.0	55.0	60.6	71.3	54.2	29.0	48.2	54.2	46.0	41.2	48.7	48.4
River Thames	38.2	68.7	71.9	50.7	63.1	68.7	55.6	28.8	47.0	52.2	43.5	43.7	51.2	50.2
River Coln	30.7	59.2	60.3	43.0	46.8	48.4	43.6	25.8	43.7	48.1	38.5	36.9	42.8	41.8
The Cut	50.7	99.4	90.9	59.3	82.9	79.4	59.5	37.3	63.4	68.6	51.6	55.5	63.1	55.1
Lydiard Stream	46.0	77.1	84.2	59.2	64.4	73.4	59.9	32.9	51.0	57.9	49.7	43.8	52.4	53.3
Halfacre Brook	60.4	81.6	82.0	65.7	71.5	75.6	67.3	49.0	65.2	73.9	56.2	57.4	68.3	60.0
Roundmoor Ditch	45.5	83.4	80.4	61.6	73.0	73.9	64.9	36.3	66.6	73.0	54.6	58.3	67.3	59.8
Summerstown Ditch	41.3	72.4	73.5	56.1	62.4	66.2	59.7	31.4	53.7	60.7	50.3	47.4	56.7	56.8
Crendon Stream	41.2	72.7	72.6	54.9	62.9	64.2	50.6	31.9	59.1	63.9	49.4	52.3	57.5	47.5
Wheatley Ditch	40.4	70.3	72.4	57.7	59.5	64.1	58.4	30.5	50.6	57.1	51.0	43.7	52.0	55.0
Crawters Brook	39.5	68.6	70.1	49.0	57.5	61.6	48.7	28.7	48.3	52.2	43.7	40.4	45.8	46.3
Catherine Bourne	60.5	76.7	77.3	56.4	65.6	68.9	57.4	42.2	55.6	61.4	49.2	48.7	56.6	53.1
F	43.8	74.8	76.4	55.7	63.8	67.9	56.6	33.0	53.8	59.7	48.6	46.9	54.7	52.2
Upper confidence limit	50.2	81.6	81.7	59.5	69.8	73.1	60.9	37.9	59.2	65.5	51.8	51.9	60.3	55.8
Mean F value	44.6	75.3	76.5	55.7	64.2	68.0	56.7	33.7	54.4	60.3	48.7	47.4	55.2	52.3
Lower confidence limit	38.9	69.0	71.4	51.9	58.5	62.8	52.4	29.5	49.5	55.0	45.5	43.0	50.1	48.7

Table 8.16 Jacknife values of F for combined-season data												
	Combined-season sample (untransformed)						Combined-season sample (log transformed)					
	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI	TAXA	BMWP	ASPT	TAXA EQI	BMWP EQI	ASPT EQI
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	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	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	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	116	91.5	68.2	76.5	73.7	56.7	67	74.3
Catherine Bourne	112	126	91	106	131	92.8	79.5	86.2	67	69.9	79.5	69.4
Upper confidence limit	119	138	95.1	110	140	96.9	89.2	94.9	70.4	77.9	86.7	72.6
Mean jacknife F	110	125	89.9	101	128	91.3	78.7	85.3	66.6	68.5	78.1	68.7
Lower confidence limit	100	112	84.7	92.4	116	85.8	68.2	75.6	62.7	59	69.5	64.9

Figure 8.4 **Comparison of the discrimination shown by biotic indices (using jacknife analysis)**

Key

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



[1] Note the biotic index with the highest discrimination (highest Jacknife 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, I had a statistically higher power of discrimination than all other indices. B, T and BE were not statistically separable from each other, but B and T did have statistically higher discrimination than A, TE and AE. BE, A, TE and AE were not statistically separable in terms of discrimination.

Figure 8.4 Comparison of the discrimination shown by biotic indices (using jacknife analysis)

<u>Key</u>

A = ASPT
AE = ASPT.EQI
B = BMWP
BE = BMWP.EQI
I = IBG
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	I	A	AE
Single samples spring or autumn	Log	B	T	A	BE	AE	TE	I
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	

9. Comparison of the IBG, Saprobien and BMWP systems for biological water quality assessment

9.1 Aims

The first part of this project (Chapters 1 - 8) investigated the effects of sampling variability on water quality assessment, using the BMWP system. In the second part of the project, described in Chapters 9 and 10, a preliminary comparison of three representative European biotic indices was undertaken. The three systems compared were the UK BMWP system, the French Indice Biologique Globale, and the German Saprobien System.

The objective of the analysis was to determine whether the results of river water quality monitoring in different member states of the European Union (EU) were broadly comparable. The study thus provides information relevant to the harmonisation of biological water quality monitoring in the EU member states.

The study was divided into two sections:

(i) raw index values used in the three systems were compared (i.e. EQIs from the BMWP system, IBG and GI scores, saprobic index) using regression analysis. This work is reported in the current chapter.

(ii) the raw index values were used to band sites (using the 5M for UK data, the 5 classes of the IBG system and the 7 classes of the Saprobien system). The banding of sites was then compared (see Chapter 10).

9.2 Approach to the analysis

9.2.1 Datasets used for the comparison

Comparative analysis of the three water quality assessment systems was undertaken using data from two sources:

(i) invertebrate data from the 12 sites sampled in this study. The samples collected were specifically sorted and identified to allow direct comparison between the different assessment methods. Note, however, that the samples were not collected using the field sampling techniques routinely used for IBG and Saprobien system work (see 9.2.2 below).

(ii) data from 43 sites already collected by Pond Action for the National Rivers Authority Thames Region in the course of the South West Oxfordshire Reservoir Development Study (SWORDS). This information was not specifically collected or identified for the project, but included both family level and species level data. The SWORDS data therefore provides:

  (a) an additional source of family level data, similar to that used by the NRA in routine monitoring in the UK.

  (b) species level data, similar to that held by some NRA regions in the UK.

Use of the SWORDS data, therefore, allowed an assessment of the potential for further studies of harmonisation using existing UK data (and by implication, data from other European states) to calculate IBG scores and saprobic indices.

9.2.2 Constraints on the analysis

There were several constraints on the analysis, principally concerned with the invertebrate sampling methods used. These included:

(i) All samples for the survey were collected using RIVPACS methods so did not exactly follow either the IBG methods of sampling or those of the Saprobien system. Instead, each index was applied to the same set of samples, identified to the appropriate taxonomic levels. Whilst this constraint inevitably reduces the validity of the comparisons, all three methods are fairly robust. It was therefore agreed with NRA Thames that collection using the RIVPACS methodology would be acceptable in this exploratory study, and allow a greater number of sites to be included in the survey.

The recommended IBG sampling technique uses Surber sampling in eroding areas and a pond net in depositing areas. The RIVPACS methodology would probably lead to larger numbers of invertebrates being collected with a resultant overestimate of the IBG score. The GI index, which uses abundance data is also likely to be affected.

In both cases, it is likely that using different survey methods will modify the results to some extent. The effect is probably more important for IBG (which reflects length of taxa list) and GI, which uses abundance data, than for saprobic index, which only uses relative abundance and is not dependent on taxon richness.

(ii) For the Saprobien system only macro organisms (invertebrates and fish) were included in the comparisons, whereas the Saprobien system can also include a separate assessment of micro- invertebrates.

(iii) As has already been noted, three-season BMWP system data was not collected in this study. Instead, the differences between combined-season and single- or dual-season data were tested more economically by collecting samples in two seasons only. Use of single- and two-season data is more common in the NRA Thames region during routine surveying than use of three-season data.

9.2.3 Data from the 12 sites in the present study (see Table 9.1).

Approach to the analysis

The analysis compared scores derived from three European biotic index systems at the 12 sites investigated in this study. In addition to the level of taxonomic identification required for BMWP, additional specimen identification was required for the IBG and the Saprobien system. For the IBG analysis this required identification of additional taxa at family level not routinely identified in the UK. The Saprobien system required species level data and a subset of samples were therefore identified to species (see Tables 9.2 and 9.3).

The relationships between the British and other European indices were investigated by regression analysis, comparing IBG and saprobic indices with TAXA.EQI, BMWP.EQI and ASPT.EQI.

Data set used

A total of 96 samples were available from the present study (12 sites x 4 samples in each season x 2 seasons) were analysed to family level with abundance data, and are compatible with the IBG system. In addition, 24 samples from the present study (one sample from each site in each season) were analysed to species level with abundance data, and are compatible with the Saprobien system.

The UK EQI system commonly uses combined-season data whereas in the French and German systems there is no equivalent use of cumulative samples. In the following analysis, EQI combined samples were therefore compared with single-season data from the IBG and Saprobien systems. Random selection of IBG samples was used to give data sets of equal size.

9.2.4 Data from the SWORDS study

The SWORDS study, undertaken by Pond Action for NRA Thames Region, in 1992/3 collected family and species level data from 42 sites in the Upper Thames catchment.

The 42 samples were analysed to species level in several groups, but did not include the Diptera and Oligochaeta which are used by the Saprobien system, or some of the families and broad groups used in IBG system. The SWORDS samples could therefore only be used to give approximate IBG and saprobic indices. The data from the current study were used to investigate the relationship between approximate and actual IBG and saprobic indices. The 42 SWORDS samples were all single-season samples so no combined species data could be analysed from this study.

9.2.5 Background to the IBG and the Saprobien system

The features of the IBG system and the Saprobien system are described in Boxes 9.1 and 9.2. An example of the way in which the biotic scores for the three systems (BMWP, IBG, Saprobien) are calculated is given in Tables 9.4 and 9.5.

Table 9.1 Data-set for the comparison of European biotic indices					
	Number of samples available for each biotic index system				
Data-set	**BMWP**	**IBG**	**Saprobien**	**Approximate IBG**	**Approximate Saprobien**
This study	96	96	24	96	24
SWORDS study	42	0	0	42	42
Total samples	**138**	**96**	**24**	**138**	**66**

Table 9.2 Levels of identification used to calculate IBG (Indice Biologique Globale)

Note: levels of identification are <u>additional</u> to those necessary for BMWP scores. Abundance of all taxa was noted, using subsampling where necessary. All 96 samples were identified to this level.

The term 'Separate' in parenthesis indicates families or subfamilies which are put together in the BMWP system but separated in the IBG system.

Gastropoda
Bithyniidae (separate)
Hydrobiidae (separate)
Trichoptera
Psychomyiidae (separate)
Ecnomidae (separate)
Rhyacophilidae (separate)
Glossosomatidae (separate)
Coleoptera
Donaciidae (separated from Chrysomelidae)
Eubriidae (Psephenidae)
Hydrophilinae (separate)
Hydraeninae (separate)
Hydrochinae (separate)
Limnebiinae (separate)
Spercheidae
Neuroptera
Osmylidae (as larvae)
Hymenoptera (whole order)*2
Lepidoptera (as larvae/pupae)
Nemathelminths
Hydracarina
Hydrozoa

Diptera
Anthomyidae
Athericidae*1
Ceratopogonidae
Chaoboridae
Culicidae
Dixidae
Dolichopodidae
Empididae
Ephydridae
Limoniidae (separated from Tipulidae)
Psychodidae
Ptychopteridae
Scathophagidae
Sciomyzidae
Stratiomyidae
Syrphidae
Tabanidae
Thaumaleidae
Spongilidae
Bryozoa
Nemertea

*1. Athericidae = Athericidae (s.s.) and Rhagionidae (s.s.).
*2Hymenoptera = as obvious parasites of Trichoptera etc.

Table 9.3 Levels of identification used for the Saprobien system

Note: Taxa are not listed exhaustively but placed in group where determination below family level is necessary. 24 samples were identified to this level.

Porifera
Genus level, and species level within *Ephydatia*.

Coelenterata
One species level determination.

Tricladida
Species level

Gastropoda
Species level within:
Ancylidae
Planorbidae
Hydrobiidae
Physidae
Valvatidae

Lamellibranchiata
Species level within:
Unionidae
Sphaeriidae

Oligochaeta
Tubifex spp.*
Limnodrilus spp.*
Branchiura sowerbyi
Lumbriculus variegatus.

Hirudinea
Erpobdella octoculata
Glossiphonia complanata
Glossiphonia heteroclita
Helobdella stagnalis

Crustacea
Asellus aquaticus
Gammarus pulex
Gammarus tigrinus

Ephemeroptera
Species level within:
Baetidae
Heptageniidae
Ephemeridae
Ephemerellidae
Leptophlebiidae

Odonata
Aeshna cyanea
Calopteryx splendens
Calopteryx virgo
Platycnemis pennipes
Pyrrhosoma nymphula

Plecoptera
Species level within:
Leuctridae
Taeniopterigidae
Perlidae
Perlodidae
Genus level within:
Nemouridae
Chloroperlidae

Megaloptera
Species level within:
Sialidae

Coleoptera
A limited range of species identifications (21) within the following families.
Dryopidae (1 sp)
Dytiscidae (6 spp)
Elmidae (5 spp)
Haliplidae (2 spp)
Hydraenidae (4 spp)
Hydrophilidae (2 spp)
Gyrinidae (1 spp)

Trichoptera
A limited range (21) of mainly species level identifications within the following families:
Limnephilidae (*Anabolia nervosa*)
Hydropsychidae (*Cheumatopsyche lepida* and *Hydropsyche siltalai*)
Lepidostomatidae (all)
Glossosomatidae (to genus)
Goeridae (all)
Philopotamidae (genus)
Polycentropodidae (genus)
Psychomyiidae (*Psychmyia pusilla*).
Rhyacophilidae (species level)
Sericostomatidae (species level)

Diptera
The following taxa:
Atherix ibis
Chironomus plumosus group
Chironomus thummi group
Eristalinae
Odagma ornata
Prosimulium hirtipes
Psychoda spp.

Bryozoa
Species level in three genera.

Pisces
Cottus gobio
Lampetra planeri

* Identification of *Tubifex* spp. and *Limnodrilus* spp. followed keys intended for use with the Saprobien System kindly supplied by Professor G.Friedrich. The key separates *Limnodrilus* s.s. and *Tubifex* s.l. Other species keying out with *Tubifex* in this study included the common *Psammoryctides barbatus* and *Rhyacodrilus coccineus*. The former was present in some numbers in some of the better water quality sites. In keeping with practice, however, these were recorded as *Tubifex* s.l.

Box 9.1 Principal features of the IBG system

Recommended sampling strategy

Invertebrates are collected using a Surber Sampler and a hoop net (which resembles a pond net with a 65cm deep net bag). The sample is collected from a site, the length of which is about 10 times the width of the river bed at the time of sampling. Samples should be taken when flow has been stable for 10 days.

The sample consists of 8 sub-samples, each taken from one of 10 predefined substrate types (if there are less than 8 substrate types, 8 samples are taken from whatever substrates there are). The substrates categories are:
(i) mosses (Bryophyta), (ii) submerged higher plants (Spermatophyta), (iii) coarse organic elements (litter, branches), (iv) large mineral sediments (stones and pebbles) >= 25mm and <= 250mm, (v) coarse aggregates >= 2.5mm and < 25mm, (vi) sand and alluvium <2.5mm, (vii) fine sediment <= 0.1mm (including helophytes and roots), (viii) natural and artificial surfaces (rock, slabs, soils, walls) and blocks >250mm, (ix) marl and clay; (x) bacteria and fungus.

A Surber sampler is used to collect the samples in eroding zones and a hoop net in depositing zones. With both types of sampler the objective is to sample an area of $0.05m^2$ (i.e. an area of about 22cm x 22cm).

Note that samples in the present study were taken using standard RIVPACS methodology. It is likely that this would produce more taxa per sample than the IBG system.

Calculating the IBG and GI

The IBG system produces two indices of faunal composition.

(i) the faunal indicator group (GI)
(ii) the Indice Biologique Globale (IBG)

The GI is used to indicate the water quality of a site and has a value between 0 (low quality) and 9 (high quality). The GI is derived from a list of indicative taxa (mostly families plus a few groups of families). Occurrence of a particular family (at or above a set abundance) from this list indicates that the water quality is not less than the GI of that family. The GI of a site is, then, derived from the taxon present at the site which is highest in the GI list (see Table 9.2 showing the scores of the IBG system).

The IBG is used to indicate the 'biogenic capacity' of the environment and has a value between 0 (low quality) and 20 (high quality). The IBG of any site is derived from the GI and the number of a given list of taxa present at a site. The list of taxa used to calculate the IBG is longer than that used for assessment of GI. The formula used to calculate IBG is:

$$IBG = GI + T - 1$$

with the two conditions that IBG =< 20 and that IBG = 0 when no macroinvertebrates are present. Note that there is no provision in the system for sites with taxa but no GI taxa.

T is a 'varietal class' (between 1 and 14) given to a set range of taxa numbers. e.g. the varietal class for taxa numbers between 25 and 28 is 8. The division of the varietal classes is not constant but increases with increasing taxa number till 50 or greater ('varietal class' 14). As can be seen from the formula the IBG cannot fall below that of the GI, and if the GI is low then there is a limit to the IBG (e.g. an IBG of 20 cannot be achieved by any site with a GI less than 7), irrespective of the numbers of other taxa present.

Differences between the IBG and BMWP systems

The principal differences between the IBG system and the BMWP system are as follows:

(i) The IBG system has a group of taxa (GI taxa) which influence the IBG more heavily than others (as opposed to the EQIs where all scoring taxa have a graded influence).
(ii) The IBG (and GI) system have defined boundaries, unlike the BMWP system indices which have an upper limit which is never likely to be achieved.
(iii) The IBG system relies partially on limited information on the abundance of invertebrates (only used in assessing GI).
(iv) The IBG system produces two distinct indices of ecological quality (GI and IBG). These are roughly analogous to ASPT and BMWP.
(v) The French water quality system uses no reference sites to assess whether or not the IBG or GI of a site is above or below expected for a site (unlike the RIVPACS application of the BMWP system).

Box 9.2 Principal features of the Saprobien system

Calculation of the saprobic index

The Saprobien system is calculated following surveys for two lists of organisms (micro fauna and macro fauna). Survey techniques for these two types differ and only macro-organisms were included in this survey. The list of macro-organisms is, principally, at species level, and includes two species of fish in addition to invertebrates. The list of indicative taxa is quite selective and at some sites the majority of species recorded will not be used in calculating the saprobic index.

3 features of a listed taxon recorded are used by the Saprobien system:

i) the abundance on a scale for 1 to 7 (signified in the equations for calculating saprobic index by the letter A). Normally this scale is described qualitatively, (e.g. 1 = single-occurrence, 7 = mass occurrence etc.). For the purposes of this study a more formal scale was used:

1=1; 2=2 - 5; 3=6 - 25; 4=26 - 125; 5=126 - 625; 6=626 - 3125; 7=>3126.

ii) the saprobic valence (s). This is a number between 1 and 4 which indicates the believed preferred position of the taxon in a scale of saprobic enrichment. 1 = low tolerance to enrichment, 4 = high tolerance.

iii) the weighting factor (G). The weighting factor indicates the width of the affinity of the organism for waters with different organic c.ntent. For example, 16 would indicate that an organism is very narrowly restricted to a particular level of organic matter. The G values used in the German standard system are 4, 8 and 16. (4 = broad affinity, 16 = narrow affinity). The Saprobien system does allow for weighting factors of 1 and 2 o be used, but the German standard includes no organisms with such broad affinities.

The saprobic index S is calculated from the following formula:

$$S = \text{SUM } (i=1 \text{ to n}) \text{ of}(s_i.A_i.G_i) \ / \ S = \text{SUM } (i=1 \text{ to n}) \text{ of } (A_i.G_i)$$

(where subscript i represents the value of s, A or G for the ith taxon, and n=no. of taxa)

In addition to the saprobic index, an index of dispersion (SM) is also calculated. This index reflects how reliably the S of the site has been assessed (values in excess of 0.2 indicate that S does not clearly reflect the degree of organic pollution).

$$SM \ \pm \text{ square root of}\{ [\text{SUM } (i=1 \text{ to } n) \text{ of}(s_i - S)^2.A_i.G_i] \ / \ [(n - 1).[\text{SUM } (i=1 \text{ to } n) \text{ of } A_i.G_i]\}$$

In addition, S values from samples where SUM (i=1 to n) of A_i <15, are also not believed to assess organic pollution reliably.

The principal differences between the Saprobien system and the BMWP system are as follows:

(i) the Saprobien system uses (principally) species level determinations in assessments
(ii) only a limited number of the taxa recorded from a site are used in assessments
(iii) the system uses abundance data
(iv) the system has a defined range (1 to 4), though these extremes are, arguably, very unlikely.
(v) the system is an index and the value of this is not affected by faunal richness.
(vi the system includes a means of assessing how reliable the index will be in assessing pollution
(vii) the Saprobien system uses no reference sites to assess whether or not the S of a site is above or below that expected for a site (unlike the RIVPACS application of the BMWP system).

Table 9.4 Example of the calculation of IBG score and GI

Catherine Bourne, Autumn 1993, JB sample 1

TAXA	Abundance	GI rating taxa	IBG taxa
Lymnaeaidae	1		4
Hydrobiidae	147		4
Mollusca (all snails)	148	2	
Total Oligochaeta	848	1	4
Erpobdellidae	4		4
Glossiphoniidae	9		4
Achaeta (all leeches)	13	1	
Asellus aquaticus	432	1	4
Gammaridae	28	1	4
Hydracarina	1		4
Corixidae	1		4
Sialidae	2		4
Limnephilidae	1	<10 individuals so no GI rating	4
Haliplidae	4		4
Dytiscidae	7		4
Simuliidae	5		4
Ceratopogonidae	1		4
Stratiomyidae	1		4
Chironomidae	960	1	4

Highest GI	2
Total IBG taxa (I)	17
Varietal class (V)	6
IBG = GI + (V-1)	7
GI =	2

Table 9.5 Example of the calculation of saprobic Index							
Site: Catherine Bourne Autumn 1993 JB sample 1							
TAXA	Abundance	Abundance code (A)	Saprobic value (s)	Weighting factor (G)	s x A x G	A x G	$(s-S)^2$ x A x G
Lymnaeaidae	1	1	None				
Potamopyrgus jenkinsi	1472	6	2.3	4	55.2	24	7.69
Tubifex tubifex	320	5	3.5	4	70	20	8.04
Tubificidae	96	4	None				
(not Tubifex s.l., or Limnodrilus)							
Limnodrilus hoffmeisteri	432	5	3.3	4	66	20	3.77
Trocheta subviridis	4	2	None				
Glossiphonia complanata	9	3	2.2	8	52.8	24	10.65
Asellus aquaticus	432	5	2.7	4	54	20	0.55
Crangonyx pseudogracilis	28	4	None				
Hydracarina	1	1	None				
Corixidae	1	1	None				
Sialidae	2	2	2.3	4	18.4	8	2.56
Limnephilidae	1	1	None				
Haliplus sp	4	2	None				
Dytiscidae larvae	7	3	None				
Simuliidae (not Saprobien spp.)	5	2	None				
Ceratopogonidae	1	1	None				
Stratiomyidae	1	1	None				
Chironomidae indet.	736	6	None				
Chironomus plumosus agg.	192	5	3.4	4	68	20	5.70
Chironomus thummi agg.	32	4	3.2	4	51.2	16	1.78
Totals		63		Totals	435.6	152	41.10

Saprobic index S = sum s x A x G / A x G	2.866
No of Saprobien taxa (n)	8
Dispersion (SM) = ± sqrt(sum((s-S)squared x A x G)/((n-1)xsum(A x G)))	0.197
Sum A	62

9.4 Methods and approach to the analysis

Correlation of the different biotic indices was undertaken using linear regression analysis.

Three main analyses were performed:

i) an investigation of the differences between true and approximate IBG and saprobic indices (using data from the current study to correlate the true IBG with the approximate IBG and the true saprobic indices with the approximate saprobic indices).

ii) an investigation of the difference between EQIs and the French and German systems using data derived from this study (correlating true IBG and true saprobic index, with TAXA.EQI, BMWP.EQI and ASPT.EQI from the current study).

iii) an investigation of the use of approximate data for IBG and saprobic indices using data from this study and the SWORDS study.

9.5 Correlation of true and approximate scores

9.5.1 Correlation of true and approximate IBG scores

Results of the analysis show that the IBG and approximate IBG were strongly correlated, both for single samples and combined samples (see Appendix 4, Figures 1 and 2). Variation in approximate IBG (measured as adjusted R^2) explains 98.5% of the variation in true IBG for single-season samples and 96.9% for combined samples. In general, differences between the true and approximate values were small. For example, in the raw data, approximate IBG based on single-season data were lower than true IBG by 2 points on one occasion only and by 1 point on 36 occasions. By definition, it is impossible for the approximate IBG to exceed true IBG, because approximate IBG is derived from fewer scoring taxa.

9.5.2 Correlation of true and approximate saprobic indices

There was a strong correlation between the true and approximate values of saprobic index, however approximate saprobic index only explained about 65% of saprobic index variation (see Appendix 4, Figure 3). Differences appeared to be most marked at high values of the index. This is likely to be due, particularly, to the omission of sub family-level determinations of Chironomidae and Oligochaeta from approximate saprobic index. These two groups often make up a large percentage of the fauna in poor quality sites, and have a marked effect on the saprobic indices.

The approximate saprobic index value was always lower than saprobic index. As saprobic index is an index (similar in some ways to ASPT), there is no intrinsic reason why this should be so, and the reason probably lies, once again, in the omission of Chironomidae and Oligochaeta.

The relatively low percentage of the variation in the true saprobic index explained by the approximate saprobic index casts some doubt on the use of approximate saprobic index in further analysis.

9.6 Differences between the French, German and UK systems investigated using data from the current study

9.6.1 IBG: correlation of true IBG with EQIs

True IBG values were correlated with TAXA.EQI, BMWP.EQI and ASPT.EQI for single-and combined-seasons data.

The results showed that IBG was strongly correlated with both TAXA.EQI and BMWP.EQI. Regression analysis indicated that the relationship between IBG and EQIs is linear. Most variation was explained with single-season data (89.8% and 90.0% respectively). Slightly less variation was explained with combined-season data (83.1% and 84.2% respectively) (see Table 9.6).

The relationship between IBG and ASPT.EQI was not as strong, with 76.0% and 71.4% of variation explained by single-and combined-season data (see Table 9.6). Regression analysis suggested that the relationship with ASPT.EQI was not linear, and was more complex than for TAXA.EQI and BMWP.EQI.

Table 9.6 Relationship between true IBG and EQIs using data from the current study

EQI index	Appendix figure number	IBG system sample combination	Adjusted R^2 value
TAXA.EQI Single season	4	IBG Single season	89.8
TAXA.EQI Combined season	5	IBG Combined season	83.1
BMWP.EQI Single season	6	IBG Single season	90.0
BMWP.EQI Combined season	7	IBG Combined season	84.2
ASPT.EQI Single season	8	IBG Single season	76.0
ASPT.EQI Combined season	9	IBG Combined season	71.4

Note: Adjusted R^2 value describes the % of variation explained in the regression analysis.

9.6.2 The relationship between Saprobien system and the EQI system

The relationship between Saprobien indices and EQIs was not as good as for IBG. In regressions, EQIs explained between 55.2% and 70.8% of variation in saprobic index (see Table 9.7 and Figures 10 to 15 in Appendix 4). Single-season data explained a slightly greater amount of the variation than combined samples. As with IBG the variation explained by ASPT.EQI was less than that explained by the other EQIs.

Table 9.7 Relationship between the Saprobien system and EQIs using data from the current study

EQI index	Appendix figure number	Saprobien system sample combination	Adjusted R^2 value
TAXA.EQI Single season	10	True Saprobien Single season	70.8
TAXA.EQI Combined season	11	True Saprobien Combined season	67.9
BMWP.EQI Single season	12	True Saprobien Single season	72.2
BMWP.EQI Combined season	13	True Saprobien Combined season	69.5
ASPT.EQI Single season	14	True Saprobien Single season	62.4
ASPT.EQI Combined season	15	True Saprobien Combined season	55.2

Note: Adjusted R^2 value describes the % of variation explained in the regression analysis.

9.7 Difference between true and approximated data

Two analyses were made using approximated data: (i) analysis using approximated data derived from this study alone (ii) further analysis with the addition of the data from the SWORDS study.

9.7.1 Comparison between true and approximate IBG results

This analysis used family level data, equivalent to standard data collected in the course of routine monitoring by NRA staff.

Approximate IBG results calculated from the data in the current study, and also using additional data from the SWORDS study, are shown in Table 9.8 below.

The results suggested a very strong relationship between single-season BMWP.EQI and TAXA.EQI, and approximated IBG (89.8% and 90.6% of variation explained, respectively) in this survey. ASPT was somewhat lower (76.0%). Single-season data explained slightly more variation than combined data (~6% less in all cases). Adding further sites from the SWORDS database increased the variation explained by all EQIs.

Approximate IBG and true IBG results were very similar for TAXA.EQI, BMWP.EQI and ASPT.EQI (see Tables 9.6 and 9.8).

Table 9.8 Relationship between approximate IBG and EQIs

EQI index	Appendix figure number	IBG system sample combination	Adjusted R^2 value
TAXA.EQI Single season	16	Approximate IBG Single season - this survey	89.8
TAXA.EQI Combined season	17	Approximate IBG Combined season - this survey	83.6
TAXA.EQI Single season	18	Approximate IBG Single season - all samples	90.5
BMWP.EQI Single season	19	Approximate IBG Single season - this survey	90.6
BMWP.EQI Combined season	20	Approximate IBG Combined season - this survey	85.5
BMWP.EQI Single season	21	Approximate IBG Single season - all samples	90.6
ASPT.EQI Single season	22	Approximate IBG Single season - this survey	76.0
ASPT.EQI Combined season	23	Approximate IBG Combined season - this survey	70.3
ASPT.EQI Single season	24	Approximate IBG Single season - all samples	79.4

Note: Adjusted R^2 value describes the % of variation explained in the regression analysis.

9.7.2 Approximate saprobic index

As with the true data study, the relationships between saprobic indices and EQIs were not particularly strong. In regressions, EQIs explained between 41.6% and 76.0% of the variation in the approximate saprobic indices (see Table 9.9).

Both approximate TAXA.EQI and BMWP.EQI had a reasonably good fit with saprobic indices at higher water quality sites, but a poor fit where water quality was lower. This may be primarily due to the absence of Chironomidae and Oligochaeta in the calculation of approximate saprobic index. ASPT.EQI showed a close relationship with approximate saprobic index at both high and low water quality sites.

All the relationships are approximately linear (see Appendix 4, Figures 25 to 33).

For TAXA.EQI and BMWP.EQI, approximate saprobic indices explained less variation than true saprobic indices. However, for ASPT.EQI, this pattern was reversed and approximate saprobic indices explained more variation than true values. Indeed, the strongest relationship observed was between single-season approximate saprobic index and ASPT.EQI (76%).

Table 9.9 Correlation of approximate Saprobien system data with EQIs.			
EQI index	**Appendix figure number**	**Saprobien system sample combination**	**Adjusted R^2 value**
TAXA.EQI Single season	9.25	Approximate Saprobien Single season - this survey	48.5
TAXA.EQI Combined season	9.26	Approximate Saprobien Combined season - this survey	50.8
TAXA.EQI Single season	9.27	Approximate Saprobien Single season - all samples	41.7
BMWP.EQI Single season	9.28	Approximate Saprobien Single season - this survey	54.6
BMWP.EQI Combined season	9.29	Approximate Saprobien Combined season - this survey	55.7
BMWP.EQI Single season	9.30	Approximate Saprobien Single season - all samples	44.6
ASPT.EQI Single season	9.31	Approximate Saprobien Single season - this survey	76.0
ASPT.EQI Combined season	9.32	Approximate Saprobien Combined season - this survey	65.7
ASPT.EQI Single season	9.33	Approximate Saprobien Single season - all samples	64.2

9.8 Predictive equations linking the IBG and Saprobien systems to the EQIs

In the following section the best regression equations for predicting IBG and saprobic index are suggested. It should be noted that these equations are only known to work over the range of values (BMWP system indices, IBG and saprobic index) which were seen in this study.

