Investigation of the relationship between the LIFE index and RIVPACS

Putting LIFE into RIVPACS

R&D Technical Report W6-044/TR1

R T Clarke, P D Armitage, D Hornby, P Scarlett & J Davy-Bowker

CEH Dorset

Publishing Organisation

Environment Agency, Rio House, Waterside Drive, Aztec West, Almondsbury, Bristol
BS32 4UD
Tel: 01454 624400 Fax: 01454 624409
Website: www.environment-agency.gov.uk

 June 2003

ISBN : 1844321495

Dissemination status
Internal: Released to Regions
External: Public Domain

Statement of Use
This report examines the potential for RIVPACS to enable standardisation of LIFE scores between sites in order to then estimate the relative severity of flow-related stress at a site.

Keywords:
LIFE; RIVPACS; Biological monitoring; macroinvertebrates; low flows; slow flows; ecological stress; Catchment Abstraction Management Strategies (CAMS); Resource Assessment and Management (RAM) Framework

Research Contractor
This document was produced under R&D Project W6-044 by :
CEH Dorset, Winfrith Technology Centre, Winfrith Newburgh, DORCHESTER,
Dorset DT2 8ZD Tel : 01305 213500 Fax : 01305 213600

Environment Agency Project Manager
The Environment Agency's Project Manager for R&D Project W6-044 was
Doug Wilson, Head Office, Bristol.

Further copies of this report are available from:
Environment Agency R&D Dissemination Centre
WRc, Frankland Road, Swindon, Wilts. SN5 8YF
Tel: 01793 865000 Fax: 01793 514562 E-mail: publications@wrcplc.co.uk

ACKNOWLEDGEMENTS

The authors are grateful to Terry Marsh and Felicity Sanderson of CEH Wallingford for providing the flow gauging station data. It has been a pleasure to work with Doug Wilson, the Environment Agency's manager for this R&D project. Many useful comments on an earlier draft were provided by the Project Board members and others, notably Doug Wilson, Chris Extence, Richard Chadd, Alice Hiley, John Murray-Bligh, Philip Smith, Juliette Hall, Stuart Homann and Brian Hemsley-Flint.

EXECUTIVE SUMMARY

In the UK, there are competing demands for both surface and groundwater resources. Sustained or repeated periods of low flows and/or slow flows are expected to impact on the plant and animal communities within rivers. To assess the potential impact of flow-related stresses on lotic macroinvertebrate communities, Chris Extence and colleagues from Anglian Region of the Environment Agency developed the Lotic-invertebrate Index for Flow Evaluation (LIFE). Extence *et al*. (1999) showed that for several individual sites, temporal variation in LIFE could be correlated with recent and preceding flow conditions.

RIVPACS (River InVertebrate Prediction And Classification System), developed by CEH, the Environment Agency and their predecessors, is the principal methodology currently used by the UK government environment agencies to assess the biological condition of UK rivers. RIVPACS assesses biological condition at a site by comparing the observed macroinvertebrate fauna with the fauna expected at the site if it is unstressed and unpolluted, as predicted from its environmental characteristics. Biological condition is estimated currently using two Ecological Quality Indices (EQI) represented by the ratio (O/E) or observed (O) to expected (E) values of the number of Biological Monitoring Working Party (BMWP) taxa present and the ASPT (Average Score Per Taxon), denoted by EQI_{TAXA} and EQI_{ASPT} respectively. LIFE is based on the same macroinvertebrate sampling procedures as RIVPACS.

In this R&D project, an assessment was made of the potential to use the RIVPACS reference sites and methodology to standardise LIFE across all physical types of site, as a ratio of observed to expected LIFE, denoted LIFE O/E. LIFE O/E then provides a standardised estimate of the severity of the impacts of any flow-related stress on the macroinvertebrate fauna at a site.

The Environment Agency intend to use expected LIFE calculated using RIVPACS and LIFE O/E to determine the macroinvertebrate component in the Environmental Weighting (EW) system being developed within their Resource Assessment and Management (RAM) Framework for abstraction licensing and water resource assessments for Catchment Abstraction Management Strategies (CAMS).

CEH have derived a numerical algorithm to provide predictions of the expected LIFE for any river site based on its values for the standard RIVPACS environmental predictor variables. This algorithm is compatible with the derivation of expected ASPT, gives appropriate lower weighting to taxa with lower expected probabilities of occurrence and hence should be used in preference to the current LIFECALCULATOR method.

It is recommended that this new algorithm is incorporated into an updated Windows version of the RIVPACS software system to provide automatic calculation of observed LIFE, expected LIFE and hence LIFE O/E for any macroinvertebrate sample and river site.

All analyses were based on family level log abundance category data from single season samples. The relative merits of using the minimum or average values of single season LIFE O/E or combined season sample LIFE O/E for annual assessments of flow related stress at a site need further investigation. Natural sampling variability alone can cause lower minimum values. An agreed standard method is needed for combining abundance category data for historical samples (i.e. pre- 2002) to enable sites assessments for future samples to be compared with historical data to estimate changes and trends.

Seventy percent of the total variation in LIFE across all the high quality RIVPACS reference sites was explained by differences between the biological groupings of sites formed in the development of RIVPACS; this explanatory power was as high as for ASPT. Amongst these high quality unstressed sites, observed LIFE was correlated with the physical characteristics of a site. LIFE was positively correlated with site altitude and slope and the percentage substratum cover of boulders and cobbles; it was negatively correlated with stream depth and in-stream alkalinity and the percentage cover of sand and fine silt or clay sediment.

When based on its standard suite of environmental predictor variables, RIVPACS predictions of expected LIFE were very effective overall, with correlations between observed life and expected LIFE of 0.78 for the 614 RIVPACS reference sites. Expected LIFE can vary between 5.93 and 7.92.

LIFE O/E was centred around unity for the RIVPACS reference sites, with a small standard deviation of 0.056, less than the equivalent standard deviation for EQI_{ASPT}. Observed and expected LIFE should be recorded to two decimal places and LIFE O/E to three decimal places.

Variation in observed LIFE and LIFE O/E was assessed for over 6000 of the biological sites sampled in the 1995 General Quality Assessment (GQA) national survey. These sites covered a very wide range of types and biological quality of site, including some which had been impacted by varying degrees of flow-related stress. Although observed LIFE ranged from 4.60 to 9.45, 90% of GQA sites had values in the narrow range 5.91-7.85.

A provisional six grade system for LIFE O/E was developed based on the frequency distributions of values of LIFE O/E for the high quality reference sites and the wide ranging GQA sites. The lower limits for the grades were set at 1.00, 0.97, 0.93, 0.88 and 0.83; the lower limit of 1.00 for the top grade was chosen to give compatibility with the GQA grading system based on EQI_{ASPT}.

The LIFE and ASPT indices are naturally correlated to some extent; macroinvertebrate families which require fast flowing conditions tend to also be susceptible to organic pollution, and vice versa. However, amongst the GQA sites the correlation between LIFE O/E and EQI_{ASPT} is only 0.69; the correlation between LIFE O/E and EQI_{TAXA} is only 0.39. The LIFE and GQA grades for the GQA sites were cross-compared.

The LIFE and BMWP scoring systems do not appear to be completely confounded; suggesting that it may be possible to use the biota to differentiate flow-related stress from organic dominated stress. However, the apparent lack of agreement in site assessments using the two scoring systems must be at least partly due to the effects of sampling variation on both sets of O/E ratios. This will be correlated variation as the O/E ratios for a site are all calculated from the same sample(s).

Further research is needed urgently to assess the influence of sampling variation on the observed relationship between LIFE O/E and EQI_{ASPT} and thus the extent to which they can be used to identify different forms of stress.

The sensitivity of RIVPACS predictions of expected LIFE to flow related characteristics at a site was assessed by simulating alterations to stream width, depth, discharge category and substratum composition. Within a site type, realistic changes led to relatively small changes, usually less than 0.3, in expected LIFE. This suggest that RIVPACS predictions of expected LIFE are robust and mostly vary with the major physical types of site.

Ideally, the RIVPACS predictions of the 'target' or expected LIFE, should not involve variables whose values when measured in the field may have already been altered by the flow-related stresses whose effects LIFE O/E is being used to detect. Using new predictions not involving the RIVPACS variables based on substratum particle size composition, stream width and depth, the change in expected LIFE is less than 0.10 for over 70% of sites and the change in LIFE O/E is less than 0.02 for 80% of sites.

However, omitting these variables, especially mean substratum particle size, lead to significant increases and hence over-predictions of expected LIFE for large and/or slow-flowing lowland river sites (notably in RIVPACS site groups 33-35), which then under-estimated LIFE O/E for this type of site. This problem needs resolving.

Further research is needed to assess the potential for improving predictions without these flow-related variables using temporally-invariant GIS-derived variables such as upstream catchment or river corridor geological composition.

An ecological or environmental index is of little value without some knowledge of its susceptibility to sampling variation and other estimation errors. Sampling variation in observed LIFE was assessed using the replicated sampling study sites involved in quantifying sampling variation of ASPT and number of BMWP taxa, as used in the uncertainty assessment of EQIs in RIVPACS III+. Sampling variation in LIFE was found to be small relative to differences between physical types of site. There was no evidence that sampling differences between operators affected LIFE.

The sampling standard deviation of LIFE decreased with the number of LIFE-scoring families present at a site; a predictive equation has been derived. It is recommended that this relationship is used in any future assessment of uncertainty in values of LIFE O/E.

The RIVPACS reference sites were selected because, at the time of sampling, they were considered to be of high biological quality and not subject to any form of environmental stress, whether from toxic or organic pollution or flow-related problems. The current study included the first quantitative assessment of the flow conditions in the year of sampling each reference site relative to the flows in other years at the same site. Reference sites were carefully linked to the most appropriate national flow gauging station using the CEH national river network GIS (Geographic Information System) derived from the CEH-corrected Ordnance Survey 1:50000 blue-line river data. For most types of reference site there was no relationship between autumn sample LIFE O/E and the relative mean summer (June-August) flow in the immediately preceding summer.

Three lowland stream reference sites of the same biological type were identified as having low LIFE O/E and sampled in years of relatively low summer flows. It is recommended that these three sites are not involved in RIVPACS predictions of expected LIFE. Removing these three sites, which are all from RIVPACS site group 33, may also reduce the problem, discussed above, of over-predicting expected LIFE for large lowland river sites in RIVPACS site groups 33-35 when flow-related variables are excluded from the predictions.

A large subset (c. 2000) of the biological GQA sites sampled in the 1995 national survey were linked, using the GIS, to suitable gauging stations of similar Strahler stream order within 10km which had complete summer flow data in 1995 and in at least four other years. One important factor influencing the ability to detect relationships between LIFE and flows was that river flows were less, often much less, than average in all regions of England and Wales in 1995.

The general correlations between autumn sample LIFE O/E and relative summer flows in the preceding summer were statistically significant, but weak, both overall and for sites within each biological type. Correlations were strongest for intermediate size non-lowland streams occurring mainly in northern and south-west England and Wales, which include flashy rivers where the macroinvertebrates are more likely to be dependent on recent flows.

However, the vast majority of the GQA sites with very low values of LIFE O/E (i.e. less than 0.8) had mean summer flows in 1995 which were ranked amongst the lowest 20% of all years with flow data available. These GQA sites are likely to have been suffering from flow related stress in 1995. In contrast, a large proportion of GQA sites with relatively low flows had relatively high values of LIFE O/E in autumn 1995. The autumn 1995 macroinvertebrate fauna at many of these sites may be dependent on flow conditions over longer or earlier periods than just the preceding summer.

In this study, the only flow variable considered was relative mean summer flow and this was correlated with autumn sample LIFE O/E across all GQA sites. The correlations were less than those found by Extence *et al* (1999) within individual sites between observed LIFE and the best of a large range of flow variables measured over a period of years.

More research is needed on developing relationships between LIFE O/E and flow parameters whose time period and form vary with the type of site.

Autumn 2000 was a period of very high flows in many regions, which contrast with the generally low flows in 1995. It may be useful to compare differences in LIFE O/E with differences in flows between the two years amongst those sites with matched flow data that were surveyed in both the 1995 and 2000 GQA surveys.

CONTENTS

1. INTRODUCTION

1.1 Background

In the UK, periods of drought and low flows are becoming more frequent. These are considered to be related to changing weather patterns, possibly linked to global climate change, and also to the high demands for both surface and ground water. Sustained or repeated periods of low flows and/or slow flows are expected to impact on the plant and animal communities within rivers.

To assess the potential impact of flow-related stresses on lotic macroinvertebrate communities, Chris Extence and colleagues from the Anglian Region of the Environment Agency developed the Lotic-invertebrate Index for Flow Evaluation (LIFE) (Extence *et al.* 1999). As the acronym LIFE includes the word index, we will hereafter refer to this index simply as LIFE.

In their paper, Extence *et al.* (1999) attempted to use LIFE to link the riverine benthic macroinvertebrate community of a site to the prevailing flow regime. They showed that for several individual sites for which macroinvertebrate sample data are available for reasonably long periods (range 16-28 years), temporal variation in LIFE could be correlated with flow statistics characterising flow conditions at the site. In particular, streams from chalk and limestone catchment areas were usually most highly correlated with the mean or lower five percentile "summer" (March/April to September/October) flows during the preceding 120-480 "summer" days in the current and sometimes preceding years. There was also some evidence that the macroinvertebrate communities and values of LIFE for rivers draining impermeable catchments are more influenced by short-term hydrological extreme events.

LIFE is based on assigning macroinvertebrate species or families in one of six flow groups according to their perceived ecological association with different flow conditions (Table 1.1).

Table 1.1 Benthic freshwater macroinvertebrate flow groups, their ecological associations and defined current velocities

Group	Ecological flow association	Mean current velocity
I	Taxa primarily associated with rapid flows	Typically > 100 cm s^{-1}
II	Taxa primarily associated with moderate to fast flows	Typically 20-100 cm s^{-1}
III	Taxa primarily associated with slow to sluggish flows	Typically < 20 cm s^{-1}
IV	Taxa primarily associated with flowing (usually slow) and standing waters	---
V	Taxa primarily associated with standing waters	---
VI	Taxa frequently associated with drying or drought impacted sites	---

The calculation and analysis of LIFE in the study of Extence *et al.* (1999) and in this R&D project are both based on benthic macroinvertebrate samples taken according to the standard Environment Agency protocols developed jointly by the Environment Agency and CEH (Murray-Bligh 1999). This involves timed 3 minute hand net sampling of all habitats at a site, with different habitats sampled in proportion to their occurrence or cover. The detailed sampling and sample processing protocols are required for the samples and their site biological condition to be assessed using the RIVPACS software system (Clarke *et al.* 1997). The sampling processing techniques (Murray-Bligh 1999) provide mechanisms to estimate not only the presence-absence of taxa but also their abundance, recorded in RIVPACS logarithmic abundance categories (Table 1.2). The abundance category data are usually denoted and recorded in databases used in RIVPACS as 1-5, but Extence *et al.* (1999) denoted the classes A-E to more easily differentiate them from flow groups I-VI. Notice that, for example, abundance category 2 representing cases of 10-99 individuals, does not mean that the logarithm to base 10 of the actual abundance is two point something (i.e. 2.0 to <3.0). In fact it is one point something (i.e. 1.0 to <2.0). In general, if the actual abundance of a taxon which is present is X, then the RIVPACS abundance category is K, where K = 1 + integer part of $\log_{10}(X)$. In reverse, if the RIVPACS abundance category is K, then the actual abundance is between antilog(K-1) and one individual less than antilog(K) (i.e. 10^{K-1} - < 10^{K}).

Table 1.2 Macroinvertebrate abundance categories

Category	Estimated number of individuals in sample
0 .	0
1 = A	1-9
2 = B	10-99
3 = C	100-999
4 = D	1000-9999
5 = E	10000+

The LIFE calculation for a sample involves assigning flow scores (f_{Si}) (values between 1 and 12) for each scoring taxon *i* present in the sample according to the its assigned flow group association (Table 1.1) and its estimated abundance class (Table 1.2), as specified in Table 1.3. The value of LIFE for a sample is the average of the flow scores (f_{Si}) for each of the *n* taxa present in the sample:

$$\text{LIFE} = \sum_{i=1}^{n} f_{Si} / n$$

Table 1.3 Flow scores (f_S) for different abundance categories of taxa associated with each flow group (I-VI)

Flow group		Abundance categories			
		1 (A)	2 (B)	3 (C)	4/5 (D/E)
I	Rapid	9	10	11	12
II	Moderate/fast	8	9	10	11
III	Slow/sluggish	7	7	7	7
IV	Flowing/standing	6	5	4	3
V	Standing	5	4	3	2
VI	Drought resistant	4	3	2	1

LIFE can be based on macroinvertebrates identified to either species or family. Although some taxa may be found in a range of habitats and flow conditions, each taxon was assigned to the flow group which is considered to be its primary ecological affiliation or, in its sense its optimum or most preferred habitat. Appendix A in Extence *et al.* (1999) lists the flow groups for many macroinvertebrate species.

In this project, for reasons detailed below, all the assessments of the LIFE index are made using all family level log abundance category data. Table 1.4 gives the flow groups and BMWP scores of all of the macroinvertebrate families within the RIVPACS system for which flow groups or BMWP scores have been assigned. (The BMWP score and flow group classification for families and, more specifically, the ASPT and LIFE scoring systems for sites are compared in section 3.5). Appendix B of Extence *et al.* (1999) gives the flow group classification for all these families and for other, usually rarer, families not included in RIVPACS III+.

Table 1.4 LIFE flow group (I-VI) and BMWP score for all families included in the BMWP system.