9.8.1 Predicting IBG from EQIs

The best predictive equation for IBG from single-season data using true data alone was:

$$\text{IBG} = 8.817\ \text{BMWP.EQI} + 2.121 \qquad \text{(Equation 9.1)}$$

It would appear from the data that combined season samples will not model IBG as effectively as single-season. Nevertheless, the best predictive equation for IBG from combined-season data is:

$$\text{IBG} = 8.797\ \text{BMWP.EQI} + 2.407 \qquad \text{(Equation 9.2)}$$

9.8.2 Predicting saprobic index from EQIs

The best predictive equation for saprobic index from single-season data, using true data alone is:

$$\text{Saprobic index} = -0.591\ \text{BMWP.EQI} + 3.033 \qquad \text{(Equation 9.3)}$$

and from combined-seasons data

$$\text{Saprobic index} = -0.598\ \text{BMWP.EQI} + 3.000 \qquad \text{(Equation 9.4)}$$

Though the true and approximated saprobic index do not correlate particularly well, they might be expected to behave similarly in relationship to different sites. The data from the smaller data set, therefore, seem to be a fair representation of the types of samples over which saprobic index and EQIs might vary.

9.9 Summary and conclusions

9.9.1 Relationships between IBG (true and approximate) and EQIs

Overall, IBG and approximate IBG were highly correlated. Both also correlated well, and normally linearly, with TAXA.EQI and BMWP.EQI. The relationship with ASPT.EQI was more complex, however. The regressions using only data from the present study give very similar results to those also using SWORDS data.

9.9.2 Relationships between saprobic index (true and approximate) and EQIs

Overall, saprobic index and approximate saprobic index were poorly correlated. In regressions with true saprobic index, EQIs explained a low to moderate proportion of the variation (~50 -70%), with ASPT.EQI the poorest predictor. TAXA.EQI and BMWP.EQI explained a similar proportion of the variation in approximate saprobic index (48-76%) but, in contrast to the results with true saprobic index, ASPT.EQI was the best predictor. Adding SWORDS data to the analysis gave similar or slightly lower prediction results.

9.9.3 Preliminary implications for EU water quality harmonisation

The results from this preliminary study suggest that:

(i) the IBG and EQI methodologies produce indices which are strongly correlated. The relationship between the indices appears to be linear and, using existing data, it is possible to predict IBG from BMWP EQIs and vice versa using equations 9.1 (for single-season data) and 9.2 (for combined-season data).

(ii) There was a strong correlation between true and approximate IBG results. This suggests that it <u>may</u> be possible to use existing EQI data routinely collected by the NRA to estimate IBG scores. This would need some further analysis, as routinely collected EQI data does not have abundance data. Note that the IBG recording scheme already includes all BMWP families so that it is possible to directly calculate true EQI scores from IBG data.

(iii) the Saprobien and EQI methodologies are not as similar as IBG & EQIs. However the two sets of results are still strongly correlated. Using existing data, the best prediction equations are given in equations 9.3 and 9.4.

(iv) There was a relatively poor correlation between true and approximate Saprobien results. The implication is that approximate saprobic indices, calculated from data collected during some NRA work, may not be sufficiently similar to true saprobic indices to make the calculation worthwhile. Additional analysis could also be undertaken to calculate EQI results using family level data calculated from the raw Saprobien results

Because of the constraints on this work noted in Section 9.2.2, the results of this study must be viewed as a preliminary comparison. Further work is required to assess:

(i) the difference made if the sampling methods <u>specific to each index type</u> is used (rather than the RIVPACS sampling method which was used for all samples in this study)

(ii) the comparative results from samples taken over a wider range of geographical areas, preferably in both Britain and mainland Europe.

10. Comparison of UK, French and German water quality banding systems

10.1 Introduction

In Chapter 9 the relationships between the water quality indices produced by the BMWP, IBG and Saprobien systems were described. In this chapter the scores derived from these three systems are used to band sites and the banding systems are compared.

Four banding systems are considered, produced by the three sets of biotic indices:

5M band	This banding system has been trailed in the UK, and is derived from a combination of classes of the three EQIs. The band can be produced from single-or combined-seasons data. It has four values between A and D.
GI band	The French banding system which represents water quality (as opposed to IBG). It has values between 1 and 5.
IBG band	The IBG band represents 'biogenic capacity'. It has values between 1 and 5.
Saprobien band	This is the German Güteklasse or quality class. It has 4 broad bands (I-IV) which can be subdivided.

The chapter addresses two questions:

(i) what is the difference between the 5M band and the French and German banding systems?

(ii) how is the comparison between banding system affected by using single- and combined samples?

10.2 Comparison of 5M band with the IBG system

10.2.1 Methods

The IBG system has two approaches to banding using both the IBG values and the GI values (see Section 10.1.1).

The following comparisons were made:

(i) single-season 5M bands with IBG
(ii) combined-season 5M bands with IBG
(iii) single-season 5M bands with GI
(iv) combined-season 5M bands with GI

For single-season comparisons 96 samples were available (see Tables 3.1 and 3.2) and for combined-season 48 samples. For combined-season comparisons, the 48 paired samples (see Table 3.4) were compared with randomly selected single samples from the pair collected by each person.

IBG bands run from 1 to 5 (high to low quality), equivalent to the colour codes used in the system (blue [high quality] through green, yellow and orange, to red [low quality]). Values delimiting the GI and IBG classes are shown in Table 10.1.

Table 10.1 The classes of the IBG system		
Quality class	**GI values**	**IBG values**
1	9	≥ 17
2	8 - 7	13 - 16
3	6 - 5	9 - 12
4	4 - 3	5 - 8
5	2 - 1	1 - 4

10.2.2 Results

Single-season 5M band data

Tables 10.2 to 10.5 compare single- and combined-seasons 5M bands with IBG and GI bands. They show that the IBG band consistently rated sites as lower in quality than the 5M banding system (summarised in Table 10.6). Using single-season data, samples placed in band A of 5M were spread between four of the five IBG bands (see Table 10.2). Three of the 38 samples placed in 5M band A were in band D of the IBG. Similar trends are evident in 5M bands B and C.

The GI band rated many of the samples even lower than IBG (see Table 10.3). The majority of the sites placed in 5M band A were placed in GI bands C and D. There were no samples in GI band 1.

The approximate equivalent IBG and GI bands for single-season 5M bands are shown in Table 10.6.

Combined-season 5M band data

A similar trend for both IBG and GI was seen with the combined-season 5M bands (Tables 10.4 and 10.5). However, the difference was not as great as in single samples. This was to be expected as combined 5M samples generally rated sites lower in water quality than single 5M samples (see Chapter 3).

The approximate equivalent IBG and GI bands for combined-season 5M bands are shown in Table 10.7.

Table 10.2 Correspondence of 5M bands and IBG bands - Single-season data

	% of samples in IBG bands 1-5					
Single-sample 5M band	Band 1	Band 2	Band 3	Band 4	Band 5	% of all 96 samples
Band A	13.2%	39.5%	39.5%	7.9%	-	39.6
Band B	-	-	17.1%	60%	22.9%	36.5
Band C	-	-	-	14.3%	85.7%	21.9
Band D	-	-	-	-	100%	2.1

Table 10.3 Correspondence of 5M bands and GI bands - Single-season data						
	% of samples in GI band.					
Single-sample 5M band	Band 1	Band 2	Band 3	Band 4	Band 5	% of all 96 samples
Band A	-	23.7%	31.6%	31.6%	13.2%	39.6%
Band B	-	-	14.3%	8.6%	77.1%	36.5%
Band C	-	-	-	-	100%	21.9%
Band D	-	-	-	-	100%	2.1%

Table 10.4 Correspondence of 5M bands and IBG bands - Combined-season data						
	% of samples in IBG band.					
Combined- sample 5M band	Band 1	Band 2	Band 3	Band 4	Band 5	% of all 48 samples
Band A	12.5%	56.3%	31.3%	-	-	33.3%
Band B	-	-	28.6%	57.1%	14.3%	29.2%%
Band C	-	-	9.1%	36.4%	63.6%	22.9
Band D	-	-	-	14.3%	85.7%	14.6%

Table 10.5 Correspondence of 5M bands and GI bands - Combined-season data						
	% of samples in GI band					
Combined-sample 5M band	Band 1	Band 2	Band 3	Band 4	Band 5	No. of samples
Band A	-	31.3%	37.5%	31.3%	-	33.3%
Band B	-	-	21.4%	7.1%	71.4%	29.2%%
Band C	-	-	-	9.1%	90.9%	22.9
Band D	-	-	-	-	100%	14.6%

Table 10.6 The approximate equivalence of 5M bands and IBG system bands: single-season data		
5M band	**IBG band**	**GI band**
A	2 or 3	3 or 4
B	4	5
C	5	5
D	5	5

Table 10.7 The approximate equivalence of 5M bands and IBG system bands: single-season data		
5M Band	**IBG band**	**GI band**
A	2	3
B	4	5
C	5	5
D	5	5

10.4 Comparison of 5M bands from combined- and single-season samples with the Saprobien band

10.4.1 Introduction

There are 4 bands in the Saprobien system (I to IV) and the upper three of these (I to III) are split into two sub-bands giving, a total of 7 bands. Table 10.8 shows the bands and the description of water quality associated with them. A total of 24 samples were available for the analysis.

Table 10.8 The classes of the Saprobien system

Quality class	Degree of organic stress	Saprobien index	Saprobity
I	Unstressed to very slightly stressed	1.0 - < 1.5	Oligosaprobic
I-II	Slightly stressed	1.5 - < 1.8	Oligosaprobic with beta-mesosaprobic impacts
II	Moderately stressed	1.8 - < 2.3	Evenly beta-mesosaprobic
II-III	Critically stressed	2.3 - < 2.7	beta-alpha-mesosaprobic
III	Heavily polluted	2.7 - < 3.2	Markedly alpha-mesosaprobic
III-IV	Very heavily polluted	3.2 - <3.5	Polysaprobic with a mesosaprobic tendencies
IV	Excessively polluted	3.5 - < 4.0	Polysaprobic

10.4.2 Results

<u>Single-season 5M bands</u>

In this study all 5M band values were concentrated in middle Saprobien bands II, II-III and III. No samples were placed in either the top two bands I and I-II ('unstressed or moderately stressed'), or the three lowest bands III-IV or IV ('very heavily' or 'excessively' polluted) (see Tables 10.6 and 10.7).

Thus values for each 5M band are, in all cases, spread over only two Saprobien bands (three sub-bands). This contrasts with the spread of banding seen with the IBG system, where 5M banded sites were spread over all five IBG categories and four of the five GI categories. There does, however, appear to be a relatively smooth transition between the bands, so that it might be possible, if appropriate,to further subdivide the Saprobien bands.

The very strong clustering of Thames Region sites in the central bands of the Saprobien banding system, suggests that this system has a wider range than either the IBG or 5M systems. This may be because the Saprobien system is designed to be used over a wider range of water quality types than was seen in this study (very clean mountain streams to grossly polluted water courses for example). The approximate equivalence of Saprobien and 5M bands for single-season data are shown in Table 10.1.

<u>Combined-season 5M bands</u>

Once again there is a difference between single- and combined-season bands, though this is not as obvious as with the IBG system due to the lesser discrimination of the Saprobien bands. This difference is presumably due to the difference between single- and combined-sample EQI bands on which the 5M band is based. See Chapter 3. The approximately equivalent Saprobien and 5M bands for combined-season data are shown in Table 10.12.

Table 10.9 Correspondence of 5M bands and Saprobien bands - Single-season data

	% of samples in Saprobien band							
Single-sample 5M band	I	I-II	II	II-III	III	III-IV	IV	No. of samples
A	-	-	40.0	60.0	-	-	-	10
B	-	-	-	40.0	60.0	-	-	10
C	-	-	-		100.0	-	-	4
D	-	-	-	-	-	-	-	0

Table 10.10 Correspondence of 5M bands and Saprobien bands - Combined-season data

	% of samples in Saprobien band							
Combined-sample 5M band	I	I-II	II	II-III	III	III-IV	IV	No. of samples
A	-	-	50.0	50.0	-	-	-	8
B	-	-	-	66.7	33.3	-	-	6
C	-	-	-	16.7	83.3	-	-	6
D	-	-	-	25.0	75.0	-	-	4

Table 10.11 Correspondence between combined-season 5M bands and Saprobien bands

5M band	Saprobien band
A	II to II-III
B	II-III
C	III
D	III

Table 10.12 Correspondence between single-season 5M bands and Saprobien bands

5M band	Saprobien band
A	II-III
B	III
C	III

10.4 Conclusions

Comparison of the 5M band and IBG bands

The IBG band consistently rated single-season and combined-season sites as lower in quality than the 5M banding system. For example, band A from 5M were spread between four of the five IBG bands using single-season data. This trend was generally less pronounced for combined- than for single-season data

The GI band rated many of the samples even lower than IBG, with the majority of the sites placed in band A sites from the 5M system placed in GI bands C and D.

Comparison of the 5M band and Saprobien bands

In this study, all 5M band values were concentrated in middle Saprobien bands, and spread over only two of the Saprobien bands (and three of the seven sub-bands). This contrasts with the spread of banding seen with the IBG system, where 5M banded sites were spread over all five IBG categories and four of the five GI categories. As noted before, this strong clustering of Thames Region sites in the central bands of the Saprobien system may reflect the wider range of water quality types which this system is used to assess.

Overall conclusions

Comparison of the British and European banding systems system generally suggests that what is considered good water quality in the UK would not be banded so highly abroad. However, whereas the IBG system systematically grades sites lower that the 5M, the Saprobien system concentrates all the Thames sites in the central bands, suggesting that it has the potential to discriminate between sites of much lower water quality than the range found in the Thames Region.

Further work

(i) further analyses using the existing data could be undertaken to:

- directly compare the data for the IBG and Saprobien systems
- compare IBG and Saprobien band results with the three EQI bands

(ii) as noted in Chapter 8, the results of this analysis must be regarded as preliminary because (i) sampling for the European indices was only undertaken using RIVPACS methodologies (ii) the survey area was restricted only to the Thames Region. Further steps which develop this work further would clearly benefit from (i) use of appropriate survey methodologies and (ii) a sampling programme which covers a wider geographical range.

11. Conclusions and discussion

11.1 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 NRA Thames Region. 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 NRA 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.

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

11.2.1 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 NRA contracts.

11.2.2 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 NRA 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 also seems likely to have been complicated by other psychological factors, e.g. a tendency to 'hurry through' the first sample.

Between-sample bias does not have any significant implications for the NRA's current monitoring programme which uses single samples from each site, in each season. However, should a dual sampling strategy be implemented by the NRA, 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 11.6.

11.2.3 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 NRA, but randomisation at a local level, at least between seasons, for combined-sample assessments, would seem feasible.

In practice NRA 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, <u>differences</u> in the variability of samplers was not a significant effect.

11.2.4 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.

11.2.5 The relative contribution of season to variability

<u>Variability due to systematic trends between season</u>

Comparison of spring and autumn data across all sites showed that there was generally little difference between the biotic indices of <u>all</u> samples collected in autumn compared to <u>all</u> 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.

<u>Variability due to non-systematic differences between seasons.</u>

In contrast, most biotic indices did show a significant difference between their values at <u>any one</u> site in spring, and their values in autumn. In a sampling programme which collected samples in either spring <u>or</u> 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.

11.2.6 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.

11.2.7 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

11.3 Sampler variability when making RIVPACS assessments

There were no significant differences between the measurement of RIVPACS field variables (width, depth and substrate) made by different recorders. Not surprisingly, then, there were also 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 phi was ~0.22 units (it is not possible to calculate a coefficient of variation for phi.).

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 (phi) 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 NRA does not move to a policy of fixed RIVPACS variables, it would seem prudent to train operators in the consistent measurement of this variable.

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

11.4.1 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 has implications for the development of banding systems and is discussed further in Section 11.7.3.

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

At present, NRA 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 NRA 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.

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

As shown in Section 11.4.2 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).

11.5 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 NRA should take an index's ability to discriminate into account.

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

11.6.1 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

11. 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.

11.6.3 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.

11.7 Practical implications of these analyses

11.7.1 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 11.2.3 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 NRA, 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).

11.7.2 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 NRA 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 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 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 half 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.

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

The existing limitations of the 5M system have been recognised by NRA 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 of 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.

11.8 Comparison of the IBG, Saprobien and BMWP systems

11.8.1 Practical problems associated with harmonising biological water quality assessment

There are two main ways in which it may be possible to harmonise the assessment of biological water quality across the European Union (EU) Member States:

(i) all river sites throughout Europe could be assessed using the same system of scoring and banding, so that all results are directly comparable.

(ii) A correction factor could be applied to existing survey systems to make them comparable.

The advantages and disadvantages of these two approaches are outlined below.

11.8.2 All river sites throughout Europe are assessed using a single system of scoring and banding

The application of a Single European Index, used for all water quality monitoring across Europe, is an intuitively attractive option However, there are a number of constraints to such an approach. Indices used in any country are likely to be designed (a) to work with the taxonomic diversity of that country and (b) to reflect ecological relationships in rivers within that country. For example, the richness of river faunas is generally greater in continental Europe than in Britain or Ireland, making it difficult to apply a single index related to taxon richness throughout the Member States. Similarly, taxa may respond differently to pollutants across their European range, so that even index related scores (such as ASPT or saprobic index) would require further testing before they are reliably applied outside the country of origin.

In addition, this method would require that the existing sampling programmes of most/all countries would need to be modified or extended to derive data for the Single European Index.

11.8.3 Different survey methods have correction factors applied to them based on the known relationships between indices

The alternative to assessing all sites in the same way is to directly equate the data of existing European systems (see Table 11.1), using appropriate correction factors. This approach has been developed further in the present study.

Inter-calibration of existing indices used by different countries has three main advantages. First, UK sites are assessed using biological criteria appropriate to the UK and these can be directly compared with German sites assessed using criteria appropriate to Germany. Second, this approach is considerably less disruptive to existing sampling programmes. Finally, intercalibration should also allow retrospective comparisons of existing water quality data.

The principal disadvantage of index intercalibration is that it is difficult to ensure that sites which are regarded as the best (or worst) quality sites in one country would also be regarded as the best (or worst) in another.

The focus of this study has been to investigate the relationship between three nationally applied biotic indices (the UK 5M system, the French IBG system and the German Saprobien system).

Intercalibrations between these systems were undertaken at two levels:

(i) biotic indices were compared directly (e.g. BMWP.EQI, with IBG score, and saprobic index etc.) to see if they were mathematically related.

(ii) banding systems were compared (e.g. 5M bands were compared with Saprobien Classes I to IV) to assess whether what was termed 'good' in one country was 'good' in another.

11.8.4 Intercalibration of the UK data with the French and German systems.

The results from the preliminary analyses undertaken here suggested that:

(i) the IBG and EQI methodologies produce indices which are strongly correlated and the relationship between the indices appears to be linear.

Using existing data, it is therefore possible to predict IBG from BMWP EQIs and vice versa using the equations IBG = 8.817 BMWP.EQI + 2.121 for single-season data and IBG = 8.797 BMWP.EQI + 2.407 for combined-season data.

(iii) the Saprobien and EQI methodologies are not as similar as IBG & EQIs. However the two sets of results are still strongly correlated and the relationship is relatively linear.

Using existing data, the best prediction equations are: Saprobic index = -0.591 BMWP.EQI + 3.033 for single-season data and Saprobic index = -0.598 BMWP.EQI + 3.000 for combined-season data

Table 1.1 Countries using biotic score or index systems

Country	Index name	Method originally based on or modified from
Countries using the methods based on the biotic scores or indices		
Belgium	Belgian Biotic Index	Modified Trent Biotic Index and Indice Biotique
France	IBG	Modified Trent Biotic Index
Ireland	Q rating	Modified Trent Biotic Index
Italy	EBI	Modified Trent Biotic Index
Luxembourg	IB	Modified Trent Biotic Index
Portugal	(Trials of Belgian Biotic Index)	Modified Trent Biotic Index and Indice Biotique
Spain	(Trials of BMWP)	Chandler Score, plus average score per taxon
United Kingdom	BMWP	Chandler Score, plus average score per taxon
Countries using the methods based on the Saprobien system		
Denmark	Dansk Fauna Index	Modified saprobic score
Germany	Saprobic index	Saprobien system
Netherlands	K Index	Saprobien system

11.8.5 Differences in the banding of sites using three European systems

When sites were banded using their respective national systems, differences between band types became rather more apparent. The two main trends were:

(i) The 5M banding system tended to 'over-rate' sites, placing them into higher categories than the IBG and Saprobien banding systems. For example, samples graded 5M Band A were spread over the top 3 of 5 IBG bands and the 2nd and 3rd GI band, whilst about half of the samples placed in 5M band A were placed in Saprobien Class II-III, 'critically stressed'.

(ii) In addition, the Saprobien system, compressed the Thames Region sites into the centre of the banding system, with all sites confined to 3 bands of the 7 band system. This implied that the NRA Thames region sites were neither as good as the 'best' German sites, nor as bad as the worst. The Thames sites were confined to the Saprobien bands which, descriptively, are known as 'moderately stressed', 'critically stressed' and 'heavily polluted'[1].

Differences in the results given by the different systems could be due, either to real differences in perceptions of water quality, or to the imperfect correspondence of the indices and their respective banding systems. A number of factors could be responsible for the differences seen:

(i) The 5M system (which is currently being replaced) over-rated sites, placing them in too high a category. There is certainly some evidence that this occurred, since the 5M Band A is open ended, and many EQIs are well above the theoretical upper limit of the band. Effectively, Band A in 5M is at least twice as wide as the other bands.

(ii) The differences between the banding systems simply reflect a difference in the perception of pollution in the different countries.

(iii) The EQI system may overate sites because of the design of the RIVPACS database. RIVPACS makes the implicit assumption that the best available site is 'unpolluted'. Clearly, this is rarely true in lowland Britain, with many rivers which are generally regarded as being of high biological quality in fact carrying significant burdens of pollutants. 'High quality' sites in the Thames Region (such as the Thames itself) would be quite typical of this tendency. When run through the Saprobien system, or the IBG system, neither of which take any account of the expected fauna at a site, one might expect such sites to be relatively downgraded.

[1] Friedrich, G. (1990). *Eine revision des Saprobiensysytems.* Z. Wasser- Abwasser- Forsch. 23. 141-152.

(iv) Taxonomic differences between countries, which are inevitably taken account of in indices developed in particular countries, create biases when applied out of area. For example, if UK rivers of the same water quality naturally supported fewer taxa than French rivers, one would expect IBG scores for UK rivers to be lower than rivers of similar quality in France. Such an effect might be less expected with the Saprobien system and indeed in some ways the Saprobien could be considered to be producing less biased results in this study than the IBG. It is probably not unreasonable to regard the higher quality sites in this study as 'moderately' to 'critically stressed'.

(v) Using non-standard sampling methods for the IBG system and the Saprobien system could have significantly biased results. It is possible that the 3 minute RIVPACS sampling (used to collect samples for all the water quality assessments i.e. IBG and Saprobien as well as RIVPACS samples) collected fewer taxa than would be collected using the standard IBG methods (although from the literature description of methods these, this seems most unlikely).

At present, it is not possible to tell which of these factors is likely to be responsible for the differences seen. To establish what is really causing differences in responses it would be necessary to look at a series of sites where:

(i) samples were collected using the correct sampling method for the systems being investigated.

(ii) the biological data was related to chemical water quality data to determine how invertebrate communities were actually responding in different river systems.

11.9 Summary of suggestions for future work

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

11.9.1 Variability of the BMWP system and RIVPACS data

- 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 and pollutant 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.

11.9.2 Comparison of the European indices

- Comparison of European indices using data collected with sampling methods specific to its index type (rather than the RIVPACS sampling method which was used for all samples in this study)
- Comparison of European indices using data from sites spread over a wider range of water qualities, and in both Britain and mainland Europe.
- Correlation between, and calibration of, different European biotic indices with chemical water quality data.

- Investigation of the similarity of other European indices (e.g. Italian IBG, Danish Dansk Fauna Index)..

- Direct comparison of IBG and Saprobien indices using existing information gathered for this study.

- Further analysis, using existing data, to investigate the possibility of using existing family data routinely collected by the NRA (with and without estimated abundance) to directly calculate IBG scores or to use and saprobic indices to make estimations of EQIs.

APPENDICES

Appendix 1 Macroinvertebrates recorded in NRA methods study

Samples analysed for Saprobien Index

Site	Bow Brook							
Season	Autumn				Spring			
Sampler	JB		DW		JB		DW	
Sample	1	2	1	2	1	2	1	2
TRICLADIDA								
Planariidae	-	-	-	-	-	-	-	-
Polycelis felina		-				-		
Polycelis nigra		-				-		
Polycelis tenuis		-				-		
Dugesidae	-	-	-	-	-	-	-	-
Dendrocoelidae	-	2	-	1	-	-	-	-
Dendrocoelum lacteum		2				-		
Mollusca	227	736	228	396	36	51	173	13
Neritidae	-	-	-	-	-	-	-	-
Theodoxus fluviatilis		-				-		
Valvatidae	-	112	8	12	-	14	14	1
Valvata piscinalis		112				14		
Hydrobiidae	1	11	1	4	-	-	2	1
Potamopyrgus jenkinsi		11				-		
Bithyniidae	6	5	4	3	-	2	6	1
Bithynia tentaculata		5				2		
Physidae	2	4	-	1	-	-	-	-
Physa acuta		4				-		
Lymnaeidae	-	10	1	-	1	1	-	1
Planorbidae	196	588	197	358	34	25	145	5
Ancylidae & Acroloxidae	1	2	-	14	1	1	1	1
Ancylus fluviatilis		-				-		
Acroloxus lacustris		2				1		
Unionidae	5	3	1	-	-	4	2	1
Unio pictorum		-				-		
Anodonta anatina		3				4		
Sphaeriidae	16	1	16	4	-	4	3	2
Sphaerium corneum		1				4		
NEMATODA								
OLIGOCHAETA	144	40	80	40	240	35	196	240
Lumbriculus variegatus		-				-		
Branchiura sowerbyi		-				-		
Tubifex s.l.		20				20		
Limnodrilus spp.		-				-		
ACHAETA	3	5	9	7	5	9	13	4
Piscicolidae	1	-	-	-	-	-	2	-
Piscicola geometra		-				-		
Glossiphoniidae	-	-	2	4	1	3	7	3
Glossiphonia complanata		-				1		
Glossiphonia heteroclita		-				-		
Helobdella stagnalis		-				1		
Erpobdellidae	2	5	7	3	4	6	4	1
Erpobdella octoculata		5				6		
Erpobdella octoculata coccoon		-				-		
CRUSTACEA								
Asellidae	176	368	192	504	58	34	300	11
Asellus aquaticus		368				34		
Corophiidae	-	-	-	-	-	-	-	-
Gammaridae and Crangonyctidae	54	500	141	38	79	87	393	37
Gammarus pulex		498				75		

Appendix 1 (continued) Macroinvertebrates recorded in NRA methods study

Samples analysed for Saprobien Index

Site	Bow Brook							
Season	Autumn				Spring			
Sampler	JB		DW		JB		DW	
Sample	1	2	1	2	1	2	1	2
HYDRACARINA	2	40	9	32	23	1	64	7
EPHEMEROPTERA								
Baetidae	1	4	1	1	4	8	16	-
Baetis rhodani		-				8		
Baetis vernus		-				-		
Cloeon dipterum		4				-		
Heptageniidae	-	-	-	-	-	-	-	-
Heptagenia sulphurea		-				-		
Leptophlebiidae	-	-	-	-	-	4	2	-
Paraleptophlebia submarginata		-				4		
Ephemeridae	9	15	4	5	4	6	8	8
Ephemera danica		3				-		
Ephemerellidae	-	-	-	-	-	-	-	-
Ephemerella ignita		-				-		
Caenidae	-	32	-	64	3	20	97	3
PLECOPTERA								
Nemouridae	-	-	-	-	1	-	-	-
ODONATA								
Platycnemididae	1	1	-	-	5	-	-	-
Platycnemis pennipes		1				-		
Coenagriidae	24	5	29	15	15	2	6	6
Pyrrhosoma nymphula		2				-		
Calopterygidae								
Calopteryx splendens		3				1		
Gomphidae	-	-	-	-	-	-	-	-
HETEROPTERA								
Hydrometridae	-	-	-	-	-	-	-	-
Veliidae	-	-	-	-	-	-	1	-
Gerridae	-	-	-	-	-	-	-	-
Nepidae	-	-	-	-	-	1	-	-
Notonectidae	1	1	1	4	-	-	-	-
Corixidae	13	47	15	81	2	6	6	9
COLEOPTERA								
Haliplidae	-	1	1	-	3	-	2	-
Brychius elevatus		-				-		
Brychius elevatus (larva)		-				-		
Dytiscidae & Noteridae	2	9	4	17	8	3	6	1
Nebrioporus depressus (elegans)		1				2		
Oreodytes sanmarkii		-				-		
Platambus maculatus		-				-		
Platambus maculatus larva		-				-		
Gyrinidae	-	-	-	-	-	-	-	-
Orectochilus villosus (larva)		-				-		
Hydrophilidae and Hydraenidae	1	-	-	-	1	-	10	1
Hydrophilinae	1	-	-	-	1	-	2	1
Helophorinae	-	-	-	-	-	-	-	-
Hydraenidae	-	-	-	-	-	-	8	-
Elmidae	-	2	-	-	1	8	56	5
Limnius volckmari		-				-		
Limnius volckmari (larva)		-				-		
Oulimnius tuberculatus		2				-		

Appendix 1 (continued) Macroinvertebrates recorded in NRA methods study

Samples analysed for Saprobien Index

Site	Bow Brook							
Season	Autumn				Spring			
Sampler	JB		DW		JB		DW	
Sample	1	2	1	2	1	2	1	2
COLEOPTERA (continued)								
Helodidae	-	-	-	-	-	-	-	-
Dryopidae	-	-	-	-	-	-	-	-
Curculionidae	-	-	-	-	-	-	-	-
MEGALOPTERA								
Sialidae	144	181	145	71	68	142	67	63
Sialis lutaria		181				142		
Rhyacophilidae	-	-	-	-	-	-	-	-
Rhyacophila dorsalis		-				-		
Glossosomatidae	-	-	-	-	-	-	-	-
Hydroptilidae	-	-	-	-	-	1	-	-
Psychomyiidae	-	-	-	-	1	-	-	-
Polycentropodidae	-	-	-		-	-	-	-
Polycentropus spp.		-				-		
Hydropsychidae	-	-	-	-	-	4	1	1
Phryganeidae	-	-	-	1	-	1	-	-
Brachycentridae	-	-	-	-	-	-	-	-
Brachycentrus subnubilus		-				-		
Limnephilidae	-	-	-	1	1	21	5	2
Anabolia nervosa		-		1		1		
Goeridae	-	-	-	-	-	-	-	-
Goera pilosa		-				-		
Silo nigricornis		-				-		
Silo pallipes		-				-		
Beraeidae	-	-	-	-	-	-	-	-
Sericostomatidae	-	-	-	-	-	-	-	-
Sericostomatinae		-				-		
Molannidae	-	-	-	-	-	-	-	-
Leptoceridae	-	8	-	2	5	1	9	3
DIPTERA								
Ceraptogonidae	5		20	1	11	1	10	9
Sciomyzidae	-	-	-	-	-	-	-	-
Culicidae	-	-	-	-	-	-	-	-
Dolichopodidae	-	-	-	-	-	-	-	-
Ptychopteridae	-	-	-	-	-	-	-	-
Scathophagidae	-	-	-	-	-	-	-	-
Stratiomyiidae	-	-	-	-	-	-	-	-
Dixidae	-	-	-	-	-	-	-	-
Ephydridae	-	-	-	-	-	-	-	-
Syrphidae	-	-	-	-	-	-	-	-
Eristalis sp		-				-		
Muscidae	-	-	-	-	-	-	-	-
Athericidae & Rhagionidae	-	-	-	-	-	-	-	-
Psychodidae	-	-	-	-	-	-	-	-
Chironomidae	497	430	352	124	492	241	1028	449
Chironomus thummi agg.		-				12		
Chironomus plumosus agg.		-				-		
Tipulidae (excl Limoniinae)	-	2	-	-	-	-	5	-
Limoniinae	-	-	-	-	-	-	-	-
Simuliidae	-	-	-	-	1	-	-	1
Odagmia ornatum (larvae)		-				-		
Odagmia ornatum (pupae)		-				-		
PORIFERA								
Spongillidae	-	-	-	-	-	-	-	-
PISCES								
Cottus gobio		-				-		