RIVPACS family code	BMWP score	LIFE flow group	Family
051Z0000	5	IV	Planariidae (incl. Dugesiidae)
05130000	5	IV	Dendrocoelidae
16110000	6	II	Neritidae
16120000	6	III	Viviparidae
16130000	3	IV	Valvatidae
161Z0000	3	IV	Hydrobiidae (incl. Bithyniidae)
16210000	3	IV	Physidae
16220000	3	IV	Lymnaeidae
16230000	3	IV	Planorbidae
162Z0000	6	II	Ancylidae (incl. Acroloxidae)
17110000		II	Margaritiferidae
17120000	6	IV	Unionidae
17130000	3	IV	Sphaeriidae
17140000		IV	Dreissenidae
20000000	1		Oligochaeta
22110000	4	II	Piscicolidae
22120000	3	IV	Glossiphoniidae
22210000	3	IV	Hirudinidae
22310000	3	IV	Erpobdellidae
34310000	8	II	Astacidae
36110000	3	IV	Asellidae
37110000	6	III	Corophiidae
371Z0000	6	II	Gammaridae (incl. Crangonyctidae & Niphargidae)
40110000	10	IV	Siphlonuridae
40120000	4	II	Baetidae
40130000	10	I	Heptageniidae
40210000	10	II	Leptophlebiidae
40310000	10	III	Potamanthidae
40320000	10	II	Ephemeridae
40410000	10	II	Ephemerellidae
40510000	7	IV	Caenidae
41110000	10	II	Taeniopterygidae
41120000	7	IV	Nemouridae
41130000	10	II	Leuctridae
41140000	10	I	Capniidae
41210000	10	I	Perlodidae
41220000	10	I	Perlidae
41230000	10	I	Chloroperlidae
42110000	6	IV	Platycnemididae

RIVPACS family code	BMWP score	LIFE flow group	Family
42120000	6	IV	Coenagriidae
42140000	8	III	Calopterygidae
42210000	8	II	Gomphidae
42220000	8	II	Cordulegasteridae
42230000	8	IV	Aeshnidae
42250000	8	IV	Libellulidae
43110000	5	V	Mesovelidae
43210000	5	IV	Hydrometridae
43220000		IV	Veliidae
43230000	5	IV	Gerridae
43310000	5	V	Nepidae
43410000	5	IV	Naucoridae
43420000	10	II	Aphelocheiridae
43510000	5	IV	Notonectidae
43610000	5	IV	Corixidae
45110000	5	IV	Haliplidae
451Z0000	5	IV	Dytiscidae (incl. Noteridae)
45150000	5	IV	Gyrinidae
453Z0000	5	IV	Hydrophilidae (incl. Hydraenidae)
45510000	5	IV	Scirtidae (=Helodidae)
45620000	5		Dryopidae
45630000	5	II	Elmidae
46110000	4	IV	Sialidae
47110000		II	Osmylidae
47120000		IV	Sisyridae
481Z0000	7	I	Rhyacophilidae (incl. Glossosomatidae)
48130000	6	IV	Hydroptilidae
48210000	8	I	Philopotamidae
482Z0000	8	II	Psychomyiidae (incl. Ecnomidae)
48240000	7	IV	Polycentropodidae
48250000	5	II	Hydropsychidae
48310000	10	IV	Phyrganeidae
48320000	10	II	Brachycentridae
48330000	10	II	Lepidostomatidae
48340000	7	IV	Limnephilidae
48350000	10	I	Goeridae
48360000	10	II	Beraeidae
48370000	10	II	Sericostomatidae
48380000	10	I	Odontoceridae
48390000	10	IV	Molannidae
48410000	10	IV	Leptoceridae
50100000	5	IV	Tipulidae
50220000		II	Ptychopteridae
50320000		V	Chaoboridae
50330000		V	Culicidae
50400000	2		Chironomidae
50360000	5	II	Simuliidae
50810000		V	Syrphidae

Most macroinvertebrate sample identification within the Environment Agency is only done to BMWP family level. This is especially true for the national biological General Quality Assessment (GQA) surveys, where many thousands of samples must be identified and their principal initial use is to provide an assessment of the biological conditions of sites and trends in condition using RIVPACS III+. The GQA system of assessing and grading the biological condition of sites is based on the use of two Ecological Quality Indices (EQI). These EQIs are the ratio of the observed to RIVPACS expected values of number of BMWP taxa and Average Score Per Taxon (ASPT) based on just the presence-absence of BMWP families, so more detailed identification is not needed (and hence not usually available) for these national survey samples.

In a recent Environment Agency R&D project (Clarke & Wright 2000), CEH have developed and tested several new biotic indices based on the use of log abundance category data (as defined in Table 1.2). As part of that project, CEH validated and developed a large database holding the GQA biological and RIVPACS environmental data for a subset of 6016 of the biological GQA sites used in 1995. All these sites had samples taken in both spring and autumn (which was the target sampling regime for the GQA survey). Moreover, the database held the log-abundance category data, rather than just presence-absence data, for all the samples. As a result, that database was readily available to this project to assess the LIFE index, at the family abundance identification level, across a very broad spectrum of sites throughout the country. In addition, for 3018 of the 1995 GQA sites, CEH also have a matched database containing the Environment Agency's equivalent River Quality Survey (RQS) macroinvertebrate data from the national survey in 1990.

Although the RIVPACS system can predict the expected probability of occurrence of individual species, it cannot currently predict the expected log abundance at species level. Therefore, when integrated with RIVPACS, the LIFE index could only be used at the species level in a presence-absence form. Extence *et al.* (1999) suggest that if only presence-absence data are available then the LIFE score (f_S) in Table 1.3 for log abundance category 3 for the flow group of each taxon should be used.

Following the work of Extence *et al.*(1999), the Environment Agency recognised the potential value of LIFE as an indicator or measure of ecological response to flow-related stresses. It was recognised that LIFE needed to be assessed across a wider range and greater number of river sites. Moreover, it was apparent that LIFE varied between different environmental types of river and thus it would not be possible to set a single constant target or lower critical values for LIFE that would be appropriate for all types of river sites. One obvious approach to overcome this problem would be to use RIVPACS to predict the site-specific fauna expected in the absence of any environmental stress (including flow-related stress). From the expected fauna, it should be possible to calculate expected LIFE. Then the ratio of the observed LIFE to expected LIFE may provide a useful standardised LIFE index, applicable to any site. The ratio of observed LIFE (O) to expected LIFE (E) will hereafter be referred to as "LIFE O/E".

The RIVPACS reference sites database contains validated biological information (family abundance and species level presence/absence) from 614 non-impacted or unstressed sites covering all major types of river from source to mouth in Great Britain (GB). The classification of these sites into 35 groups and then comparing their physico-chemical characteristics with those of sites being investigated forms the basis of the national biological assessment methodology used by the Environment Agency (RIVPACS III+) (see e.g. Wright 2000; Clarke 2000).

1.2 Aims, objectives and component modules of the project

The aim of this R&D project was to assess the potential to refine LIFE by standardising observed values of LIFE by dividing by the site-specific expected values of LIFE, as estimated by RIVPACS, to give LIFE O/E ratios.

The potential of "putting LIFE into RIVPACS" was investigated through the following series of seven inter-linked Modules:

Module 1	RIVPACS reference site variation in LIFE
Module 2	Setting targets for expected LIFE and LIFE O/E
Module 3	LIFE O/E for GQA sites
Module 4	Simulating flow-related changes in expected LIFE
Module 5	Alternative RIVPACS predictor options
Module 6	Hydrological data relationships
Module 7	Sampling variation in LIFE

The following paragraphs give a description of the work carried out in each Module, all in agreement with the project aims, objectives and research approach for each Module.

1.2.1 Module 1 RIVPACS reference site variation in LIFE

The observed LIFE for the 614 sites that comprise the RIVPACS reference database were calculated and their relation to the current RIVPACS III+ environmental variables examined. This analysis showed the relationship between river type (as defined by the 35 TWINSPAN groups of the RIVPACS classification) and LIFE. The assumption here was that the RIVPACS reference data were collected from river sites that were not impacted by flow stress. (This assumption was to be checked in Module 6). Methods to derive the expected LIFE for any site were developed.

1.2.2 Module 2 Setting targets for expected LIFE and LIFE O/E

From the analyses in Module 1, methods were derived to determine the target (i.e. expected) values of LIFE for any site. Thus, the natural range of values for specific site types was incorporated in the target-setting exercise. This was important because the role of discharge on habitat availability depended on geomorphological factors. Values of expected LIFE were calculated using the suite of environmental variables used in RIVPACS III and RIVPACS III+ environmental predictor option 1 – which is the current norm. Variation in LIFE O/E for the RIVPACS reference sites was assessed and used to provide a framework for setting the lower limit for top grade (i.e. unaffected) sites.

Values of expected LIFE used in Modules 2, 3 and 4 were all based on predictions using the environmental variables specified as option 1 in RIVPACS. These were:

- latitude, longitude (from which temperatures are derived by interpolation within RIVPACS from coded published maps)
- altitude, slope and distance from source
- Stream width and depth
- Discharge category
- Substratum composition
- Alkalinity

These were the only environmental variables that were readily available for all the RIVPACS reference sites and the GQA sites. The extra variables measured early in RIVPACS' development were not measured for any of the 200+ extra reference sites added between RIVPACS II and RIVPACS III.

1.2.3 Module 3 LIFE O/E for GQA sites

The O/E ratios for LIFE were calculated for the 6016 GQA sites analysed by Clarke *et al.* (1999). In addition, for 3018 GQA sites sampled in autumn in both 1990 and 1995, O/E LIFE was calculated and the between year changes assessed. This work was considered a crucial part of any attempt to produce a general grading scheme based on O/E LIFE akin to that based on O/Es for ASPT and number of BMWP taxa.

Correlations and patterns between LIFE O/E and EQI for ASPT and number of BMWP taxa for the 1995 GQA dataset were analysed to provide information on the extent to which O/E LIFE, which attempts to quantify flow-related stresses, varied independently of the current EQIs, which were derived predominantly to assess the effects of pollution.

1.2.4 Module 4 Simulating flow-related changes in expected LIFE using RIVPACS

Simulations were used to assess the effects on expected LIFE (based on RIVPACS III+ environmental variables option 1) of varying flow conditions at a site by altering stream width, depth and substratum composition (Armitage *et al.* 1997). This was to examine the sensitivity of RIVPACS III's predictions to flow-related variables.

1.2.5 Module 5 Alternative RIVPACS predictor options

The effects and importance of involving different combinations of the current RIVPACS III+ environmental variables on expected LIFE were investigated. In particular, the possibility of producing predictions without the use of substratum data was examined, because it may be inappropriate to use the substratum composition at the time of sampling to predict the expected biota and hence expected LIFE if substratum has already been changed by the low-flow stress whose effect we are trying to detect and measure by LIFE O/E. This required new Multivariate Discriminant Analyses (MDA) of the 614 RIVPACS reference sites to derive the appropriate equations for predicting probability of biological group membership, which were then used to obtain new predictions of the expected fauna and hence the expected LIFE.

1.2.6 Module 6 Hydrological data relationships

Module 3 above included the determination of LIFE O/E for the GQA sites and an assessment of the relationship between EQIs for ASPT and number of BMWP taxa and LIFE O/E. In order to interpret the distribution of these LIFE O/E values properly, information was gathered about the hydrological 'history' of the sites. A subset of GQA sites with flow data was derived to examine the distribution of LIFE indices in relation to flow characteristics.

An investigation was made into whether the samples from any of the RIVPACS reference sites were taken in years of abnormal flow. This was considered to be important because the samples and sites are used to set macroinvertebrate targets.

The GQA and RIVPACS reference sites that have suitable flow data were determined in order to match flow conditions with biological assessments. As agreed, CEH Wallingford provided a list of all gauging sites, including river name, site name, NGR, the type of station and information on the continuity of the record. If possible, this list was to contain information on whether the flow data adequately described the discharge conditions at the site. These gauging sites were then carefully matched against the GQA and RIVPACS reference sites using ARCINFO and the CEH Dorset's 'River Network' information. This crucial, initial analysis was to provide information to determine which biological sites could be linked to relevant hydrological data.

The next stage, which required more effort, attempted to relate the sample date to preceding flow conditions and to place these flow data within the continuum of discharge records available for that site or river. As an agreed simple first step, CEH Wallingford provided a simple standard measure of flow conditions for each site, namely average summer (June-August) flow, prior to the autumn biological sample that year. CEH Wallingford also supplied information on the long-term average summer flow (June-August), where suitable data was available. The ratio of the summer flow in the year of the biological sample relative to the long-term average summer flow was used to provide a standardised measure of summer flow conditions at each site in the year of sampling.

The analysis described above provided an initial vehicle for the interpretation of LIFE from both the RIVPACS and GQA data sets. (The use of more detailed time-specific flow variables or additional variables on flows in other seasons would have required extra subcontracting and analysis time and hence cost considerably more than allowed for in this contract.) These data were used to help interpret the relationship and discrepancies between LIFE O/E, EQI_{ASPT} and EQI_{TAXA}.

1.2.7 Module 7 Sampling variation in LIFE

In a previous R&D project (Furse *et al*. 1995), CEH carried out a replicated sampling study covering a wide range of qualities and environmental types of site to quantify the effects of both operator sampling variation and differences in estimating the RIVPACS environmental predictor variables on RIVPACS EQI values. Their results were used to develop simulation procedures in RIVPACS III+ to provide confidence limits and tests for change in EQI values (Clarke *et al*. 1997, Clarke 2000). These data were re-analysed to quantify the effects of sampling variation on the robustness of LIFE.

1.3 Use of multiple seasons abundance data

1.3.1 Restriction to single season comparisons

In RIVPACS, comparisons of the observed and expected fauna for presence-absence data at either family or species level can be made for either single season samples, two season combined samples or three season combined samples for any yearly period. The three RIVPACS seasons are spring (March – May), summer (June-August) and autumn (September – November).

Comparisons of the observed and expected log abundances can only be made for family level data and, at present, only for single season samples. This restricts the current use of abundance data for assessing site condition to single season samples. In particular, for the

1995 and 2000 GQA surveys, the target sampling regime was to take samples in two seasons, preferably spring and autumn, and base site assessments for each year on the two season combined sample EQI values. When for example, spring and autumn samples are available for a site in one year, assessments of site condition based on LIFE scores can, at present, only be made for each of the two single season samples, not for the combined season sample, as is usually done for GQA assessments. The average or the lower of the two single season sample estimates of site condition based on LIFE could be used to represent the year.

In their development of abundance-based indices of site condition, Clarke and Wright (2000) recognised that it would not currently be possible to do any GQA assessments using combined season sample data. The main "stumbling block" was that there was no agreed standard method for combining the abundance data for two or three samples when the information recorded for each sample was not the actual abundance, but only the log abundance category.

The Environment Agency has recently made a decision to overcome this problem for future samples (Murray-Bligh *pers. comm.*). From April 2002 onwards, it will be mandatory to record the actual or estimated numerical abundances in the relevant database whenever abundances are obtained for a sample. This will permit the subsequent grouping of abundances into any required abundance categories and enable the correct combining of abundances over two or more samples.

Clarke and Wright (2000) recommended that further research be carried to develop, test and agree a standard method for combining abundance category data from two or three seasons' samples. This will still be useful for most samples prior to 2002, including the 1990 RQS and many of the 1995 and 2000 GQA samples. The accuracy of any method can be assessed using sites for which the actual numerical abundances are available for two or more seasons' samples.

It is recommended that a standard method is agreed for combining abundance category data for historical samples (i.e. pre- 2002) to enable sites assessments for future samples to be compared with historical data to estimate changes and trends.

This will be pertinent to any use of the LIFE index and O/E ratios for LIFE based on combined season samples.

1.3.2 Use of minimum LIFE O/E values

There is some value in calculating observed (O), expected (E) and O/E ratios of LIFE separately for each season's sample, so that changes in the biological impacts of flow-related stress can be assessed through the seasons. It may be argued that seasonal variation in flow-related stress is important and that, rather than calculating LIFE O/E for combined season samples, the lowest of the LIFE O/E values for any single season sample from a site in one year should be used as the indicator of (maximum) flow-related stress for the site for that year.

However, because of sampling variation and estimation errors, the minimum of two or more O/E values is likely to be considerably lower than either their average value or the equivalent O/E value for the combined season sample (Figure 1.1; Table 1.5). For example, for the RIVPACS reference sites the median value of EQI_{ASPT} was 1.000 for both single season samples and three season combined samples, but only 0.96 for the minimum of the three single season sample values at a site. The minimum of the single season sample O/E values is also likely to be estimated with lower statistical precision. Because the O/E index scale is compressed downwards when the minimum is used, it can be more difficult to devise a grading system with statistical power to detect different levels of stress. By chance some unstressed sites will have relatively low minimum O/E values. For the RIVPACS reference sites the lower 10 percentile values of EQI_{ASPT} for the was 0.93 for three seasons combined samples, 0.89 for single season samples and 0.85 when based on the minimum of the three single season EQI values.

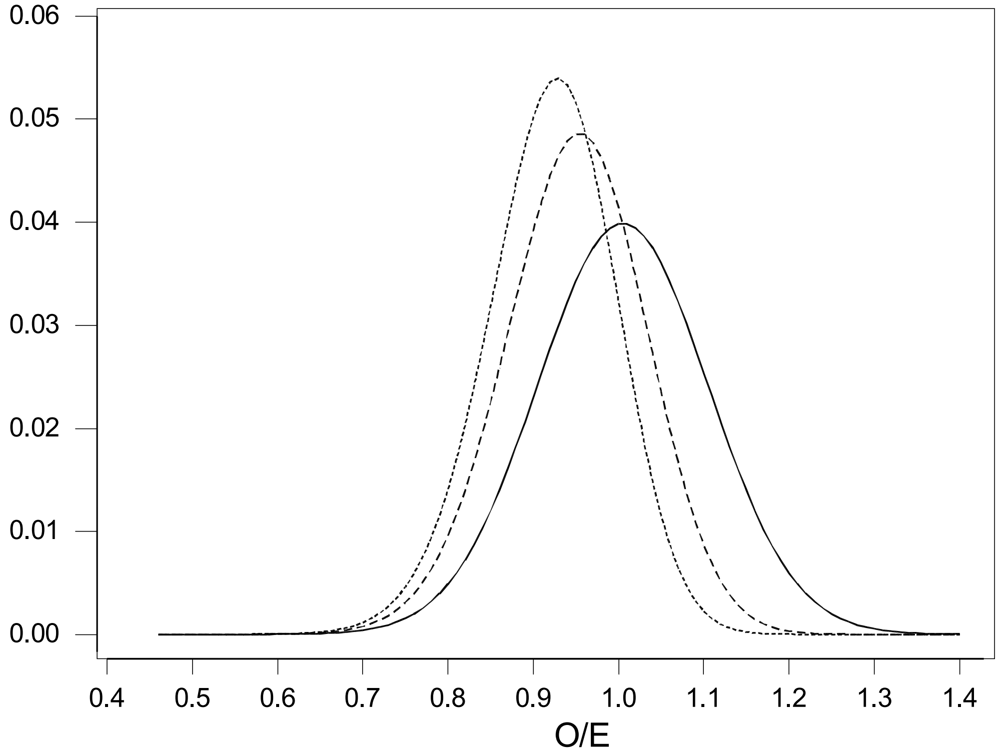


Figure 1.1 Probability distribution for singles season samples (——) from a site with true O/E of 1.0, but with a normal distribution of sampling errors with SD=0.1; together with distributions for the minimum of two (- - - -) and three (.....) single season O/E values.

Table 1.5 Effect of sampling errors (SD) in estimating O/E for each of the two or three individual seasons O/E values from a site with a true O/E of 1.0 on the values obtained for the minimum of the two or three O/E values.

	Sampling SD	0.00	0.05	0.10	0.15	0.20
Median value for O/E based on minimum of O/E values for :	2 seasons	1.000	0.972	0.944	0.916	0.887
	3 seasons	1.000	0.958	0.915	0.873	0.831

The statistical precision and consequences of using minimum values of single season LIFE O/E for annual assessments of flow related stress at a site needs further investigation.

2. LIFE FOR THE RIVPACS REFERENCE SITES

This section covers research in Modules 1 (aims and objectives in section 1.2.1) and part of Module 2 (aims and objectives in section 1.2.2).

The RIVPACS reference sites were chosen to represent as wide a range of types of running water river sites in GB as possible. In addition the reference sites were selected because they were considered to be in good biological condition and not subject to any significant pollution or other environmental stresses. As part of the development of the RIVPACS methodology, the reference sites were classified into 35 site groups based on just their macroinvertebrate fauna; this is explained further in section 2.3.1.

2.1 Variation in observed LIFE for the RIVPACS reference sites

A test version of the RIVPACS software was modified to enable the calculation of LIFE for any samples involving family level abundance data (i.e. RIVPACS III+ taxonomic option 2). The test software was then used to calculate and output the observed LIFE for each of the three single season (spring, summer and autumn) samples from each of the 614 RIVPACS reference sites, giving a total of 1842 sample values.

Table 2.1 summarises the variation in the observed LIFE amongst the RIVPACS reference sites, separately for each of the three RIVPACS seasons. The average and range of values for LIFE is fairly similar in all three seasons. Overall LIFE for the 614 reference sites ranges from 5.00 to 9.45 with an average value of 7.32.