Appendix 1

Samples analysed for Saprobien Index

Site	River Thames							
Season	Autumn				Spring			
Sampler	DW		RA		RA		JB	
Sample	1	2	1	2	1	2	1	2
TRICLADIDA								
Planariidae	-	1	-	-	-	1	1	2
Polycelis felina		-					-	
Polycelis nigra		-					-	
Polycelis tenuis		1					1	
Dugesiidae	-	-	-	-	1	-	-	-
Dendrocoelidae	-	-	-	-	-	2	-	1
Dendrocoelum lacteum		-					-	
Mollusca	38	252	49	184	81	122	69	366
Neritidae	1	2	1	-	1	12	3	2
Theodoxus fluviatilis		2					3	
Valvatidae	5	52	4	48	64	32	40	176
Valvata piscinalis		24					22	
Hydrobiidae	-	2	2	32	5	3	4	36
Potamopyrgus jenkinsi		2					4	
Bithyniidae	3	48	11	32	4	52	8	116
Bithynia tentaculata		8					4	
Physidae	5	16	-	4	-	8	4	3
Physa acuta		-					-	
Lymnaeidae	4	14	5	3	1	4	2	4
Planorbidae	13	42	22	35	2	1	3	5
Ancylidae & Acroloxidae	-	-	-	-	-	-	-	-
Ancylus fluviatilis		-					-	
Acroloxus lacustris		-					-	
Unionidae	-	-	1	2	2	1	1	-
Unio pictorum		-		1	1	1	-	
Anodonta anatina		-			1		1	
Sphaeriidae	7	76	3	28	2	9	4	24
Sphaerium corneum		76					4	
NEMATODA								
OLIGOCHAETA	13	3	9	9	85	11	45	20
Lumbriculus variegatus		-					10	
Branchiura sowerbyi		1					-	
Tubifex s.l.		-					5	
Limnodrilus spp.		-					5	
ACHAETA	1	12	2	16	5	8	5	11
Piscicolidae	-	2	-	-	-	-	-	-
Piscicola geometra		2					-	
Glossiphoniidae	1	9	-	4	3	5	4	10
Glossiphonia complanata		5					3	
Glossiphonia heteroclita		-					-	
Helobdella stagnalis		1					1	
Erpobdellidae	-	1	2	12	2	3	1	1
Erpobdella octoculata		1					1	
Erpobdella octoculata coccoon		-					-	
CRUSTACEA								
Asellidae	362	224	1001	252	460	80	308	242
Asellus aquaticus		224					302	
Corophiidae	5	1	-	4	24	2	24	3
Gammaridae and Crangonyctidae	296	140	190	68	50	52	175	52
Gammarus pulex		100					73	

Appendix 1 (continued)

Samples analysed for Saprobien Index

Site	River Thames							
Season	Autumn				Spring			
Sampler	DW		RA		RA		JB	
Sample	1	2	1	2	1	2	1	2
HYDRACARINA	1	1	1		2		2	64
EPHEMEROPTERA								
Baetidae	1	-	-	-	-	-	-	-
Baetis rhodani		-					-	
Baetis vernus		-					-	
Cloeon dipterum		-					-	
Heptageniidae	-	-	-	-	-	-	1	-
Heptagenia sulphurea		-					-	
Leptophlebiidae	-	-	-	-	-	-	-	-
Paraleptophlebia submarginata		-					-	
Ephemeridae	5	2	3	4	-	7	3	1
Ephemera danica		-					-	
Ephemerellidae	-	-	-	-	-	-	-	-
Ephemerella ignita		-					-	
Caenidae	4	5	2	6	12	-	20	1
PLECOPTERA								
Nemouridae	-	-	-	-	-	-	-	-
ODONATA								
Platycnemididae	-	-	-	-	-	-	-	-
Platycnemis pennipes		-					-	
Coenagriidae	1	1	-	4	1	-	-	-
Pyrrhosoma nymphula		-					-	
Calopterygidae								
Calopteryx splendens		4					2	
Gomphidae	-	-	-	2	-	-	-	-
HETEROPTERA								
Hydrometridae	-	1	-	-	-	-	-	-
Veliidae	-	-	-	-	-	-	-	-
Gerridae	-	-	-	-	-	-	-	-
Nepidae	-	-	-	-	-	-	-	-
Notonectidae	-	-	-	-	-	-	-	-
Corixidae		-	-	1	1	-	2	1
COLEOPTERA								
Haliplidae	-	-	-	-	-	-	1	1
Brychius elevatus		-					-	
Brychius elevatus (larva)		-					-	
Dytiscidae & Noteridae	-	1	1	1	-	-	3	-
Nebrioporus depressus (elegans)		1					1	
Oreodytes sanmarkii		-					-	
Platambus maculatus		-					-	
Platambus maculatus larva		-					1	
Gyrinidae	-	1	2	1	-	-	-	-
Orectochilus villosus (larva)		-					-	
Hydrophilidae and Hydraenidae	-	-	2	-	-	-	1	1
Hydrophilinae	-	-	2	-	-	-	-	1
Helophorinae	-	-	-	-	-	-	1	-
Hydraenidae	-	-	-	-	-	-	-	-
Elmidae	-	1	-	-	-	-	2	2
Limnius volckmari		-					-	
Limnius volckmari (larva)		-					-	
Oulimnius tuberculatus		1					-	

Appendix 1 (continued)

Samples analysed for Saprobien Index

Site	River Thames							
Season	Autumn				Spring			
Sampler	DW		RA		RA		JB	
Sample	1	2	1	2	1	2	1	2
COLEOPTERA (continued)								
Helodidae	-	-	-	-	-	-	-	-
Dryopidae	-	-	-	1	-	-	-	-
Curculionidae	1	-	-	-	-	-	-	-
MEGALOPTERA								
Sialidae	4	3	14	6	-	13	4	1
Sialis lutaria		3					4	
Rhyacophilidae	-	-	-	-	-	-	-	-
Rhyacophila dorsalis		-					-	
Glossosomatidae	-	-	-	-	-	-	-	-
Hydroptilidae	-	-	-	-	-	-	2	-
Psychomyiidae	-	1	-	1	-	1	1	2
Polycentropodidae	1	4	-	5	1	1	3	1
Polycentropus spp.		-					-	
Hydropsychidae	-	1	-	-	-	-	-	-
Phryganeidae	-	-	-	-	-	-	-	-
Brachycentridae	-	-	-	-	-	-	-	-
Brachycentrus subnubilus		-					-	
Limnephilidae	3		-	3	17	7	10	10
Anabolia nervosa		-					-	
Goeridae	-	-	-	-	-	-	-	-
Goera pilosa		-					-	
Silo nigricornis		-					-	
Silo pallipes		-					-	
Beraeidae	-	-	-	-	-	-	-	-
Sericostomatidae	-	-	-	-	-	-	-	-
Sericostomatinae		-					-	
Molannidae	-	-	1	5	-	-	8	-
Leptoceridae	5	13	4	4	13	4	46	4
DIPTERA								
Ceraptogonidae				9	2	9	1	48
Sciomyzidae	1	-	-	4	-	-	-	-
Culicidae	-	-	-	-	-	-	-	-
Dolichopodidae	-	-	-	-	-	-	-	-
Ptychopteridae	-	-	-	-	-	-	-	-
Scathophagidae	-	-	-	1	-	-	-	-
Stratiomyiidae	-	-	-	-	-	-	-	-
Dixidae	-	-	-	-	-	-	-	-
Ephydridae	-	-	-	-	-	-	-	-
Syrphidae	-	1	-	-	-	-	-	-
Eristalis sp		-					-	
Muscidae	-	-	-	-	-	-	-	-
Athericidae & Rhagionidae	-	-	-	-	-	1	-	-
Psychodidae	-	-	-	-	-	-	1	-
Chironomidae	78	94	240	243	110	220	152	28
Chironomus thummi agg.		-					-	
Chironomus plumosus agg.		-					-	
Tipulidae (excl Limoniinae)	2	11	17	3	1	3	1	-
Limoniinae	-	-	-	-	-	-	-	-
Simuliidae	-	-	-	-	-	1	2	1
Odagmia ornatum (larvae)		-					-	
Odagmia ornatum (pupae)		-					-	
PORIFERA								
Spongillidae	-	-	-	-	-	-	-	-
PISCES								
Cottus gobio		-					-	

Appendix 1

Samples analysed for Saprobien Index

Site	River Coln							
Season	Autumn				Spring			
Sampler	DW		MW		JB		RA	
Sample	1	2	1	2	1	2	1	2
TRICLADIDA								
Planariidae	1	1	-	-	-	1	-	-
Polycelis felina				-	-			
Polycelis nigra				-	-			
Polycelis tenuis				-	-			
Dugesiidae	-	-	-	-	-	-	-	-
Dendrocoelidae	-	-	-	-	-	-	-	-
Dendrocoelum lacteum				-	-			
Mollusca	211	104	140	65	50	187	16	387
Neritidae	-	-	-	-	-	-	-	-
Theodoxus fluviatilis				-	-			
Valvatidae	3	5	16	5	3	12	1	1
Valvata piscinalis				5	2			
Hydrobiidae	144	53	32	40	19	144	8	368
Potamopyrgus jenkinsi				40	19			
Bithyniidae	-	-	-	-	-	-	-	-
Bithynia tentaculata				-	-			
Physidae	-	-	2	-	-	2	1	4
Physa acuta				-	-			
Lymnaeidae	-	1	2	6	-	-	-	2
Planorbidae	3	2	44	6	6	3	1	2
Ancylidae & Acroloxidae	29	28	32	6	20	8	5	6
Ancylus fluviatilis				6	20			
Acroloxus lacustris				-	-			
Unionidae	-	-	-	-	-	-	-	-
Unio pictorum				-	-			
Anodonta anatina				-	-			
Sphaeriidae	32	15	12	2		18	-	4
Sphaerium corneum				2	2			
NEMATODA								
OLIGOCHAETA	300	40	100	44	4222	11	2009	11
Lumbriculus variegatus				-	-			
Branchiura sowerbyi				-	-			
Tubifex s.l.				-	150			
Limnodrilus spp.				-	-			
ACHAETA	285	22	45	7	55	47	21	56
Piscicolidae	4	1	6	1	3	3	5	3
Piscicola geometra				1	3			
Glossiphoniidae	280	20	39	6	50	44	16	52
Glossiphonia complanata				5	50			
Glossiphonia heteroclita				-	-			
Helobdella stagnalis				1	-			
Erpobdellidae	1	1	-	-	2	-	-	1
Erpobdella octoculata				-	2			
Erpobdella octoculata coccoon				-	-			
CRUSTACEA								
Asellidae	-	-	-	1	-	-	1	1
Asellus aquaticus				1	-			
Corophiidae	-	-	-	-	-	-	-	-
Gammaridae and Crangonyctidae	8640	2000	2912	3100	2572	2752	2091	3088
Gammarus pulex				3100	2572			

Appendix 1 (continued)

Samples analysed for Saprobien Index

Site	River Coln							
Season	Autumn				Spring			
Sampler	DW		MW		JB		RA	
Sample	1	2	1	2	1	2	1	2
HYDRACARINA	16	1	20	28		3		1
EPHEMEROPTERA								
Baetidae	30	32	312	92	228	152	360	256
Baetis rhodani				76	228			
Baetis vernus				16	-			
Cloeon dipterum				-	-			
Heptageniidae	-	-	-	-	1	1	1	1
Heptagenia sulphurea				-	1			
Leptophlebiidae	1	2	4	2	4	-	-	-
Paraleptophlebia submarginata				2	4			
Ephemeridae	31	34	68	46	86	88	35	96
Ephemera danica				46	70			
Ephemerellidae	-	1	-	-		-	8	-
Ephemerella ignita				-	4			
Caenidae	5	1	1	7	-	3	12	-
PLECOPTERA								
Nemouridae	-	1	-	-	8	5	76	4
ODONATA								
Platycnemididae	-	-	-	-	-	-	-	-
Platycnemis pennipes				-	-			
Coenagriidae	-	-	-	1	-	-	-	-
Pyrrhosoma nymphula				-	-			
Calopterygidae								
Calopteryx splendens				-	-			
Gomphidae	-	-	-	-	-	-	-	-
HETEROPTERA								
Hydrometridae	-	-	1	-	-	-	-	-
Veliidae	-	-	-	-	-	-	-	-
Gerridae	-	-	-	-	-	-	-	-
Nepidae	-	-	-	-	-	-	-	-
Notonectidae	-	-	-	1	-	-	-	-
Corixidae	6	1	1	4	1	1	1	-
COLEOPTERA								
Haliplidae	2	3	3	2	-	1	2	-
Brychius elevatus				1	-			
Brychius elevatus (larva)				-	-			
Dytiscidae & Noteridae	12	4	13	5	1	-	1	-
Nebrioporus depressus (elegans)				-	-			
Oreodytes sanmarkii				4	-			
Platambus maculatus				-	-			
Platambus maculatus larva				-	-			
Gyrinidae	3	1	-	-	20	1	-	1
Orectochilus villosus (larva)				-	20			
Hydrophilidae and Hydraenidae	2	-	3	2	-	1	-	1
Hydrophilinae	-	-	2	2	-	-	-	-
Helophorinae	-	-	-	-	-	-	-	-
Hydraenidae	2	-	1	-	-	1	-	1
Elmidae	337	14	23	108	212	368	102	256
Limnius volckmari				8	4			
Limnius volckmari (larva)				-	-			
Oulimnius tuberculatus				-	4			

Appendix 1 (continued)

Samples analysed for Saprobien Index

Site	River Coln							
Season	Autumn				Spring			
Sampler	DW		MW		JB		RA	
Sample	1	2	1	2	1	2	1	2
COLEOPTERA (continued)								
Helodidae	-	-	-	-	-	-	-	-
Dryopidae	-	1	-	-	12	2	14	6
Curculionidae	-	-	-	-	-	-	-	-
MEGALOPTERA								
Sialidae	1	-	-	-	-	-	-	-
Sialis lutaria				-	-			
Rhyacophilidae	8	8	3	4	64	6	20	12
Rhyacophila dorsalis				4	64			
Glossosomatidae	448	24	2	1	272	288	88	480
Hydroptilidae	-	1	-	-	48	-	-	3
Psychomyiidae	-	-	-	-	-	-	-	-
Polycentropodidae	-	-	-	-	-	-	-	1
Polycentropus spp.				-	-			
Hydropsychidae	33	23	16	7	92	8	44	13
Phryganeidae	-	-	-	-	-	-	-	-
Brachycentridae	-	1	-	-	8	2	-	16
Brachycentrus subnubilus				-	8			
Limnephilidae	8	5	118	25	401	77	526	266
Anabolia nervosa				-	-			
Goeridae	1124	168	96	45	240	696	328	752
Goera pilosa				1	-			
Silo nigricornis				44	176			
Silo pallipes				-	64			
Beraeidae	-	-	2	-	-	-	-	-
Sericostomatidae	5	8	1	-	48			
Sericostomatinae				-	48			
Molannidae	-	-	-	-	-	-	-	-
Leptoceridae	-	-	-	-	16	1	-	2
DIPTERA								
Ceraptogonidae	3	1	2		1	3		1
Sciomyzidae	-	-	-	-	-	-	-	-
Culicidae	-	-	-	-	-	-	-	-
Dolichopodidae	-	-	-	-	-	-	-	-
Ptychopteridae	-	1	-	-	-	-	-	-
Scathophagidae	-	-	-	-	-	-	-	-
Stratiomyiidae	1	-	-	-	-	-	-	-
Dixidae	-	1	14	1	-	-	-	-
Ephydridae	-	-	-	-	-	-	-	-
Syrphidae	-	-	-	-	-	-	-	-
Eristalis sp				-	-			
Muscidae	-	-	-	-	-	-	-	-
Athericidae & Rhagionidae	-	-	-	-	2	-	-	-
Psychodidae	-	1	1	-	-	1	-	-
Chironomidae	10	1	6	28	40	10	32	15
Chironomus thummi agg.				-	-			
Chironomus plumosus agg.				-	-			
Tipulidae (excl Limoniinae)	-	1	1	-		1	-	1
Limoniinae	2	5	1	1	5	2	-	-
Simuliidae	-	4	10	1	1005	1	324	1
Odagmia ornatum (larvae)				1	307			
Odagmia ornatum (pupae)				-	56			
PORIFERA								
Spongillidae	-	-	-	-	-	-	-	-
PISCES								
Cottus gobio				1	4			

Appendix 1

Samples analysed for Saprobien Index

Site	The Cut							
Season	Autumn				Spring			
Sampler	JB		RA		MW		RA	
Sample	1	2	1	2	1	2	1	2
TRICLADIDA								
Planariidae	2	-	2	2	1	4	-	24
Polycelis felina				-	-			
Polycelis nigra				-	-			
Polycelis tenuis				1	-			
Dugesidae	-	-	-	-	-	-	-	-
Dendrocoelidae	1	-	2	1	-	-	3	-
Dendrocoelum lacteum				1	-			
Mollusca	192	167	151	198	40	12	8	7
Neritidae	-	-	-	-	-	-	-	-
Theodoxus fluviatilis				-	-			
Valvatidae	-	-	1	-	-	-	-	-
Valvata piscinalis				-	-			
Hydrobiidae	-	-	12	-	1	2	-	-
Potamopyrgus jenkinsi				-	1			
Bithyniidae	1	2	7	2	-	1	-	1
Bithynia tentaculata				2	-			
Physidae	168	144	76	160	32	4	6	1
Physa acuta				-	-			
Lymnaeidae	9	7	17	12	5	1	1	5
Planorbidae	13	13	36	23	2	4	1	-
Ancylidae & Acroloxidae	-	-	-	-	-	-	-	-
Ancylus fluviatilis				-	-			
Acroloxus lacustris				-	-			
Unionidae	-	-	-	-	-	-	-	-
Unio pictorum				-	-			
Anodonta anatina				-	-			
Sphaeriidae	1	1	2	1	-	-	-	-
Sphaerium corneum	1	1	2	1	-			
NEMATODA								
OLIGOCHAETA	7	20	20	41	32	500	200	48
Lumbriculus variegatus				2	4			
Branchiura sowerbyi				-	-			
Tubifex s.l.				20	14			
Limnodrilus spp.				13	10			
ACHAETA	114	304	111	376	47	98	324	232
Piscicolidae	-	-	-	-	-	-	-	-
Piscicola geometra				-	-			
Glossiphoniidae	8	32	23	87	3	8	20	23
Glossiphonia complanata				14	2			
Glossiphonia heteroclita				64	1			
Helobdella stagnalis				-	-			
Erpobdellidae	106	272	88		44	90	304	209
Erpobdella octoculata				288	44			
Erpobdella octoculata coccoon				-	-			
CRUSTACEA								
Asellidae	832	2256	720	2464	368	1028	542	1472
Asellus aquaticus				2464	368			
Corophiidae	-	-	-	-	-	-	-	-
Gammaridae and Crangonyctidae	4	9	12	2	10	8	16	8
Gammarus pulex				2	8			

Appendix 1 (continued)

Samples analysed for Saprobien Index

Site	The Cut							
Season	Autumn				Spring			
Sampler	JB		RA		MW		RA	
Sample	1	2	1	2	1	2	1	2
HYDRACARINA	6	1	8	5			1	
EPHEMEROPTERA								
Baetidae	-	8	4	7	-	-	-	-
Baetis rhodani				7	-			
Baetis vernus				-	-			
Cloeon dipterum				-	-			
Heptageniidae	-	-	-	-	-	-	-	-
Heptagenia sulphurea				-	-			
Leptophlebiidae	-	-	-	-	-	-	-	-
Paraleptophlebia submarginata				-	-			
Ephemeridae	-	-	-	-	-	-	-	-
Ephemera danica				-	-			
Ephemerellidae	-	-	-	-	-	-	-	-
Ephemerella ignita				-	-			
Caenidae	-	-	1	1	-	-	-	-
PLECOPTERA								
Nemouridae	-	-	-	-	-	-	-	-
ODONATA								
Platycnemididae	-	-	-	-	-	-	-	-
Platycnemis pennipes				-	-			
Coenagriidae	20	12	21	5	5	9	-	3
Pyrrhosoma nymphula				1	-			
Calopterygidae								
Calopteryx splendens				1	-			
Gomphidae	-	-	-	-	-	-	-	-
HETEROPTERA								
Hydrometridae	-	-	-	-	-	-	-	-
Veliidae	-	-	-	-	-	-	-	-
Gerridae	-	-	-	-	-	-	-	-
Nepidae	-	-	-	-	-	-	-	-
Notonectidae	-	-	-	-	-	-	-	-
Corixidae	-	-	-	-	1	-	-	-
COLEOPTERA								
Haliplidae	-	7	2	1	-	-	-	1
Brychius elevatus				-	-			
Brychius elevatus (larva)				-	-			
Dytiscidae & Noteridae	-	-	-	-	-	-	-	-
Nebrioporus depressus (elegans)				-	-			
Oreodytes sanmarkii				-	-			
Platambus maculatus				-	-			
Platambus maculatus larva				-	-			
Gyrinidae	-	-	-	-	-	-	-	-
Orectochilus villosus (larva)				-	-			
Hydrophilidae and Hydraenidae	-	-	-	1	-	-	-	-
Hydrophilinae	-	-	-	1	-	-	-	-
Helophorinae	-	-	-	-	-	-	-	-
Hydraenidae	-	-	-	-	-	-	-	-
Elmidae	1	-	-	1	-	-	-	-
Limnius volckmari				-	-			
Limnius volckmari (larva)				-	-			
Oulimnius tuberculatus				-	-			

Appendix 1 (continued)

Samples analysed for Saprobien Index

Site	The Cut							
Season	Autumn				Spring			
Sampler	JB		RA		MW		RA	
Sample	1	2	1	2	1	2	1	2
COLEOPTERA (continued)								
Helodidae	-	-	-	-	-	-	-	-
Dryopidae	-	-	-	-	-	-	-	-
Curculionidae	-	1	-	-	-	-	-	-
MEGALOPTERA								
Sialidae	-	-	-	-	-	-	-	-
Sialis lutaria				-	-			
Rhyacophilidae	-	-	-	-	-	-	-	-
Rhyacophila dorsalis				-	-			
Glossosomatidae	-	-	-	-	-	-	-	-
Hydroptilidae	-	-	-	-	-	-	-	-
Psychomyiidae	-	-	-	-	-	-	-	-
Polycentropodidae	-	-	-	-	-	-	-	-
Polycentropus spp.				-	-			
Hydropsychidae	6	13	4	6	-	1	1	8
Phryganeidae	-	-	-	-	-	-	-	-
Brachycentridae	-	-	-	-	-	-	-	-
Brachycentrus subnubilus				-	-			
Limnephilidae	-	-	-	-	-	1	-	-
Anabolia nervosa				-	-			
Goeridae	-	-	-	-	-	-	-	-
Goera pilosa				-	-			
Silo nigricornis				-	-			
Silo pallipes				-	-			
Beraeidae	-	-	-	-	-	-	-	-
Sericostomatidae	-	-	-	-	-	-	-	-
Sericostomatinae				-	-			
Molannidae	-	-	-	-	-	-	-	-
Leptoceridae	-	-	-	-	-	-	-	-
DIPTERA								
Ceraptogonidae	3	1	4	32	5	1		64
Sciomyzidae	-	-	-	-	-	-	-	-
Culicidae	-	-	-	-	-	-	-	-
Dolichopodidae	-	-	-	-	-	-	-	-
Ptychopteridae	-	-	-	-	-	-	-	-
Scathophagidae	-	-	-	-	-	-	-	-
Stratiomyiidae	1	-	-	1	-	-	-	-
Dixidae	-	-	-	-	-	-	-	-
Ephydridae	-	-	-	-	-	-	-	-
Syrphidae	-	-	-	-	-	-	-	-
Eristalis sp				-	-			
Muscidae	3	-	2	2	-	4	6	2
Athericidae & Rhagionidae	-	-	-	-	-	-	-	-
Psychodidae	-	-	-	-	-	-	-	-
Chironomidae	4	5	4	11	48	200	30	24
Chironomus thummi agg.				-	-			
Chironomus plumosus agg.				-	-			
Tipulidae (excl Limoniinae)	1	-	1	6	-	-	-	2
Limoniinae	-	-	-	-	-	-	-	-
Simuliidae	1	-	1	-	-	-	-	-
Odagmia ornatum (larvae)				-	-			
Odagmia ornatum (pupae)				-	-			
PORIFERA								
Spongillidae	8	8	8	8	-	-	-	-
PISCES								
Cottus gobio				-	-			

Appendix 1

Samples analysed for Saprobien Index

Site	Lydiard Brook							
Season	Autumn				Spring			
Sampler	DW		MW		JB		DW	
Sample	1	2	1	2	1	2	1	2
TRICLADIDA								
Planariidae	-	-	-	-	-	-	-	-
Polycelis felina	-				-			
Polycelis nigra	-				-			
Polycelis tenuis	-				-			
Dugesidae	-	-	-	-	-	-	-	-
Dendrocoelidae	-	-	-	-	-	-	-	-
Dendrocoelum lacteum	-				-			
Mollusca	8647	5520	5148	1134	2349	3351	2144	2640
Neritidae	-	-	-	-	-	-	-	-
Theodoxus fluviatilis	-				-			
Valvatidae	-	-	3	-	1	-	-	2
Valvata piscinalis	-				1			
Hydrobiidae	2106	292	1000	152	172	904	204	144
Potamopyrgus jenkinsi	2106				172			
Bithyniidae	-	-	3	-	-	-	-	-
Bithynia tentaculata	-				-			
Physidae	-	-	-	-	-	-	-	-
Physa acuta	-				-			
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	-	-
Ancylus fluviatilis	-				-			
Acroloxus lacustris	1				-			
Unionidae	18	44	9	5	7	22	13	13
Unio pictorum	-				-			
Anodonta anatina	18				7			
Sphaeriidae	6000	5120	3886	896	2117	2416	1862	2464
Sphaerium corneum	6000				2117			
NEMATODA								
OLIGOCHAETA	508	1	100	32	304	76	13	668
Lumbriculus variegatus	-				-			
Branchiura sowerbyi	-				-			
Tubifex s.l.	296				236			
Limnodrilus spp.	32				36			
ACHAETA	6	21	4	5	31	10	27	9
Piscicolidae	-	-	-	-	-	-	-	-
Piscicola geometra	-				-			
Glossiphoniidae	6	17	2	4	19	4	18	8
Glossiphonia complanata	4				18			
Glossiphonia heteroclita	-				-			
Helobdella stagnalis	1				1			
Erpobdellidae	-	4	2	1	12	6	9	1
Erpobdella octoculata	-				7			
Erpobdella octoculata coccoon	-				-			
CRUSTACEA								
Asellidae	6	1	9	2	27	16	20	24
Asellus aquaticus	6				27			
Corophiidae	-	-	-	-	-	-	-	-
Gammaridae and Crangonyctidae	214	16	21	6	74	102	81	184
Gammarus pulex	214				74			

Appendix 1 (continued)

Samples analysed for Saprobien Index

Site	Lydiard Brook							
Season	Autumn				Spring			
Sampler	DW		MW		JB		DW	
Sample	1	2	1	2	1	2	1	2
HYDRACARINA		3	1	2	1		5	1
EPHEMEROPTERA								
Baetidae	-	-	-	-	6	17	8	16
Baetis rhodani	-				6			
Baetis vernus	-				-			
Cloeon dipterum	-				-			
Heptageniidae	-	-	-	-	-	-	-	-
Heptagenia sulphurea	-				-			
Leptophlebiidae	-	-	-	-	-	-	-	-
Paraleptophlebia submarginata	-				-			
Ephemeridae	-	-	-	-	-	1	-	-
Ephemera danica	-				-			
Ephemerellidae	-	-	-	-	-	-	-	-
Ephemerella ignita	-				-			
Caenidae	-	-	-	1	3	-	1	8
PLECOPTERA								
Nemouridae	-	-	-	-	-	-	-	-
ODONATA								
Platycnemididae	-	-	-	-	-	-	-	-
Platycnemis pennipes	-				-			
Coenagriidae	-	-	-	1	2	-	1	2
Pyrrhosoma nymphula	-				-			
Calopterygidae								
Calopteryx splendens	5				13			
Gomphidae	-	-	-	-	-	-	-	-
HETEROPTERA								
Hydrometridae	1	-	-	-	-	-	-	-
Veliidae	1	1	1	2	-	1	-	-
Gerridae	-	1	-	-	-	-	-	-
Nepidae	-	-	-	-	-	-	-	-
Notonectidae	-	-	-	-	-	-	-	-
Corixidae	1	-	6	-	34	13	15	34
COLEOPTERA								
Haliplidae	2	-	3	3	7	6	4	6
Brychius elevatus	1				2			
Brychius elevatus (larva)	-				-			
Dytiscidae & Noteridae	-	1	-	3	8	6	3	3
Nebrioporus depressus (elegans)	-				6			
Oreodytes sanmarkii	-				-			
Platambus maculatus	-				-			
Platambus maculatus larva	-				-			
Gyrinidae	-	-	-	-	-	-	-	-
Orectochilus villosus (larva)	-				-			
Hydrophilidae and Hydraenidae	-	-	-	1	3	-	2	-
Hydrophilinae	-	-	-	1	3	-	2	-
Helophorinae	-	-	-	-	-	-	-	-
Hydraenidae	-	-	-	-	-	-	-	-
Elmidae	133	9	12	26	11	48	23	240
Limnius volckmari	-				-			
Limnius volckmari (larva)	-				-			
Oulimnius tuberculatus	8				1			

Appendix 1 (continued)

Samples analysed for Saprobien Index

Site	Lydiard Brook							
Season	Autumn				Spring			
Sampler	DW		MW		JB		DW	
Sample	1	2	1	2	1	2	1	2
COLEOPTERA (continued)								
Helodidae	-		-	-	-	-	-	-
Dryopidae	-	-	-	-	-	-	-	-
Curculionidae	-	-	-	-	-	-	-	-
MEGALOPTERA								
Sialidae	11	12	5	14	52	12	11	13
Sialis lutaria	11				52			
Rhyacophilidae	-	-	-	-	-	-	-	-
Rhyacophila dorsalis	-				-			
Glossosomatidae	-	-	-	-	-	-	-	-
Hydroptilidae	-	-	-	-	-	-	-	-
Psychomyiidae	-	-	-	2	1	-	-	-
Polycentropodidae	-	-	-	-	-	-	-	-
Polycentropus spp.	-				-			
Hydropsychidae	380	80	21	-	200	30	174	53
Phryganeidae	-	-	-	-	-	-	-	-
Brachycentridae	-	-	-	-	-	-	-	-
Brachycentrus subnubilus	-				-			
Limnephilidae	2	3	5	4	108	94	150	38
Anabolia nervosa	-				48			
Goeridae	-	-	-	-	-	-	-	-
Goera pilosa	-				-			
Silo nigricornis	-				-			
Silo pallipes	-				-			
Beraeidae	-	-	-	-	-	-	-	-
Sericostomatidae	-	-	-	-	-	-	-	-
Sericostomatinae	-				-			
Molannidae	-	-	-	-	-	-	-	-
Leptoceridae	-	-	-	-	1	8	1	1
DIPTERA								
Ceraptogonidae		1		1	7		5	
Sciomyzidae	2	-	-	-	-	-	-	-
Culicidae	-	-	-	-	-	-	-	-
Dolichopodidae	-	-	-	-	-	-	-	-
Ptychopteridae	-	-	-	-	-	-	-	-
Scathophagidae	-	-	-	-	-	-	-	-
Stratiomyiidae	-	-	-	-	-	-	-	-
Dixidae	-	-	-	-	-	-	-	-
Ephydridae	-	-	-	-	-	-	-	-
Syrphidae	-	-	-	-	-	-	-	-
Eristalis sp	-				-			
Muscidae	-	-	-	-	-	-	-	-
Athericidae & Rhagionidae	-	-	-	-	-	-	-	-
Psychodidae	-	-	1	2	-	1	1	-
Chironomidae	54	29	72	36	510	104	456	540
Chironomus thummi agg.	-				-			
Chironomus plumosus agg.	-				-			
Tipulidae (excl Limoniinae)	2	-	2	-	2	2	1	2
Limoniinae	-	-	-	-	2	-	2	3
Simuliidae	1	5	1	2	1	-	1	-
Odagmia ornatum (larvae)	-				-			
Odagmia ornatum (pupae)	-				-			
PORIFERA								
Spongillidae	-	-	-	-	-	-	-	-
PISCES								
Cottus gobio	1				-			

Appendix 1

Samples analysed for Saprobien Index

Site	Halfacre Brook							
Season	Autumn				Spring			
Sampler	JB		RA		JB		MW	
Sample	1	2	1	2	1	2	1	2
TRICLADIDA								
Planariidae	-	-	-	-	-	-	-	-
Polycelis felina			-					-
Polycelis nigra			-					-
Polycelis tenuis			-					-
Dugesidae	-	-	-	-	-	-	-	-
Dendrocoelidae	-	-	-	-	-	-	-	-
Dendrocoelum lacteum			-					-
Mollusca	3	0	0	14	7	20	13	3
Neritidae	-	-	-	-	-	-	-	-
Theodoxus fluviatilis			-					-
Valvatidae	-	-	-	9	6	20	12	3
Valvata piscinalis			-					-
Hydrobiidae	-	-	-	-	-	-	-	-
Potamopyrgus jenkinsi			-					-
Bithyniidae	-	-	-	-	-	-	-	-
Bithynia tentaculata			-					-
Physidae	-	-	-	-	-	-	-	-
Physa acuta			-					-
Lymnaeidae	3	-	-	5	1	-	1	-
Planorbidae	-	-	-	-	-	-	-	-
Ancylidae & Acroloxidae	-	-	-	-	-	-	-	-
Ancylus fluviatilis			-					-
Acroloxus lacustris			-					-
Unionidae	-	-	-	-	-	-	-	-
Unio pictorum			-					-
Anodonta anatina			-					-
Sphaeriidae	-	-	-	-	-	-	-	-
Sphaerium corneum			-					-
NEMATODA								
OLIGOCHAETA	4	1	12	1	49	50	50	15
Lumbriculus variegatus			3					9
Branchiura sowerbyi			-					-
Tubifex s.l.			6					-
Limnodrilus spp.			-					6
ACHAETA	1	-	3	2	2	4	4	3
Piscicolidae	-	-	-	-	1	1	2	2
Piscicola geometra			-					2
Glossiphoniidae	1	-	3	2	1	3	2	-
Glossiphonia complanata			3					-
Glossiphonia heteroclita			-					-
Helobdella stagnalis			-					-
Erpobdellidae	-	-	-	-	-	-	-	1
Erpobdella octoculata			-					-
Erpobdella octoculata coccoon			-					-
CRUSTACEA								
Asellidae	8	8	4	6	35	50	35	30
Asellus aquaticus			-					-
Corophiidae	-	-	-	-	-	-	-	-
Gammaridae and Crangonyctidae	504	208	105	348	100	120	104	150
Gammarus pulex			105					150

Appendix 1 (continued)

Samples analysed for Saprobien Index

Site	Halfacre Brook							
Season	Autumn				Spring			
Sampler	JB		RA		JB		MW	
Sample	1	2	1	2	1	2	1	2
HYDRACARINA		1	2					20
EPHEMEROPTERA								
Baetidae	-	-	-	-	-	-	-	-
Baetis rhodani			-					-
Baetis vernus			-					-
Cloeon dipterum			-					-
Heptageniidae	-	-	-	-	-	-	-	-
Heptagenia sulphurea			-					-
Leptophlebiidae	-	-	-	-	-	-	-	-
Paraleptophlebia submarginata			-					-
Ephemeridae	-	-	5	1	-	2	1	1
Ephemera danica			5					-
Ephemerellidae	-	-	-	-	-	-	-	-
Ephemerella ignita			-					-
Caenidae	-	-	-	-	-	-	-	-
PLECOPTERA								
Nemouridae	-	-	-	-	-	-	-	-
ODONATA								
Platycnemididae	-	-	-	-	-	-	-	-
Platycnemis pennipes			-					-
Coenagriidae	3	22	7	14	4	5	4	4
Pyrrhosoma nymphula			7					4
Calopterygidae								
Calopteryx splendens			-					-
Gomphidae	-	-	-	-	-	-	-	-
HETEROPTERA								
Hydrometridae	-	-	-	-	-	-	-	-
Veliidae	-	-	-	-	-	-	-	-
Gerridae	-	-	-	-	-	-	-	-
Nepidae	-	-	-	-	-	-	-	-
Notonectidae	-	-	-	-	-	-	-	-
Corixidae	-	-	-	-	-	-	-	-
COLEOPTERA								
Haliplidae	-	-	-	-	-	-	-	-
Brychius elevatus			-					-
Brychius elevatus (larva)			-					-
Dytiscidae & Noteridae	3	1	3	-	-	4	1	4
Nebrioporus depressus (elegans)			-					-
Oreodytes sanmarkii			-					-
Platambus maculatus			-					-
Platambus maculatus larva			-					-
Gyrinidae	-	-	-	-	-	-	-	-
Orectochilus villosus (larva)			-					-
Hydrophilidae and Hydraenidae	-	3	-	-	4	1	6	2
Hydrophilinae	-	3	-	-	4	-	6	2
Helophorinae	-	-	-	-	-	1	-	-
Hydraenidae	-	-	-	-	-	-	-	-
Elmidae	-	-	-	-	-	-	-	-
Limnius volckmari			-					-
Limnius volckmari (larva)			-					-
Oulimnius tuberculatus			-					-

Appendix 1 (continued)

Samples analysed for Saprobien Index

Site	Halfacre Brook							
Season	Autumn				Spring			
Sampler	JB		RA		JB		MW	
Sample	1	2	1	2	1	2	1	2
COLEOPTERA (continued)								
Helodidae	-	-	-	-	-	-	-	-
Dryopidae	-	-	-	-	-	-	-	-
Curculionidae	-	-	-	-	-	-	-	-
MEGALOPTERA								
Sialidae	-	-	3	4	1	8	2	2
Sialis lutaria			3					2
Rhyacophilidae	-	-	-	-	-	-	-	-
Rhyacophila dorsalis			-					-
Glossosomatidae	-	-	-	-	-	-	-	-
Hydroptilidae	-	-	-	-	-	-	-	-
Psychomyiidae	-	-	-	-	-	-	-	-
Polycentropodidae	-	-	-	-	-	-	-	-
Polycentropus spp.			-					-
Hydropsychidae	-	-	-	-	-	-	-	-
Phryganeidae	-	-	-	-	-	-	-	-
Brachycentridae	-	-	-	-	-	-	-	-
Brachycentrus subnubilus			-					-
Limnephilidae	-	-	-	-	-	2	4	5
Anabolia nervosa			-					-
Goeridae	-	-	-	-	-	-	-	-
Goera pilosa			-					-
Silo nigricornis			-					-
Silo pallipes			-					-
Beraeidae	-	-	-	-	-	-	-	-
Sericostomatidae	-	-	-	-	-	-	-	-
Sericostomatinae			-					-
Molannidae	-	-	-	-	-	-	-	-
Leptoceridae	-	-	-	-	-	-	-	-
DIPTERA								
Ceraptogonidae		8			1	10	1	20
Sciomyzidae	-	-	-	-	-	-	-	-
Culicidae	-	-	-	-	-	-	-	-
Dolichopodidae	-	-	-	-	-	-	-	-
Ptychopteridae	-	-	-	-	-	-	-	-
Scathophagidae	-	-	-	-	-	-	-	-
Stratiomyiidae	-	-	-	-	-	-	-	-
Dixidae	-	-	-	-	-	-	-	-
Ephydridae	-	-	-	-	-	-	-	-
Syrphidae	-	-	-	-	-	-	-	-
Eristalis sp			-					-
Muscidae	-	-	-	-	-	-	-	-
Athericidae & Rhagionidae	-	-	-	-	-	-	-	-
Psychodidae	-	3	-	-	-	-	2	-
Chironomidae	232	224	282	532	1075	1050	1100	450
Chironomus thummi agg.			-					-
Chironomus plumosus agg.			17					40
Tipulidae (excl Limoniinae)	-	-	-	-	-	-	-	-
Limoniinae	-	-	-	-	-	-	-	-
Simuliidae	-	-	-	-	-	-	-	-
Odagmia ornatum (larvae)			-					-
Odagmia ornatum (pupae)			-					-
PORIFERA								
Spongillidae	-	-	-	-	-	-	-	-
PISCES								
Cottus gobio			-					-

Appendix 1

Samples analysed for Saprobien Index

Site	Roundmoor Ditch							
Season	Autumn				Spring			
Sampler	RA		MW		MW		DW	
Sample	1	2	1	2	1	2	1	2
TRICLADIDA								
Planariidae	-	-	-	-	-	-	1	1
Polycelis felina		-			-			
Polycelis nigra		-			-			
Polycelis tenuis		-			-			
Dugesidae	-	-	-	-	-	-	-	-
Dendrocoelidae	-	-	-	-	-	-	-	-
Dendrocoelum lacteum		-			-			
Mollusca	752	390	213	1317	524	720	81	172
Neritidae	-	-	-	-	-	-	-	-
Theodoxus fluviatilis		-			-			
Valvatidae	176	64	7	40	236	192	2	4
Valvata piscinalis		-			-			
Hydrobiidae	-	-	-	-	-	-	-	-
Potamopyrgus jenkinsi		-			-			
Bithyniidae	-	-	-	-	-	-	-	-
Bithynia tentaculata		-			-			
Physidae	-	-	-	-	-	-	-	-
Physa acuta		-			-			
Lymnaeidae	-	2	1	1	-	-	1	-
Planorbidae	576	324	205	1276	288	528	78	168
Ancylidae & Acroloxidae	-	-	-	-	-	-	-	-
Ancylus fluviatilis		-			-			
Acroloxus lacustris		-			-			
Unionidae	-	-	-	-	-	-	-	-
Unio pictorum		-			-			
Anodonta anatina		-			-			
Sphaeriidae	-	-	-	-	-	-	-	-
Sphaerium corneum		-			-			
NEMATODA								
OLIGOCHAETA	40	38	96	40	28	160	13	64
Lumbriculus variegatus		24			28			
Branchiura sowerbyi		-			-			
Tubifex s.l.		2			-			
Limnodrilus spp.		-			-			
ACHAETA	26	6	4	8	40	5	8	24
Piscicolidae	-	-	-	-	-	-	-	-
Piscicola geometra		-			-			
Glossiphoniidae	26	6	4	8	40	5	8	24
Glossiphonia complanata		-			-			
Glossiphonia heteroclita		-			-			
Helobdella stagnalis		6			40			
Erpobdellidae	-	-	-	-	-	-	-	-
Erpobdella octoculata		-			-			
Erpobdella octoculata coccoon		-			-			
CRUSTACEA								
Asellidae	-	-	-	-	-	-	-	-
Asellus aquaticus		-			-			
Corophiidae	-	-	-	-	-	-	-	-
Gammaridae and Crangonyctidae	-	-	-	-	-	-	-	-
Gammarus pulex		-			-			

Appendix 1 (continued)

Samples analysed for Saprobien Index

Site	Roundmoor Ditch							
Season	Autumn				Spring			
Sampler	RA		MW		MW		DW	
Sample	1	2	1	2	1	2	1	2
HYDRACARINA								
EPHEMEROPTERA								
Baetidae	-	1	1	2	-	-	-	-
Baetis rhodani		-			-			
Baetis vernus		-			-			
Cloeon dipterum		1			-			
Heptageniidae	-	-	-	-	-	-	-	-
Heptagenia sulphurea		-			-			
Leptophlebiidae	-	-	-	-	-	-	-	-
Paraleptophlebia submarginata		-			-			
Ephemeridae	-	-	-	-	-	-	-	-
Ephemera danica		-			-			
Ephemerellidae	-	-	-	-	-	-	-	-
Ephemerella ignita		-			-			
Caenidae	-	-	-	-	-	-	-	-
PLECOPTERA								
Nemouridae	-	-	-	-	-	-	-	-
ODONATA								
Platycnemididae	-	-	-	-	-	-	-	-
Platycnemis pennipes		-			-			
Coenagriidae	-	-	2	2	1	-	1	2
Pyrrhosoma nymphula		-			-			
Calopterygidae								
Calopteryx splendens		-			-			
Gomphidae	-	-	-	-	-	-	-	-
HETEROPTERA								
Hydrometridae	-	-	-	-	-	-	-	-
Veliidae	-	-	1	1	-	-	-	-
Gerridae	-	-	-	-	-	-	-	-
Nepidae	-	1	-	-	-	-	-	-
Notonectidae	-	1	-	-	-	-	-	-
Corixidae	1	-	1	-	1	1	-	-
COLEOPTERA								
Haliplidae	-	-	-	-	-	-	-	-
Brychius elevatus		-			-			
Brychius elevatus (larva)		-			-			
Dytiscidae & Noteridae	6	9	17	6	3	3	2	1
Nebrioporus depressus (elegans)		-			-			
Oreodytes sanmarkii		-			-			
Platambus maculatus		-			-			
Platambus maculatus larva		-			-			
Gyrinidae	-	-	-	-	-	-	-	-
Orectochilus villosus (larva)		-			-			
Hydrophilidae and Hydraenidae	1	3	6	1	2	-	-	-
Hydrophilinae	1	3	6	1	1	-	-	-
Helophorinae	-	-	-	-	1	-	-	-
Hydraenidae	-	-	-	-	-	-	-	-
Elmidae	-	-	-	-	-	-	-	-
Limnius volckmari		-			-			
Limnius volckmari (larva)		-			-			
Oulimnius tuberculatus		-			-			

Appendix 1 (continued)

Samples analysed for Saprobien Index

Site	Roundmoor Ditch							
Season	Autumn				Spring			
Sampler	RA		MW		MW		DW	
Sample	1	2	1	2	1	2	1	2
COLEOPTERA (continued)								
Helodidae	-	-	1	-	-	-	-	-
Dryopidae	-	-	-	-	-	-	-	-
Curculionidae	-	-	-	1	-	-	-	-
MEGALOPTERA								
Sialidae	-	1	-	1	-	-	-	-
Sialis lutaria		1			-			
Rhyacophilidae	-	-	-	-	-	-	-	-
Rhyacophila dorsalis		-			-			
Glossosomatidae	-	-	-	-	-	-	-	-
Hydroptilidae	-	-	-	-	-	-	-	-
Psychomyiidae	-	-	-	-	-	-	-	-
Polycentropodidae	-	-	-	-	-	-	-	-
Polycentropus spp.		-			-			
Hydropsychidae	-	-	-	-	-	-	-	-
Phryganeidae	-	-	-	-	-	-	-	-
Brachycentridae	-	-	-	-	-	-	-	-
Brachycentrus subnubilus		-			-			
Limnephilidae	-	-	-	-	-	-	-	-
Anabolia nervosa		-			-			
Goeridae	-	-	-	-	-	-	-	-
Goera pilosa		-			-			
Silo nigricornis		-			-			
Silo pallipes		-			-			
Beraeidae	-	-	-	-	-	-	-	-
Sericostomatidae	-	-	-	-	-	-	-	-
Sericostomatinae		-			-			
Molannidae	-	-	-	-	-	-	-	-
Leptoceridae	-	-	-	-	-	-	-	-
DIPTERA								
Ceraptogonidae		1						
Sciomyzidae	-	-	2	1	-	-	-	-
Culicidae	1	28	5	32	2	3	73	-
Dolichopodidae	-	-	-	-	-	-	-	-
Ptychopteridae	-	-	-	-	-	-	-	-
Scathophagidae	-	-	-	-	-	-	-	-
Stratiomyiidae	-	1	-	-	-	-	-	-
Dixidae	-	-	-	-	-	-	3	-
Ephydridae	-	1	-	-	-	-	-	-
Syrphidae	-	1	-	1	1	-	-	-
Eristalis sp		1			1			
Muscidae	-	-	-	-	-	-	-	-
Athericidae & Rhagionidae	-	-	-	1	-	-	-	-
Psychodidae	1	1	6	1	3	-	1	2
Chironomidae	3458	576	850	1481	2001	2000	1001	1236
Chironomus thummi agg.		8			64			
Chironomus plumosus agg.		472			1743			
Tipulidae (excl Limoniinae)	-	-	-	4	1	-	-	-
Limoniinae	-	-	-	-	-	-	-	-
Simuliidae	-	-	-	-	-	1	-	-
Odagmia ornatum (larvae)		-			-			
Odagmia ornatum (pupae)		-			-			
PORIFERA								
Spongillidae	-	-	-	-	-	-	-	-
PISCES								
Cottus gobio		-			-			

Appendix 1

Samples analysed for Saprobien Index

Site	Summerstown Ditch							
Season	Autumn				Spring			
Sampler	MW		JB		JB		DW	
Sample	1	2	1	2	1	2	1	2
TRICLADIDA								
Planariidae	-	-	-	-	-	-	-	-
Polycelis felina				-		-		
Polycelis nigra				-		-		
Polycelis tenuis				-		-		
Dugesiidae	-	-	-	-	-	-	-	-
Dendrocoelidae	-	-	-	-	-	-	-	-
Dendrocoelum lacteum				-		-		
Mollusca	19	47	13	5	15	13	10	16
Neritidae	-	-	-	-	-	-	-	-
Theodoxus fluviatilis				-		-		
Valvatidae	-	-	-	-	-	-	-	-
Valvata piscinalis				-		-		
Hydrobiidae	-	-	-	-	-	-	-	-
Potamopyrgus jenkinsi				-		-		
Bithyniidae	-	-	-	-	-	-	-	-
Bithynia tentaculata				-		-		
Physidae	7	3	2	3	1	-	3	1
Physa acuta				-		-		
Lymnaeidae	1	2	-	-	10	5	3	3
Planorbidae	11	42	11	2	4	8	4	12
Ancylidae & Acroloxidae	-	-	-	-	-	-	-	-
Ancylus fluviatilis				-		-		
Acroloxus lacustris				-		-		
Unionidae	-	-	-	-	-	-	-	-
Unio pictorum				-		-		
Anodonta anatina				-		-		
Sphaeriidae	-	-	-	-	-	-	-	-
Sphaerium corneum				-		-		
NEMATODA								1
OLIGOCHAETA	18	2	1	87	120	10	105	50
Lumbriculus variegatus				-		-		
Branchiura sowerbyi				-		-		
Tubifex s.l.				80		10		
Limnodrilus spp.				2		-		
ACHAETA	1	2	1	4	1	3	1	2
Piscicolidae	-	-	-	-	-	-	-	-
Piscicola geometra				-		-		
Glossiphoniidae	1	2	1	3	1	3	1	2
Glossiphonia complanata				-		-		
Glossiphonia heteroclita				-		-		
Helobdella stagnalis				3		3		
Erpobdellidae	-	-	-	1	-	-	-	-
Erpobdella octoculata				-		-		
Erpobdella octoculata coccoon				-		-		
CRUSTACEA								
Asellidae	576	124	20	560	37	58	75	55
Asellus aquaticus				560		58		
Corophiidae	-	-	-	-	-	-	-	-
Gammaridae and Crangonyctidae	1	3	-	-	-	-	-	-
Gammarus pulex				-		-		

Appendix 1 (continued)

Samples analysed for Saprobien Index

Site	Summerstown Ditch							
Season	Autumn				Spring			
Sampler	MW		JB		JB		DW	
Sample	1	2	1	2	1	2	1	2
HYDRACARINA	2							
EPHEMEROPTERA								
Baetidae	-	-	-	-	-	-	-	-
Baetis rhodani				-		-		
Baetis vernus				-		-		
Cloeon dipterum				-		-		
Heptageniidae	-	-	-	-	-	-	-	-
Heptagenia sulphurea				-		-		
Leptophlebiidae	-	-	-	-	-	-	-	-
Paraleptophlebia submarginata				-		-		
Ephemeridae	-	-	-	-	-	-	-	-
Ephemera danica				-		-		
Ephemerellidae	-	-	-	-	-	-	-	-
Ephemerella ignita				-		-		
Caenidae	-	-	-	-	-	-	-	-
PLECOPTERA								
Nemouridae	-	-	-	-	-	-	-	-
ODONATA								
Platycnemididae	-	-	-	-	-	-	-	-
Platycnemis pennipes				-		-		
Coenagriidae	-	-	-	-	-	-	-	-
Pyrrhosoma nymphula				-		-		
Calopterygidae								
Calopteryx splendens				-		-		
Gomphidae	-	-	-	-	-	-	-	-
HETEROPTERA								
Hydrometridae	-	-	-	-	-	-	-	-
Veliidae	-	-	-	-	-	-	-	-
Gerridae	-	-	-	-	-	-	-	-
Nepidae	-	-	-	-	-	-	-	-
Notonectidae	-	-	-	-	-	-	-	-
Corixidae	-	-	-	-	-	-	-	-
COLEOPTERA								
Haliplidae	-	1	-	1	-	-	-	-
Brychius elevatus				-		-		
Brychius elevatus (larva)				-		-		
Dytiscidae & Noteridae	147	16	39	81	2	2	6	3
Nebrioporus depressus (elegans)				-		-		
Oreodytes sanmarkii				-		-		
Platambus maculatus				-		-		
Platambus maculatus larva				-		-		
Gyrinidae	-	-	-	-	-	-	-	-
Orectochilus villosus (larva)				-		-		
Hydrophilidae and Hydraenidae	4	3	2	3	3	2	-	6
Hydrophilinae	1	-	-	1	3	2	-	6
Helophorinae	3	3	2	2	-	-	-	-
Hydraenidae	-	-	-	-	-	-	-	-
Elmidae	-	-	-	-	-	-	-	-
Limnius volckmari				-		-		
Limnius volckmari (larva)				-		-		
Oulimnius tuberculatus				-		-		

Appendix 1 (continued)

Samples analysed for Saprobien Index

Site	Summerstown Ditch							
Season	Autumn				Spring			
Sampler	MW		JB		JB		DW	
Sample	1	2	1	2	1	2	1	2
COLEOPTERA (continued)								
Helodidae	-	-	-	-	-	-	-	-
Dryopidae	-	-	-	-	-	-	-	-
Curculionidae	-	-	-	-	-	-	-	-
MEGALOPTERA								
Sialidae	-	-	-	-	-	-	-	-
Sialis lutaria				-		-		
Rhyacophilidae	-	-	-	-	-	-	-	-
Rhyacophila dorsalis				-		-		
Glossosomatidae	-	-	-	-	-	-	-	-
Hydroptilidae	-	-	-	-	-	-	-	-
Psychomyiidae	-	-	-	-	-	-	-	-
Polycentropodidae	-	-	-	-	-	-	-	-
Polycentropus spp.				-		-		
Hydropsychidae	-	-	-	-	-	-	-	-
Phryganeidae	-	-	-	-	-	-	-	-
Brachycentridae	-	-	-	-	-	-	-	-
Brachycentrus subnubilus				-		-		
Limnephilidae	-	-	-	-	-	-	-	-
Anabolia nervosa				-		-		
Goeridae	-	-	-	-	-	-	-	-
Goera pilosa				-		-		
Silo nigricornis				-		-		
Silo pallipes				-		-		
Beraeidae	-	-	-	-	-	-	-	-
Sericostomatidae	-	-	-	-	-	-	-	-
Sericostomatinae				-		-		
Molannidae	-	-	-	-	-	-	-	-
Leptoceridae	-	-	-	-	-	-	-	-
DIPTERA								
Ceraptogonidae								
Sciomyzidae	-	-	-	-	-	-	-	-
Culicidae	-	-	-	2	1	-	-	2
Dolichopodidae	-	-	-	-	-	-	-	-
Ptychopteridae	-	-	-	-	-	-	-	-
Scathophagidae	-	-	-	-	-	-	-	-
Stratiomyiidae	-	-	-	-	-	-	-	-
Dixidae	-	-	-	-	-	-	-	-
Ephydridae	-	-	-	-	-	-	-	-
Syrphidae	-	-	-	-	-	-	-	-
Eristalis sp				-		-		
Muscidae	-	-	-	-	-	-	-	-
Athericidae & Rhagionidae	-	-	-	-	-	-	-	-
Psychodidae	-	-	-	-	-	-	-	-
Chironomidae	17349	50001	3500	21746	12000	10000	10000	11160
Chironomus thummi agg.				21664		9286		
Chironomus plumosus agg.				-		-		
Tipulidae (excl Limoniinae)	1	-	-	-	1	-	-	-
Limoniinae	-	-	-	-	-	-	-	-
Simuliidae	-	-	-	-	-	-	-	-
Odagmia ornatum (larvae)				-		-		
Odagmia ornatum (pupae)				-		-		
PORIFERA								
Spongillidae	-	-	-	-	-	-	-	-
PISCES								
Cottus gobio				-		-		

Appendix 1

Samples analysed for Saprobien Index

Site	Crendon Stream							
Season	Autumn				Spring			
Sampler	JB		RA		MW		JB	
Sample	1	2	1	2	1	2	1	2
TRICLADIDA								
Planariidae	-	-	-	-	-	-	-	-
Polycelis felina				-		-		
Polycelis nigra				-		-		
Polycelis tenuis				-		-		
Dugesidae	-	-	-	-	-	-	-	-
Dendrocoelidae	-	-	-	-	-	-	-	-
Dendrocoelum lacteum				-		-		
Mollusca	0	1	0	2	2	2	1	0
Neritidae	-	-	-	-	-	-	-	-
Theodoxus fluviatilis				-		-		
Valvatidae	-	-	-	-	-	-	-	-
Valvata piscinalis				-		-		
Hydrobiidae	-	1	-	1	1	1	1	-
Potamopyrgus jenkinsi				1		1		
Bithyniidae	-	-	-	-	-	-	-	-
Bithynia tentaculata				-		-		
Physidae	-	-	-	-	-	-	-	-
Physa acuta				-		-		
Lymnaeidae	-	-	-	1	1	1	-	-
Planorbidae	-	-	-	-	-	-	-	-
Ancylidae & Acroloxidae	-	-	-	-	-	-	-	-
Ancylus fluviatilis				-		-		
Acroloxus lacustris				-		-		
Unionidae	-	-	-	-	-	-	-	-
Unio pictorum				-		-		
Anodonta anatina				-		-		
Sphaeriidae	-	-	-	-	-	-	-	-
Sphaerium corneum				-		-		
NEMATODA								
OLIGOCHAETA	6	12	61	52	41	192	1215	1
Lumbriculus variegatus				-		-		
Branchiura sowerbyi				-		-		
Tubifex s.l.				-		138		
Limnodrilus spp.				-		12		
ACHAETA	3	1	1	2	-	-	-	-
Piscicolidae	-	-	-	-	-	-	-	-
Piscicola geometra				-		-		
Glossiphoniidae	-	1	-	1	-	-	-	-
Glossiphonia complanata				-		-		
Glossiphonia heteroclita				-		-		
Helobdella stagnalis				1		-		
Erpobdellidae	3	-	1	1	-	-	-	-
Erpobdella octoculata				-		-		
Erpobdella octoculata coccoon				-		-		
CRUSTACEA								
Asellidae	2	-	5	5	24	17	56	5
Asellus aquaticus				5		17		
Corophiidae	-	-	-	-	-	-	-	-
Gammaridae and Crangonyc	31	62	44	86	223	36	30	82
Gammarus pulex				86		36		

Appendix 1 (continued)

Samples analysed for Saprobien Index

Site	Crendon Stream							
Season	Autumn				Spring			
Sampler	JB		RA		MW		JB	
Sample	1	2	1	2	1	2	1	2
HYDRACARINA								
EPHEMEROPTERA								
Baetidae	-	-	-	-	-	-	-	-
Baetis rhodani				-		-		
Baetis vernus				-		-		
Cloeon dipterum				-		-		
Heptageniidae	-	-	-	-	-	-	-	-
Heptagenia sulphurea				-		-		
Leptophlebiidae	-	-	-	-	-	-	-	-
Paraleptophlebia submarginata				-		-		
Ephemeridae	-	-	-	-	-	-	-	-
Ephemera danica				-		-		
Ephemerellidae	-	-	-	-	-	-	-	-
Ephemerella ignita				-		-		
Caenidae	-	-	-	-	-	-	-	-
PLECOPTERA								
Nemouridae	-	-	-	-	-	-	-	-
ODONATA								
Platycnemididae	-	-	-	-	-	-	-	-
Platycnemis pennipes				-		-		
Coenagriidae	-	-	-	-	-	-	-	-
Pyrrhosoma nymphula				-		-		
Calopterygidae								
Calopteryx splendens				-		-		
Gomphidae	-	-	-	-	-	-	-	-
HETEROPTERA								
Hydrometridae	-	-	-	2	-	-	-	-
Veliidae	-	-	-	1	-	-	-	-
Gerridae	-	-	-	-	-	-	-	-
Nepidae	-	-	-	-	-	-	-	-
Notonectidae	-	-	-	-	-	-	-	-
Corixidae	-	-	-	-	-	-	-	-
COLEOPTERA								
Haliplidae	-	-	-	-	-	-	-	-
Brychius elevatus				-		-		
Brychius elevatus (larva)				-		-		
Dytiscidae & Noteridae	-	-	-	-	-	-	-	-
Nebrioporus depressus (elegans)				-		-		
Oreodytes sanmarkii				-		-		
Platambus maculatus				-		-		
Platambus maculatus larva				-		-		
Gyrinidae	-	-	-	-	-	-	-	-
Orectochilus villosus (larva)				-		-		
Hydrophilidae and Hydraenic	-	-	-	2	-	-	-	-
Hydrophilinae	-	-	-	2	-	-	-	-
Helophorinae	-	-	-	-	-	-	-	-
Hydraenidae	-	-	-	-	-	-	-	-
Elmidae	-	-	-	-	-	-	-	-
Limnius volckmari				-		-		
Limnius volckmari (larva)				-		-		
Oulimnius tuberculatus				-		-		