Table 2.1 Variation in observed LIFE for the RIVPACS reference sites for each season, including the 25 and 75 percentiles

	Mean	**Min**	**25%**	**Median (50%)**	**75%**	**Max**
spring	7.37	5.40	7.05	7.46	7.80	8.79
summer	7.34	5.37	6.95	7.44	7.80	9.00
autumn	7.24	5.00	6.90	7.34	7.67	9.45
overall	7.32	5.00	6.96	7.41	7.75	9.45

The fauna found at a site in RIVPACS macroinvertebrate samples is expected to vary to some extent with the seasons because of the life-cycles of some taxa. This is why RIVPACS provides season-specific predictions of the expected fauna for any site. Statistically powerful paired t-tests on the differences between two seasons in their values for LIFE for each site were used to assess whether one season had any tendency to have higher values of LIFE than another season. The average difference between spring and summer sample values for LIFE for the RIVPACS reference sites was only 0.030 with a standard error (SE) of 0.015, but because of the large number of sites involved the difference was just statistically significant ($p = 0.05$). However there was some tendency for values of LIFE to be lower for autumn samples, which were on average 0.13 (SE=0.014) and 0.10 (SE=0.014) lower than spring and summer values respectively; both paired t tests were significant at the $p<0.001$ probability level. Figure 2.1 highlights the tendency of observed LIFE for the reference sites to be slightly lower for autumn samples. 60-63% of sites had lower values of LIFE for autumn samples compared to spring or summer samples.

Incidentally, Figure 2.1 also shows the relatively large variation in LIFE between samples from the same reference site within a year, despite all these sites supposedly being unstressed. This suggests that basic sampling effects caused considerable variation in the observed LIFE for a site; sampling effects were investigated in detail in Module 7 (aims specified in section 1.2.7).

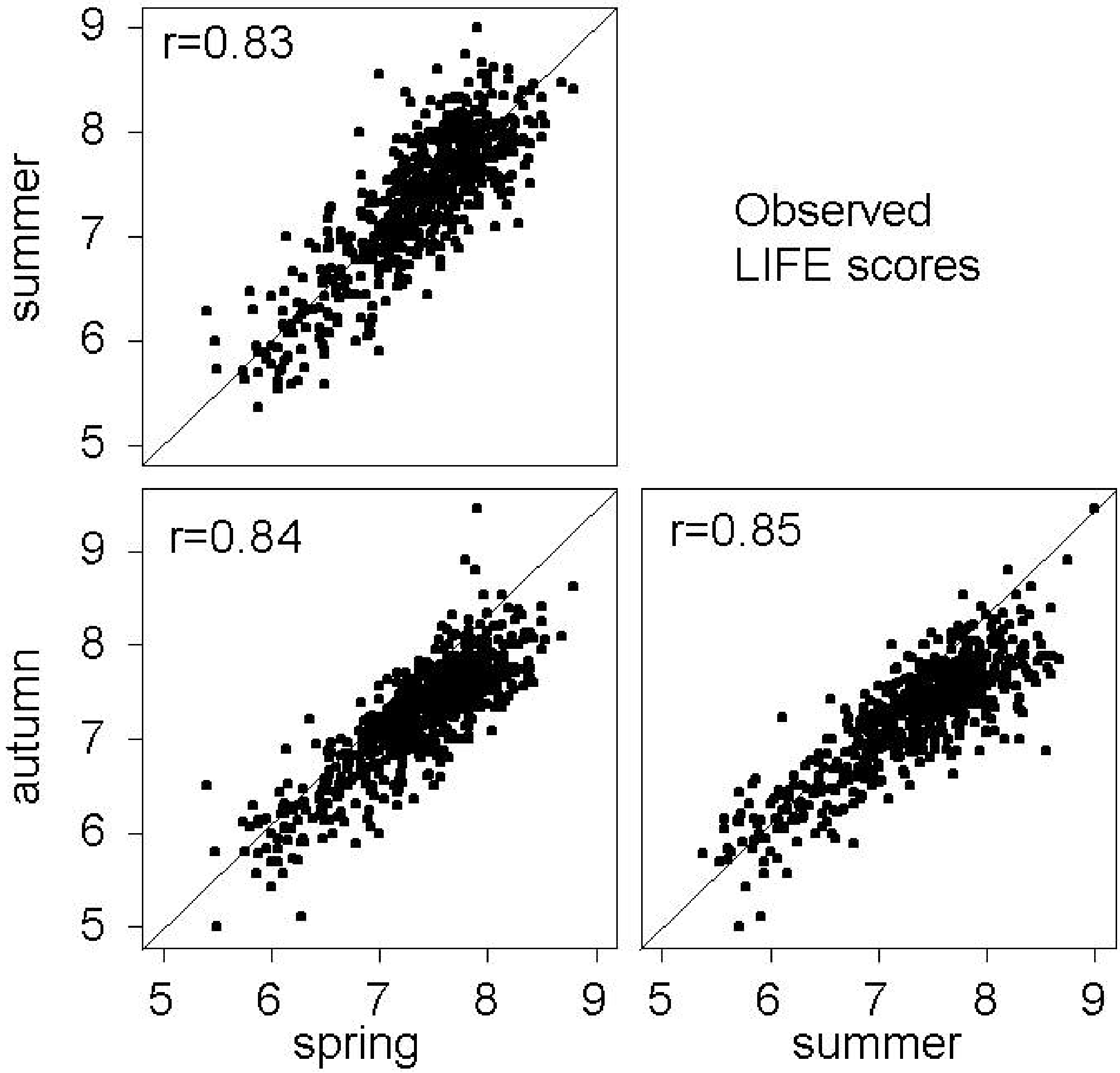


Figure 2.1 The observed LIFE of the RIVPACS III references sites in each pair of seasons, together with their correlation coefficient r. The solid line is the 1:1 line

2.2 Observed LIFE relationships with RIVPACS environmental variables and site type

2.2.1 Relationships between LIFE and RIVPACS site groups

The RIVPACS reference sites are classified into 35 site groups based solely on their macroinvertebrate sample composition (Clarke *et al.* 1997). Figure 2.2 shows the variation in observed LIFE for the reference sites in each of the site groups and the site group means are given in Table 2.2.

Table 2.2 Mean and range of observed LIFE in each season for the reference sites in each RIVPACS site group (1-35)

Site Group	Number of Sites	Spring			Summer			Autumn		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
1	34	7.70	6.82	8.40	7.62	6.78	8.50	7.59	7.00	8.80
2	6	7.47	7.00	7.89	7.54	6.56	7.94	7.49	7.33	7.77
3	20	7.90	7.50	8.38	7.75	7.06	8.07	7.70	7.06	8.21
4	11	7.79	7.23	8.50	7.87	7.33	8.56	7.88	7.24	8.53
5	12	7.39	7.00	8.33	7.19	6.71	8.25	7.21	6.64	8.07
6	14	7.69	6.95	8.39	7.64	6.88	8.31	7.52	7.04	8.17
7	16	7.68	7.19	8.16	7.60	7.00	8.35	7.56	6.55	7.90
8	22	7.22	6.73	7.74	7.11	6.22	7.65	7.11	6.40	7.76
9	10	7.30	6.61	7.58	7.10	6.18	7.78	7.02	6.38	7.50
10	13	7.40	7.07	7.71	7.41	6.69	7.92	7.23	6.50	7.59
11	10	7.78	7.24	8.22	7.83	7.41	8.16	7.86	7.48	8.35
12	8	7.69	7.39	8.17	7.65	7.25	7.93	7.62	7.42	7.82
13	20	7.90	7.33	8.42	7.94	7.18	8.60	7.82	7.47	8.22
14	32	7.96	7.35	8.79	7.83	7.06	8.50	7.80	7.00	8.62
15	12	7.82	7.15	8.35	7.73	7.38	8.32	7.63	7.11	8.13
16	31	7.92	7.33	8.50	7.91	7.30	9.00	7.78	7.32	9.45
17	28	7.84	7.00	8.69	8.05	7.47	8.75	7.69	6.87	8.91
18	13	7.36	6.96	7.82	7.31	6.69	7.83	7.18	6.67	7.96
19	16	7.37	7.00	7.65	7.30	7.00	7.70	7.23	6.63	7.84
20	20	7.57	6.83	8.25	7.73	7.24	8.19	7.52	6.67	8.06
21	16	7.36	6.79	7.73	7.41	6.45	8.28	7.40	6.80	8.21
22	39	7.51	6.54	8.13	7.56	6.90	8.38	7.30	6.36	8.53
23	15	7.70	7.14	8.11	7.90	7.11	8.56	7.51	7.09	7.95
24	17	7.37	6.92	7.96	7.51	6.52	8.29	7.15	6.30	7.70
25	21	7.07	6.46	7.48	7.02	6.45	7.54	6.99	6.26	7.50
26	12	7.11	6.52	7.60	7.18	6.18	8.00	6.95	6.36	7.48
27	25	6.77	6.11	7.65	6.83	6.11	7.75	6.73	6.12	7.30
28	10	7.12	6.54	7.69	7.06	6.22	7.53	6.98	6.59	7.64
29	9	6.93	6.70	7.07	6.58	6.05	7.05	6.65	6.07	7.29
30	24	7.00	6.00	7.82	6.80	5.90	7.40	6.81	5.89	7.43
31	10	6.66	5.80	7.57	6.66	6.07	7.20	6.57	5.73	7.14
32	10	7.12	6.70	7.60	7.09	6.59	7.61	6.98	6.48	7.44
33	31	6.22	5.40	6.65	6.06	5.53	7.00	6.10	5.00	6.90
34	13	5.95	5.74	6.16	5.79	5.37	6.16	5.95	5.58	6.53
35	14	6.38	5.93	6.79	6.24	5.85	6.60	6.19	5.92	6.45
Overall	614	7.37	5.40	8.79	7.35	5.38	9.00	7.25	5.00	9.45

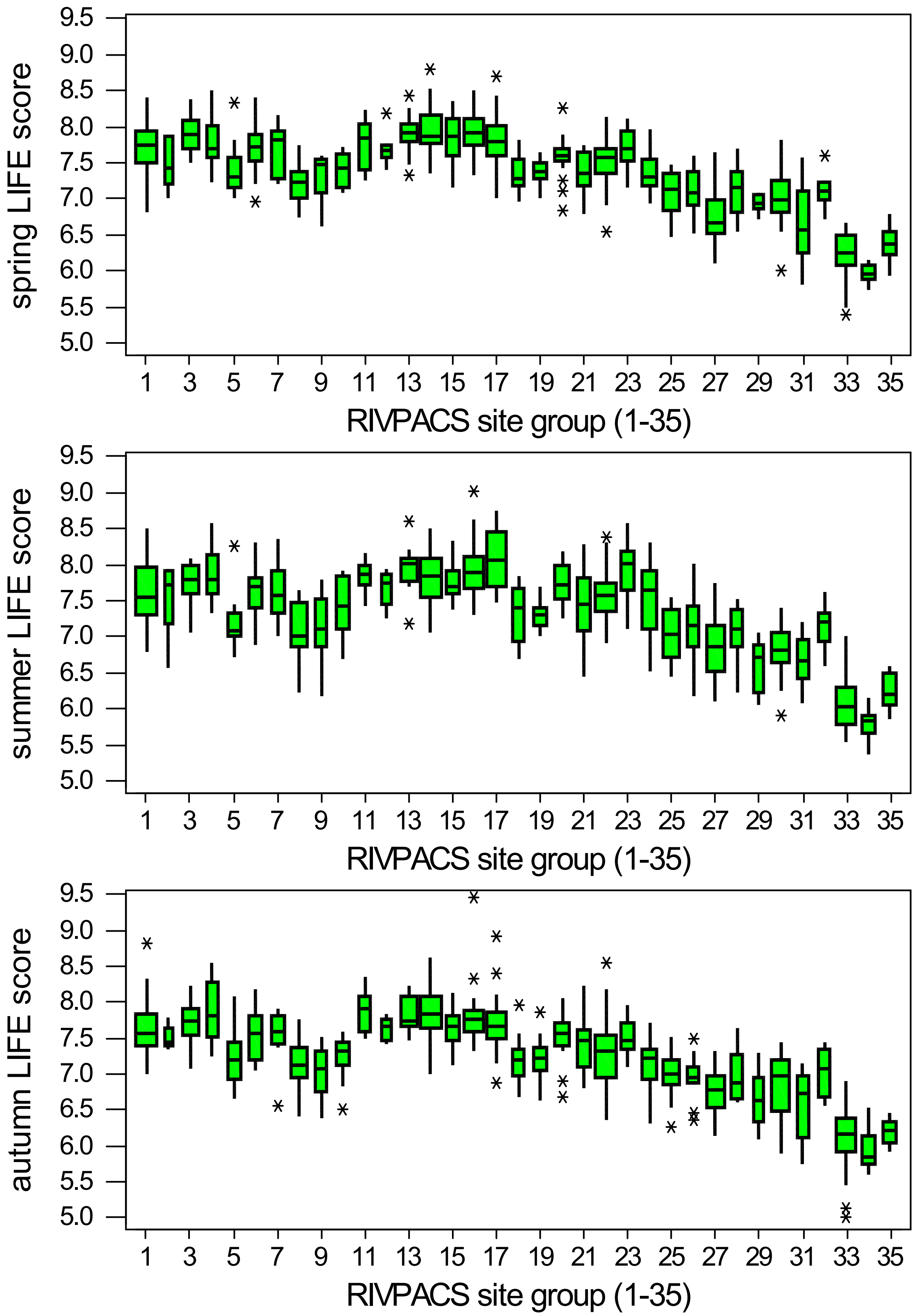


Figure 2.2 Boxplots showing variation in observed LIFE in each season for the reference sites in relation to their RIVPACS site group (1-35). [Boxplot interpretation: box denotes range of middle half of data values (25-75 percentile values), horizontal line denotes median (i.e. 50 percentile); outer lines denote range of values except for outliers which are marked individually by a *]

The general pattern of variation in LIFE is perhaps seen even more clearly when the RIVPACS reference sites are amalgamated into the four reference site super-groups within the TWINSPAN hierarchical site classification used to form the site groups (Figure 2.3). The super-group composed of site groups 10-17, labelled as "upland streams" had, on average, the highest values of LIFE, whilst site groups 25-35, labelled as "lowland rivers and streams", collectively had the lowest average LIFE. This is as expected. Steeper sloped upland streams are most likely to have macroinvertebrate communities preferring fast flowing conditions, whilst lowland river sites will be dominated more by taxa able to tolerate slow flows. However obvious, this pattern does demonstrate that in broad crude terms, the LIFE scoring system appears to work.

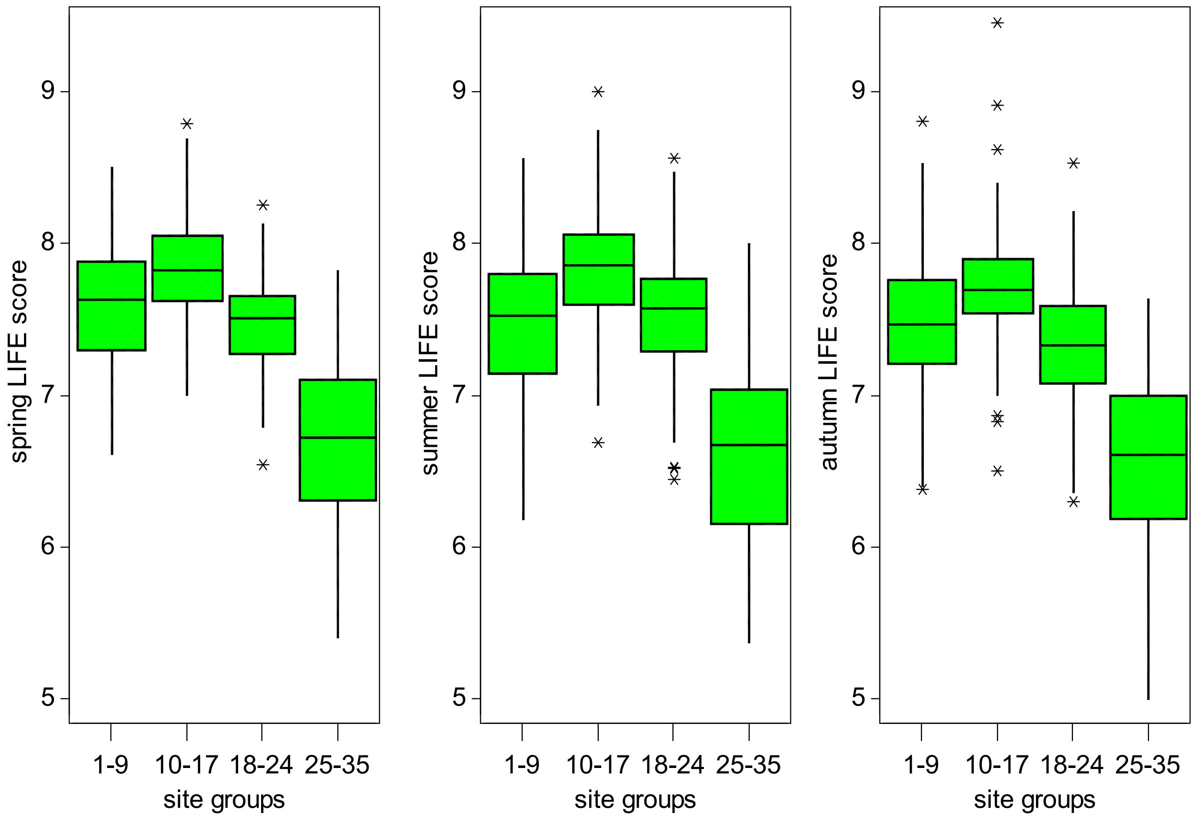


Figure 2.3 Boxplots showing variation in observed LIFE for the RIVPACS reference sites in relation to their site super-group. Site groups 1-9 = "small streams"; 10-17 = "upland streams"; 18-24 = "intermediate streams and rivers"; 25-35 = "lowland streams and rivers"; shown separately for each season's samples. See Figure 2.2 for interpretation of boxplots.

One-way analyses of variance showed that a high percentage of the total variation in observed LIFE for the RIVPACS reference sites could be explained simply by which site group (1-35) they belong to; the total percentage explained was 74%, 71% and 69% for the spring, summer and autumn samples respectively. The corresponding percentages for observed ASPT were 73%, 67% and 69% respectively This suggests that RIVPACS site group is a good predictor of the value of LIFE one can expect for high quality unstressed sites, such as the RIVPACS reference sites.

However, the site type of non-reference test sites of unknown quality is not known and it must be predicted from their environmental characteristics using the RIVPACS software. Fortunately, the RIVPACS environmental variables are able, using RIVPACS' multivariate discrimination equations, to give reasonably good predictions of the probability of belonging to each site group and from this the taxonomic composition expected at any site when it is unstressed. Therefore, RIVPACS should also be able to give reasonable predictions of the value of LIFE expected at any site when it is unstressed.

2.2.2 Relationships of LIFE with RIVPACS environmental variables

Table 2.3 gives the simple correlations between observed LIFE and each of the RIVPACS environmental variables for the reference sites. LIFE for unstressed sites is positively correlated with site altitude and slope and negatively correlated with stream depth and in-stream alkalinity. LIFE is also positively correlated with the estimated percentage substratum cover of boulders and cobbles, negatively correlated with the percentage cover of sand and fine silt or clay sediment and hence negatively correlated with the RIVPACS variable 'mean substratum'. In RIVPACS, the variable mean substratum, which is the inverse of mean particle size, is measured in phi units (ϕ) and varies from –7.8ϕ for sites with only boulders and cobbles to +8.0ϕ for sites completely covered in silt and/or clay.

Table 2.3 Correlations between observed LIFE and the RIVPACS environmental variables for the 614 RIVPACS reference sites based on the spring, summer or autumn samples.

	Spring	**Summer**	**Autumn**
Log altitude (m)	0.50	0.43	0.48
Log distance from source (km)	-0.10	-0.02	-0.10
Log slope (m $km^{-1)}$	0.48	0.40	0.43
discharge category (1-10)	0.09	0.14	0.05
Log stream width (m)	0.05	0.01	0.02
Log stream depth (cm)	-0.35	-0.28	-0.32
alkalinity (mg l^{-1} $CaCO_3$)	-0.63	-0.57	-0.57
Log alkalinity (mg l^{-1} $CaCO_3$)	-0.51	-0.44	-0.46
Mean substratum (phi units (ϕ))	-0.70	-0.69	-0.67
% substratum cover of boulders and cobbles	0.56	0.54	0.54
% substratum cover of silt and clay	-0.62	-0.63	-0.61
% substratum cover of sand, silt and clay	-0.68	-0.67	-0.64

The correlations between LIFE and the environmental variables are similar for each season, although some correlations tend to be marginally higher for the spring samples. Therefore, most further results will be presented and illustrated solely for one season, namely the autumn. Figure 2.4 shows the relationships between observed LIFE and critical environmental attributes of the sites. Where relationships exist (Figure 2.4(a)-(f)), they tend to all be roughly linear once the RIVPACS variables such as altitude and slope are transformed to their logarithms (as used in RIVPACS' site group discrimination equations). There is some evidence that LIFE reaches a plateau once percentage cover by boulders and cobbles is over 50% (Figure 2.4(e)) and that LIFE declines less dramatically with increases in the percentage cover of sand, silt and/or clay once such fine substrates predominate (Figure 2.4(f)). However, the relationship of observed LIFE with the variable mean substratum for the RIVPACS reference sites is still approximately linear (a quadratic regression term for mean substratum is not statistically significant (p=0.64)).

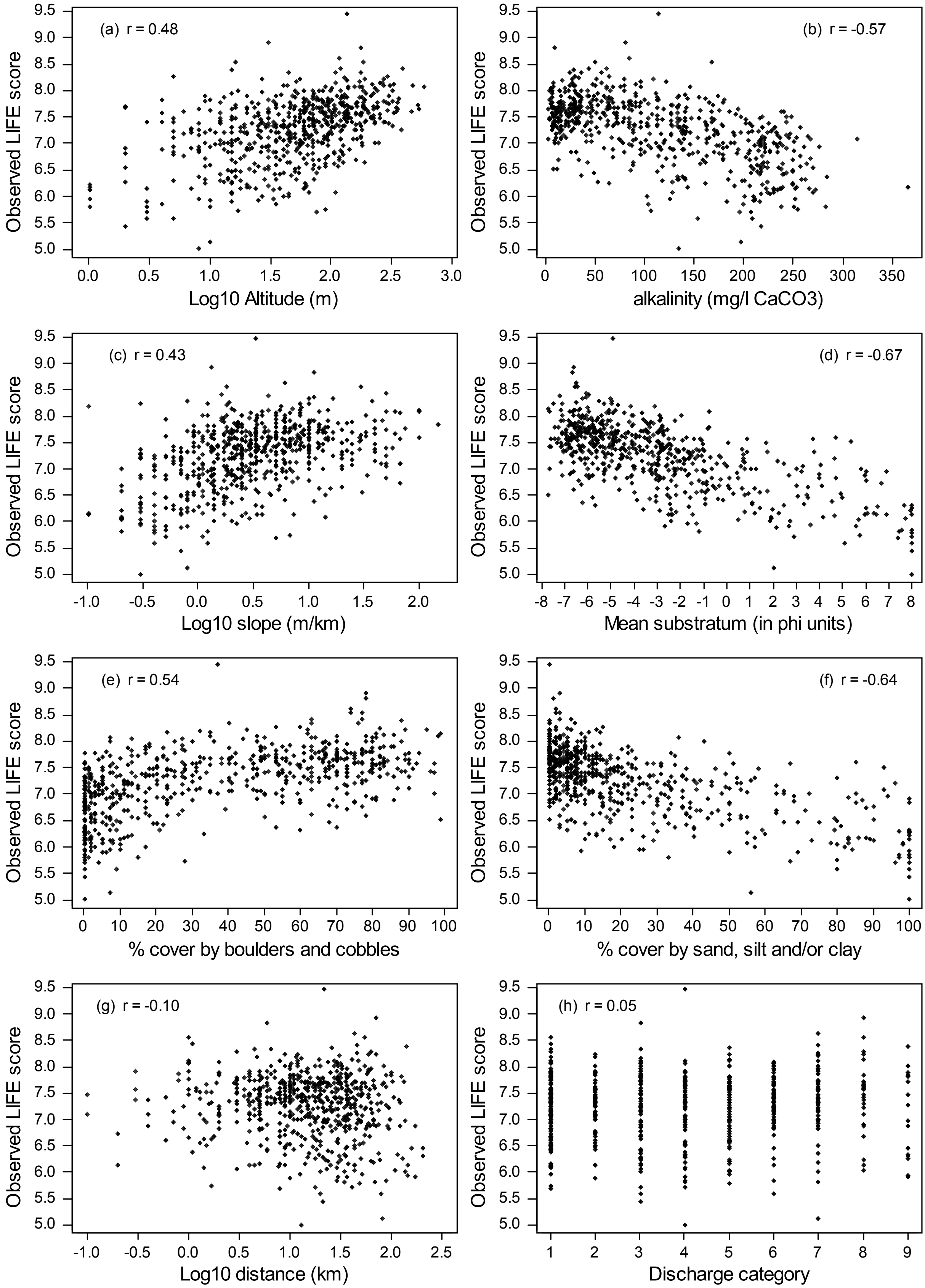


Figure 2.4 The relationship between observed LIFE (autumn samples) and environmental variables for the 614 RIVPACS reference sites

Values of LIFE for the RIVPACS reference sites show no simple relationship with their distance from source (Figure 2.4(g)).

Perhaps initially surprisingly, there are no simple correlations between LIFE and the long-term historical average discharge category for each site (Table 2.3; Figure 2.4(h)). This is principally because it is not the volume of water flowing downstream *per se*, but the flow velocity which influences the presence and abundance of individual macroinvertebrate families, and the LIFE scoring system reflects these taxonomic associations with flow velocity. Thus LIFE will be more sensitive to low flows when they affect flow rates. Conversely, macroinvertebrate families will be less sensitive to low flows if they do not greatly affect current velocities.

LIFE may be more sensitive to low flows when based on species data. For example, the family Baetidae is assigned to flow group II (Table 1.4) and under normal flow conditions several species may be co-dominant at site. If flows declined, the species *Cloeon dipterun*, which can tolerate low flows and hence was assigned by Extence *et* al (1999) to flow group IV, may dominate the Baetidae community present at a site; this would lead to a lower average contribution to LIFE score from Baetidae.

2.3 Determining the RIVPACS expected LIFE

2.3.1 Philosophy of RIVPACS approach to assessing site condition

The philosophy of the RIVPACS approach to assessing the biological condition or quality of river sites is to compare the macroinvertebrate fauna observed at a test site with its site-specific expected or 'target' macroinvertebrate fauna. The expected fauna is predicted from the test site's physical and environmental characteristics using the RIVPACS reference sites, all of which are considered to be unpolluted, unstressed and hence of good quality.

When RIVPACS was developed, the reference sites were classified into biological groups based solely on their macroinvertebrate fauna using a multivariate clustering technique called TWINSPAN. In the latest version of RIVPACS, RIVPACS III+, there are 614 reference sites for GB which are classified into 35 site groups. The reference sites have been chosen with the aim of covering all the major river systems in GB and the whole range of physical and environmental types of river sites.

The next step of RIVPACS development was to measure a wide range of environmental variables for each reference site which it was thought might influence, or be correlated with, their macroinvertebrate composition. Another multivariate statistical technique called Multiple Discriminant Analysis (MDA) was then used to identify a small number of environmental variables which most accurately predicted the biological groupings of the reference sites. MDA produces predictive equations called discriminant axes which enable RIVPACS to estimate the probability that a test site belongs to each of the site groups.

Importantly, we consider that, the biological variation across all sites in GB, is a continuum rather than sites naturally falling into completely distinct biological types. Therefore, for prediction, RIVPACS treats the biological classification of reference sites into groups merely as an intermediate convenience. On the basis of their environmental attributes, new test sites are therefore only assigned probabilistically to the site groups. Typically a test site will have a predicted probability (G_i) of greater than 1% of belonging to between one and five site groups.

From the probabilities of the test site belonging to each site group and the taxonomic composition of the reference sites in each group, RIVPACS software calculates the fauna to be expected at a test site, assuming it is unstressed (see section 2.3.3 for further details). The expected fauna for any test site is site-specific, being dependent on the environmental characteristics measured for that particular site.

Having calculated the expected fauna, it is then usually possible to calculate the expected value for any derived biotic indices which try to summarise aspects of the macroinvertebrate fauna. Currently, the most commonly used indices are the number of BMWP taxa and the ASPT based on presence-absence data, but trial indices based on abundance data have also recently been tested (Clarke & Wright 2000; Walley & Hawkes 1997).

Any Ecological Quality Index (EQI), defined as the ratio (O/E) of the observed (O) to expected (E) value of any biotic index, can be used as a standardised index to represent some aspect of the biological condition or quality of the site. This standardisation enables direct comparisons between sites irrespective of natural differences in their biological communities and therefore observed values of the index. This feature gives such EQIs great practical appeal.

It should always be remembered that the basic outputs from RIVPACS are not the EQI values or other biotic indices, but the observed and expected probabilities of occurrence and abundances of individual taxa at the test site. Observed and expected values of biotic indices are always derived from the observed and expected fauna. Moreover, this means that observed and estimated expected values of a wide range of biotic indices can be derived from the basic RIVPACS predictions for individual taxa.

2.3.2 Estimating values for the RIVPACS environmental predictor variables

The prescribed method for estimating the values for all the environmental RIVPACS predictor variables for a site is described in detail in section 2.6 of Murray-Bligh (1999). In particular, the values for the variables measured in the field, namely stream width, stream depth and substratum composition, should all be based on the average of their values measured in each of the three RIVPACS seasons. This applies to predictions of the expected macroinvertebrate fauna for all combinations of seasons, namely for single season samples, and for two or three season combined samples. This is because the environmental data for the RIVPACS reference sites, which are used to determine the expected fauna, were also based on the average of the values obtained at the times of the spring, summer and autumn sampling. Murray-Bligh (1999) actually recommend that the values should ideally be based on the averages over five years to prevent distortion of unusual conditions in any one year and that very unusually dry or wet years should be excluded.

The same protocols apply to the calculation of the expected fauna when RIVPACS is to be used to estimate the value of expected LIFE and hence LIFE O/E for a site. Values for stream width, stream depth and substratum composition should be based on the average of measurements made in each of spring, summer and autumn site visits; preferably for several years.

In fact, in assessments based on LIFE, rather than BMWP and biological GQA EQIs, it is even more sensible that the values of the environmental variables for a site are based on several years' data and that data from unusually dry or wet periods are excluded. Expected LIFE should be based on flow conditions which are considered to be either natural or a reasonable target for a site.

2.3.3 Calculating the expected abundance of macroinvertebrate families at any site

Table 2.4 illustrates how the expected abundances of families of macroinvertebrates at a test site are calculated. The expected abundance category of a taxon at a test site is calculated as a weighted average of the mean of the observed abundance categories (0, 1-5 in Table 1.2) of the taxon at the reference sites in each RIVPACS site group The weight given to each group is the probability (G_i) of the test site belonging to that group, which is calculated from the MDA. The expected log abundance category for a taxon is not usually an integer, unlike the observed data. It must be remembered that the expected log abundance category A_{Ej} for a taxon j at a site is not the logarithm to base 10 of the expected abundance at the site. The expected abundance cannot easily be obtained, but the maximum possible value must be just less than antilog(A_{Ej}). For example, if all reference sites involved in a prediction for a site have a taxon at abundance category '2', its expected abundance category will be 2.0, but the 'true' expected abundance must be between 10 and 99, less than 100 (antilog(2.0)).

Table 2.4 Illustration of method of predicting the expected abundance of a family at a test site

G_i = Probability new site belongs to RIVPACS site group i (i=1-35)
S_{ij} = Proportion of RIVPACS reference sites in site group i where taxon j is present
A_{ij} = Average log abundance category of taxon j at RIVPACS reference sites in group i

Group i	G_i	S_{ij}	A_{ij}
1	0.5	0.8	2.1
2	0.4	0.5	1.5
3	0.1	0.2	0.4

P_{Ej} = Expected probability of occurrence of taxon j at the test site
= $\sum_i (G_i.S_{ij})$ = 0.5 x 0.8 + 0.4 x 0.5 + 0.1 x 0.2 = 0.62
A_{Ej} = Expected log abundance category of taxon j at the test site
= $\sum_i (G_i.A_{ij})$ = 0.5 x 2.1 + 0.4 x 1.5 + 0.1 x 0.4 = 1.73

2.3.4 Calculating expected LIFE for any site

The expected value of LIFE for a site is hereafter referred to as expected LIFE. The observed LIFE for any sample is defined as the simple average of the (abundance-specific) flow scores (f_S) of the taxa present. However, there is no obvious method for calculating expected LIFE of a sample, because in the predictions, taxa are not simply either present or absent, but rather have expected probabilities of occurring and non-integer expected abundance categories (P_{Ej} and A_{Ej} respectively in Table 2.4).

Table 2.5 illustrates the method we have devised and used in this study for calculating the value of expected LIFE for a site from the expected abundances of each taxon at the site. This is the method we recommend to the Environment Agency for calculating expected LIFE. For any given taxon, its expected value for flow score (f_S) is obtained by interpolating between the flow scores given in Table 1.3 for the log abundance categories above and below the (usually non-integer) expected log abundance value for that taxon. The example given in Table 2.5 is for *Gammaridae* which has an expected log abundance category of 1.78 for the test site. *Gammaridae* is in LIFE flow group II (Table 1.4). Taxa in flow group II get a LIFE score (f_S) of 8 when occurring at abundance category 1 and a score of 9 when occurring at abundance category 2. With an expected abundance category of 1.78, the expected value of LIFE score (f_S) for *Gammaridae* at the test site is obtained by interpolating between the LIFE scores for abundance categories 1 and 2 as 8.78. A taxon with an non-zero expected abundance category of less than one is assigned the flow score (f_S) for abundance category '1' in Table 1.3.

Table 2.5 Method of calculating expected LIFE at a test site

P_{Ej} = Expected probability of occurrence of taxon j at site
A_{Ej} = Expected log abundance category of taxon j at site
A_{jl} = nearest integer less than or equal to A_{Ej} (subject to a minimum value of one)
A_{ju} = nearest integer greater than or equal to A_{Ej} (subject to a minimum value of one)
L_{Ajl} = flow score for log abundance category A_{jl} of taxon j (from Tables 1.3 and 1.4)
L_{Aju} = flow score for log abundance category A_{ju} of taxon j
L_{Ej} = expected flow score for taxon j at the site
$= (A_{ju} - A_{Ej}) \times L_{Ajl} + (A_{Ej} - A_{jl}) \times L_{Aju}$

Example: taxon j = *Gammaridae* in LIFE flow group II (see Table 1.4)
with expected abundance $A_{Ej} = 1.78$
$A_{jl} = 1$, $A_{ju} = 2$, so $L_{Ajl} = 8$ and $L_{Aju} = 9$ (from Table 1.3)
then $L_{Ej} = (2 - 1.78) \times 8 + (1.78 - 1) \times 9 = 8.78$

E_F = expected sum of taxa flow scores for site = $\sum_j (P_{Ej} \times L_{Ej})$
E_T = expected number of taxa present at site = $\sum_j P_{Ej}$
$LIFE_E$ = expected LIFE for site $\approx E_F / E_T$ (i.e. approximately equals)

A better and recommended estimator of expected LIFE,
which has been used throughout this R&D project, is
$LIFE_E = E_F / E_T + V_{TT}E_F/(E_T)^3 - V_{FT}/(E_T)^2$
where $V_{TT} = \sum_j (P_{Ej} \times (1 - P_{Ej}))$ and $V_{FT} = \sum_j L_{Ej} \times (P_{Ej} \times (1 - P_{Ej}))$

The overall expected LIFE could have been calculated as the simple average of the expected flow scores for all the taxa that had non-zero expected probabilities of occurring, but this did not seem optimal because it gave the same importance and weight to all taxa, including those taxa that had only a very low expected likelihood of occurring and hence were not really typical of the site. At the other extreme, taxa could have been weighted by their expected abundance but, in a sense, abundance has already been allowed for in deriving the expected flow score for each individual taxa.

Our recommended approach, as used in this study, is to calculate expected LIFE for a site by weighting the expected LIFE score for each taxon by its expected probability of occurrence (Table 2.5). This is the same as the approach used to calculate the expected values of the trial abundance-based biotic indices such as Q14-Q21, proposed and assessed by Clarke and

Wright (2000). This weighted method would also be the best approach for calculating expected LIFE for a site when it is based on just the presence-absence of taxa as the method is then identical to the approach used to calculate expected values of ASPT for a site in GQA assessments of site condition.

The expected LIFE ($LIFE_E$) for a site is not exactly equal to the expected sum of taxa flow scores for the site (E_F) divided by the expected number of taxa present at the site (E_T), as defined in Table 2.5. This is because, from mathematical statistics, the expected value of a ratio (Y/X) is not the ratio of the expected value of Y to the expected value of X. Therefore a correction term is needed, as given in Table 2.5, which is similar to that used to derive the expected value of ASPT in RIVPACS III+ (Clarke *et al.* 1997, Clarke 2000). (Note: In the formula for the expected value of ASPT, given in Appendix 1 of Clarke *et al*. (1994) and also as equation (11) in Clarke *et al.* (1996), there is a typing mistake. The last term (v_{ST} / m_T^2 and v_{ST} / E_T^2 respectively) should be subtracted not added; the term is minor and the effect is negligible. Importantly, the correct formula has always been used in all versions of RIVPACS III+ software code).

At present the expected abundance of individual families and hence values of expected LIFE can only be calculated for single season samples. The further work needed to enable observed and expected LIFE to be calculated for two and three season combined samples was discussed in section 1.3.

2.4 Expected LIFE for the RIVPACS reference sites

Expected LIFE for the RIVPACS reference sites ranges from 5.93 for one site in group 34, to 7.92 for one site in each of groups 14, 17 and 23. (Table 2.6, Figure 2.5). The average value of expected LIFE for a site group ranges from around 5.96 (group 34 in summer) to 7.82 (group 13 in summer). As could be anticipated from the pattern of variation in values of observed LIFE of the RIVPACS reference sites, the values of expected LIFE are considerable higher for sites in groups 10-17 than for sites in groups 25-35 and especially groups 33-35.

Variation in values of observed LIFE and LIFE O/E for the GQA sites in 1995 are discussed in section 3.

2.4.1 Predictive ability of RIVPACS

In RIVPACS predictions, the expected fauna, and hence expected LIFE, are based on a form of averaging of the observed data for the reference sites. In such types of predictions (which includes multiple linear regression), the predicted values always vary less than the observed values for the dataset on which the predictions were formed, in this case the reference sites.

Figure 2.6 shows the strength of the relationship between observed LIFE and expected LIFE for the RIVPACS reference sites. Expected LIFE, predicted from the values of the RIVPACS environmental variables at each site, is reasonably closely correlated with observed LIFE, explaining 60-66% of the total variation in observed LIFE for the RIVPACS reference sites (Table 2.7). The RIVPACS environmental variables explain a very high percentage (≥85%) of that part of the variation in observed LIFE which arises from differences between the 35 site groups (Table 2.7).