Appendix 1 (continued)

Samples analysed for Saprobien Index

Site	Crendon Stream							
Season	Autumn				Spring			
Sampler	JB		RA		MW		JB	
Sample	1	2	1	2	1	2	1	2
COLEOPTERA (continued)								
Helodidae	-	-	-	-	-	-	-	-
Dryopidae	-	-	-	-	-	-	-	-
Curculionidae	-	-	-	-	-	-	-	-
MEGALOPTERA								
Sialidae	-	-	-	-	-	-	-	-
Sialis lutaria				-		-		
Rhyacophilidae	-	-	-	-	-	-	-	-
Rhyacophila dorsalis				-		-		
Glossosomatidae	-	-	-	-	-	-	-	-
Hydroptilidae	-	-	-	-	-	-	-	-
Psychomyiidae	-	-	-	-	-	-	-	-
Polycentropodidae	-	-	-	-	-	-	-	-
Polycentropus spp.				-		-		
Hydropsychidae	-	-	-	-	-	-	-	-
Phryganeidae	-	-	-	-	-	-	-	-
Brachycentridae	-	-	-	-	-	-	-	-
Brachycentrus subnubilus				-		-		
Limnephilidae	-	-	-	-	-	-	-	-
Anabolia nervosa				-		-		
Goeridae	-	-	-	-	-	-	-	-
Goera pilosa				-		-		
Silo nigricornis				-		-		
Silo pallipes				-		-		
Beraeidae	-	-	-	-	-	-	-	-
Sericostomatidae	-	-	-	-	-	-	-	-
Sericostomatinae				-		-		
Molannidae	-	-	-	-	-	-	-	-
Leptoceridae	-	-	-	-	-	-	-	-
DIPTERA								
Ceraptogonidae				3				
Sciomyzidae	-	-	-	-	-	-	-	-
Culicidae	-	-	-	-	-	-	-	-
Dolichopodidae	-	-	-	-	-	-	1	-
Ptychopteridae	-	-	-	-	-	-	-	-
Scathophagidae	-	-	-	-	-	-	-	-
Stratiomyiidae	-	-	-	-	-	-	-	-
Dixidae	-	-	-	-	-	-	-	-
Ephydridae	-	-	-	-	-	-	-	-
Syrphidae	-	-	-	-	-	-	-	-
Eristalis sp				-		-		
Muscidae	-	-	-	-	-	-	-	-
Athericidae & Rhagionidae	-	-	-	-	-	-	-	-
Psychodidae	-	-	-	-	-	-	-	-
Chironomidae	5	1	4	18	46	78	39	103
Chironomus thummi agg.				1		8		
Chironomus plumosus agg.				-		-		
Tipulidae (excl Limoniinae)	-	-	-	2	-	1	3	-
Limoniinae	-	-	-	-	-	-	-	-
Simuliidae	-	-	-	-	-	-	-	-
Odagmia ornatum (larvae)				-		-		
Odagmia ornatum (pupae)				-		-		
PORIFERA								
Spongillidae	-	-	-	-	-	-	-	-
PISCES								
Cottus gobio				-		-		

Appendix 1

Samples analysed for Saprobien Index

Site	Wheatley Ditch							
Season	Autumn				Spring			
Sampler	DW		MW		JB		MW	
Sample	1	2	1	2	1	2	1	2
TRICLADIDA								
Planariidae	-	-	-	-	-	-	-	-
Polycelis felina		-						-
Polycelis nigra		-						-
Polycelis tenuis		-						-
Dugesidae	-	-	-	-	-	-	-	-
Dendrocoelidae	-	-	-	-	-	-	-	-
Dendrocoelum lacteum		-						-
Mollusca	8	2	11	0	3	2	1	7
Neritidae	-	-	-	-	-	-	-	-
Theodoxus fluviatilis		-						-
Valvatidae	-	-	-	-	-	-	-	-
Valvata piscinalis		-						-
Hydrobiidae	-	-	-	-	-	-	-	-
Potamopyrgus jenkinsi		-						-
Bithyniidae	-	-	-	-	-	-	-	-
Bithynia tentaculata		-						-
Physidae	2	-	5	-	-	-	-	-
Physa acuta		-						-
Lymnaeidae	6	2	6	-	3	2	1	7
Planorbidae	-	-	-	-	-	-	-	-
Ancylidae & Acroloxidae	-	-	-	-	-	-	-	-
Ancylus fluviatilis		-						-
Acroloxus lacustris		-						-
Unionidae	-	-	-	-	-	-	-	-
Unio pictorum		-						-
Anodonta anatina		-						-
Sphaeriidae	-	-	-	-	-	-	-	-
Sphaerium corneum		-						-
NEMATODA								1
OLIGOCHAETA	1	5	5	6	5	25	20	48
Lumbriculus variegatus		-						-
Branchiura sowerbyi		-						-
Tubifex s.l.		1						-
Limnodrilus spp.		1						24
ACHAETA	-	1	1	-	1	-	3	3
Piscicolidae	-	-	-	-	-	-	-	-
Piscicola geometra		-						-
Glossiphoniidae	-	-	-	-	1	-	2	2
Glossiphonia complanata		-						1
Glossiphonia heteroclita		-						-
Helobdella stagnalis		-						-
Erpobdellidae	-	1	1	-	-	-	1	1
Erpobdella octoculata		1						1
Erpobdella octoculata coccoon		-						-
CRUSTACEA								
Asellidae	500	570	452	580	612	750	1120	490
Asellus aquaticus		570						490
Corophiidae	-	-	-	-	-	-	-	-
Gammaridae and Crangonyctidae	2	3	1	1	-	1	1	1
Gammarus pulex		3						1

Appendix 1 (continued)

Samples analysed for Saprobien Index

Site	Wheatley Ditch							
Season	Autumn				Spring			
Sampler	DW		MW		JB		MW	
Sample	1	2	1	2	1	2	1	2
HYDRACARINA								
EPHEMEROPTERA								
Baetidae	-	-	-	-	-	-	-	-
Baetis rhodani		-						-
Baetis vernus		-						-
Cloeon dipterum		-						-
Heptageniidae	-	-	-	-	-	-	-	-
Heptagenia sulphurea		-						-
Leptophlebiidae	-	-	-	-	-	-	-	-
Paraleptophlebia submarginata		-						-
Ephemeridae	-	-	-	-	-	-	-	-
Ephemera danica		-						-
Ephemerellidae	-	-	-	-	-	-	-	-
Ephemerella ignita		-						-
Caenidae	-	-	-	-	-	-	-	-
PLECOPTERA								
Nemouridae	-	-	-	-	-	-	-	-
ODONATA								
Platycnemididae	-	-	-	-	-	-	-	-
Platycnemis pennipes		-						-
Coenagriidae	-	-	-	-	-	-	-	1
Pyrrhosoma nymphula		-						-
Calopterygidae								
Calopteryx splendens		-						-
Gomphidae	-	-	-	-	-	-	-	-
HETEROPTERA								
Hydrometridae	-	-	-	-	-	-	-	-
Veliidae	-	1	-	-	-	-	-	-
Gerridae	-	-	-	-	-	-	-	-
Nepidae	-	2	-	-	-	-	-	-
Notonectidae	-	-	-	-	-	-	-	-
Corixidae	-	-	-	-	-	-	-	-
COLEOPTERA								
Haliplidae	-	-	-	-	-	-	-	-
Brychius elevatus		-						-
Brychius elevatus (larva)		-						-
Dytiscidae & Noteridae	1	11	3	9	-	-	2	-
Nebrioporus depressus (elegans)		-						-
Oreodytes sanmarkii		-						-
Platambus maculatus		-						-
Platambus maculatus larva		-						-
Gyrinidae	-	-	-	-	-	-	-	-
Orectochilus villosus (larva)		-						-
Hydrophilidae and Hydraenidae	-	-	-	2	-	2	-	-
Hydrophilinae	-	-	-	2	-	2	-	-
Helophorinae	-	-	-	-	-	-	-	-
Hydraenidae	-	-	-	-	-	-	-	-
Elmidae	-	-	-	-	-	-	-	-
Limnius volckmari		-						-
Limnius volckmari (larva)		-						-
Oulimnius tuberculatus		-						-

Appendix 1 (continued)

Samples analysed for Saprobien Index

Site	Wheatley Ditch							
Season	Autumn				Spring			
Sampler	DW		MW		JB		MW	
Sample	1	2	1	2	1	2	1	2
COLEOPTERA (continued)								
Helodidae	-	-	-	-	-	-	-	-
Dryopidae	-	-	-	-	-	-	-	-
Curculionidae	-	-	-	-	-	-	-	-
MEGALOPTERA								
Sialidae	-	-	-	-	-	-	-	-
Sialis lutaria		-						-
Rhyacophilidae	-	-	-	-	-	-	-	-
Rhyacophila dorsalis		-						-
Glossosomatidae	-	-	-	-	-	-	-	-
Hydroptilidae	-	-	-	-	-	-	-	-
Psychomyiidae	-	-	-	-	-	-	-	-
Polycentropodidae	-	-	-	-	-	-	-	-
Polycentropus spp.		-						-
Hydropsychidae	-	-	-	-	-	-	-	-
Phryganeidae	-	-	-	-	-	-	-	-
Brachycentridae	-	-	-	-	-	-	-	-
Brachycentrus subnubilus		-						-
Limnephilidae	-	-	-	-	-	1	-	-
Anabolia nervosa		-						-
Goeridae	-	-	-	-	-	-	-	-
Goera pilosa		-						-
Silo nigricornis		-						-
Silo pallipes		-						-
Beraeidae	-	-	-	-	-	-	-	-
Sericostomatidae	-	-	-	-	-	-	-	-
Sericostomatinae		-						-
Molannidae	-	-	-	-	-	-	-	-
Leptoceridae	-	-	-	-	-	-	-	-
DIPTERA								
Ceraptogonidae		1						
Sciomyzidae	-	-	-	-	-	-	-	-
Culicidae	-	-	-	-	-	-	-	-
Dolichopodidae	-	-	-	-	-	-	-	-
Ptychopteridae	-	-	-	-	-	-	-	-
Scathophagidae	-	-	-	-	-	-	-	-
Stratiomyiidae	-	-	-	-	-	-	-	-
Dixidae	-	-	-	-	-	-	-	-
Ephydridae	-	-	-	-	-	-	-	-
Syrphidae	-	-	-	-	-	-	-	-
Eristalis sp		-						-
Muscidae	-	-	-	-	-	-	-	-
Athericidae & Rhagionidae	-	-	-	-	-	-	-	-
Psychodidae	-	-	-	-	-	-	-	-
Chironomidae	1000	1250	1000	1030	152	78	310	133
Chironomus thummi agg.		1250						115
Chironomus plumosus agg.		-						-
Tipulidae (excl Limoniinae)	-	-	-	-	-	-	-	-
Limoniinae	-	-	-	-	-	-	-	-
Simuliidae	-	-	-	-	-	-	-	-
Odagmia ornatum (larvae)		-						-
Odagmia ornatum (pupae)		-						-
PORIFERA								
Spongillidae	-	-	-	-	-	-	-	-
PISCES								
Cottus gobio		-						-

Appendix 1

Samples analysed for Saprobien Index

Site	Crawters Brook							
Season	Autumn				Spring			
Sampler	MW		DW		RA		MW	
Sample	1	2	1	2	1	2	1	2
TRICLADIDA								
Planariidae	-	-	-	-	-	-	-	-
Polycelis felina				-			-	
Polycelis nigra				-			-	
Polycelis tenuis				-			-	
Dugesidae	-	-	-	-	-	-	-	-
Dendrocoelidae	-	-	-	-	-	-	-	-
Dendrocoelum lacteum				-			-	
Mollusca	3473	5069	6953	3591	255	149	938	884
Neritidae	-	-	-	-	-	-	-	-
Theodoxus fluviatilis				-			-	
Valvatidae	-	-	-	-	-	-	-	-
Valvata piscinalis				-			-	
Hydrobiidae	17	15	1	18	-	-	-	1
Potamopyrgus jenkinsi				18			-	
Bithyniidae	-	-	-	-	-	-	-	-
Bithynia tentaculata				-			-	
Physidae	2880	5000	6692	3521	250	128	918	871
Physa acuta				3521			918	
Lymnaeidae	576	54	260	52	5	21	20	12
Planorbidae	-	-	-	-	-	-	-	-
Ancylidae & Acroloxidae	-	-	-	-	-	-	-	-
Ancylus fluviatilis				-			-	
Acroloxus lacustris				-			-	
Unionidae	-	-	-	-	-	-	-	-
Unio pictorum				-			-	
Anodonta anatina				-			-	
Sphaeriidae	-	-	-	-	-	-	-	-
Sphaerium corneum				-			-	
NEMATODA							1	
OLIGOCHAETA	12827	18000	24698	6000	2001	4640	3184	1005
Lumbriculus variegatus				-			-	
Branchiura sowerbyi				-			-	
Tubifex s.l.				-			1999	
Limnodrilus spp.				-			371	
ACHAETA	3	4	5	5	-	5	2	1
Piscicolidae	-	-	-	-	-	-	-	-
Piscicola geometra				-			-	
Glossiphoniidae	-	-	-	1	-	-	-	-
Glossiphonia complanata				-			-	
Glossiphonia heteroclita				-			-	
Helobdella stagnalis				1			-	
Erpobdellidae	3	4	5	4	-	5	2	1
Erpobdella octoculata				-			1	
Erpobdella octoculata coccoon				-			-	
CRUSTACEA								
Asellidae	832	450	68	463	431	512	864	562
Asellus aquaticus				463			864	
Corophiidae	-	-	-	-	-	-	-	-
Gammaridae and Crangonyctidae	-	1	-	-	-	1	-	-
Gammarus pulex				-			-	

Appendix 1 (continued)

Samples analysed for Saprobien Index

Site	Crawters Brook							
Season	Autumn				Spring			
Sampler	MW		DW		RA		MW	
Sample	1	2	1	2	1	2	1	2
HYDRACARINA								
EPHEMEROPTERA								
Baetidae	-	-	-	-	-	-	-	-
Baetis rhodani				-			-	
Baetis vernus				-			-	
Cloeon dipterum				-			-	
Heptageniidae	-	-	-	-	-	-	-	-
Heptagenia sulphurea				-			-	
Leptophlebiidae	-	-	-	-	-	-	-	-
Paraleptophlebia submarginata				-			-	
Ephemeridae	-	-	-	-	-	-	-	-
Ephemera danica				-			-	
Ephemerellidae	-	-	-	-	-	-	-	-
Ephemerella ignita				-			-	
Caenidae	-	-	-	-	-	-	-	-
PLECOPTERA								
Nemouridae	-	-	-	-	-	-	-	-
ODONATA								
Platycnemididae	-	-	-	-	-	-	-	-
Platycnemis pennipes				-			-	
Coenagriidae	-	-	-	-	-	-	-	-
Pyrrhosoma nymphula				-			-	
Calopterygidae								
Calopteryx splendens				-			-	
Gomphidae	-	-	-	-	-	-	-	-
HETEROPTERA								
Hydrometridae	-	-	-	-	-	-	-	-
Veliidae	-	-	-	-	-	-	-	-
Gerridae	-	-	-	-	-	-	-	-
Nepidae	-	-	-	-	-	-	-	-
Notonectidae	-	-	-	-	-	-	-	-
Corixidae	-	-	-	-	-	-	-	-
COLEOPTERA								
Haliplidae	-	-	-	-	-	-	-	-
Brychius elevatus				-			-	
Brychius elevatus (larva)				-			-	
Dytiscidae & Noteridae	-	-	-	-	-	-	-	-
Nebrioporus depressus (elegans)				-			-	
Oreodytes sanmarkii				-			-	
Platambus maculatus				-			-	
Platambus maculatus larva				-			-	
Gyrinidae	-	-	-	-	-	-	-	-
Orectochilus villosus (larva)				-			-	
Hydrophilidae and Hydraenidae	-	-	-	-	-	-	-	-
Hydrophilinae	-	-	-	-	-	-	-	-
Helophorinae	-	-	-	-	-	-	-	-
Hydraenidae	-	-	-	-	-	-	-	-
Elmidae	-	-	-	-	-	-	-	-
Limnius volckmari				-			-	
Limnius volckmari (larva)				-			-	
Oulimnius tuberculatus				-			-	

Appendix 1 (continued)

Samples analysed for Saprobien Index

Site	Crawters Brook							
Season	Autumn				Spring			
Sampler	MW		DW		RA		MW	
Sample	1	2	1	2	1	2	1	2
COLEOPTERA (continued)								
Helodidae	-	-	-	-	-	-	-	-
Dryopidae	-	-	-	-	-	-	-	-
Curculionidae	-	-	-	-	-	-	-	-
MEGALOPTERA								
Sialidae	-	-	-	-	-	-	-	-
Sialis lutaria				-			-	
Rhyacophilidae	-	-	-	-	-	-	-	-
Rhyacophila dorsalis				-			-	
Glossosomatidae	-	-	-	-	-	-	-	-
Hydroptilidae	-	-	-	-	-	-	-	-
Psychomyiidae	-	-	-	-	-	-	-	-
Polycentropodidae	-	-	-	-	-	-	-	-
Polycentropus spp.				-			-	
Hydropsychidae	-	-	-	-	-	-	-	-
Phryganeidae	-	-	-	-	-	-	-	-
Brachycentridae	-	-	-	-	-	-	-	-
Brachycentrus subnubilus				-			-	
Limnephilidae	-	-	-	-	-	-	-	-
Anabolia nervosa				-			-	
Goeridae	-	-	-	-	-	-	-	-
Goera pilosa				-			-	
Silo nigricornis				-			-	
Silo pallipes				-			-	
Beraeidae	-	-	-	-	-	-	-	-
Sericostomatidae	-	-	-	-	-	-	-	-
Sericostomatinae				-			-	
Molannidae	-	-	-	-	-	-	-	-
Leptoceridae	-	-	-	-	-	-	-	-
DIPTERA								
Ceraptogonidae								
Sciomyzidae	-	-	-	-	-	-	-	-
Culicidae	-	-	-	-	-	-	-	-
Dolichopodidae	-	-	-	-	-	-	-	-
Ptychopteridae	-	-	-	-	-	-	-	-
Scathophagidae	-	-	-	-	-	-	-	-
Stratiomyiidae	-	-	-	-	-	-	-	-
Dixidae	-	-	-	-	-	-	-	-
Ephydridae	-	-	-	-	-	-	-	-
Syrphidae	-	-	-	-	-	-	-	-
Eristalis sp				-			-	
Muscidae	-	-	-	-	-	-	-	-
Athericidae & Rhagionidae	-	-	-	-	-	-	-	-
Psychodidae	-	-	-	-	-	-	-	-
Chironomidae	5	8	6	6	50	196	80	100
Chironomus thummi agg.				2			-	
Chironomus plumosus agg.				-			-	
Tipulidae (excl Limoniinae)	-	1	-	-	-	-	15	-
Limoniinae	-	-	-	-	-	-	4	-
Simuliidae	-	-	-	-	-	-	-	-
Odagmia ornatum (larvae)				-			-	
Odagmia ornatum (pupae)				-			-	
PORIFERA								
Spongillidae	-	-	-	-	-	-	-	-
PISCES								
Cottus gobio				-			-	

Appendix 1

Samples analysed for Saprobien Index

Site	Catherine Bourne							
Season	Autumn				Spring			
Sampler	DW		JB		MW		DW	
Sample	1	2	1	2	1	2	1	2
TRICLADIDA								
Planariidae	-	-	-	-	-	-	1	-
Polycelis felina			-				-	
Polycelis nigra			-				1	
Polycelis tenuis			-				-	
Dugesidae	-	-	-	-	-	-	-	-
Dendrocoelidae	-	-	-	-	-	-	-	-
Dendrocoelum lacteum			-				-	
Mollusca	720	28	1473	61	33	60	241	57
Neritidae	-	-	-	-	-	-	-	-
Theodoxus fluviatilis			-				-	
Valvatidae	-	-	-	-	-	-	-	-
Valvata piscinalis			-				-	
Hydrobiidae	720	28	1472	61	32	60	240	50
Potamopyrgus jenkinsi			1472				240	
Bithyniidae	-	-	-	-	-	-	-	-
Bithynia tentaculata			-				-	
Physidae	-	-	-	-	-	-	-	-
Physa acuta			-				-	
Lymnaeidae	-	-	1	-	1	-	1	7
Planorbidae	-	-	-	-	-	-	-	-
Ancylidae & Acroloxidae	-	-	-	-	-	-	-	-
Ancylus fluviatilis			-				-	
Acroloxus lacustris			-				-	
Unionidae	-	-	-	-	-	-	-	-
Unio pictorum			-				-	
Anodonta anatina			-				-	
Sphaeriidae	-	-	-	-	-	-	-	-
Sphaerium corneum			-				-	
NEMATODA								
OLIGOCHAETA	300	300	848	300	32	84	270	95
Lumbriculus variegatus			-				-	
Branchiura sowerbyi			-				-	
Tubifex s.l.			320				84	
Limnodrilus spp.			432				116	
ACHAETA	19	61	13	39	10	16	41	
Piscicolidae	-	-	-	-	-	-	-	-
Piscicola geometra			-				-	
Glossiphoniidae	13	44	9	36	1	3	5	4
Glossiphonia complanata			9				3	
Glossiphonia heteroclita			-				-	
Helobdella stagnalis			-				2	
Erpobdellidae	6	17	4	3	9	13	36	3
Erpobdella octoculata			-				-	
Erpobdella octoculata coccoon			-				-	
CRUSTACEA								
Asellidae	384	944	432	435	92	70	480	120
Asellus aquaticus			432				480	
Corophiidae	-	-	-	-	-	-	-	-
Gammaridae and Crangonyctidae	52	352	28	30	32	30	112	50
Gammarus pulex			-				-	

Appendix 1 (continued)

Samples analysed for Saprobien Index

Site	Catherine Bourne							
Season	Autumn				Spring			
Sampler	DW		JB		MW		DW	
Sample	1	2	1	2	1	2	1	2
HYDRACARINA			1					
EPHEMEROPTERA								
Baetidae	1	2	-	-	1	-	2	1
Baetis rhodani			-				1	
Baetis vernus			-				-	
Cloeon dipterum			-				1	
Heptageniidae	-	-	-	-	-	-	-	-
Heptagenia sulphurea			-				-	
Leptophlebiidae	-	-	-	-	-	-	-	-
Paraleptophlebia submarginata			-				-	
Ephemeridae	-	-	-	-	-	-	-	-
Ephemera danica			-				-	
Ephemerellidae	-	-	-	-	-	-	-	-
Ephemerella ignita			-				-	
Caenidae	-	-	-	-	-	-	-	-
PLECOPTERA								
Nemouridae	-	-	-	-	13	34	124	84
ODONATA								
Platycnemididae	-	-	-	-	-	-	-	-
Platycnemis pennipes			-				-	
Coenagriidae	-	-	-	-	-	-	-	-
Pyrrhosoma nymphula			-				-	
Calopterygidae								
Calopteryx splendens			-				-	
Gomphidae	-	-	-	-	-	-	-	-
HETEROPTERA								
Hydrometridae	-	-	-	-	-	-	-	-
Veliidae	1	-	-	-	-	2	1	-
Gerridae	-	-	-	-	-	-	-	-
Nepidae	-	-	-	-	-	-	-	-
Notonectidae	-	-	-	-	-	-	-	-
Corixidae	1	-	1	-	1	1	-	-
COLEOPTERA								
Haliplidae	-	3	4	1	-	1	-	-
Brychius elevatus			-				-	
Brychius elevatus (larva)			-				-	
Dytiscidae & Noteridae	9	21	7	17	1	-	2	2
Nebrioporus depressus (elegans)			-				-	
Oreodytes sanmarkii			-				-	
Platambus maculatus			-				-	
Platambus maculatus larva			-				-	
Gyrinidae	-	-	-	-	-	-	-	-
Orectochilus villosus (larva)			-				-	
Hydrophilidae and Hydraenidae	-	-	-	1	-	-	-	-
Hydrophilinae	-	-	-	1	-	-	-	-
Helophorinae	-	-	-	-	-	-	-	-
Hydraenidae	-	-	-	-	-	-	-	-
Elmidae	-	-	-	-	-	-	-	-
Limnius volckmari			-				-	
Limnius volckmari (larva)			-				-	
Oulimnius tuberculatus			-				-	

Appendix 1 (continued)

Samples analysed for Saprobien Index

Site	Catherine Bourne							
Season	Autumn				Spring			
Sampler	DW		JB		MW		DW	
Sample	1	2	1	2	1	2	1	2
COLEOPTERA (continued)								
Helodidae	-	1	-	1	-	-	-	-
Dryopidae	-	-	-	-	-	-	-	-
Curculionidae	-	-	-	-	-	-	-	-
MEGALOPTERA								
Sialidae	3	1	2	14	-	1	-	-
Sialis lutaria			2			1	-	
Rhyacophilidae	-	-	-	-	-	-	-	-
Rhyacophila dorsalis			-				-	
Glossosomatidae	-	-	-	-	-	-	-	-
Hydroptilidae	-	-	-	-	-	-	-	-
Psychomyiidae	-	-	-	-	-	-	-	-
Polycentropodidae	-	-	-	-	-	-	-	-
Polycentropus spp.			-				-	
Hydropsychidae	-	-	-	-	-	-	-	-
Phryganeidae	-	-	-	-	-	-	-	-
Brachycentridae	-	-	-	-	-	-	-	-
Brachycentrus subnubilus			-				-	
Limnephilidae	-	4	1	1	2	2	5	-
Anabolia nervosa			-				-	
Goeridae	-	-	-	-	-	-	-	-
Goera pilosa			-				-	
Silo nigricornis			-				-	
Silo pallipes			-				-	
Beraeidae	-	-	-	-	-	-	-	-
Sericostomatidae	-	-	-	-	-	-	-	-
Sericostomatinae			-				-	
Molannidae	-	-	-	-	-	-	-	-
Leptoceridae	-	-	-	-	-	-	-	-
DIPTERA								
Ceraptogonidae	2	20	1	4	3		80	5
Sciomyzidae	-	-	-	-	1	-	-	-
Culicidae	-	-	-	-	-	-	-	-
Dolichopodidae	-	-	-	-	-	-	-	-
Ptychopteridae	-	-	-	-	-	-	-	-
Scathophagidae	-	-	-	-	-	-	-	-
Stratiomyiidae	2	-	1	2	1	-	2	-
Dixidae	-	-	-	-	-	-	-	-
Ephydridae	-	-	-	-	-	-	-	-
Syrphidae	-	-	-	-	-	-	-	-
Eristalis sp			-				-	
Muscidae	-	-	-	-	-	-	-	-
Athericidae & Rhagionidae	-	-	-	-	-	-	-	-
Psychodidae	-	-	-	-	-	2	4	3
Chironomidae	574	268	960	275	332	889	1696	995
Chironomus thummi agg.			32				-	
Chironomus plumosus agg.			192				-	
Tipulidae (excl Limoniinae)	-	-	-	-	5	-	-	-
Limoniinae	-	-	-	-	-	-	-	-
Simuliidae	2	-	5	1	17	36	53	50
Odagmia ornatum (larvae)			-				-	
Odagmia ornatum (pupae)			-				-	
PORIFERA								
Spongillidae	-	-	-	-	-	-	-	-
PISCES								
Cottus gobio			-				-	

Appendix 2. 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 2. Variability of TAXA.EQI (single season)

% 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	53	47	1	2	52
0.67	50	50	50	50	50	50	49	1	2	50

Appendix 2. Variability of TAXA.EQI (single season)

% probability of inclusion in 5M bands

	TAXA=5			TAXA=8			TAXA=10			TAXA=12			TAXA=14		
TAXA.EQI	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
0.67	50	50	0	50	50	0	50	50	0	50	50	0	50	50	0
0.66	42	58	0	43	57	0	44	56	0	44	56	0	44	56	0
0.65	35	65	0	37	63	0	37	63	0	39	61	0	39	61	0
0.64	29	71	0	31	70	0	32	68	0	33	67	0	34	66	0
0.63	23	77	0	25	75	0	26	74	0	28	72	0	29	71	0
0.62	17	83	0	20	80	0	21	79	0	23	77	0	25	75	0
0.61	13	87	0	15	85	0	17	83	0	19	81	0	21	79	0
0.60	9	91	0	12	88	0	14	86	0	15	85	0	17	83	0
0.59	7	93	0	9	91	0	10	90	0	12	88	0	14	86	0
0.58	5	95	0	6	94	0	8	92	0	9	91	0	11	89	0
0.57	3	97	0	5	95	0	6	94	0	7	93	0	9	91	0
0.56	2	98	0	3	97	0	4	96	0	5	95	0	7	93	0
0.55	1	99	0	2	98	0	3	97	0	4	96	0	5	95	0
0.54	1	99	0	1	99	0	2	98	0	3	97	0	4	96	0
0.53	0	100	0	1	99	0	1	99	0	2	98	0	3	97	0
0.52	0	100	0	1	99	0	1	99	0	1	98	0	2	97	1
0.51	0	100	0	0	99	0	1	99	0	1	98	1	1	98	1
0.50	0	100	0	0	99	0	0	99	1	1	98	1	1	98	1
0.49	0	100	0	0	99	1	0	99	1	0	98	1	1	97	2
0.48	0	100	0	0	99	1	0	99	1	0	98	2	0	97	3
0.47	0	99	1	0	99	1	0	98	2	0	97	3	0	96	4
0.46	0	99	1	0	98	2	0	97	3	0	96	4	0	95	5
0.45	0	98	2	0	97	3	0	96	4	0	95	5	0	93	7
0.44	0	97	3	0	95	5	0	94	6	0	93	7	0	91	9
0.43	0	95	5	0	94	6	0	92	8	0	91	9	0	89	11
0.42	0	93	7	0	91	9	0	90	10	0	88	12	0	86	14
0.41	0	91	9	0	88	12	0	86	14	0	85	15	0	83	17
0.40	0	87	13	0	85	15	0	83	17	0	81	19	0	79	21
0.39	0	83	17	0	80	20	0	79	21	0	77	23	0	75	25
0.38	0	77	23	0	75	25	0	74	26	0	72	28	0	71	29
0.37	0	71	29	0	70	31	0	68	32	0	67	33	0	66	34
0.36	0	65	35	0	63	37	0	63	37	0	61	39	0	61	39
0.35	0	58	42	0	57	43	0	56	44	0	56	44	0	56	44
0.34	0	50	50	0	50	50	0	50	50	50	0	50	50	0	50