Table 2.6 Mean and range of expected LIFE for the RIVPACS reference sites in each site group (1-35); separately for each season

Site Group	Spring			Summer			Autumn		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
1	7.67	7.56	7.85	7.62	7.51	7.85	7.58	7.45	7.72
2	7.47	7.24	7.61	7.45	7.12	7.60	7.44	7.08	7.56
3	7.71	7.45	7.82	7.70	7.47	7.82	7.61	7.46	7.73
4	7.68	7.48	7.78	7.71	7.51	7.82	7.66	7.49	7.80
5	7.34	7.07	7.39	7.24	6.96	7.29	7.20	6.98	7.25
6	7.65	7.37	7.81	7.65	7.41	7.79	7.57	7.32	7.76
7	7.52	6.89	7.81	7.47	6.88	7.80	7.41	6.86	7.67
8	7.17	6.40	7.69	7.09	6.20	7.67	7.06	6.30	7.57
9	7.22	6.70	7.58	7.12	6.68	7.50	7.08	6.69	7.46
10	7.59	7.46	7.81	7.56	7.43	7.84	7.48	7.33	7.71
11	7.73	7.57	7.83	7.77	7.57	7.88	7.66	7.48	7.80
12	7.59	7.52	7.66	7.56	7.50	7.61	7.50	7.42	7.59
13	7.79	7.54	7.85	7.82	7.52	7.91	7.68	7.45	7.74
14	7.76	7.48	7.85	7.77	7.45	7.92	7.62	7.35	7.70
15	7.73	7.51	7.79	7.70	7.57	7.74	7.63	7.45	7.68
16	7.72	7.46	7.85	7.77	7.53	7.91	7.61	7.40	7.74
17	7.71	7.49	7.84	7.82	7.60	7.92	7.59	7.36	7.69
18	7.49	7.31	7.70	7.53	7.37	7.82	7.36	7.21	7.63
19	7.20	6.47	7.42	7.18	6.29	7.52	7.10	6.38	7.30
20	7.55	7.24	7.78	7.61	7.13	7.84	7.46	7.08	7.69
21	7.36	7.01	7.74	7.42	7.03	7.80	7.29	6.96	7.59
22	7.53	7.03	7.77	7.62	6.98	7.88	7.41	6.93	7.67
23	7.64	7.43	7.74	7.78	7.51	7.92	7.51	7.36	7.60
24	7.41	7.20	7.58	7.52	7.28	7.70	7.29	7.13	7.45
25	6.97	6.60	7.20	6.98	6.47	7.24	6.91	6.51	7.16
26	6.94	6.44	7.29	6.97	6.31	7.38	6.87	6.30	7.24
27	6.95	6.61	7.32	6.99	6.58	7.42	6.91	6.56	7.21
28	7.25	7.03	7.57	7.26	6.99	7.68	7.17	6.95	7.48
29	6.97	6.70	7.13	6.83	6.75	6.98	6.81	6.74	6.97
30	6.98	6.42	7.29	6.93	6.23	7.26	6.90	6.32	7.19
31	6.75	6.44	7.21	6.77	6.25	7.11	6.76	6.34	7.09
32	7.02	6.41	7.35	6.95	6.21	7.28	6.92	6.30	7.23
33	6.58	6.09	6.99	6.47	5.97	7.04	6.51	6.13	6.96
34	6.08	6.04	6.42	5.96	5.93	6.26	6.12	6.10	6.30
35	6.55	6.44	6.87	6.47	6.31	6.98	6.42	6.26	6.88
Overall	7.34	6.04	7.85	7.35	5.93	7.92	7.25	6.10	7.80

Table 2.7 Percentage of total variation in observed LIFE for the RIVPACS reference sites explained by (a) their site group (1-35) or (b) from their expected LIFE predicted from RIVPACS environmental variables

	Spring	Summer	Autumn
(a) Site group	74%	71%	69%
(b) RIVPACS prediction	66%	60%	60%
(b) / (a)	89%	85%	87%

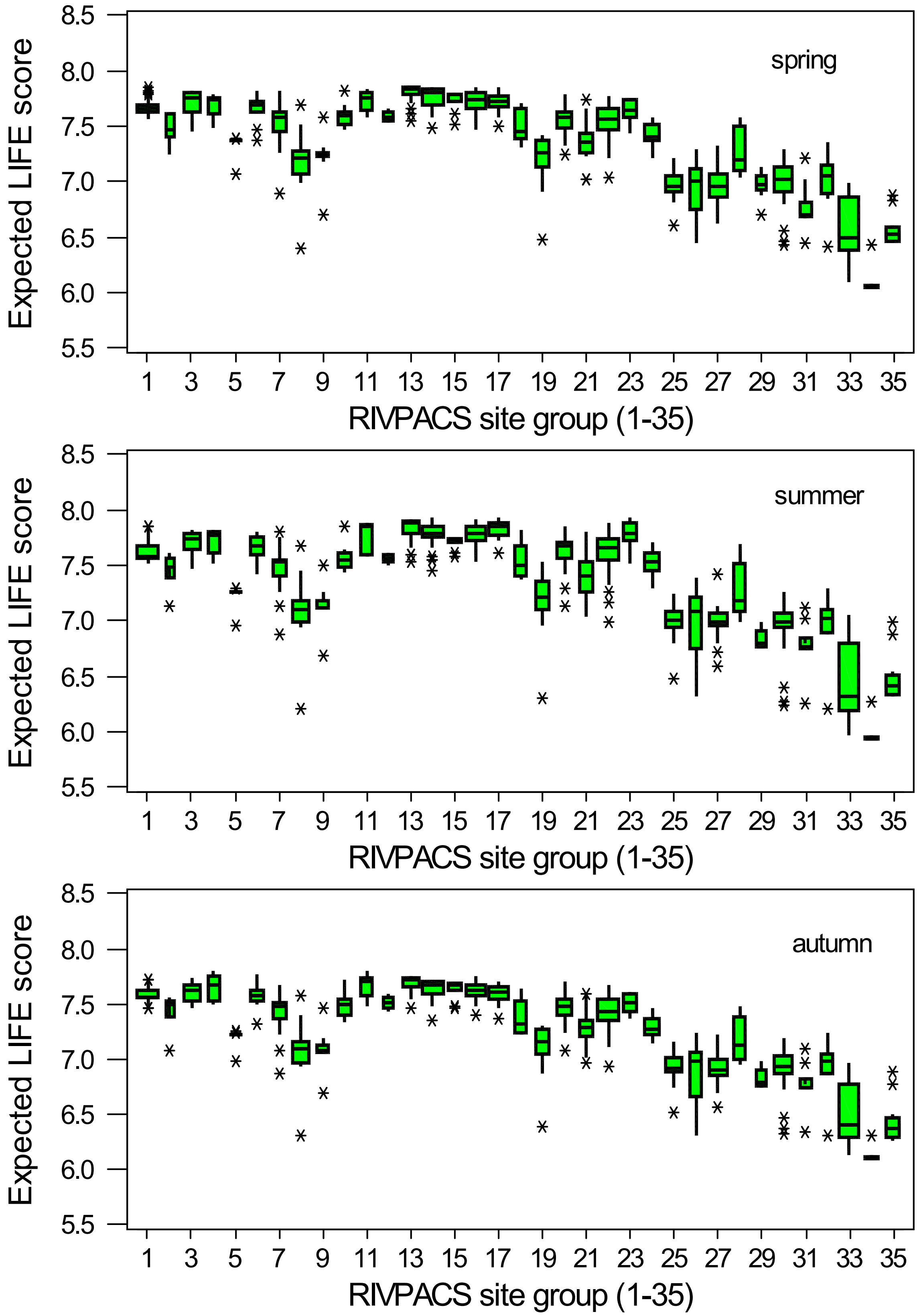


Figure 2.5 Boxplots showing variation in expected LIFE for the RIVPACS reference sites in relation to their site group (1-35); shown separately for each season's samples. See Figure 2.2 for interpretation of boxplots

This is very encouraging in that it indicates that RIVPACS is effective at predicting the value of LIFE to be expected in the absence of any flow-related or other stress. Thus there will be a substantial improvement in the information content of observed LIFE by dividing by its value for expected LIFE, to produce a standardised LIFE O/E ratio which removes the confounding influence of natural variations in observed LIFE due to the environmental characteristics of sites (see section 2.5).

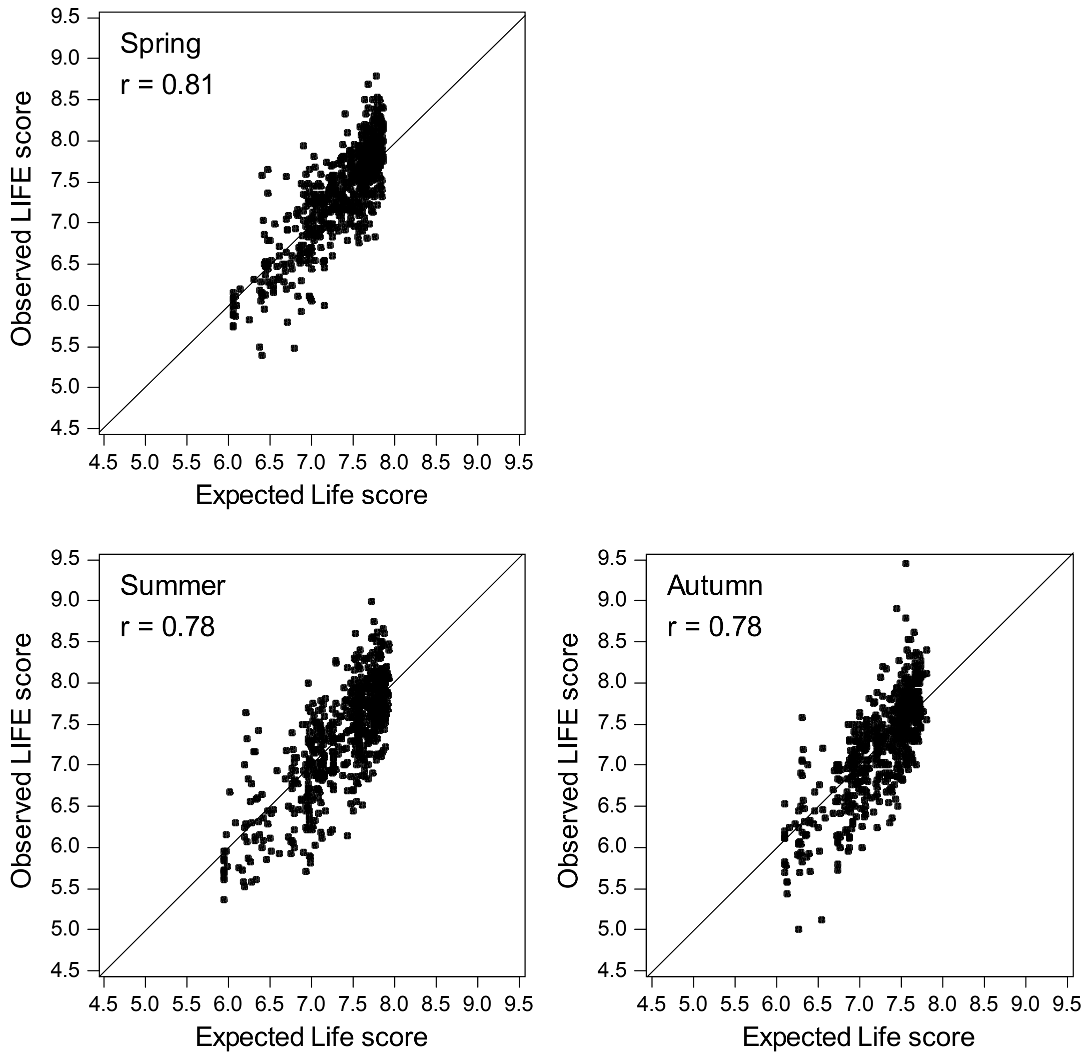


Figure 2.6 Observed LIFE versus expected LIFE for the RIVPACS reference sites, separately for each season. Solid line equals 1:1 line.

Figure 2.7 shows how expected LIFE varies with the critical RIVPACS environmental predictor variables. Expected LIFE is always high for sites which are at high altitude, or on steep slopes, or are mostly covered by boulders and cobbles; in GB many sites tend to have all three attributes. Sites with low alkalinity also have relatively high expected LIFE (Figure 2.7(b)). This is probable because, in Britain at least, base-poor acidic water sites tend to occur at high altitudes on general steep slopes and/or with coarse substrates. Thus it is not a direct effect of alkalinity. However, alkalinity does improve predictions of the expected fauna and expected LIFE at sites; in a multiple regression of expected LIFE which allowed for the effect of these three variables, the partial correlation with alkalinity was still highly statistically significant ($p < 0.001$).

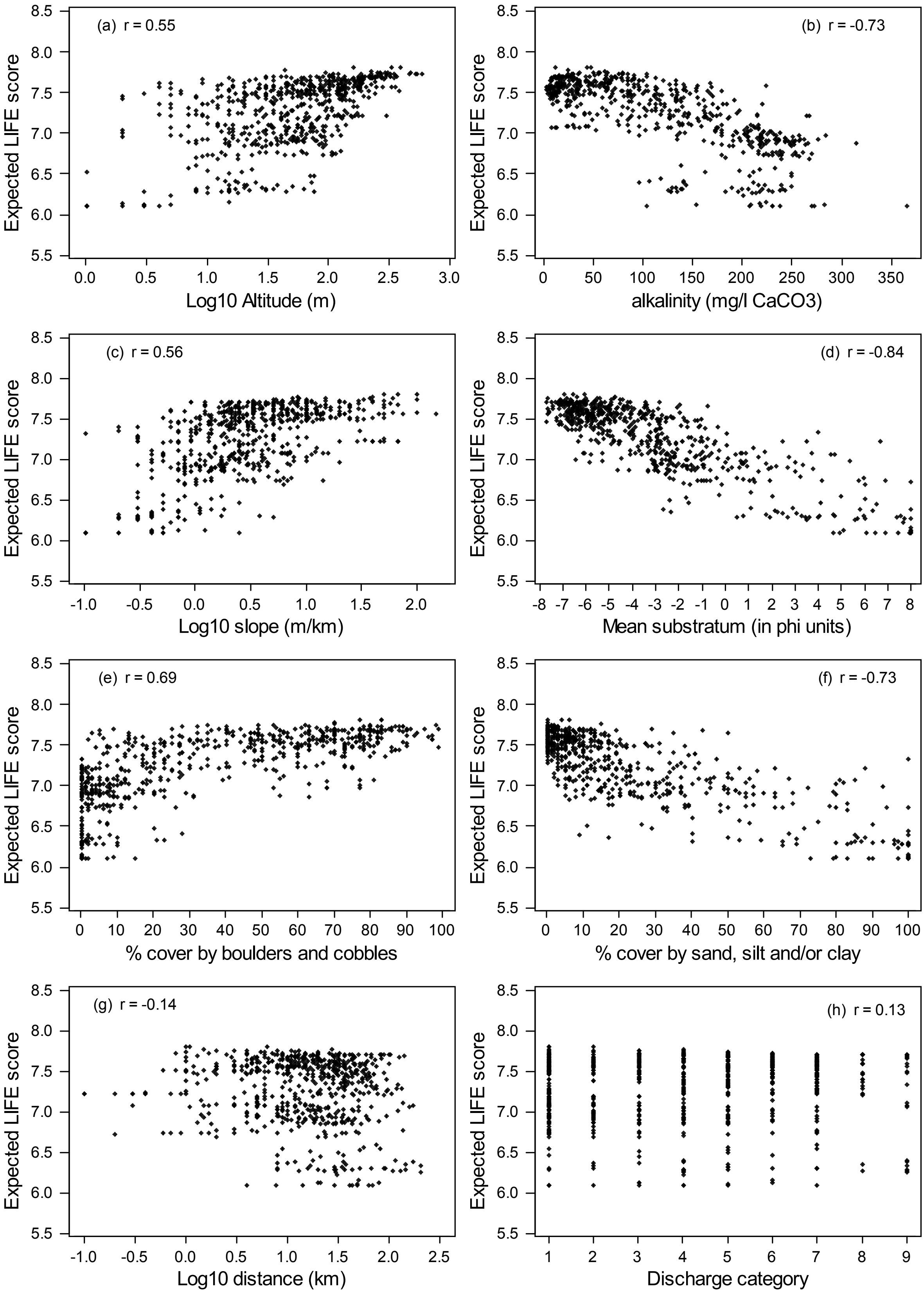


Figure 2.7 The relationship between expected LIFE (autumn samples) and environmental variables for the 614 RIVPACS reference sites

In contrast, sites at low altitude, or on gentle slopes or with little cover of boulders and cobbles can have a wide range of values of expected LIFE (Figure 2.7).

There is no general relationship between expected LIFE for a site and its long-term historical average discharge category (Figure 2.7(h); nor with its distance from source, although none of the sites with low expected LIFE (i.e. <6.5) are near their source (i.e. within 3 km) (Figure 2.7(g)).

2.5 Variation in LIFE O/E for the RIVPACS reference sites

The above sub-sections indicated that the value of LIFE to be expected at a site in the absence of any environmental stress (including flow-related stress) is not constant, but varies according the physical characteristics of the site. Therefore, to make the values of LIFE at contrasting sites comparable in terms of their measurement of potential flow-related stress, they need to be adjusted or standardised in some way to remove these "natural" differences in expected LIFE. Adopting the same approach as used for the GQA biological determinants 'number of BMWP taxa' and ASPT, LIFE can be standardised onto a common scale by dividing the value of observed LIFE (O) by the values of expected LIFE (E). This O/E ratio will hereafter be referred to as the "LIFE O/E". Table 2.8 and Figure 2.8 show the distribution of LIFE O/E for RIVPACS reference sites in each site group for each season.

2.5.1 Reasons for the variation

It is important to remember that the value of expected LIFE for any site, including a reference site, is based on the weighted average fauna found at RIVPACS reference sites of similar environmental characteristics. Although not strictly mathematically true, expected LIFE for a site can be regarded as a weighted average of the values of observed LIFE for the RIVPACS reference sites which are environmentally similar. Therefore, roughly half of the reference sites will have observed LIFE lower than their expected LIFE and half will have observed LIFE higher than their expected LIFE. In terms of LIFE O/E, half of the reference sites will LIFE O/E values less than 1.0 and half will have values greater than 1.0. A LIFE O/E value of 1.0 should not be thought of as the maximum achievable, but perhaps as the average value amongst the "top class" of sites whose macroinvertebrate fauna do not appear to show any effects of stress. RIVPACS does not (and never could) include predictor variables representing all the habitat factor determining the macroinvertebrate communities at a site. Also the high quality, assumed unstressed, reference sites, are not all of the same quality or condition, however that is defined. Therefore, it is to be expected that LIFE O/E for the reference sites will vary. The LIFE O/E value for a site at a point in time is only an estimate of condition of the site in terms of flow-related stresses; the value will be subject to the effects of sampling variation. The size of the effects of sampling variation on observed LIFE and hence LIFE O/E will be assessed in Module 7 of this R&D project (see section 1.2.7).

2.5.2 Variation in relation to site group

As one would expect, the values of LIFE O/E for the RIVPACS reference sites are centred around unity. The overall average and median ratios are both 1.00 in each of the three seasons. However, there is some tendency for the average or median of the LIFE O/E for a few groups of sites to be slightly higher or lower than this. In particular, the RIVPACS reference sites in large lowland site groups 33-35 have average values of LIFE O/E of 0.94 - 0.98, whilst, in contrast, sites in groups 16 or 17 have average ratios of 1.02 – 1.03 (Table

2.8). Although, intuitively undesirable, this phenomenon has occurred before in RIVPACS O/E ratios and has a logical explanation and is explained below.

Table 2.8 Mean and range of the LIFE O/E for the RIVPACS reference sites in each site group (1-35); separately for each season.

Site Group	*N*	Spring			Summer			Autumn		
		Mean	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**
1	34	1.00	0.88	1.10	1.00	0.90	1.11	1.00	0.93	1.16
2	6	1.00	0.92	1.06	1.01	0.87	1.08	1.01	0.98	1.05
3	20	1.02	0.98	1.08	1.01	0.91	1.07	1.01	0.92	1.07
4	11	1.01	0.93	1.10	1.02	0.94	1.10	1.03	0.96	1.12
5	12	1.01	0.95	1.13	0.99	0.93	1.13	1.00	0.92	1.11
6	14	1.00	0.91	1.08	1.00	0.91	1.09	0.99	0.92	1.12
7	16	1.02	0.95	1.16	1.02	0.93	1.11	1.02	0.89	1.09
8	22	1.01	0.91	1.19	1.01	0.89	1.23	1.01	0.91	1.21
9	10	1.01	0.91	1.05	1.00	0.87	1.09	0.99	0.90	1.06
10	13	0.98	0.94	1.01	0.98	0.90	1.06	0.97	0.87	1.02
11	10	1.01	0.94	1.07	1.01	0.96	1.04	1.03	0.97	1.08
12	8	1.01	0.97	1.08	1.01	0.96	1.04	1.02	0.98	1.05
13	20	1.01	0.94	1.07	1.02	0.91	1.14	1.02	0.97	1.07
14	32	1.03	0.95	1.13	1.01	0.92	1.08	1.02	0.91	1.13
15	12	1.01	0.93	1.07	1.00	0.97	1.10	1.00	0.93	1.07
16	31	1.03	0.95	1.11	1.02	0.94	1.17	1.02	0.96	1.25
17	28	1.02	0.92	1.13	1.03	0.95	1.13	1.01	0.92	1.20
18	13	0.98	0.92	1.06	0.97	0.89	1.05	0.98	0.91	1.05
19	16	1.03	0.97	1.18	1.02	0.95	1.14	1.02	0.96	1.10
20	20	1.00	0.91	1.07	1.02	0.95	1.10	1.01	0.90	1.07
21	16	1.00	0.91	1.06	1.00	0.86	1.14	1.01	0.93	1.13
22	39	1.00	0.91	1.09	0.99	0.89	1.09	0.99	0.86	1.13
23	15	1.01	0.92	1.05	1.02	0.91	1.11	1.00	0.94	1.07
24	17	0.99	0.93	1.08	1.00	0.86	1.10	0.98	0.86	1.06
25	21	1.02	0.91	1.06	1.01	0.93	1.08	1.01	0.89	1.09
26	12	1.03	0.94	1.14	1.03	0.86	1.17	1.01	0.92	1.12
27	25	0.97	0.88	1.10	0.98	0.83	1.11	0.97	0.87	1.10
28	10	0.98	0.89	1.10	0.97	0.86	1.06	0.98	0.89	1.09
29	9	0.99	0.96	1.03	0.96	0.89	1.02	0.98	0.90	1.05
30	24	1.00	0.84	1.11	0.98	0.85	1.10	0.99	0.85	1.14
31	10	0.99	0.87	1.13	0.99	0.90	1.06	0.97	0.85	1.03
32	10	1.02	0.97	1.10	1.02	0.93	1.18	1.01	0.91	1.12
33	31	0.95	0.81	1.01	0.94	0.83	1.13	0.94	0.78	1.10
34	13	0.98	0.93	1.02	0.97	0.90	1.03	0.97	0.91	1.07
35	14	0.97	0.86	1.05	0.96	0.84	1.04	0.97	0.89	1.03
Overall	614	1.00	0.81	1.19	1.00	0.83	1.23	1.00	0.78	1.25

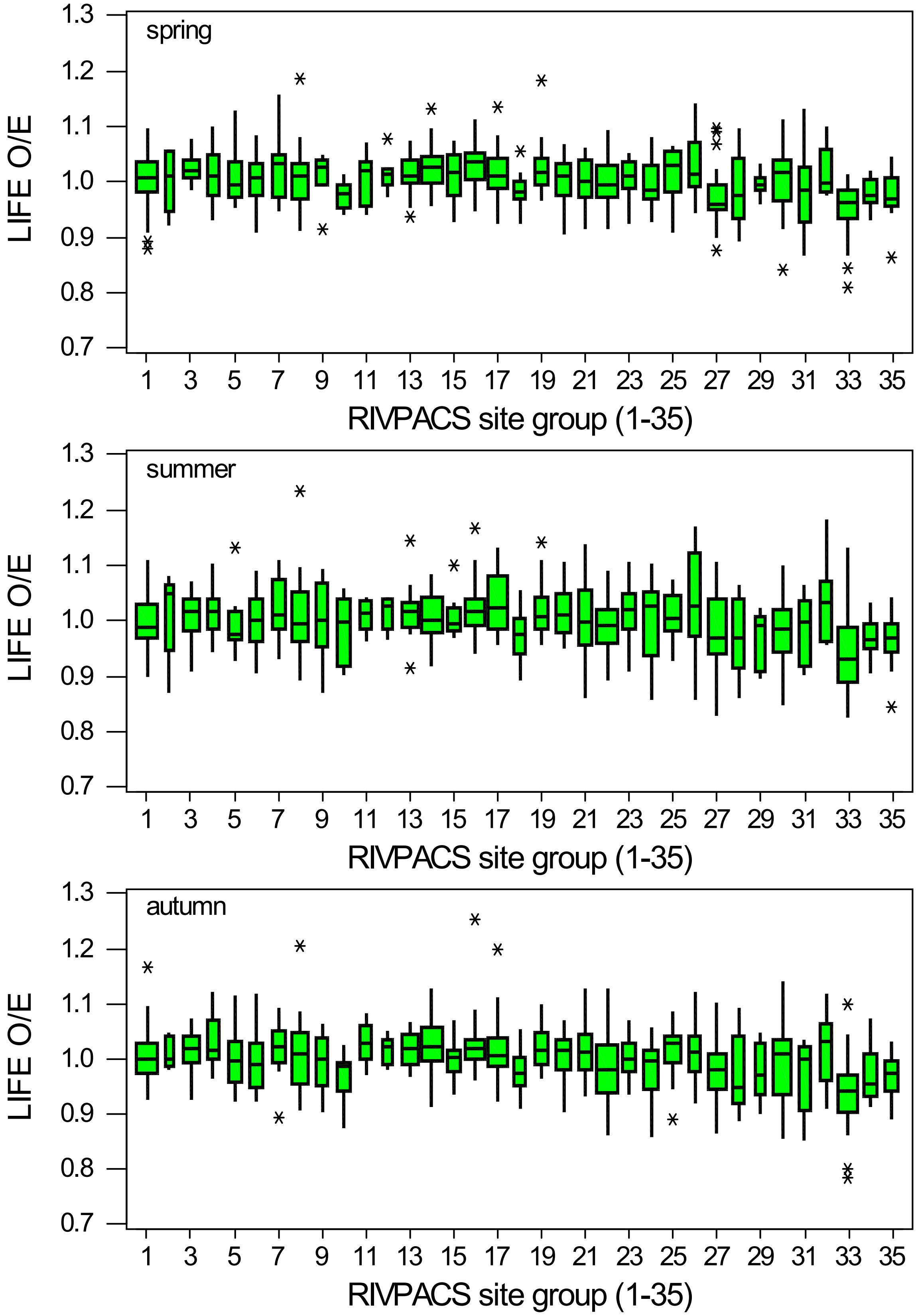


Figure 2.8 Variation in LIFE O/E for the 614 RIVPACS reference sites in relation to their site groups (1-35); shown separately for each season's samples. See Figure 2.2 for interpretation of boxplots.

Reference groups 16 and 17 have among the highest observed LIFE, whilst groups 33-35 have the lowest average LIFE (Table 2.2). The expected fauna for any site, and hence its expected LIFE (or ASPT), is estimated from the RIVPACS reference sites in the groups to which it is predicted to have a (non-zero) probability of belonging. Therefore when sites in extreme groups 33-35 have substantial predicted probabilities of also belonging to other groups with higher observed LIFE, their expected LIFE will tend to be slightly higher than the average LIFE of groups 33-35. Similarly sites in groups 16-17, which have among the highest values of observed LIFE, will tend to have values for expected LIFE which are "pulled-down" by the lower values of observed LIFE in other groups to which the RIVPACS environmental discrimination equations estimate they have a substantial probability of belonging. This statistical phenomenon of predicted values being less extreme than the observed values is a feature of all multiple linear regression type techniques.

Figure 2.9 is a frequency histogram showing the overall distribution of values of LIFE O/E for all the RIVPACS reference sites for all three seasons together. For these assumed unstressed sites, LIFE O/E has a relatively narrow range, varying between 0.78 and 1.25 (Table 2.8). Over all three seasons' samples, the standard deviation (SD) of the LIFE O/E for the reference sites is 0.056; this is considerably less than the equivalent SD for the two GQA EQIs, namely EQI_{ASPT} (SD=0.081) and EQI_{TAXA} (SD=0.204). This is partly because LIFE for unstressed sites is well predicted by RIVPACS, but partly because LIFE, as defined in section 1.1, takes in practice only a relatively narrow range of values, even for non-reference sites, as investigated in section 3. One consequence is that a range of 0.01 in LIFE O/E can encompass a large number of sites.

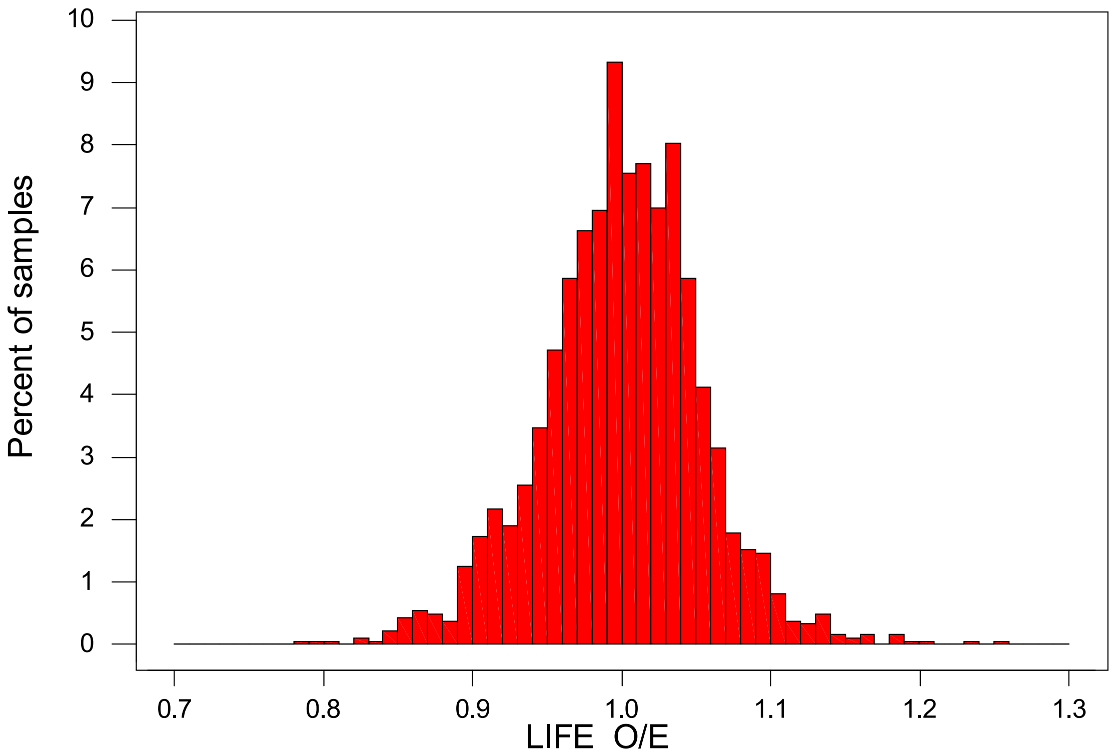


Figure 2.9 Histogram of the overall distribution of LIFE O/E for the RIVPACS reference sites (*n* = 614 sites x 3 seasons = 1842 samples)

Therefore it is recommended that LIFE O/E be calculated, stored and presented to an accuracy of 3 decimal places rather than 2 decimal places as used in RIVPACS III+ for

EQI_{TAXA} and EQI_{ASPT} (For example, record both 0.9357 and 0.9364 as 0.936, rather than as 0.94). The observed (O) and expected (E) LIFE only need to be calculated, stored and presented to an accuracy of 2 decimal places, so that O, E and O/E values are all stored to 3 significant figures.

This recommendation is based on the limited range of values obtained for LIFE O/E in practice (including for potentially stressed sites such as many of the GQA sites analysed in section 3). It does not necessarily imply that LIFE O/E can be estimated more precisely than EQI_{ASPT} or that it is less prone to the effects of sampling variation. (The effects of sampling variation on LIFE are assessed in section 6).

This recording accuracy has been used in the calculation, storage and use of all values of LIFE O/E for the RIVPACS reference sites and the 1990 and 1995 GQA sites used throughout this report. However, for clarity and where appropriate, tables of means, minimum and maximums may only be quoted to the nearest 2 decimal places.

The overall lower 5 and 10 percentile values of LIFE O/E, to three decimal places, for all the three seasons samples are 0.907 (4.9% of sample values are less than or equal to 0.907) and 0.931 (9.9%) respectively.

The implications of the distribution of LIFE O/E for the RIVPACS reference sites are discussed further, and more appropriately, in section 3.4, where comparison with the LIFE O/E distribution for the 1995 GQA sites is used to set trial lower limits for deciding which sites have probably not been subject to flow-related stresses and for setting limits for further grades or degrees of implied flow-related stress.

2.6 Summary and recommendations

Over 70% of the total variation in observed LIFE amongst the 614 RIVPACS reference sites can be explained by differences between the 35 biological site groups into which the reference sites are classified within RIVPACS.

The methods prescribed in Murray-Bligh (1999) for estimating the values for all the environmental RIVPACS predictor variables for a site should be used in any prediction of expected LIFE for a site.

LIFE was positively correlated with site altitude and slope and the percentage substratum cover of boulders and cobbles; it was negatively correlated with stream depth and in-stream alkalinity and the percentage cover of sand and fine silt or clay sediment.

CEH have derived a numerical algorithm to provide predictions of the expected LIFE for any river site based on its values for the standard RIVPACS environmental predictor variables. This algorithm is compatible with the derivation of expected ASPT, gives appropriate lower weighting to taxa with lower expected probabilities of occurrence and hence should be used in preference to the current LIFECALCULATOR method.

It is recommended that this new algorithm is incorporated into an updated Windows version of the RIVPACS software system to provide automatic calculation of observed LIFE, expected LIFE and hence LIFE O/E for any macroinvertebrate sample and river site.

The predictions of expected LIFE were very effective overall, with correlations between observed life and expected LIFE of 0.78 for the 614 RIVPACS reference sites.

It is recommended that LIFE O/E be calculated, stored and presented to an accuracy of 3 decimal places. The observed (O) and expected (E) LIFE only need to be calculated, stored and presented to an accuracy of 2 decimal places, so that O, E and O/E values are all stored to 3 significant figures.

3. LIFE FOR THE 1995 GQA SITES

This section covers research in Module 3 (aims in section 1.2.3).

The previous section assessed variation in observed LIFE, derived RIVPACS expected LIFE and assessed variation in the ratio of observed LIFE to expected LIFE for the RIVPACS reference sites. The reference sites were chosen because they were considered to be of good or high biological quality for their physical type and not subject to environmental stress, including from flow-related stresses.

It is important that the variation in observed LIFE and even more importantly, LIFE O/E are also assessed for a wide range of sites, a proportion of which are subject to flow-related stresses to their macroinvertebrate fauna. Therefore, in this section, we assess the LIFE index for a very large subset of sites from the Environment Agency's General Quality Assessment (QGA) national survey in 1995. This set of 6016 sites are the same as those analysed in previous recent studies by CEH (Davy-Bowker *et al*, 2000; Clarke *et al*, 2000; Furse *et al*. 2000) and are those sites for which there was both a spring and autumn biological sample and validated RIVPACS environmental data.

Although the best dataset readily available, the GQA sites are unlikely to adequately represent the range and frequency of sites most affected by low flow problems. GQA sites tend to be concentrated at the lower ends of watercourses whereas the upper reaches of catchments are often worst affected by low flow. Also, sites tend to be excluded from GQA where low flow problems can be so extreme that there may be no flow - crucial to RIVPACS sampling !

3.1 Variation in observed LIFE for the 1995 GQA sites

Figure 3.1(a) shows the overall variation in observed LIFE across all GQA sites using samples from both seasons. Values of observed LIFE for the GQA sites vary from 4.60 to 9.00, with 50% of sites having values between 6.43 and 7.37 (Table 3.1). Assuming the GQA sites cover all major types and qualities of sites, then this range, 4.6 to 9.0, gives the approximate limits within which practically all values of LIFE will lie (when based on RIVPACS standardised three minute samples). However, there are relatively few headwaters in the GQA network, so some may have more extreme values of observed LIFE.

There were 14 spring samples and six autumn samples which did not contain any taxa that have LIFE flow scores (f_S) and hence had an undefined value for LIFE for the sample and site. All these samples contained only Oligochaeta and/or Chironomidae. It is therefore not obvious whether or how to classify such very poor quality sites in terms of LIFE; although very poor in biological quality, this may not actually be the result of any flow-related stresses.

Figure 3.1(b) gives the equivalent histogram of observed LIFE for the RIVPACS reference sites, whilst Figure 3.1(c) compares the cumulative distribution of observed LIFE for the GQA and reference sites. Although the overall general range across all types of sites is similar, observed LIFE tends to be relatively low for a higher proportion of the GQA sites. For example, 57.4% of GQA sites have observed LIFE less than or equal to 7.0, but only 27.5% of the RIVPACS reference sites. However, it is best to compare sites in terms of observed to expected ratio of LIFE, which then automatically eliminates the major differences in LIFE due to the physical characteristics of sites.

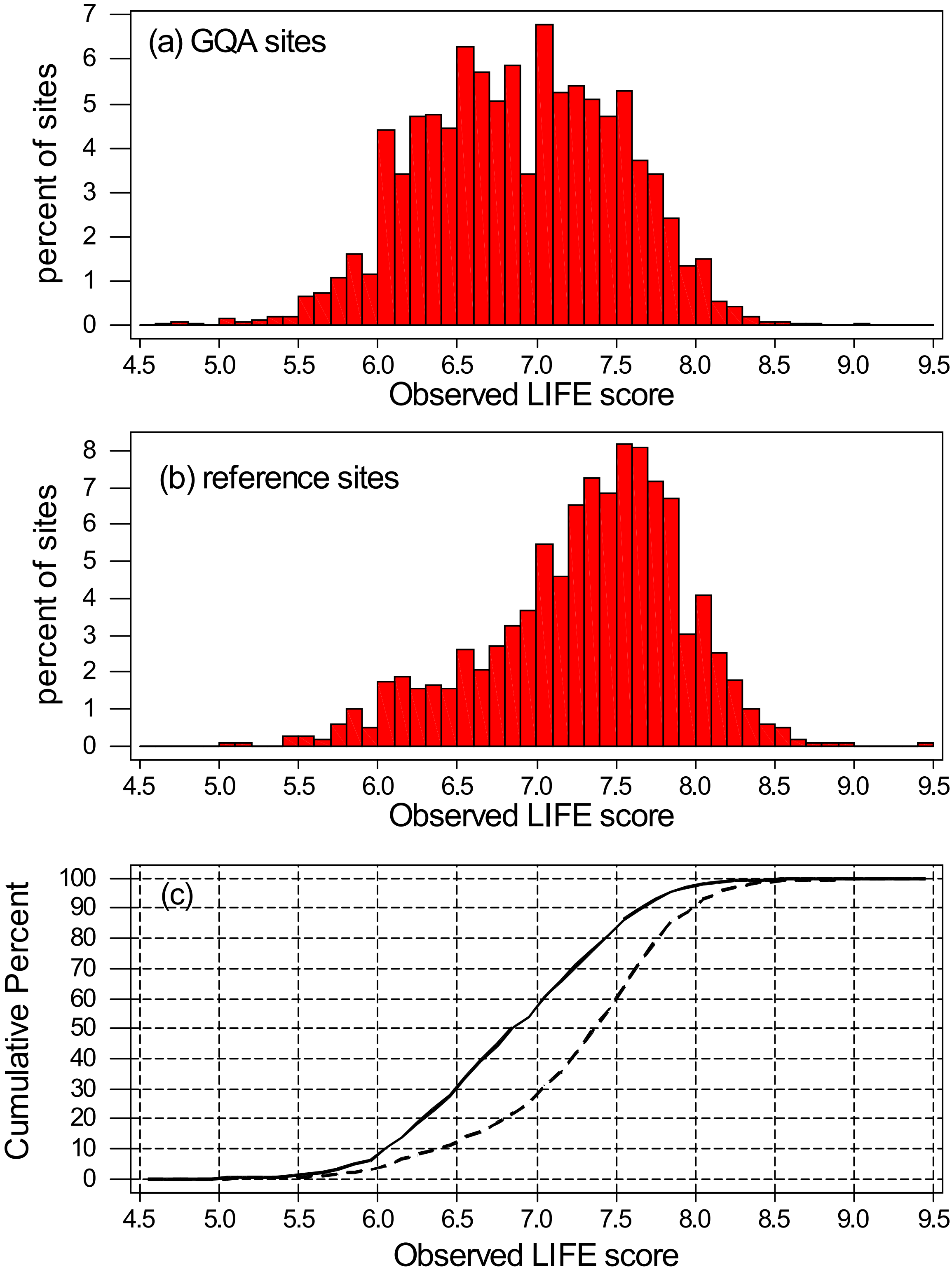


Figure 3.1 Comparison of the frequency distributions of observed LIFE (spring and autumn samples) for (a) 6016 GQA sites in 1995 and (b) the 614 RIVPACS reference sites; (c) compares the two cumulative frequency distributions (GQA = solid, reference = dashed line).