	TAXA=5			TAXA=8			TAXA=10			TAXA=12			TAXA=14		
	B	C	D	B	C	D	B	C	D	B	C	D	B	C	D
0.33	42	58	0	43	57	0	44	56	0	44	56	0	44	56	0
0.32	35	65	0	37	63	0	37	63	0	39	61	0	39	61	0
0.31	29	71	0	31	70	0	32	68	0	33	67	0	34	66	0
0.30	23	77	0	25	75	0	26	74	0	28	72	0	29	71	0
0.29	17	83	0	20	80	0	21	79	0	23	77	0	25	75	0
0.28	13	87	0	15	85	0	17	83	0	19	81	0	21	79	0
0.27	9	91	0	12	88	0	14	86	0	15	85	0	17	83	0
0.26	7	93	0	9	91	0	10	90	0	12	88	0	14	86	0
0.25	5	95	0	6	94	0	8	92	0	9	91	0	11	89	0
0.24	3	97	0	5	95	0	6	94	0	7	93	0	9	91	0
0.23	2	98	0	3	97	0	4	96	0	5	95	0	7	93	0
0.22	1	99	0	2	98	0	3	97	0	4	96	0	5	95	0
0.21	1	99	0	1	99	0	2	98	0	3	97	0	4	96	0
0.20	0	100	0	1	99	0	1	99	0	2	98	0	3	97	0
0.19	0	100	0	1	99	0	1	99	0	1	98	0	2	97	1
0.18	0	100	0	0	99	0	1	99	0	1	98	1	1	98	1
0.17	0	100	0	0	99	0	0	99	1	1	98	1	1	98	1
0.16	0	100	0	0	99	1	0	99	1	0	98	1	1	97	2
0.15	0	100	0	0	99	1	0	99	1	0	98	2	0	97	3
0.14	0	99	1	0	99	1	0	98	2	0	97	3	0	96	4
0.13	0	99	1	0	98	2	0	97	3	0	96	4	0	95	5
0.12	0	98	2	0	97	3	0	96	4	0	95	5	0	93	7
0.11	0	97	3	0	95	5	0	94	6	0	93	7	0	91	9
0.10	0	95	5	0	94	6	0	92	8	0	91	9	0	89	11
0.09	0	93	7	0	91	9	0	90	10	0	88	12	0	86	14
0.08	0	91	9	0	88	12	0	86	14	0	85	15	0	83	17
0.07	0	87	13	0	85	15	0	83	17	0	81	19	0	79	21

Appendix 2. Variability of TAXA.EQI (single season)

% probability of inclusion in 5M bands

	TAXA=16			TAXA=18		
TAXA.EQI	A	B	C	A	B	C
0.67	50	50	0	50	50	0
0.66	45	55	0	45	55	0
0.65	40	60	0	41	59	0
0.64	35	65	0	36	64	0
0.63	31	70	0	32	68	0
0.62	26	74	0	27	73	0
0.61	22	78	0	24	76	0
0.60	18	82	0	20	80	0
0.59	15	85	0	17	83	0
0.58	13	87	0	14	86	0
0.57	10	90	0	12	88	0
0.56	8	92	0	10	90	0
0.55	6	93	0	8	92	1
0.54	5	95	1	6	93	1
0.53	4	96	1	5	94	1
0.52	3	96	1	4	95	2
0.51	2	96	2	3	95	2
0.50	2	96	2	2	95	3
0.49	1	96	3	2	95	4
0.48	1	96	4	1	94	5
0.47	1	95	5	1	93	6
0.46	0	93	6	1	92	8
0.45	0	92	8	0	90	10
0.44	0	90	10	0	88	12
0.43	0	87	13	0	86	14
0.42	0	85	15	0	83	17
0.41	0	82	18	0	80	20
0.40	0	78	22	0	76	24
0.39	0	74	26	0	73	27
0.38	0	70	31	0	68	32
0.37	0	65	35	0	64	36
0.36	0	60	40	0	59	41
0.35	0	55	45	0	55	45
0.34	50	0	50	50	0	50

	TAXA=16			TAXA=18		
	B	C	D	B	C	D
0.33	45	55	0	45	55	0
0.32	40	60	0	41	59	0
0.31	35	65	0	36	64	0
0.30	31	70	0	32	68	0
0.29	26	74	0	27	73	0
0.28	22	78	0	24	76	0
0.27	18	82	0	20	80	0
0.26	15	85	0	17	83	0
0.25	13	87	0	14	86	0
0.24	10	90	0	12	88	0
0.23	8	92	0	10	90	0
0.22	6	93	0	8	92	1
0.21	5	95	1	6	93	1
0.20	4	96	1	5	94	1
0.19	3	96	1	4	95	2
0.18	2	96	2	3	95	2
0.17	2	96	2	2	95	3
0.16	1	96	3	2	95	4
0.15	1	96	4	1	94	5
0.14	1	95	5	1	93	6
0.13	0	93	6	1	92	8
0.12	0	92	8	0	90	10
0.11	0	90	10	0	88	12
0.10	0	87	13	0	86	14
0.09	0	85	15	0	83	17
0.08	0	82	18	0	80	20
0.07	0	78	22	0	76	24

Appendix 3. 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	100	0	100	0	100	0	100	0	0	100	0	0
1.05	100	0	100	0	100	0	100	0	100	0	0	99	1	0
1.04	100	0	100	0	100	0	100	0	100	0	0	99	1	0
1.03	100	0	100	0	100	0	100	0	100	0	0	99	1	0
1.02	100	0	100	0	100	0	100	0	100	0	0	99	1	0
1.01	100	0	100	0	100	0	100	0	99	1	0	99	1	0
1.00	100	0	100	0	100	0	100	0	99	1	0	98	2	0
0.99	100	0	100	0	100	0	100	0	99	1	0	98	2	0
0.98	100	0	100	0	100	0	99	1	99	1	0	97	3	0
0.97	100	0	100	0	100	0	99	1	98	2	0	97	3	0
0.96	100	0	100	0	99	1	99	1	98	2	0	96	4	0
0.95	100	0	100	0	99	1	98	2	97	3	0	95	5	0
0.94	100	0	100	0	99	1	98	2	96	4	0	94	6	0
0.93	100	0	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	2	53	56	44	56	44	55	45	54	45	1	54	45	1
0.77	2	50	50	50	50	50	50	50	50	49	1	50	48	2

Appendix 2. Variability of TAXA.EQI (combined season)

% probability of inclusion in 5M bands

	TAXA=5			TAXA=10			TAXA=15			TAXA=18			TAXA=20		
TAXA.EQI	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
0.77	50	50	0	50	50	0	50	50	0	50	50	0	50	50	0
0.76	41	59	0	42	58	0	43	57	0	44	56	0	44	56	0
0.75	32	68	0	34	66	0	36	64	0	37	63	0	38	62	0
0.74	25	75	0	27	73	0	30	70	0	31	69	0	32	68	0
0.73	18	82	0	21	79	0	24	76	0	26	74	0	27	73	0
0.72	13	87	0	16	84	0	19	81	0	21	79	0	22	78	0
0.71	9	91	0	11	89	0	14	85	0	16	83	0	18	82	0
0.70	5	95	0	8	92	0	11	89	0	13	87	0	14	85	1
0.69	3	97	0	5	95	0	8	92	0	10	90	1	11	88	1
0.68	2	98	0	4	96	0	6	94	1	7	92	1	8	90	2
0.67	1	99	0	2	97	0	4	95	1	5	93	2	6	92	2
0.66	1	99	0	1	98	1	3	96	2	4	94	3	4	92	3
0.65	0	99	1	1	98	1	2	96	3	3	94	4	3	92	4
0.64	0	99	1	0	97	2	1	95	4	2	93	5	2	92	6
0.63	0	98	2	0	96	4	1	94	6	1	92	7	2	90	8
0.62	0	97	3	0	95	5	0	92	8	1	90	10	1	88	11
0.61	0	95	5	0	92	8	0	89	11	0	87	13	1	85	14
0.60	0	91	9	0	89	11	0	85	14	0	83	16	0	82	18
0.59	0	87	13	0	84	16	0	81	19	0	79	21	0	78	22
0.58	0	82	18	0	79	21	0	76	24	0	74	26	0	73	27
0.57	0	75	25	0	73	27	0	70	30	0	69	31	0	68	32
0.56	0	68	32	0	66	34	40	0	59	0	63	37	0	62	38
0.55	0	59	41	0	58	42	45	0	55	0	56	44	0	56	44
0.54	0	50	50	50	0	50	1	1	49	0	50	50	0	50	50

	TAXA=5			TAXA=10			TAXA=15			TAXA=20			TAXA=25		
TAXA.EQI	B	C	D	B	C	D	B	C	D	B	C	D	B	C	D
0.53	41	59	0	42	58	0	43	57	0	44	56	0	44	55	0
0.52	32	68	0	34	66	0	36	64	0	38	62	0	39	60	0
0.51	25	75	0	27	73	0	30	70	0	32	68	0	34	66	0
0.50	18	82	0	21	79	0	24	76	0	27	73	0	29	70	1
0.49	13	87	0	16	84	0	19	81	0	22	78	0	25	74	1
0.48	9	91	0	11	89	0	14	85	0	18	82	0	21	78	1
0.47	5	95	0	8	92	0	11	89	0	14	85	1	17	81	2
0.46	3	97	0	5	95	0	8	92	0	11	88	1	14	84	2
0.45	2	98	0	4	96	0	6	94	1	8	90	2	11	86	3
0.44	1	99	0	2	97	0	4	95	1	6	92	2	9	87	4
0.43	1	99	0	1	98	1	3	96	2	4	92	3	7	88	5
0.42	0	99	1	1	98	1	2	96	3	3	92	4	5	88	7
0.41	0	99	1	0	97	2	1	95	4	2	92	6	4	87	9
0.40	0	98	2	0	96	4	1	94	6	2	90	8	3	86	11
0.39	0	97	3	0	95	5	0	92	8	1	88	11	2	84	14
0.38	0	95	5	0	92	8	0	89	11	1	85	14	2	81	17
0.37	0	91	9	0	89	11	0	85	14	0	82	18	1	78	21
0.36	0	87	13	0	84	16	0	81	19	0	78	22	1	74	25
0.35	0	82	18	0	79	21	0	76	24	0	73	27	1	70	29
0.34	0	75	25	0	73	27	0	70	30	0	68	32	0	66	34
0.33	0	68	32	0	66	34	0	64	36	0	62	38	0	60	39
0.32	0	59	41	0	58	42	0	57	43	0	56	44	0	55	44
0.31	0	50	50	0	50	50	0	50	50	0	50	50	0	50	50

	T=5		T=10		T=15	
TAXA.EQI	C	D	C	D	C	D
0.30	41	59	42	58	43	57
0.29	32	68	34	66	36	64
0.28	25	75	27	73	30	70
0.27	18	82	21	79	24	76
0.26	13	87	16	84	19	81
0.25	9	91	11	89	14	86
0.24	5	95	8	92	11	89
0.23	3	97	5	95	8	92
0.22	2	98	4	96	6	94
0.21	1	99	2	98	4	96

Appendix 2. Variability of TAXA.EQI (combined season)

% probability of inclusion in 5M bands

	TAXA=22			TAXA=24			TAXA=26		
TAXA.EQI	A	B	C	A	B	C	A	B	C
0.77	50	50	0	50	50	0	50	50	0
0.76	44	56	0	44	55	0	45	55	0
0.75	39	61	0	39	61	0	40	60	0
0.74	33	67	0	34	66	0	34	65	0
0.73	28	72	0	29	71	0	30	70	1
0.72	23	76	0	24	75	1	25	74	1
0.71	19	80	1	20	79	1	21	77	1
0.70	15	84	1	17	82	1	18	80	2
0.69	12	87	1	13	85	2	14	83	2
0.68	9	89	2	11	87	3	12	85	3
0.67	7	90	3	8	88	4	9	86	4
0.66	5	91	4	6	89	5	7	87	6
0.65	4	91	5	5	89	6	6	87	7
0.64	3	90	7	4	88	8	4	86	9
0.63	2	89	9	3	87	11	3	85	12
0.62	1	87	12	2	85	13	2	83	14
0.61	1	84	15	1	82	17	2	80	18
0.60	1	80	19	1	79	20	1	77	21
0.59	0	76	23	1	75	24	1	74	25
0.58	0	72	28	0	71	29	1	70	30
0.57	0	67	33	0	66	34	0	65	34
0.56	0	61	39	0	61	39	0	60	40
0.55	0	56	44	0	55	44	0	55	45
0.54	0	50	50	0	50	50	0	50	50

Appendix 2. 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 2. Variability of BMWP.EQI (single season)

% 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 2. Variability of BMWP.EQI (single season)

% 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	93	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 2. Variability of BMWP.EQI (single season)

% 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 2. 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	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	99	1
0.96	100	0	100	0	100	0	100	0	100	0	100	0	100	0	99	1
0.95	100	0	100	0	100	0	100	0	100	0	100	0	99	1	99	1
0.94	100	0	100	0	100	0	100	0	100	0	99	1	99	1	99	1
0.93	100	0	100	0	100	0	100	0	99	1	99	1	99	1	98	2
0.92	100	0	100	0	100	0	99	1	99	1	99	1	98	2	98	2
0.91	100	0	100	0	99	1	99	1	99	1	98	2	98	2	97	3
0.90	100	0	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 2. Variability of BMWP.EQI (combined season)

% 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	100	0	100	0	0	100	0	0	100	0	0	100	0	0	100	0	0
1.06	100	0	100	0	100	0	0	100	0	0	100	0	0	100	0	0	99	1	0
1.05	100	0	100	0	100	0	0	100	0	0	100	0	0	100	0	0	99	1	0
1.04	100	0	100	0	100	0	0	100	0	0	100	0	0	99	1	0	99	1	0
1.03	100	0	100	0	100	0	0	100	0	0	99	1	0	99	1	0	99	1	0
1.02	100	0	100	0	100	0	0	99	1	0	99	1	0	99	1	0	99	1	0
1.01	100	0	100	0	100	0	0	99	1	0	99	1	0	99	1	0	98	2	0
1.00	100	0	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 2. 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	86	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 2. 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 2. 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 3. Nested analysis of variance tables

Appendix table 3.1 IBG (untransformed), spring and autmn samples

Summary of all Effects
1-SITE, 2-SEASON, 3-SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained	% of variation not due to site
1	11	155.1468	24	0.864583	179.4469*	.000000*	91.8667	
2	1	0.0938	24	0.864583	0.1084	0.744791	-0.0417	-0.5130
3	24	0.8646	48	1.177083	0.7345	0.791293	-0.4059	-4.9905
12	11	5.6847	24	0.864583	6.5750*	.000061*	2.8701	35.2885
						Error	5.7108	70.2150

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
IBG	--	0.171233	-20.615	37	--

Appendix table 3.2 TAXA (untransformed), spring and autmn samples

Summary of all Effects
1-SITE, 2-SEASON, 3-SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained	% of variation not due to site
1	11	624.4091	24	5.270833	118.4650*	.000000*	91.5975	
2	1	0.375	24	5.270833	0.0711	0.791954	-0.0658	-0.7836
3	24	5.2708	48	4.416667	1.1934	0.294428	0.2757	3.2816
12	11	20.2386	24	5.270833	3.8397*	.002834*	2.2144	26.3539
						Error	5.9782	71.1482

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
TAXA	--	0.191038	4.179639	38	1

Appendix table 3.3 BMWP (untransformed), spring and autmn samples

Summary of all Effects
1-SITE, 2-SEASON, 3-SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained	% of variation not due to site
1	11	21329.74	24	180.9688	117.8642*	.000000*	91.7934	
2	1	256.76	24	180.9688	1.4188	0.245247	0.0299	0.3644
3	24	180.97	48	152.6979	1.1851	0.301301	0.2678	3.2628
12	11	608.83	24	180.9688	3.3643*	.006261*	1.8571	22.6291
						Error	6.0518	73.7437

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
BMWP	--	0.206358	30.9022	44	0.932083

Appendix 3. Nested analysis of variance tables (continued) (continued)

Appendix table 3.4 ASPT (untransformed), spring and autmn samples

Summary of all Effects
1-SITE, 2-SEASON, 3-SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained	% of variation not due to site
1	11	5.504041	24	0.055464	99.23650*	.000000*	90.1674	
2	1	0.023688	24	0.055464	0.42709	0.519632	-0.0478	-0.4862
3	24	0.055464	48	0.06437	0.86164	0.646202	-0.3215	-3.2700
12	11	0.129596	24	0.055464	2.33658*	.039841*	1.2268	12.4769
						Error	8.9751	91.2793

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
ASPT	--	0.220387	14.96051	43	0.999978

Appendix table 3.5 TAXA.EQI (untransformed), spring and autmn samples

Summary of all Effects
1-SITE, 2-SEASON, 3-SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained	% of variation not due to site
1	11	1.216999	24	0.011	110.6343*	.000000*	91.0393	
2	1	0.000401	24	0.011	0.0365	0.850175	-0.0727	-0.8117
3	24	0.011	48	0.009262	1.1877	0.299133	0.2863	3.1949
12	11	0.04225	24	0.011	3.8408*	.002829*	2.3590	26.3263
						Error	6.3881	71.2905

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
TAXA.EQI	--	0.144605	1.272017	38	1

Appendix table 3.6 BMWP.EQI (untransformed), spring and autmn samples

Summary of all Effects
1-SITE, 2-SEASON, 3-SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained	% of variation not due to site
1	11	1.808062	24	0.015461	116.9457*	.000000*	92.0708	
2	1	0.000051	24	0.015461	0.0033	0.954714	-0.0720	-0.9074
3	24	0.015461	48	0.013198	1.1715	0.312937	0.2536	3.1986
12	11	0.046184	24	0.015461	2.9872*	.012088*	1.5780	19.9010
						Error	6.1695	77.8079

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
BMWP.EQI	--	0.152317	26.37285	44	0.983722

Appendix 3. Nested analysis of variance tables (continued) (continued)

Appendix table 3.7 ASPT.EQI (untransformed), spring and autmn samples

Summary of all effects
1-SITE, 2-SEASON, 3-SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained	% of variation not due to site
1	11	0.237977	24	0.002634	90.34180*	.000000*	89.7910	
2	1	0.009494	24	0.002634	3.60425	0.069721	0.2379	2.3307
3	24	0.002634	48	0.002779	0.9479	0.543925	-0.1207	-1.1823
12	11	0.005148	24	0.002634	1.95436	0.082369	0.9592	9.3953
						Error	9.1326	89.4563

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
ASPT.EQI	--	0.204196	24.70111	43	0.98862

Appendix table 3.8 IBG (log10 transformed), spring and autmn samples

Summary of all Effects
1-SITE, 2-SEASON, 3-SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained	% of variation not due to site
1	11	0.455289	24	0.003964	114.8510*	.000000*	89.8108	
2	1	0.001518	24	0.003964	0.3829	0.541906	-0.0442	-0.4343
3	24	0.003964	48	0.004512	0.8785	0.626103	-0.2379	-2.3348
12	11	0.018404	24	0.003964	4.6425*	.000814*	2.8735	28.2010
						Error	7.5979	74.5681

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
LIBG	--	0.164083	-16.3427	37	--

Appendix table 3.9 TAXA (log10 transformed), spring and autmn samples

Summary of all Effects
1-SITE, 2-SEASON, 3-SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained	% of variation not due to site
1	11	0.497424	24	0.005103	97.48569*	.000000*	90.3154	
2	1	0.002624	24	0.005103	0.51416	0.480263	-0.0413	-0.4269
3	24	0.005103	48	0.004042	1.26235	0.241502	0.4247	4.3857
12	11	0.018215	24	0.005103	3.56977*	.004422*	2.4054	24.8371
						Error	6.8958	71.2041

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
LTAXA	--	0.302169	2.424206	38	1

Appendix 3. Nested analysis of variance tables (continued)

Appendix table 3.10 BMWP (log10 transformed), spring and autmn samples

Summary of all Effects
1-SITE, 2-SEASON, 3-SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained	% of variation not due to site
1	11	0.901226	24	0.008477	106.3144*	.000000*	90.9824	
2	1	0.002554	24	0.008477	0.3013	0.588153	-0.0549	-0.6085
3	24	0.008477	48	0.007479	1.1334	0.346967	0.2219	2.4611
12	11	0.027873	24	0.008477	3.2881*	.007136*	1.9767	21.9204
						Error	6.8739	76.2270

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
LBMWP	--	0.239844	21.7917	44	0.997981

Appendix table 3.11 ASPT (log10 transformed), spring and autmn samples

Summary of all effects
1-SITE, 2-SEASON, 3-SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained	% of variation not due to site
1	11	0.06621	24	0.000695	95.31119*	.000000*	89.2740	
2	1	0.000001	24	0.000695	0.00072	0.978801	-0.0860	-0.8015
3	24	0.000695	48	0.000951	0.73065	0.795353	-0.7609	-7.0936
12	11	0.001447	24	0.000695	2.08318	0.064402	1.0247	9.5535
						Error	10.5482	98.3416

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
LASPT	--	0.245902	15.91821	43	0.999947

Appendix table 3.12 TAXA.EQI (log10 transformed), spring and autmn samples

Summary of all effects
1-SITE, 2-SEASON, 3-SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained	% of variation not due to site
1	11	0.430914	24	0.005074	84.92967*	.000000*	88.9689	
2	1	0.010177	24	0.005074	2.00578	0.169549	0.0969	0.8786
3	24	0.005074	48	0.004059	1.25011	0.25032	0.4628	4.1951
12	11	0.017556	24	0.005074	3.46013*	.005318*	2.6078	23.6406
						Error	7.8636	71.2857

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
LTAXA.EQ	--	0.300933	--	38	--

Appendix 3. Nested analysis of variance tables (continued)

Appendix table 3.13 BMWP.EQI (log10 transformed), spring and autmn samples

Summary of all effects
1-SITE, 2-SEASON, 3-SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained	% of variation not due to site
1	11	0.819028	24	0.008601	95.22703*	.000000*	90.0493	
2	1	0.028479	24	0.008601	3.31116	0.081308	0.2008	2.0179
3	24	0.008601	48	0.007489	1.14845	0.333256	0.2696	2.7095
12	11	0.026137	24	0.008601	3.03893*	.011028*	1.9485	19.5815
						Error	7.5318	75.6912

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
LBMWP.EQ	--	0.23952	--	44	--

Appendix table 3.14 ASPT.EQI (log10 transformed), spring and autmn samples

Summary of all effects
1-SITE, 2-SEASON, 3-SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained	% of variation not due to site
1	11	0.068447	24	0.000735	93.18062*	.000000*	88.9330	
2	1	0.004403	24	0.000735	5.99374*	.022045*	0.4380	3.9574
3	24	0.000735	48	0.00095	0.7733	0.749026	-0.6159	-5.5656
12	11	0.001475	24	0.000735	2.00751	0.07441	0.9719	8.7822
						Error	10.2730	92.8261

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
LASPT.EQ	--	0.246121	--	43	--

Appendix table 3.15 IBG (untransformed), autumn samples

Summary of all effects
1-SITE, 2 SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained
1	11	73.44697	12	1.25	58.75758*	.000000*	93.0846
2	12	1.25	24	1.208333	1.03448	0.451071	0.0586
						Error	6.8568

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
IBG	--	0.253968	1.705814	16	0.999997

Appendix 3. Nested analysis of variance tables (continued)

Appendix table 3.16 TAXA (untransformed), autumn samples

Summary of all effects
1-SITE, 2 SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained
1	11	279.9148	12	4.8125	58.16411*	.000000*	92.2845
2	12	4.8125	24	5.729167	0.84	0.611861	-0.3354
						Error	8.0508

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
TAXA	--	0.294545	10.88118	17	0.862638

Appendix table 3.17 BMWP (untransformed), autumn samples

Summary of all effects
1-SITE, 2 SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained
1	11	9079.818	12	130.4167	69.62161*	.000000*	92.5869
2	12	130.417	24	198	0.65867	0.772173	-0.7623
						Error	8.1754

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
BMWP	--	0.318287	28.3606	20	0.101236

Appendix table 3.18 ASPT (untransformed), autumn samples

Summary of all effects
1-SITE, 2 SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained
1	11	2.288887	12	0.059831	38.25613*	.000000*	90.4621
2	12	0.059831	24	0.047887	1.24941	0.308558	0.5290
						Error	9.0089

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
ASPT	--	0.19355	13.16094	20	0.870328

Appendix 3. Nested analysis of variance tables (continued)

Appendix table 3.19 TAXA.EQI (untransformed), autumn samples

Summary of all effects
1-SITE, 2 SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained
1	11	0.518748	12	0.01193	43.48418*	.000000*	90.7167
2	12	0.01193	24	0.011841	1.0075	0.4718	0.0174
							Error 9.2659

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
TAXA.EQI	--	0.226212	9.077503	17	0.937772

Appendix table 3.20 BMWP.EQI (untransformed), autumn samples

Summary of all effects
1-SITE, 2 SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained
1	11	0.767585	12	0.01509	50.86769*	.000000*	91.4292
2	12	0.01509	24	0.017241	0.87524	0.581072	-0.2850
							Error 8.8558

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
BMWP.EQI	--	0.233194	25.67222	20	0.177019

Appendix table 3.21 ASPT.EQI (untransformed), autumn samples

Summary of all effects
1-SITE, 2 SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained
1	11	0.104091	12	0.002971	35.03983*	.000000*	90.0728
2	12	0.002971	24	0.002137	1.39006	0.237056	0.8110
							Error 9.1162

Summary of all effects

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
ASPT.EQI	--	0.204964	19.64689	20	0.480236

Appendix 3. Nested analysis of variance tables (continued)

Appendix table 3.22 IBG (logtransformed), autumn samples

Summary of all effects
1-SITE, 2 SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained
1	11	0.209763	12	0.006548	32.03460*	.000000*	88.8368
2	12	0.006548	24	0.005156	1.27006	0.29702	0.6642
						Error	10.4990

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
LIBG	--	0.348073	5.401123	16	0.993366

Appendix table 3.23 TAXA (logtransformed), autumn samples

Summary of all effects
1-SITE, 2 SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained
1	11	0.229995	12	0.006098	37.71750*	.000000*	90.2852
2	12	0.006098	24	0.004944	1.23342	0.317748	0.5079
						Error	9.2070

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
LTAXA	--	0.494106	10.54499	17	0.879182

Appendix table 3.24 BMWP (logtransformed), autumn samples

Summary of all effects
1-SITE, 2 SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained
1	11	0.401797	12	0.010728	37.45439*	.000000*	90.7567
2	12	0.010728	24	0.007527	1.42526	0.22164	0.8109
						Error	8.4323

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
LBMWP	--	0.47664	23.04278	20	0.286787

Appendix 3. Nested analysis of variance tables (continued)

Appendix table 3.25 ASPT (logtransformed), autumn samples

Summary of all effects
1-SITE, 2 SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained
1	11	0.028221	12	0.000853	33.09945*	.000000*	89.3636
2	12	0.000853	24	0.00064	1.33184	0.264676	0.7592
						Error	9.8772

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
LASPT	--	0.312689	15.23372	20	0.762843

Appendix table 3.26 TAXA.EQI (logtransformed), autumn samples

Summary of all effects
1-SITE, 2 SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained
1	11	0.187943	12	0.006033	31.15038*	.000000*	88.3351
2	12	0.006033	24	0.004977	1.21225	0.330261	0.5597
						Error	11.1053

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
LTAXA.EQ	--	0.490811	10.34721	17	0.888388

Appendix table 3.27 BMWP.EQI (logtransformed), autumn samples

Summary of all effects
1-SITE, 2 SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained
1	11	0.349715	12	0.010612	32.95475*	.000000*	89.5386
2	12	0.010612	24	0.007547	1.40611	0.229912	0.8835
						Error	9.5779

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
LBMWP.EQI	--	0.475361	22.93907	20	0.291884

Appendix 3. Nested analysis of variance tables (continued)

Appendix table 3.28 ASPT.EQI (logtransformed), autumn samples

Summary of all effects
1-SITE, 2 SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained
1	11	0.029401	12	0.000898	32.75241*	.000000*	89.4794
2	12	0.000898	24	0.000638	1.40594	0.229986	0.8911
							Error 9.6296

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
LASPT.EQI.	--	0.313521	21.64527	20	0.360134

Appendix table 3.29 IBG (untransformed), spring samples

Summary of all effects
1-SITE, 2 SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained
1	11	87.38447	12	0.479167	182.3676*	.000000*	96.0802
2	12	0.47917	24	1.145833	0.4182	0.941129	-0.8035
							Error 4.7233

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
IBG	--	0.301205	8.105774	20	0.991136

Appendix table 3.30 TAXA (untransformed), spring samples

Summary of all effects
1-SITE, 2 SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained
1	11	364.7329	12	5.729167	63.66248*	.000000*	94.9051
2	12	5.7292	24	3.104167	1.84564	0.097328	0.7575
							Error 4.3374

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
TAXA	--	0.241611	6.162246	20	0.998658

Appendix 3. Nested analysis of variance tables (continued)

Appendix table 3.31 BMWP (untransformed), spring samples

Summary of all effects
1-SITE, 2 SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained
1	11	12858.75	12	231.5208	55.54035*	.000000*	94.4679
2	12	231.52	24	107.3958	2.15577	0.052782	1.0139
						Error	4.5182

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
BMWP	342.25	0.265567	17.61008	23	0.778234

Appendix table 3.32 ASPT (untransformed), spring samples

Summary of all effects
1-SITE, 2 SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained
1	11	3.344749	12	0.051097	65.45861*	.000000*	91.9618
2	12	0.051097	24	0.080853	0.63198	0.794749	-0.9057
						Error	8.9438

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
ASPT	--	0.350917	28.48025	22	0.160423

Appendix table 3.33 TAXA.EQI (untransformed), spring samples

Summary of all effects
1-SITE, 2 SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained
1	11	0.7405	12	0.010071	73.52946*	.000000*	95.2343
2	12	0.010071	24	0.006682	1.5071	0.189287	0.4822
						Error	4.2835

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
TAXA.EQI	--	0.256949	5.429893	20	0.999476

Appendix 3. Nested analysis of variance tables (continued)

Appendix table 3.34 BMWP.EQI (untransformed), spring samples

Summary of all effects
1-SITE, 2 SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained
1	11	1.086661	12	0.015832	68.63893*	.000000*	95.1557
2	12	0.015832	24	0.009154	1.72939	0.122459	0.6477
						Error	4.1966

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
BMWP.EQI	308.3666	0.234971	16.05136	23	0.853008

Appendix table 3.35 ASPT.EQI (untransformed), spring samples

Summary of all effects
1-SITE, 2 SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained
1	11	0.139034	12	0.002298	60.50953*	.000000*	91.6376
2	12	0.002298	24	0.003421	0.67168	0.760982	-0.8205
						Error	9.1828

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
ASPT.EQI	--	0.331759	28.73598	22	0.152671

Appendix table 3.36 IBG (log10 transformed), spring samples

Summary of all effects
1-SITE, 2 SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained
							3.0126
1	11	0.26393	12	0.00138	191.2065*	.000000*	95.8203
2	12	0.00138	24	0.003869	0.3568	0.966813	-0.9901
						Error	5.1698

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
LIBG	--	0.310411	5.852419	20	0.999081

Appendix 3. Nested analysis of variance tables (continued)

Appendix table 3.37 TAXA (log10 transformed), spring samples

Summary of all effects
1-SITE, 2 SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained
1	11	0.285644	12	0.004107	69.54645*	.000000*	94.6825
2	12	0.004107	24	0.00314	1.30791	0.276823	0.3549
						Error	4.9627

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
LTAXA	--	0.205713	3.904555	20	0.999962

Appendix table 3.38 BMWP (log10 transformed), spring samples

Summary of all effects
1-SITE, 2 SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained
1	11	0.527302	12	0.006226	84.68886*	.000000*	94.5909
2	12	0.006226	24	0.007431	0.83787	0.613734	-0.2386
						Error	5.6476

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
LBMWP	1464.344	0.211556	17.56369	23	0.780658

Appendix table 3.39 ASPT (log10 transformed), spring samples

Summary of all effects
1-SITE, 2 SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained
1	11	0.039436	12	0.000537	73.47512*	.000000*	90.8390
2	12	0.000537	24	0.001261	0.42553	0.937498	-1.8416
						Error	11.0026

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
LASPT	--	0.370709	32.12099	22	0.075458

Appendix 3. Nested analysis of variance tables (continued)

Appendix table 3.40 TAXA.EQI (log10 transformed), spring samples

Summary of all effects
1-SITE, 2 SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained
1	11	0.260527	12	0.004114	63.32476*	.000000*	94.1864
2	12	0.004114	24	0.00314	1.3101	0.275688	0.3904
						Error	5.4232

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
LTAXA.EQI.	--	0.205713	3.904555	20	0.999962

Appendix table 3.41 BMWP.EQI (log10 transformed), spring samples

Summary of all effects
1-SITE, 2 SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained
1	11	0.495451	12	0.00659	75.18643*	.000000*	94.1109
2	12	0.00659	24	0.007431	0.88676	0.571123	-0.1766
						Error	6.0657

Tests of homogeneity of variance

Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
LBMWP.EQI	1464.344	0.211556	17.56369	23	0.780658

Appendix table 3.42 ASPT.EQI (log10 transformed), spring samples

Summary of all effects
1-SITE, 2 SAMPLER

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level	% variation explained
1	11	0.040521	12	0.000571	70.90830*	.000000*	90.9048
2	12	0.000571	24	0.001261	0.45306	0.922847	-1.7104
						Error	10.8056

Tests of homogeneity of variance

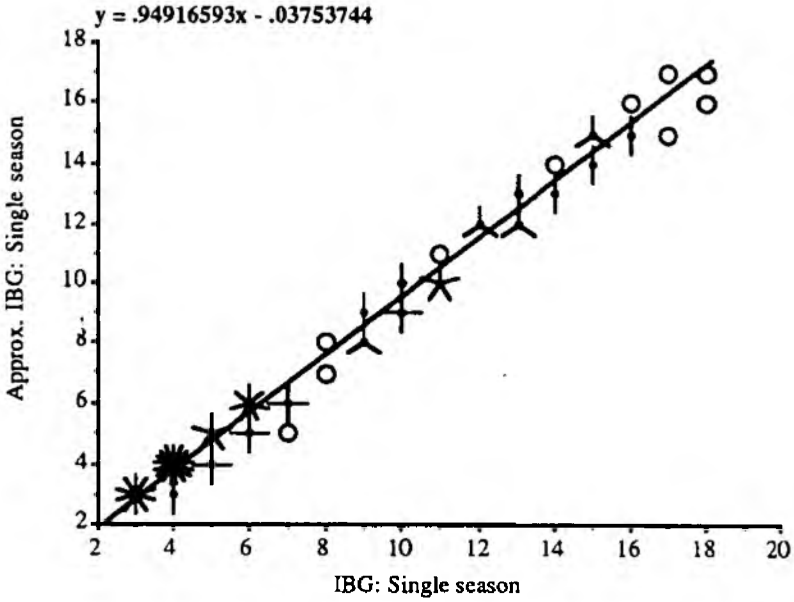
Variable	Hartley F-max	Cochran C	Bartlett Chi-sqr	df	p
LASPT.EQI.	--	0.370709	32.12099	22	0.075458

Appendix 4 Regressions of TAXA, BMWP and ASPT.EQIs against IBG and Saprobic Index

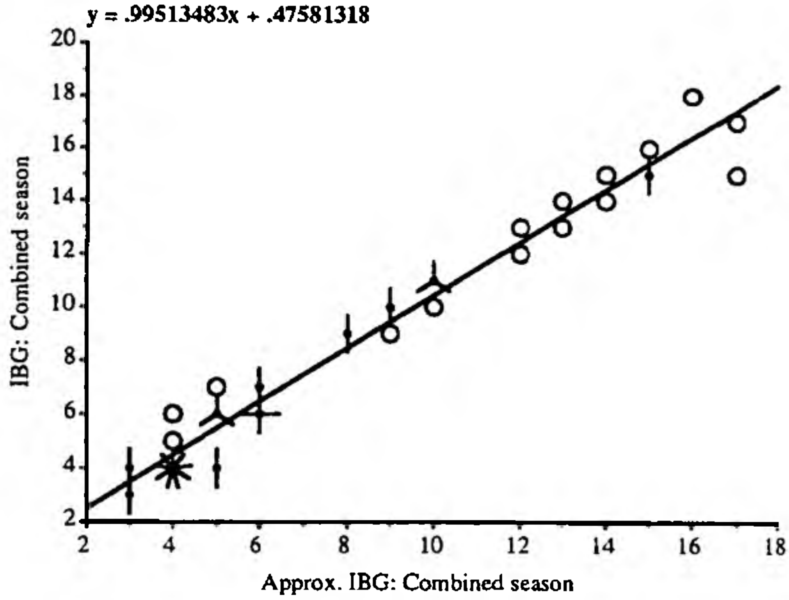
True and approximated IBG

Both graphs show the strong correlation between IBG and approximated IBG. The trend appears to be linear and passes very close to the origin.

Appendix figure 1. True IBG against approximated IBG (single-season).



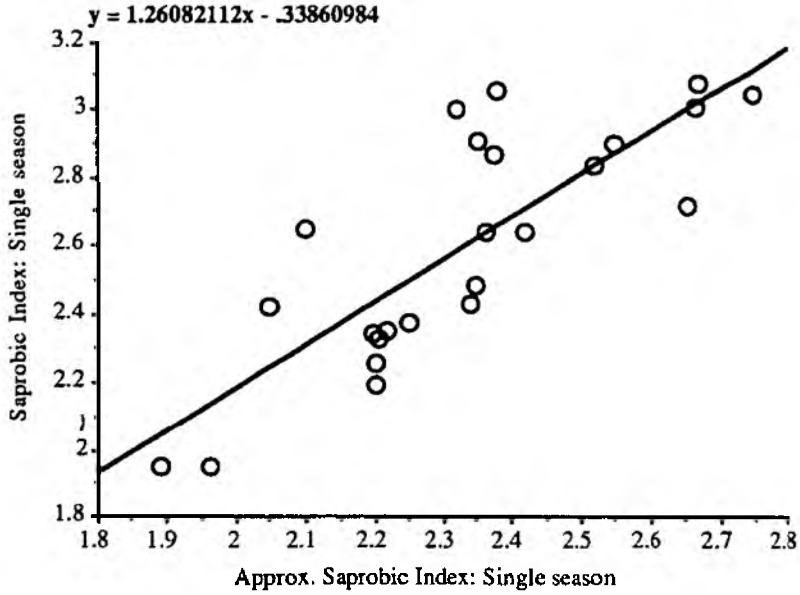
Appendix figure 2. True IBG against approximated IBG (combined-seasons)



True and approximated saprobic index

Though there is good correlation between the true and approximated saprobic index, there is, nevertheless, a lot of unexplained variation, as seen by the scatter of points about the line. The correlation is not as good as was seen with IBG and approximated IBG.

Appendix figure 3 True saprobic index against approximated saprobic index

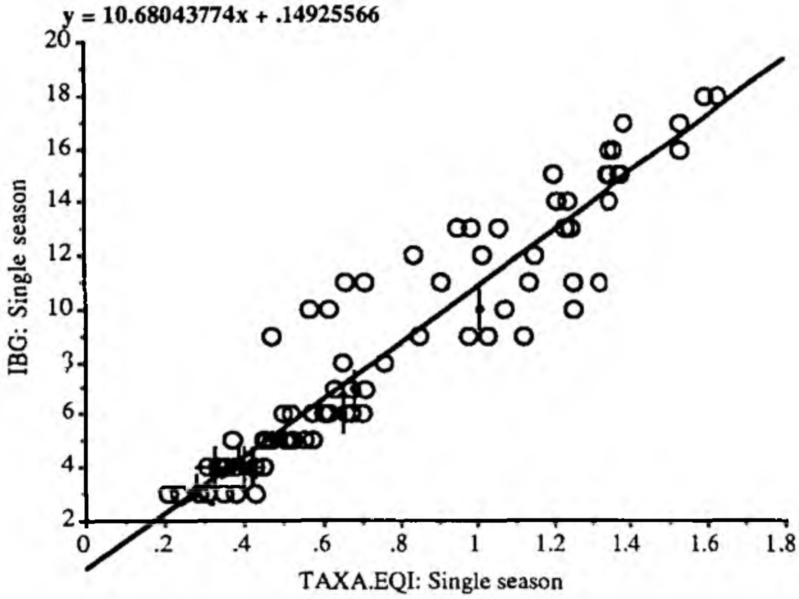


TAXA.EQI and IBG

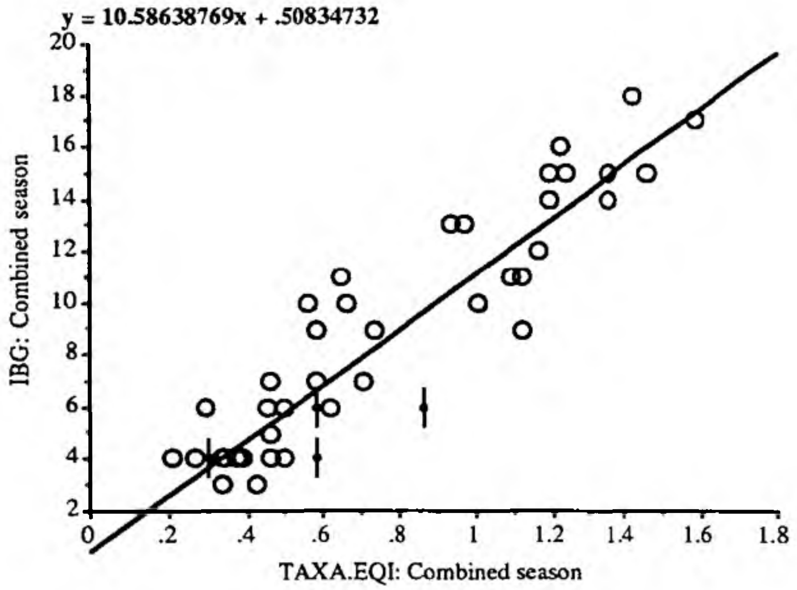
Both graphs (single- and combined-season) show a good fit, which is linear and passes close to the origin. The single-season data show rather more variability about the regression line in the centre (at a TAXA.EQI of about 1) than at higher or lower values. This trend is not as marked with combined-seasons data.

According to the regression equations, single-season samples and combined-season samples with TAXA.EQIs of 1.0 would have IBG scores of 10.8 and 1.1 respectively (i.e. 11 would be the most likely IBG score).

Appendix figure 4 TAXA.EQI against IBG (single-season)



Appendix figure 5 TAXA.EQI against IBG (combined-season)

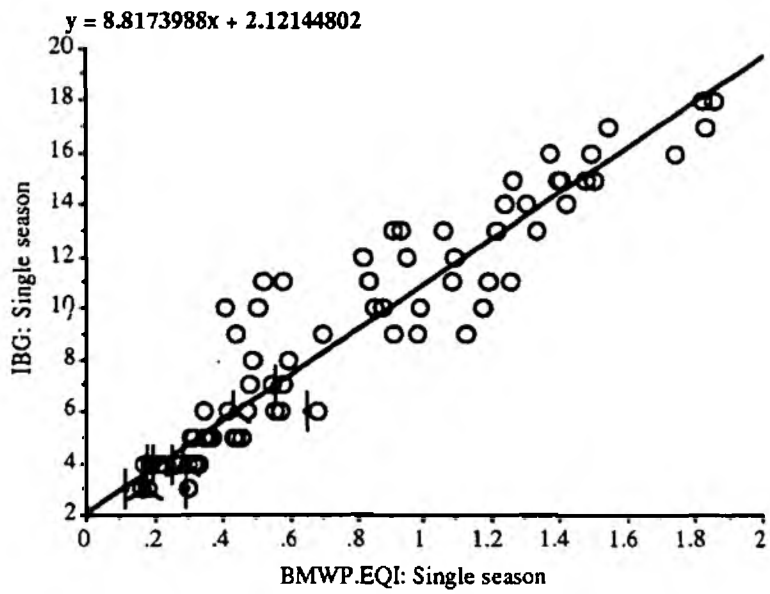


BMWP.EQI and IBG

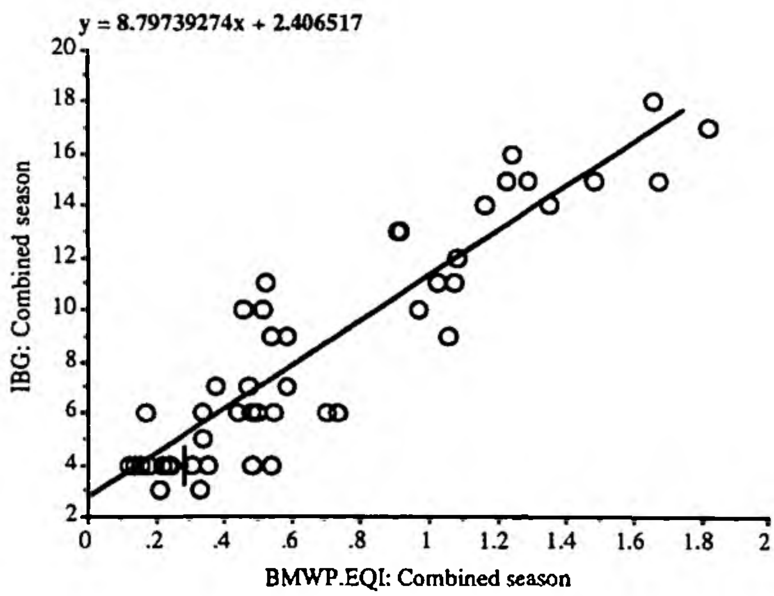
As with TAXA.EQI, both graphs (single- and combined-season) show a good linear fit. In this case, however, the regression line does not pass as closely to zero as with the TAXA.EQI regression. As with TAXA.EQI there is rather more variability about the regression line in the centre (at a BMWP.EQI of about 1) than at higher or lower values. With BMWP.EQI, this increased variation is also evident with the combined-seasons data.

According to the regression equations, single-season samples and combined-season samples with BMWP.EQIs of 1.0 would have IBG scores of 10.9 and 11.2 respectively (i.e. 11 would be the most likely IBG score).

Appendix figure 6 BMWP.EQI against IBG (single-season)



Appendix figure 7 BMWP.EQI against IBG (combined-season)

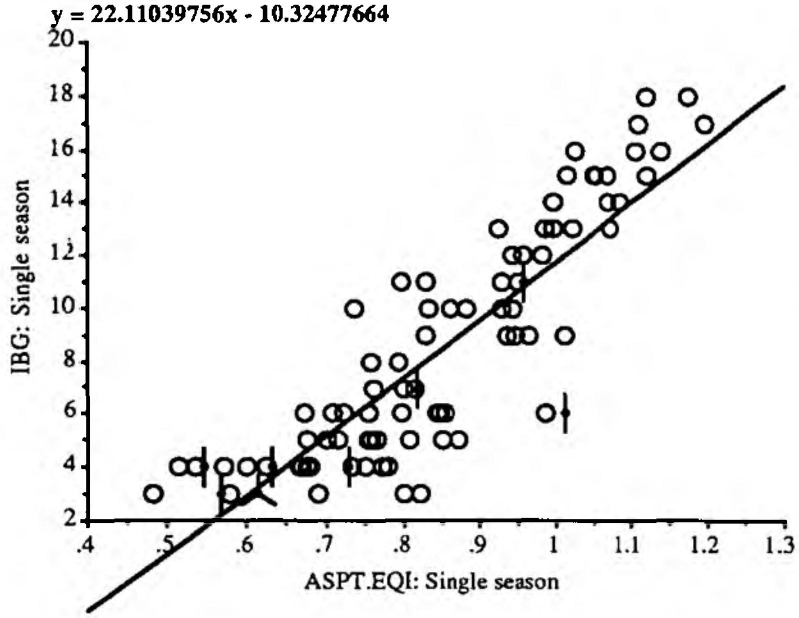


ASPT.EQI and IBG

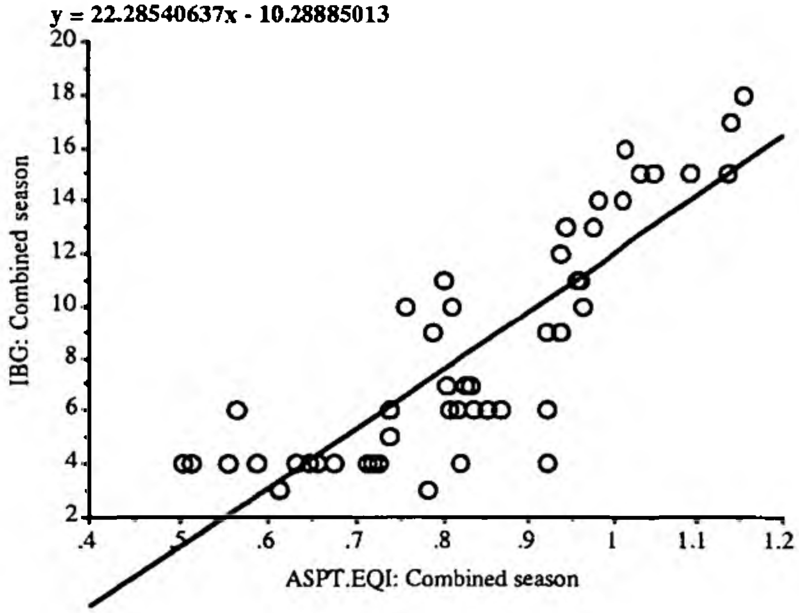
Both single- and combined-season ASPT.EQIs show a much poorer correlation with IBG than TAXA.EQI or BMWP.EQI. In both graphs, the correlation of ASPT.EQI and IBG is quite good at higher values of the two indices but poor at the lower values. Neither single- nor combined-season graphs show a linear fit and, perhaps because of this, neither pass close to the expected origin. Clearly, if there is a need to relate IBG to ASPT.EQI, this would better be done by considering the relationship of IBG to TAXA and BMWP.EQI.

According to the regression equations, single-season samples and combined-season samples with BMWP.EQIs of 1.0 would have IBG scores of 11.8 and 12.0 respectively (i.e. 12 would be the most likely IBG score). The graphs below, however, suggest that this would be an underestimate.

Appendix figure 8 ASPT.EQI against IBG (single-season)



Appendix figure 9 ASPT.EQI against IBG (combined-season)

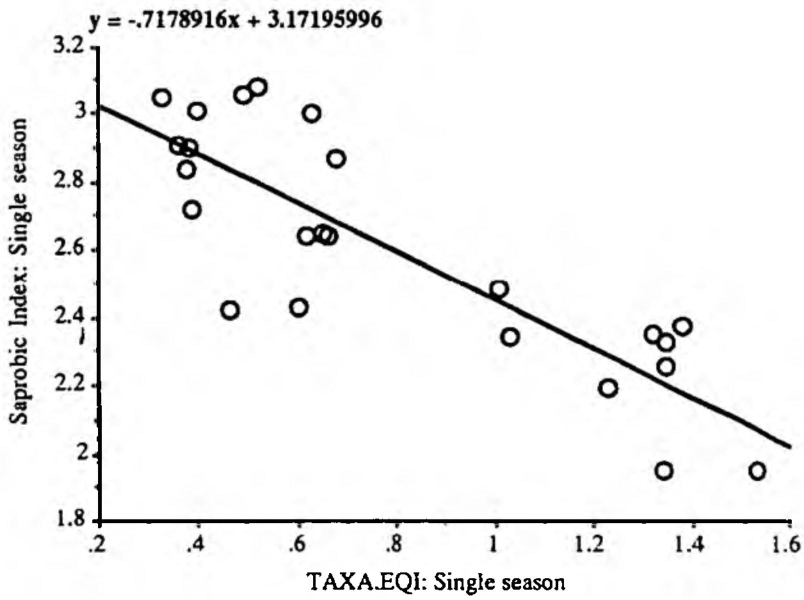


TAXA.EQI and saprobic index

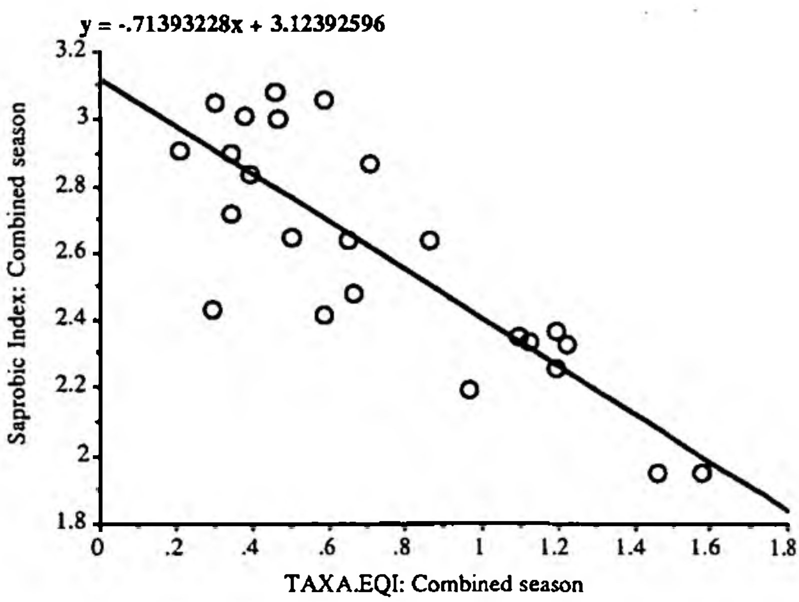
Both graphs (single- and combined-season) show a reasonable fit, which within the limitations of the data appears to be linear. The graphs pass some way from the origin (the origin would be 4.0 for the saprobic index and 0 for TAXA.EQI). Both regressions show greater variability at low water quality (high saprobic index) and this is particularly notable with combined-seasons data.

According to the regression equations, single-season samples and combined-season samples with TAXA.EQIs of 1.0 would have Saprobic Indices of 2.45 and 2.41 respectively.

Appendix figure 10 TAXA.EQI against saprobic index (single-season)



Appendix figure 11 TAXA.EQI against saprobic index (combined-season)

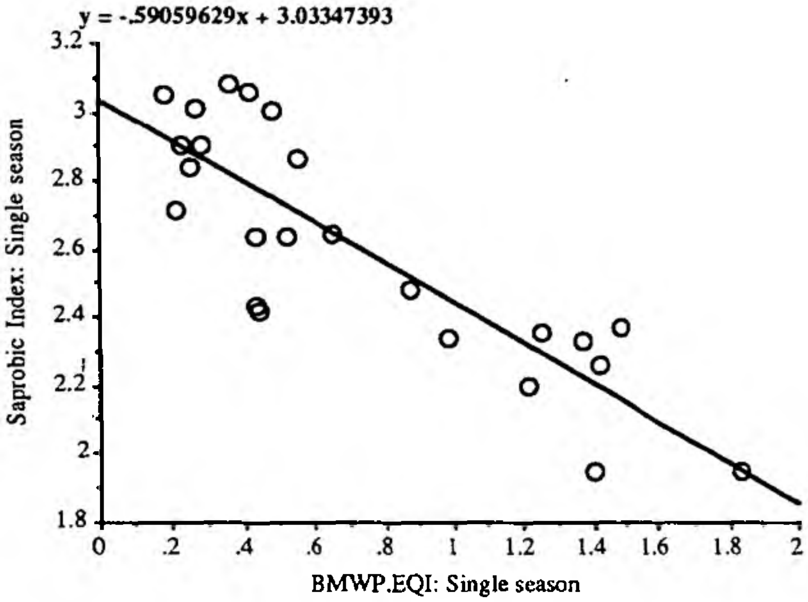


BMWP.EQI and saprobic index

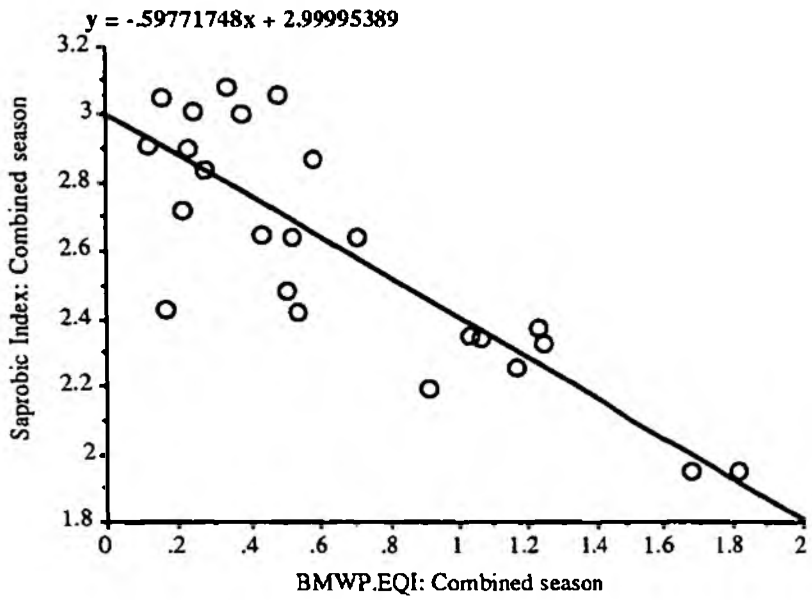
As with TAXA.EQI, both graphs (single- and combined-season) show a reasonable, apparently linear, fit, passing some way from the origin.. Also similar to the TAXA.EQI regressions is the increase in variability towards higher Saprobic Indices and lower water quality. This is very marked using combined-seasons data.

According to the regression equations, single-season samples and combined-season samples with BMWP.EQIs of 1.0 would have Saprobic Indices of 2.44 and 2.40 respectively.

Appendix figure 12 BMWP.EQI against saprobic index (single-season)



Appendix figure 13 BMWP.EQI against saprobic index (combined-season)

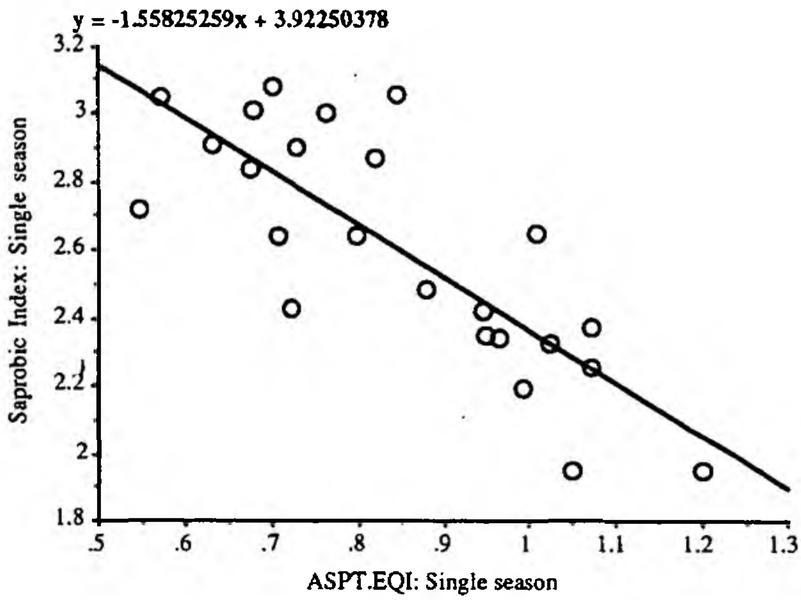


ASPT.EQI and saprobic index

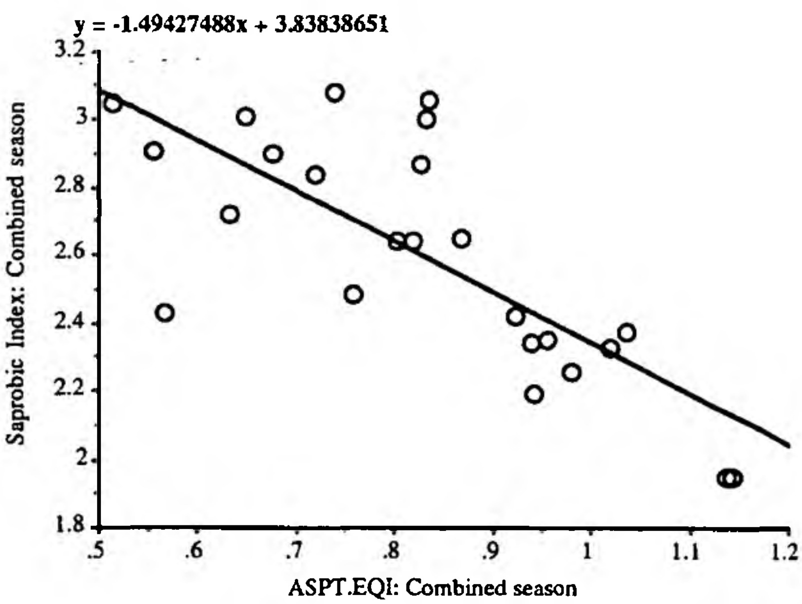
The regressions with ASPT.EQI are not as good as with TAXA and BMWP.EQI. There is a great deal of variability about the regression line and an indication that this variability increases as Saprobic index increases. The line is apparently linear and passes close to the expected origin in both cases (single- and combined-season).

According to the regression equations, single-season samples and combined-season samples with ASPT.EQIs of 1.0 would have Saprobic Indices of 2.36 and 2.34 respectively.

Appendix figure 14 ASPT.EQI against saprobic index (single-season)



Appendix figure 15 ASPT.EQI against saprobic index (single-season)

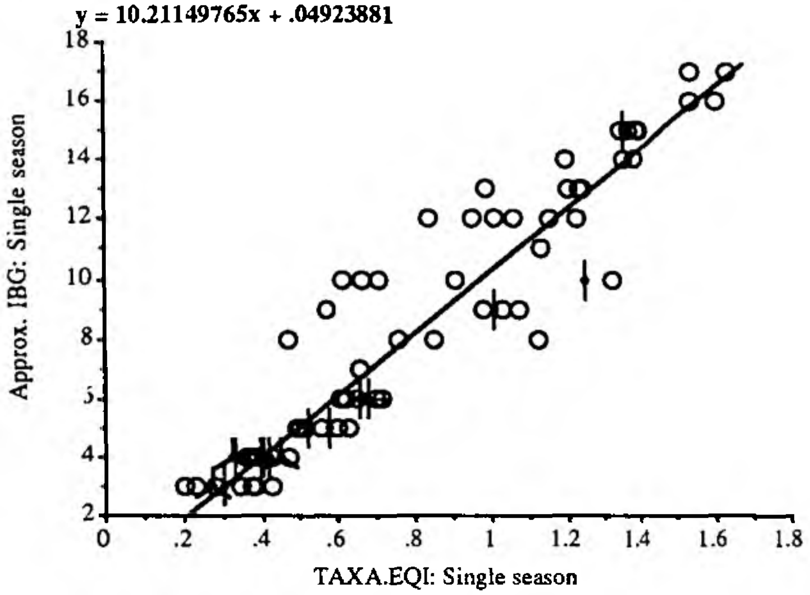


TAXA.EQI and approximated IBG (this study)

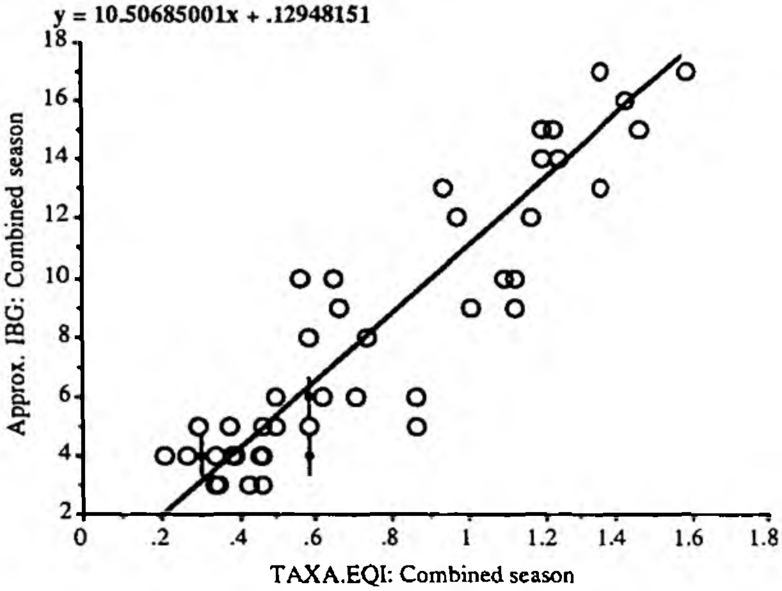
Both graphs (single- and combined-season) using data from this study alone are very similar to the graphs seen for true IBG and TAXA.EQI. This reflects the close correlation seen between approximated IBG and true IBG.