Table 3.1 Range and cumulative probability distribution for observed LIFE for the 1995 GQA sites and the RIVPACS reference sites for comparison.

Observed LIFE	GQA sites	RIVPACS reference sites
Min	4.60	5.00
Max	9.00	9.45
lower 5 percentile	5.91	6.08
lower 10 percentile	6.08	6.40

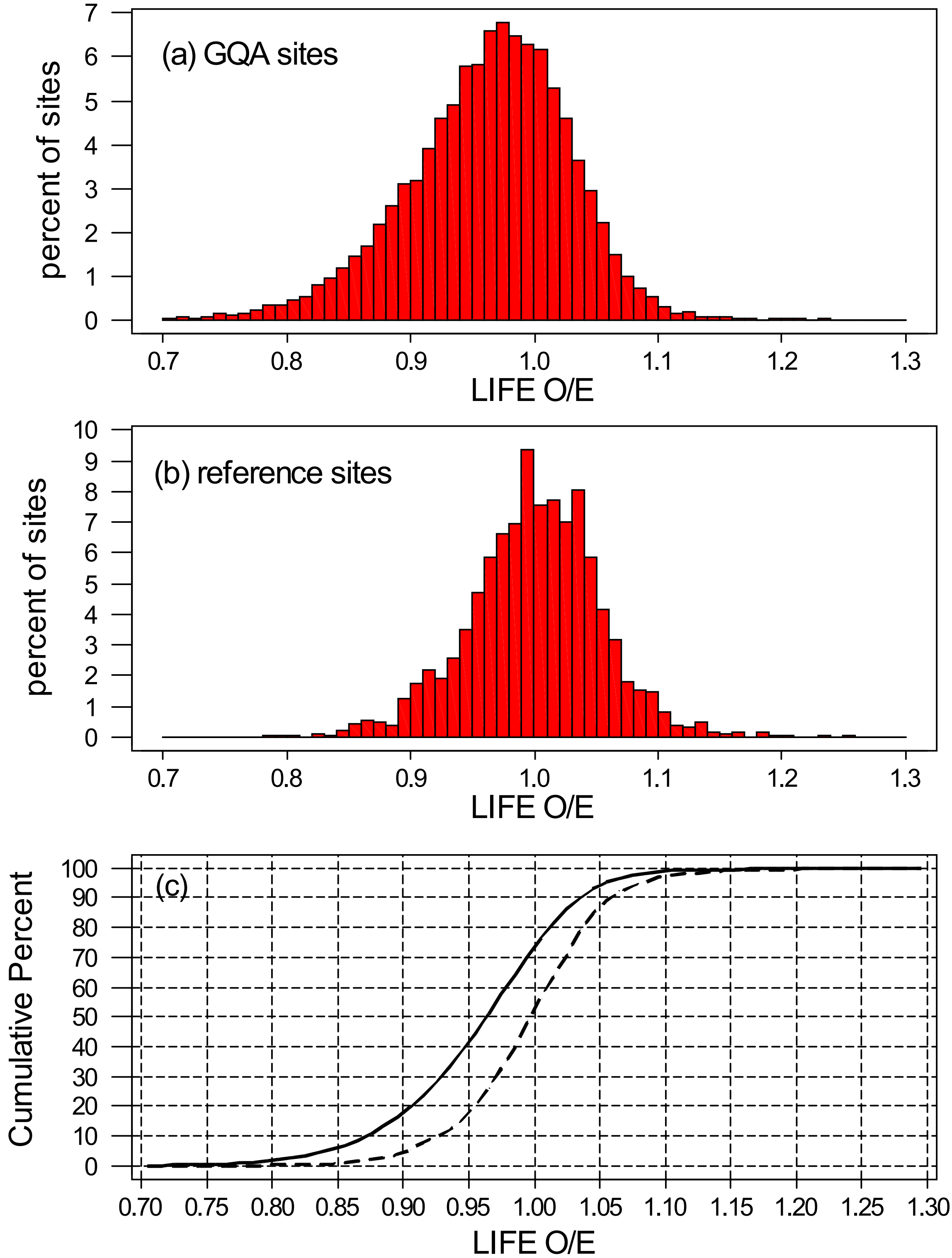
Observed LIFE	Cumulative % of sites	
	GQA sites	RIVPACS reference sites
5.0	0.2	0.1
5.5	1.1	0.4
5.8	3.4	1.6
6.0	8.8	3.8
6.2	14.2	6.7
6.4	24.0	9.8
6.6	34.7	13.9
6.8	45.7	18.6
7.0	57.5	27.5
7.2	66.6	35.6
7.4	76.9	50.1
7.6	86.8	65.2
7.8	93.8	80.0
8.0	98.1	91.3
8.2	99.3	95.9
8.4	99.8	98.7
8.6	99.9	99.5
8.8	99.9	99.8
9.0	100.0	99.9

3.2 Variation in LIFE O/E for the 1995 GQA sites

The site- and season- specific values for expected LIFE for each of the 6016 GQA sites were calculated using the methods detailed in section 2.3. Figure 3.2 and Table 3.2 compare the probability distribution of LIFE O/E for the GQA sites in 1995 with that for the RIVPACS reference sites. As expected a large proportion of GQA sites have high LIFE O/E like many of the reference sites. However, a much larger proportion of GQA sites have relatively low LIFE O/E, many of which were lower than those for all or most of the reference sites.

All GQA sites have values of LIFE O/E less than 1.24 except for two unusual sites which have just two or three high LIFE scoring taxa present which have LIFE O/E of 1.36 and 1.37. For example, the spring 1995 sample from Cawood on the Yorkshire Ouse (site code 100012034) had only two taxa with LIFE flow groups, Gammaridae at abundance category 3, getting a flow score of 10, and Hydropsycidae at abundance category 1, getting a flow score of 8, giving an overall observed LIFE of (8+10)/2 = 9.0. Expected LIFE was 6.62, leading to an LIFE O/E of 1.36. This example reminds us that a few sites can have high LIFE O/E, or high EQI_{ASPT}, even though they have very few taxa present and hence have low EQI for number of BMWP taxa.

Figure 3.2 Comparison of the frequency distributions of LIFE O/E (spring and autumn



samples) for (a) 6016 GQA sites in 1995 and (b) the 614 RIVPACS reference sites; (c) compares the two cumulative frequency distributions (GQA = solid, reference = dashed line)

Table 3.2 Range and cumulative probability distribution of LIFE O/E for all single season samples for the 1995 GQA sites (spring and autumn) and the RIVPACS reference sites (spring , summer and autumn).

LIFE O/E	RIVPACS reference sites	GQA sites
Min	0.78	0.64
Median	1.00	0.96
Max	1.28	1.37

LIFE O/E	cumulative % of sites < LIFE O/E value	
	RIVPACS reference sites	GQA sites
0.70	0.0	0.1
0.75	0.0	0.4
0.77	0.0	0.6
0.78	0.0	0.9
0.79	0.1	1.2
0.80	0.1	1.5
0.81	0.2	2.0
0.82	0.2	2.5
0.83	0.3	3.3
0.84	0.3	4.3
0.85	0.5	5.5
0.86	1.0	6.9
0.87	1.5	8.6
0.88	2.0	10.7
0.89	2.4	13.3
0.90	3.6	16.4
0.91	5.4	19.6
0.92	7.5	23.4
0.93	9.5	28.0
0.94	12.3	33.6
0.95	15.5	38.7
0.96	20.2	44.5
0.97	26.1	51.1
0.98	32.7	57.8
0.99	39.6	64.3
1.00	49.0	70.5
1.01	56.5	76.7
1.02	64.2	82.0
1.03	71.2	86.6
1.04	79.3	90.2
1.05	85.1	93.1
1.06	89.2	95.4
1.07	92.4	96.8
1.08	94.2	97.8
1.09	95.7	98.5
1.10	97.2	99.0
1.15	99.3	99.8
1.20	99.8	99.9

As mentioned above, a significant percentage of the GQA sites have values of LIFE O/E which are less than the values for all except one to three of the samples from RIVPACS reference sites (Figure 3.2(c), Table 3.2). For example, 4.3% of GQA sites have LIFE O/E less than 0.84 compared to only 0.3% of the reference sites. At a less extreme threshold, 19.6% of the GQA sites have LIFE O/E less than 0.91, compared to only 5.4% of the reference sites.

These comparisons suggest that a significant proportion of the GQA sites may be subject to some form of flow-related stress based on their values for LIFE O/E. However, a low LIFE O/E for a site may be partly or entirely caused by other factors such as organic pollution or other forms of environmental stress. That such causes result in a diminished macroinvertebrate fauna coincidentally leads to a lower observed LIFE and hence lower LIFE O/E. In addition, low water quality arising from organic pollution may itself be at least partly due to low flows leading to lower dilution of organic inputs. The relationship between LIFE O/E and O/E for ASPT and number of BMWP taxa was investigated in section 3.5.

LIFE O/E should not be interpreted in isolation. Any interpretation of LIFE O/E for a site should involve calculating O/E for both ASPT and number of BMWP taxa and assessing all potential causes of any biological stress at the site, whether from organic or toxic pollution, acidification, degraded habitat or flow-related stresses.

3.3 Changes in LIFE O/E between the 1990 RQS and 1995 GQA surveys

Clarke *et al.* (1999) derived a matched dataset of 3018 biological GQA sites which were sampled in all three seasons in the 1990 River Quality Survey (RQS) and in spring and autumn in the 1995 GQA survey and could confidently be matched as the same river site in both years. This dataset provided a readily available large set of sites for which observed LIFE scores and LIFE O/E could be compared between two years. The change in LIFE scores at any particular site will be due to a mixture of sampling variation and real changes in the macroinvertebrate community at each site, perhaps as a result of changes in flow conditions, but also from changes in other stresses. Any interpretation of the changes requires information on the flow conditions and stresses operating prior to the times of sampling. (Module 6 of this R&D project (see section 1.2.6) will assess the flow conditions prevailing at each prior to taking autumn 1995 samples, whilst Module 7 will quantify the effects of sampling variation on LIFE score.) However, the general magnitude of the changes in observed LIFE score and LIFE O/E amongst such a wide range of sites is of interest in itself.

Figure 3.3 compares the 1990 and 1995 values for both observed LIFE score and LIFE O/E. The inter-year correlation in observed LIFE scores is 0.80, whilst for LIFE O/E the correlation seemed initially surprisingly low (r=0.63). The implication is that, to some extent, the degree of flow-related stress at a site varies considerably between years and/or the sites suffering most from flow or other related stresses changes from year to year. However, part of the differences in LIFE O/E between years will be due to the effects of sampling variation on the observed values of LIFE. This is discussed further in section 6.

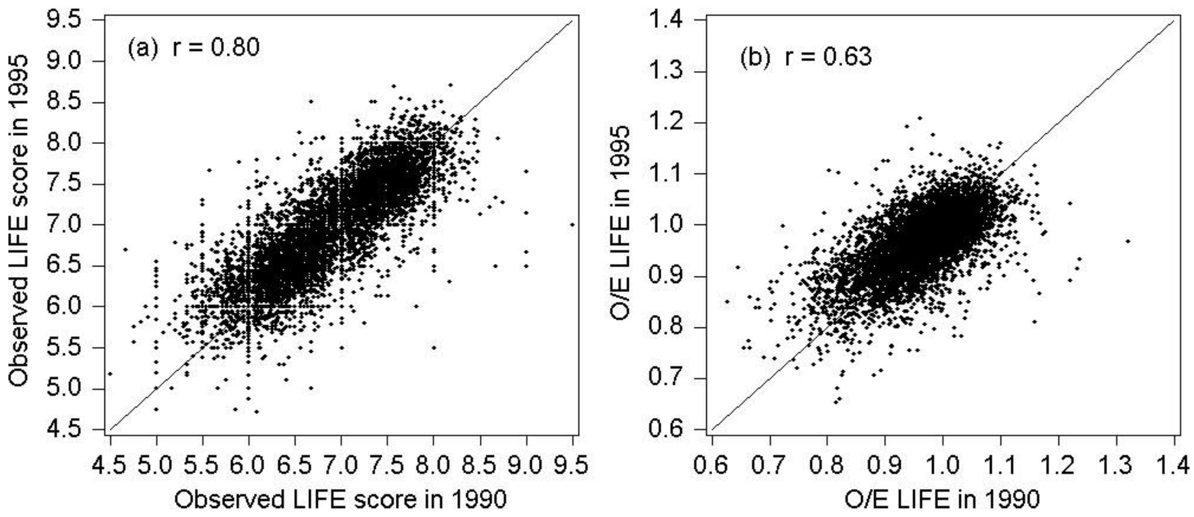


Figure 3.3 Inter-year comparison of (a) observed LIFE and (b) LIFE O/E for 3018 matched GQA sites sampled in both the 1990 RQS survey and 1995 GQA survey (spring and autumn samples together). The solid line is the 1:1 line.

3.4 Deriving a grading system for LIFE O/E

This sub-section forms part of Module 2 (aims in section 1.2.3), whose objective was to use the variation in LIFE O/E for the RIVPACS reference sites "to provide a framework for setting the lower limit for top grade (i.e. unaffected) sites". In this context "unaffected" means in terms of flow-related stresses.

We have delayed reporting on a potential grading system for LIFE O/E until here, so that we can make use of our findings about variation in LIFE O/E for the GQA sites in conjunction with that for the RIVPACS reference sites. Table 3.2 (above) compares the cumulative probability distribution for the two datasets.

There are no fixed a priori rules for setting the upper and lower limits for any system of grading sites based on their LIFE O/E.

Although the RIVPACS reference sites are assumed to be of high quality, they are not all of the same quality, however that is defined. However, the RIVPACS reference sites are assumed to be unstressed, including in terms of impacts of their river flow regime. (Assessments of the flow condtions of the reference sites at the time of sampling for RIVPACS are summarised in section 7.) On the assumption that few, if any reference sites were sampled at times of flow-related stresses, it is logical that the lower limit for the top grade of any biotic index should be set so that at least the vast majority of the RIVPACS reference sites are assigned to the top condition grade. This was the approach recommended by CEH in the setting of the lower limit for the top grade based on the EQIs for ASPT and number of BMWP taxa (Wright *et al* 1991). For example, they recommended that the lower 5 percentile value of EQI_{ASPT} for the RIVPACS reference sites be used to set the lower limit for top grade 'a' based on ASPT and the lower 10 percentile value of EQI_{TAXA} for the RIVPACS reference sites be used as the lower limit for grade 'a' based on number of taxa.

Table 3.3 gives the values of the LIFE O/E which are exceeded by all except 5% or 10% of the RIVPACS reference sites. These estimated critical percentile values vary slightly between the three seasons, being slightly higher for spring and lowest for summer samples. In theory, different lower limits for the top grade of sites (which are assumed to have suffered little or no flow-related stress) could be set for each season. However, a parsimonious single set of limits used for all seasons is more practical and appealing.

The overall lower 5 and 10 percentile values of LIFE O/E for the RIVPACS reference sites for all three seasons' samples together are 0.907 and 0.931 respectively. More precisely, 4.9% of reference sites had LIFE O/E of less than 0.908 and 9.9% had values of less than 0.932. Either of these two values could arguable be used as the lower limit of LIFE O/E for sites to be classified to the top grade.

Table 3.3 Lower 5 and 10 percentile values for LIFE O/E for the RIVPACS reference sites, separately for each season and overall; exact percentages of reference sites less than the specified value are given in brackets

Lower percentile	Spring	Summer	Autumn	Overall
5 %	0.924(5.0%)	0.899(5.0%)	0.907(4.9%)	0.907(4.9%)
10%	0.945(9.8%)	0.919(9.9%)	0.924(9.8%)	0.931(9.9%)

We suggest that all sites with LIFE O/E of 0.93 or more be treated as not subject to any significant flow-related stress. With this lower limit all except 9.5% of the RIVPACS reference site samples would be assigned to the top LIFE grade.

If required by the Environment Agency, to highlight sites which may be developing stress problems, this top class of sites could be further subdivided to identify those sites with LIFE O/E values less than 0.97 but greater than or equal to 0.93; 16.6% of RIVPACS reference site samples fall in this class. Furthermore, the top class of sites could be further subdivided into two grades depending on whether or not their LIFE O/E was greater than unity; this would then be analogous to the Environment Agency's GQA grading system in which the Ecological Quality Index (EQI) based on ASPT was subdivided according to whether or not EQI_{ASPT} was greater than unity. Because the average O/E (or EQI) for the references sites is by its definition around unity, it should be remembered that having a lower limit for grade a at unity forces roughly half of the references sites to be placed in grade b (or lower).

Using these ideas, and by reference to the probability distribution of LIFE O/E for the GQA sites in 1995 (Table 3.2), we have devised a provisional trial grading scheme for sites based on their LIFE O/E (Table 3.4). It has six grades to give some comparability with the GQA grading system. If only five grades are required to comply with the Water Framework Directive (WFD) (Council of the European Communities (2000)), then the top two grades should be combined.

The lower limits for the lower grades are currently somewhat arbitrary and require further research relating changes in LIFE O/E at a site to changes in flow conditions. Also, the number of grades into which sites should be classified should depend on the errors and uncertainty in estimating LIFE O/E and hence in the risks of mis-classifying sites to their wrong grade. Having a scheme with more grades gives finer apparent discrimination but greater actual mis-grading rates. This topic is discussed in detail in Clarke *et al* (1996) and Clarke (2000).