According to the regression equations, single-season samples and combined-season samples with TAXA.EQIs of 1.0 would have approximated IBG scores of 10.3 and 10.4 respectively (i.e. 10 would be the most likely IBG score).

Appendix figure 16 TAXA.EQI against approximated IBG (this study, single-season)



Appendix figure 17 TAXA.EQI against approximated IBG (this study, combined-season)

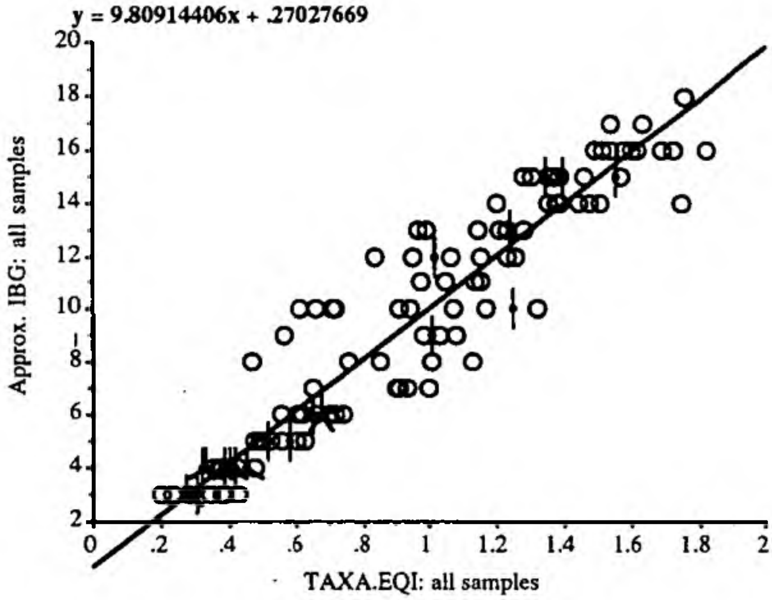


TAXA.EQI and approximated IBG (this study and SWORDS study)

The addition of the data from the SWORDS study does not greatly affect the relationship between approximated IBG and TAXA. The gradient is slightly less and he intercept is slightly further from zero than with the results from this study alone. As with previous graphs, there appears to be rather more deviation from the line around the middle (at a TAXA.EQI if ~1.00).

According to the regression equations, a single-season samples with TAXA.EQIs of 1.0 would have an approximated IBG score of 10.1 (i.e. 10 would be the most likely IBG score). This value is slightly lower (0.2) than seen with this study alone.

Appendix figure 18 TAXA.EQI against approximated IBG (this study and SWORDS study).

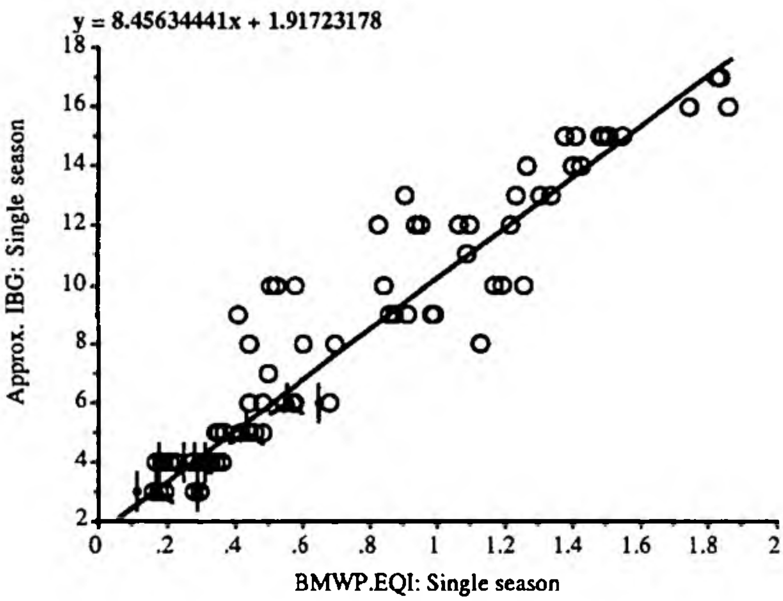


BMWP.EQI and approximated IBG (this study)

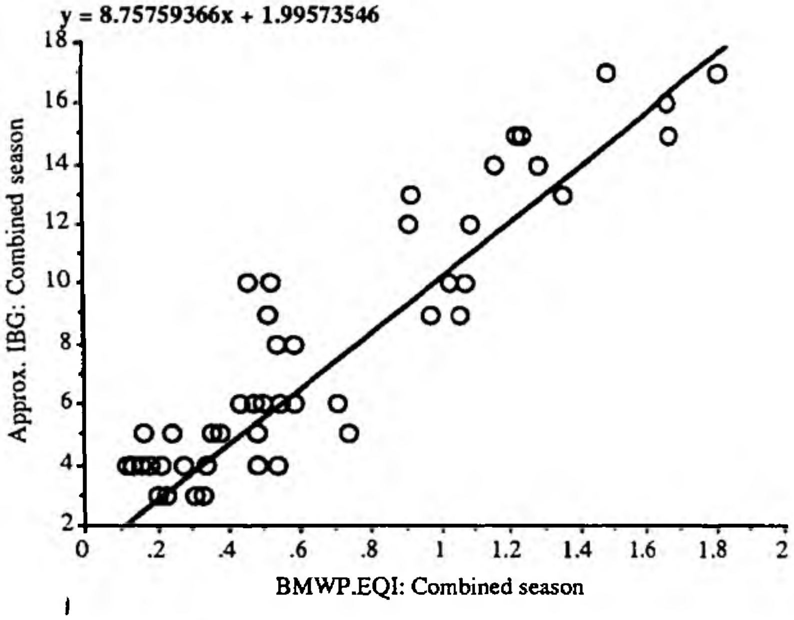
Both graphs (single- and combined-season) using data from this study alone are very similar to the graphs seen for true IBG and BMWP.EQI. This reflects the close correlation seen between approximated IBG and true IBG.

According to the regression equations, single-season and combined-season samples with TAXA.EQIs of 1.0 would have approximated IBG scores of 10.3 and 10.6 respectively (i.e. 10 and 11 would be the most likely IBG scores).

Appendix figure 19 BMWP.EQI against approximated IBG (this study, single-season)



Appendix figure 20 BMWP.EQI against approximated IBG (this study, combined-season)

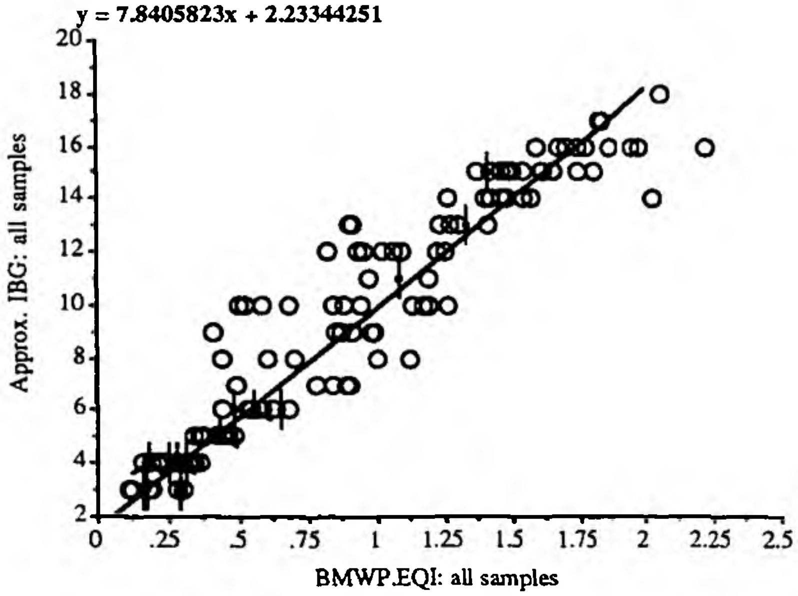


BMWP.EQI and approximated IBG (this study and SWORDS study)

The addition of the data from the SWORDS study has a slightly greater effect on the BMWP. results than TAXA.EQI. Once again the gradient is slightly less and the intercept is slightly further from zero than with the results from this study alone. As with previous graphs, there appears to be rather more deviation from the line around the middle (at a BMWP.EQI if ~1.00).

According to the regression equations, a single-season samples with a BMWP.EQI of 1.0 would have an approximated IBG score of 10.1 (i.e. 10 would be the most likely IBG score). This value is slightly lower (0.2) than seen with this study alone.

Appendix figure 21 BMWP.EQI against approximated IBG (this study and SWORDS study).

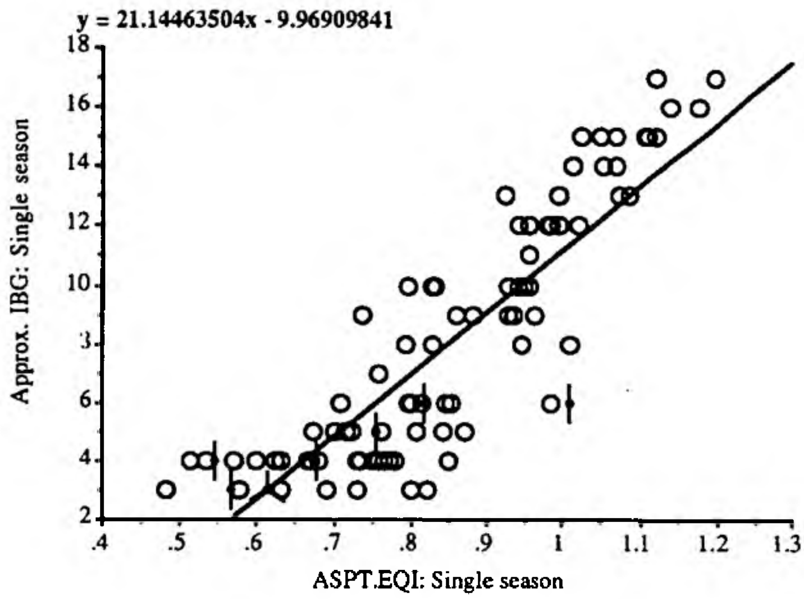


ASPT.EQI and approximated IBG (this study)

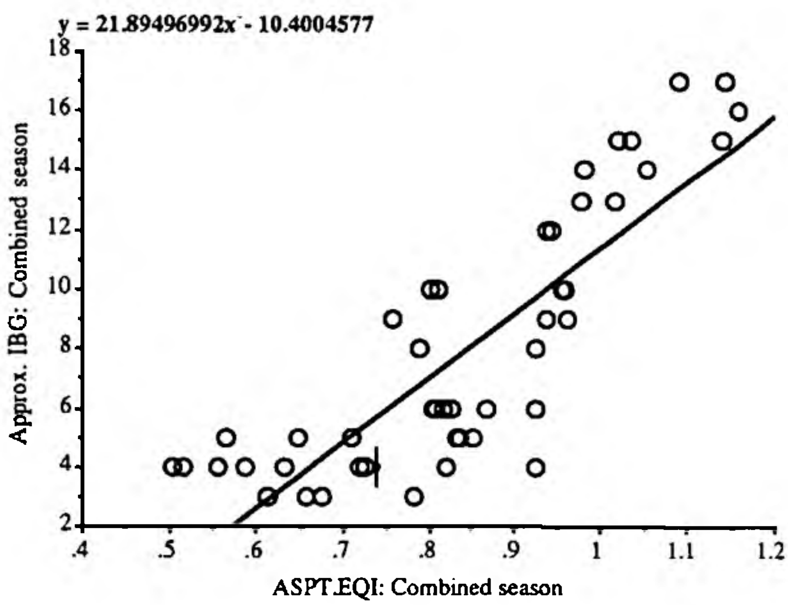
Both graphs (single- and combined-season) using data from this study alone show a similar pattern to those using true IBG scores, with anon-linear spread of data and an increase in variation at lower water quality.

According to the regression equations, single-season samples and combined-season samples with ASPT.EQIs of 1.0 would have approximated IBG scores of 11.2 and 11.5 respectively (i.e. 11 and 12 would be the most likely IBG scores).

Appendix figure 22 ASPT.EQI against approximated IBG (this study, single-season)



Appendix figure 23 ASPT.EQI against approximated IBG (this study, combined-season)

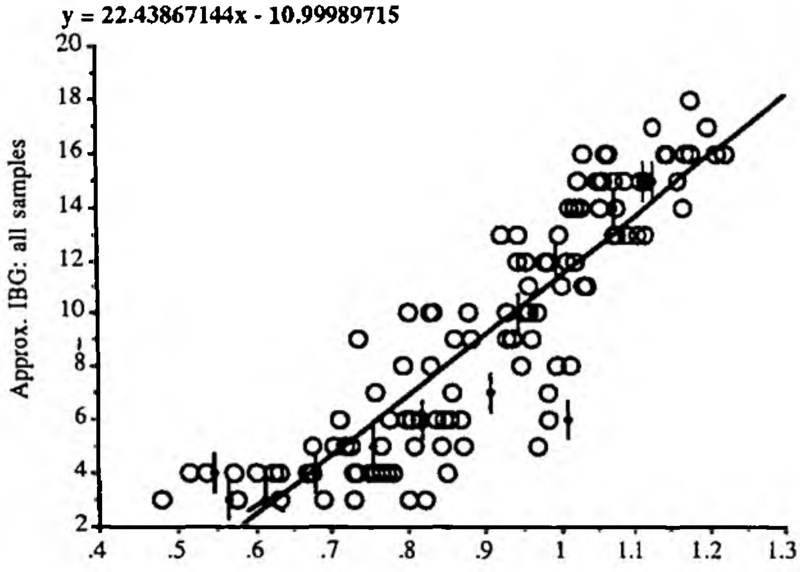


ASPT.EQI and approximated IBG (this study and SWORDS study)

The addition of the data from the SWORDS study has a small effect on the relationship between ASPT.EQI and Approximated IBG. The gradient becomes slightly higher and the intercept slightly further away from zero. Once again the gradient is slightly less and the intercept is slightly further from zero than with the results from this study alone. A: with previous graphs, there appears to be rather more deviation from the line at lower values.

According to the regression equations, a single-season samples with a BMWP.EQI of 1.0 would have an approximated IBG score of 11.4 (i.e. 11 would be the most likely IBG score). This value is slightly higher (0.2) than seen with this study alone.

Appendix figure 24 ASPT.EQI against approximated IBG (this study and SWORDS study).

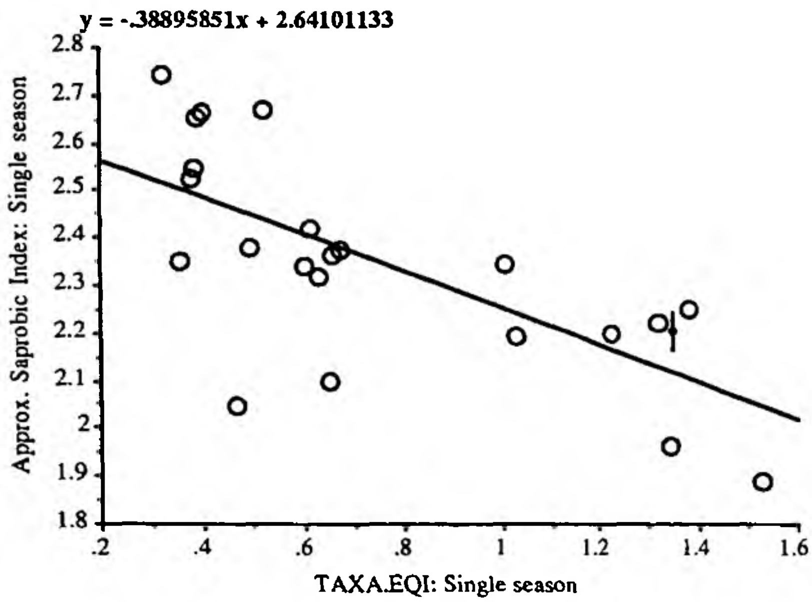


TAXA.EQI and approximated saprobic index (this study)

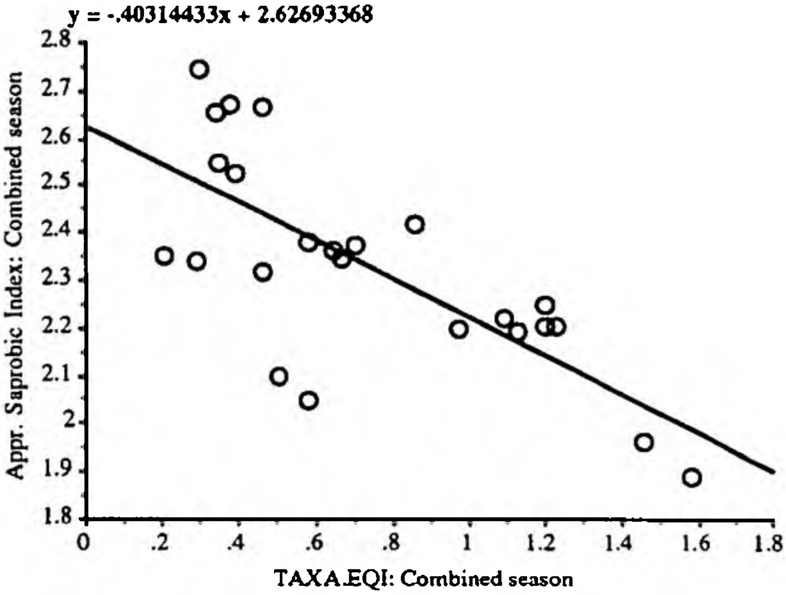
Both graphs (single- and combined-season) are similar to the regressions of TAXA.EQI and true Saprobic index. The fit to the line, however is not as good as for true saprobic index and the graphs pass further from their expected origin. Once again, there is a poor correlation at sites with low water quality.

According to the regression equations, single-season samples and combined-season samples with TAXA.EQIs of 1.0 would have Saprobic Indices of 2.25 and 2.22 respectively.

Appendix figure 25 TAXA.EQI against approximated saprobic index (this study, single-season)



Appendix figure 26 TAXA.EQI against approximated saprobic index (this study, combined-season)

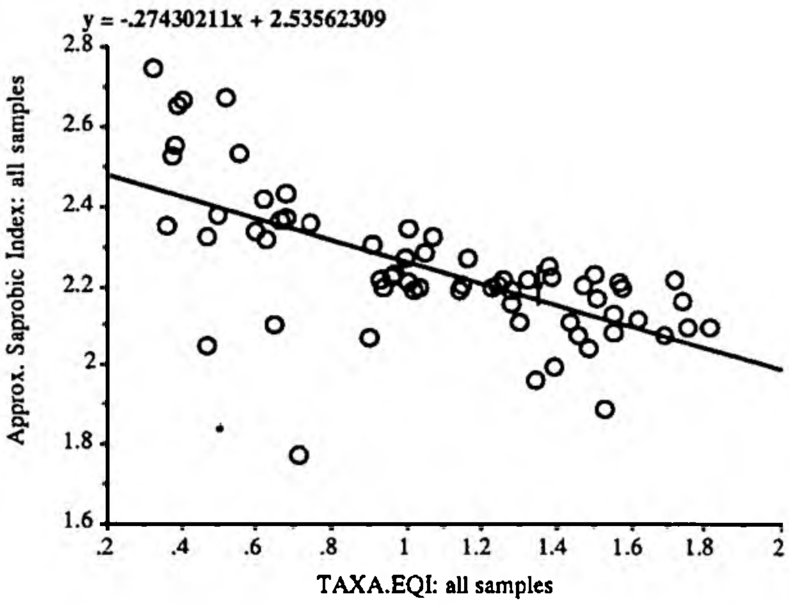


TAXA.EQI and approximated saprobic index (this study and SWORDS study)

With the addition of the data from the SWORDS study the relationship between TAXA.EQI and approximated saprobic index does not alter greatly in form, but the gradient is noticeably less. There is on point which is markedly different from the rest; this was the Ginge at West Hendred which is, at this point, close to its source and at the time of survey had very little water in it. Subjectively, the Saprobic index would seem to give the best estimation of water quality at this site.

According to the regression equations, a single-season samples with TAXA.EQIs of 1.0 would have an approximated saprobic index of 2.25 . This value is slightly higher (0.01) than seen with this study alone.

Appendix figure 27 TAXA.EQI against approximated saprobic index (this study and SWORDS study).

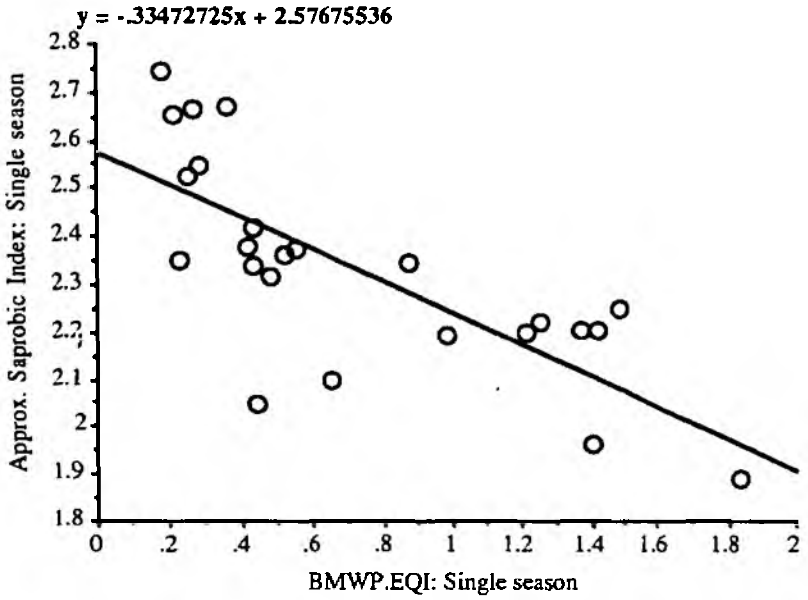


BMWP.EQI and approximated saprobic index (this study)

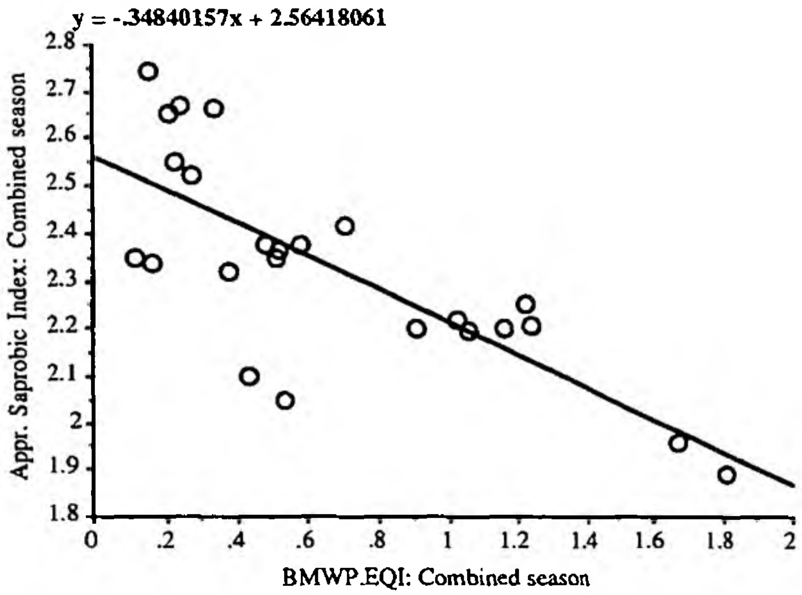
As with TAXA.EQI, both graphs (single- and combined-season) are similar to the regressions of BMWP.EQI and true saprobic index. Once again, the fit to the line is not as good as with the true Saprobic index and the graphs pass further from their expected origin. A poorer correlation at sites with low water quality is again evident.

According to the regression equations, single-season samples and combined-season samples with BMWP.EQIs of 1.0 would have Saprobic Indices of 2.24 and 2.22 respectively.

Appendix figure 28 BMWP.EQI against approximated saprobic index (this study, single-season)



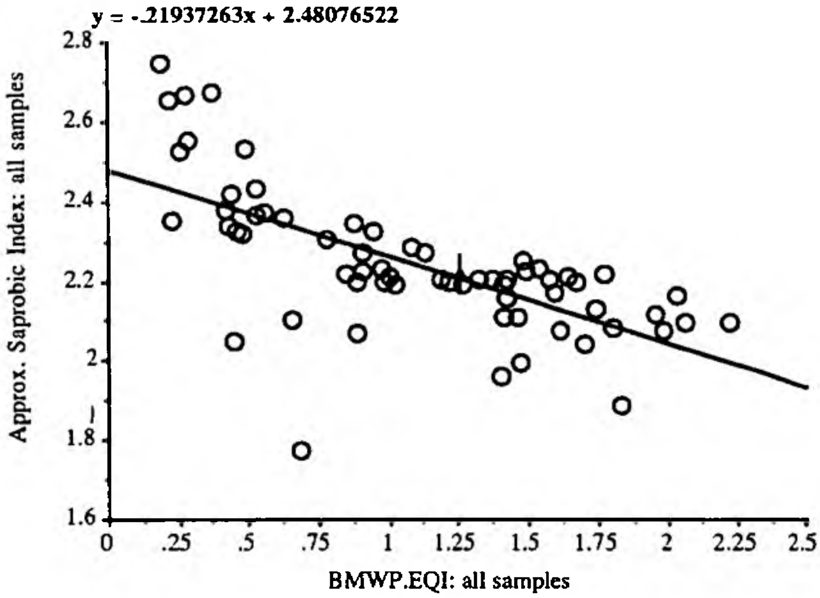
Appendix figure 29 BMWP.EQI against approximated saprobic index (this study, combined-season)



BMWP.EQI and approximated saprobic index (this study and SWORDS study)

As with TAXA.EQI, the addition of the data from the SWORDS leads to a reduction in gradient of the graph. Once again, the Ginge at West Hendred is a noticeable outlier, though several other samples also vary noticeably from the main trend.
According to the regression equations, a single-season samples with BMWP.EQIs of 1.0 would have an approximated saprobic index of 2.26 . This value is slightly higher (0.02) than seen with this study alone.

Appendix figure 30 BMWP.EQI against approximated saprobic index (this study and SWORDS study).

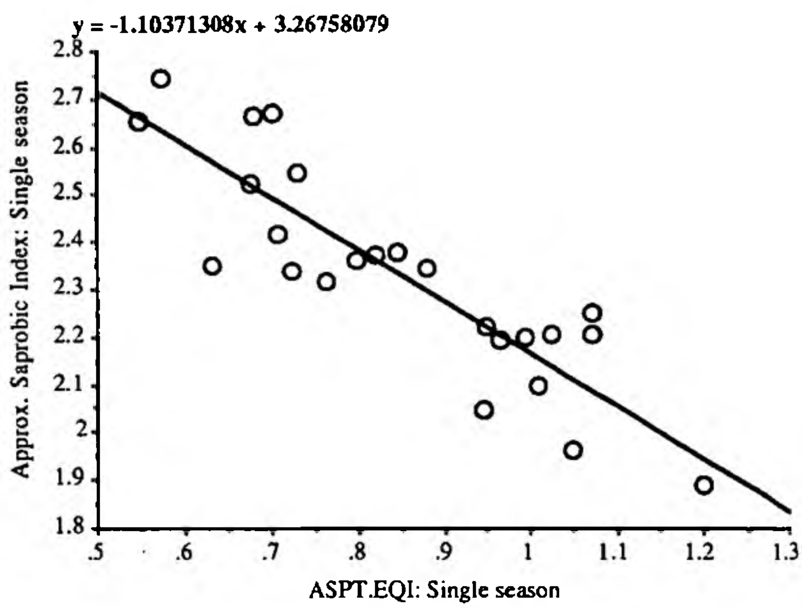


ASPT.EQI and approximated saprobic index (this study)

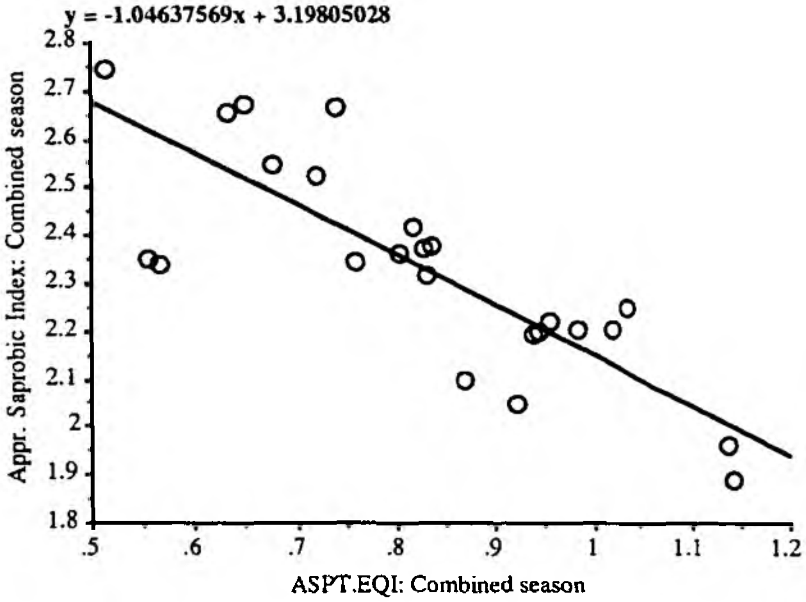
As with TAXA.EQI AND BMWP.EQI, both graphs (single- and combined-season) are similar to the regressions of ASPT.EQI and true saprobic index. In the case of ASPT.EQI, however, the fit to the line is much better than with the true saprobic index. There is a suggestion that variability about the regression line might increase with increasing saprobic index, but in general the fit to the line is fairly constant over its length. The regression line does not pass close to the expected origin, but it is arguable that the origin of the approximated saprobic index could not be 4 as the higher scoring taxa are left out in its calculation.

According to the regression equations, single-season samples and combined-season samples with ASPT.EQIs of 1.0 would have Saprobic Indices of 2.16 and 2.15 respectively.

Appendix figure 31 ASPT.EQI against approximated saprobic index (this study, single-season)



Appendix figure 32 ASPT.EQI against approximated saprobic index (this study, combined-season)



ASPT.EQI and approximated saprobic index (this study and SWORDS study)

As with TAXA.EQI, the addition of the data from the SWORDS leads to a reduction in gradient of the graph. With ASPT.EQI, the only noticeable outlier is the Ginge at West Hendred. As with the other graphs of ASPT.EQI and approximated saprobic index, the relationship is good with an even distribution of points about the line.

According to the regression equations, a single-season sample with BMWP.EQIs of 1.0 would have an approximated saprobic index of 2.21 . This value is slightly higher (0.05) than seen with this study alone.

Appendix figure 33 ASPT.EQI against approximated saprobic index (this study and SWORDS study).