Table 3.4 Provisional grading scheme for sites based on their LIFE O/E

Grade	LIFE O/E range	% RIVPACS reference sites in grade	% GQA sites in grade
a	≥1.00	51.0%	29.5%
b	≥0.97– <1.00	22.9%	19.4%
c	≥0.93– <0.97	16.6%	23.1%
d	≥0.88 – <0.93	7.5%	17.3%
e	≥0.83 - <0.88	1.7%	7.4%
f	<0.83	0.3%	3.3%

When a trial grading system for LIFE O/E is agreed, it would be useful for the Environment Agency to derive codes (e.g. a, b, c, etc.) and appropriate names to refer to each grade; as has been done for the biological and chemical GQA grading systems. There is merit in having the same number of grades for LIFE O/E as for the GQA grading system based on EQI_{ASPT} and EQI_{TAXA}, namely six, denoted a-f. Furthermore, if the percentage of all GQA sites in a particular grade was forced to be the same for both the EQI- and LIFE-based grading systems, then it would make it easier to identify sites which had notable differences in the grades under the two systems. With such comparable grading systems, a site assigned to a high quality GQA grade, but low quality LIFE grade could then more confidently be assumed to be subject to some form of flow-related stress rather than pollution problems. However, it is not a trivial task to make truly comparable systems with the same proportions of all river stretches in the country in each grade under both GQA and LIFE system. In particular, the GQA sites, which provide the only readily available national dataset, are not randomly selected but concentrated in lower catchments and under-represent sites in the upper catchments and headwater streams, many of which are prone to low-flow problems.

An alternative approach for providing compatibilty of EQI and LIFE grading systems is to use biologists' collective experience to subjectively set each LIFE O/E grade so that it corresponds to what is perceived to be roughly the same degree of stress as for the equivalent GQA grade.

3.5 Relationship between LIFE, ASPT, number of taxa and their O/E ratios

3.5.1 Background relationship between ASPT, number of taxa and their EQIs

The BMWP scoring system was designed to provide a quantitative index of macroinvertebrate community response to pollution and, in particular, organic pollution. Most macroinvertebrate families were assigned a BMWP score 1-10, according to their perceived tolerance to organic pollution (10 = least tolerant) (Table 1.4). The two BMWP-based indices used by the Environment Agency in their national GQA surveys are the number of BMWP scoring taxa and the average score of the taxa present (ASPT). Specifically, the ratio (O/E) of the observed (O) value to the RIVPACS prediction of the expected (E) value of each of these two indices are used to assess each site's biological condition. The O/E ratios are usually referred to as Ecological Quality Indices (EQI), the EQI based on number of BMWP taxa will be denoted as EQI_{TAXA} and that the EQI based on ASPT will be denoted as EQI_{ASPT}. The biological GQA system for grading sites is based on their values for these two EQIs and the overall grade for a site is taken as the lower of its two grades based on each EQI (Clarke *et al* 1997).

Amongst the RIVPACS reference sites the two indices EQI_{ASPT} and EQI_{TAXA} are not correlated to any practical extent (Figure 3.4).

The LIFE index is based on an average score per taxon, akin to ASPT. Although the aim of the LIFE index is different to the main aim of the BMWP system, it is important to know the extent to which LIFE for a site is correlated with the site's taxonomic richness and ASPT, and more importantly, the extent to which LIFE O/E is correlated with EQI_{TAXA} and EQI_{ASPT}.

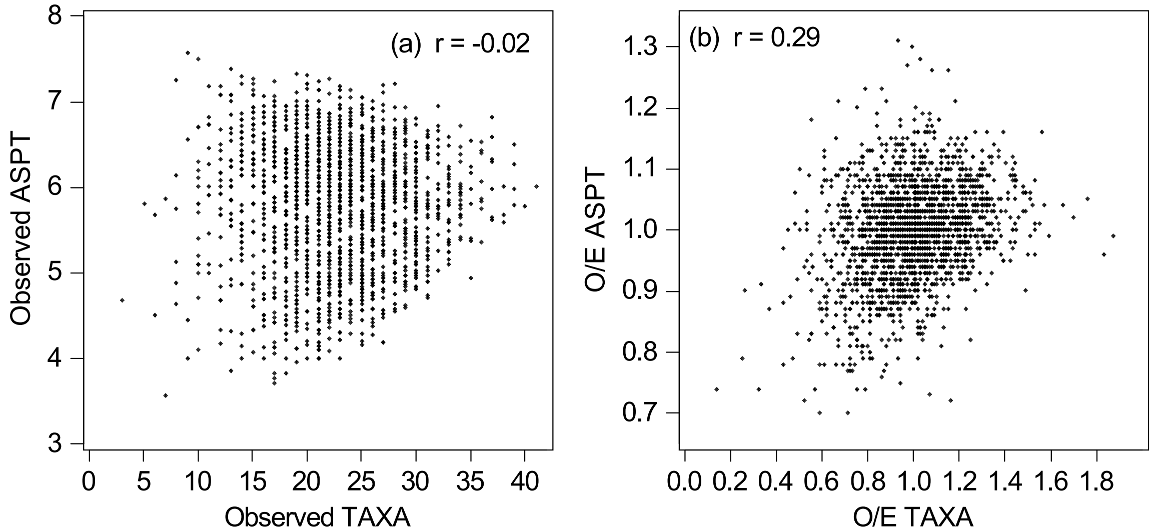


Figure 3.4 Relationship between observed ASPT and number of BMWP taxa present and between EQI_{ASPT} and EQI_{TAXA} for the RIVPACS reference sites (all three seasons samples together, *n* = 1842)

Table 1.4 lists the LIFE flow group classification and BMWP score for all families incorporated within the RIVPACS system. Table 3.5 shows the number of BMWP families in each flow group with each BMWP score.

Table 3.5 Number of families with each BMWP score in each LIFE flow group

LIFE flow group	BMWP score 1	2	3	4	5	6	7	8	10	Total families
I							1	1	7	9
II				2	3	2		4	10	21
III						2		1	1	4
IV			10		14	4	4	4	4	40
V					3					3
VI										0
Total			10	2	20	8	5	10	22	77

It is immediately obvious that the two scoring systems are not independent. Of the 22 families with the maximum BMWP score of 10, 77% (17) were assigned to LIFE flow group I or II. At the other extreme, all of the 10 families considered to be tolerant to organic pollution and given a BMWP score of 3 were considered to be taxa primarily associated with slow flowing and standing waters and assigned to LIFE flow group IV. Therefore it is likely that the indices based on LIFE and ASPT will be correlated to some extent.

This lack of independence in the two systems is not a criticism. It partly arises simply because many organisms that can survive or do well in slow flowing or still water are also naturally tolerant or can compete well when there are organic stresses or reduced oxygen levels.

3.5.2 Relationship amongst the RIVPACS reference sites

Amongst the RIVPACS reference sites, there is very little relationship between observed LIFE and the number of taxa present, or between LIFE O/E and EQI_{TAXA} (Figure 3.5(a), 3.6(a)). However, observed LIFE is positively correlated ($r = 0.78$) with observed ASPT (Figure 3.5(b)), indicating that even amongst supposedly unstressed sites, the types of site with the higher values of ASPT tend to have higher values of LIFE, and vice versa. Once standardised by their expected values, LIFE O/E is still moderately positively correlated ($r = 0.53$) with EQI_{ASPT} (Figure 3.6(b)).

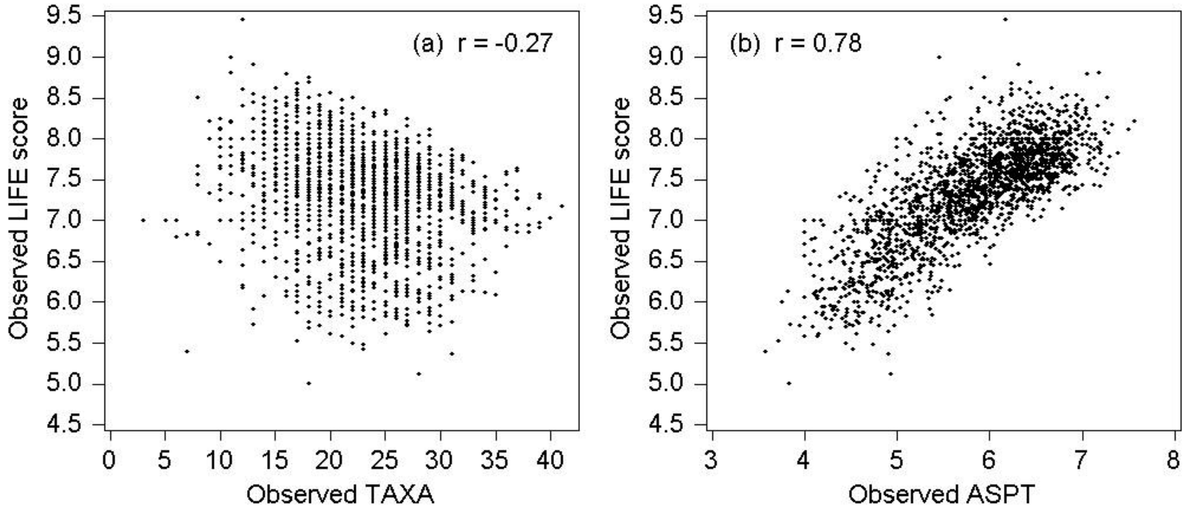


Figure 3.5 Relationship between observed LIFE and (a) observed number of taxa or (b) observed ASPT for the RIVPACS reference sites (n = 614 sites x 3 seasons = 1842)

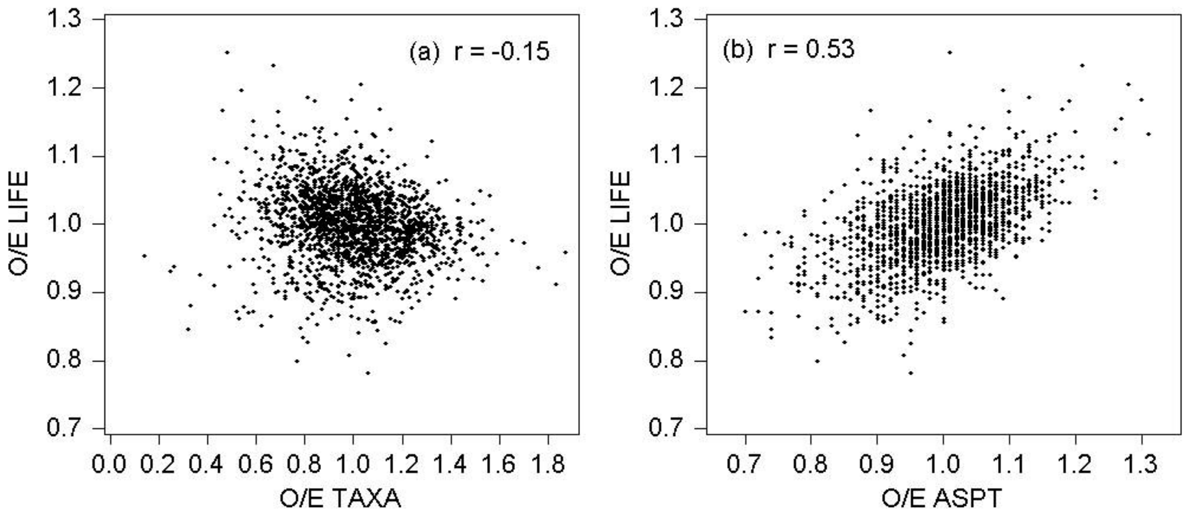


Figure 3.6 Relationship between LIFE O/E and (a) EQI_{TAXA} or (b) EQI_{ASPT} for the RIVPACS reference sites (n = 614 sites x 3 seasons = 1842)

3.5.3 Relationship amongst the 1995 GQA sites

A better assessment of the correlation between site assessments based on LIFE, the BMWP system and associated EQIs can be obtained by examining their inter-relationships across a large set of sites encompassing a wide range of conditions, qualities and degrees of stress. The GQA sites dataset for 1995 includes sites from practically all physical river types in England and Wales; although there may be under-representation of headwater streams as the sites were chosen primarily to monitor pollution-related effects not flow-related stresses.

Figure 3.7(a) reminds us that all taxon-rich sites have relatively high ASPT values; taxon poor sites tend to have low ASPT values, but there are exceptions. This is why the GQA biological grading system is defined as the lower of the two grades based on EQI_{TAXA} and EQI_{ASPT}. The two GQA indices EQI_{TAXA} and EQI_{ASPT} are not independent in practice; they have a correlation of 0.77 amongst all the single season samples for the 6016 GQA sites in spring and autumn 1995 (Figure 3.7(b)).

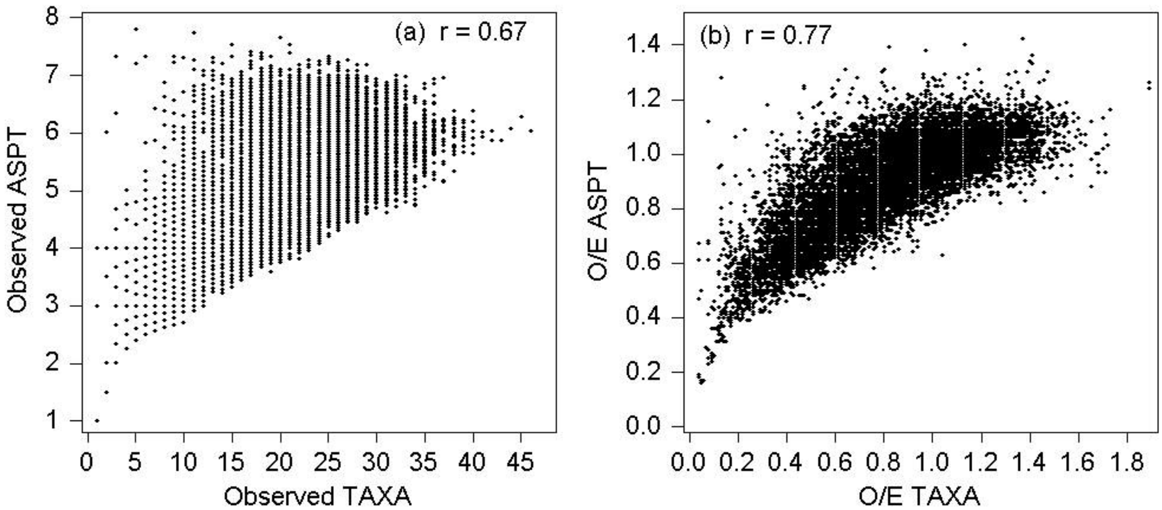


Figure 3.7 Relationship between (a) observed ASPT and observed number of BMWP taxa present and (b) between EQI_{ASPT} and EQI_{TAXA} for the 6016 GQA sites in 1995.

The observed LIFE for a sample is less dependent on the number of taxa on which it is based than ASPT, in the sense that the overall correlation between observed LIFE core and taxon richness for the 1995 GQA samples is low ($r = 0.31$, Figure 3.8(a)).

The unusual patterning in distributions in Figures 3.7(a), 3.8(a) and 3.8(b) is real. When only a single is present both ASPT and LIFE can only take integer values, with two taxa present only integer values or values ending in '.5' are possible, with three taxa present, all values are integers or end in '.333' or '.667'.

All taxon rich samples have intermediate LIFE scores being generally based on taxa from the complete range of LIFE flow groups. Samples with few taxa tend to have the lowest LIFE scores, but can have very high LIFE scores (i.e. >8.0). When there are few taxa present at a site, the LIFE score observed in any one sample may be relatively more variable, as LIFE is an average score per taxon and hence not based on many taxa in such cases. Assessments of the sampling variability in observed LIFE was summarised in section 6.

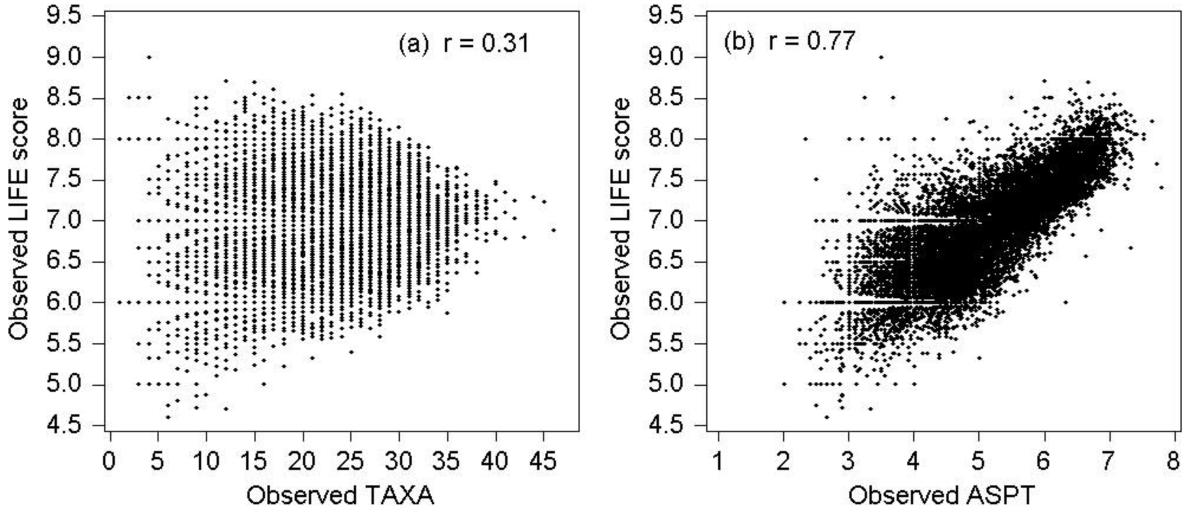


Figure 3.8 Relationship between observed LIFE and (a) observed number of BMWP taxa present or (b) observed ASPT for the 6106 GQA sites in 1995.

Figure 3.9 shows the relationship between the LIFE O/E and the two EQI indices for 6016 GQA sites in 1995. Because of the very large number of sites involved in Figure 3.9, the extent to which LIFE O/E is correlated with the two EQIs is also summarised in cross-tabulation form in Table 3.6.

Table 3.6 Cross-tabulation of values of LIFE O/E by (a) EQI_{TAXA} or (b) EQI_{ASPT}, grouped in classes of 0.1 range, for the spring and autumn GQA samples in 1995

(a)		**Lower limit of classes of EQI_{TAXA}**												
		<0.4	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**	**1.1**	**1.2**	**1.3**	**≥1.4**	**All**
Lower limit of classes of LIFE O/E	<0.7	7	2	1										10
	0.7	102	37	25	7	2								173
	0.8	406	308	276	289	193	139	81	52	25	9	4	5	1787
	0.9	364	409	475	667	730	787	831	832	636	435	195	144	6505
	1	96	98	149	247	385	463	576	545	395	236	138	93	3421
	1.1	15	9	12	10	12	13	13	14	4		1	3	106
	1.2	5			2	1								8
	≥1.3	2												2
	All	997	863	938	1222	1323	1402	1501	1443	1060	680	338	245	12012

(b)		**Lower limit of classes of EQI_{ASPT}**											
		<0.4	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**	**1.1**	**1.2**	**≥1.3**	**All**
Lower limit of classes of LIFE O/E	<0.7	1	5	4									10
	0.7	12	35	65	39	19	2	1					173
	0.8	14	90	263	476	484	323	117	19		1		1787
	0.9	3	23	136	407	772	1290	2225	1487	159	3		6505
	1	1	1	12	35	93	272	741	1567	628	61	10	3421
	1.1		1	2	4	4	4	17	22	30	18	4	106
	1.2			1	2	1				2	2		8
	≥1.3				1		1						2
	All	31	155	483	964	1373	1892	3101	3095	819	85	14	12012

There is only a moderate positive relationship between LIFE O/E and EQI_{TAXA} (r = 0.39). Nearly all the high quality sites with values of EQI_{TAXA} greater than 1.0 have values of LIFE O/E between 0.9 and 1.1. The sites with less than half their expected number of taxa (i.e. EQI_{TAXA}<0.5) have the full range of values for LIFE O/E (Figure 3.9(a)). This suggests that sites which are unexpectedly taxon-poor may, or may not, be subject to flow-related stresses, as indicated by LIFE.

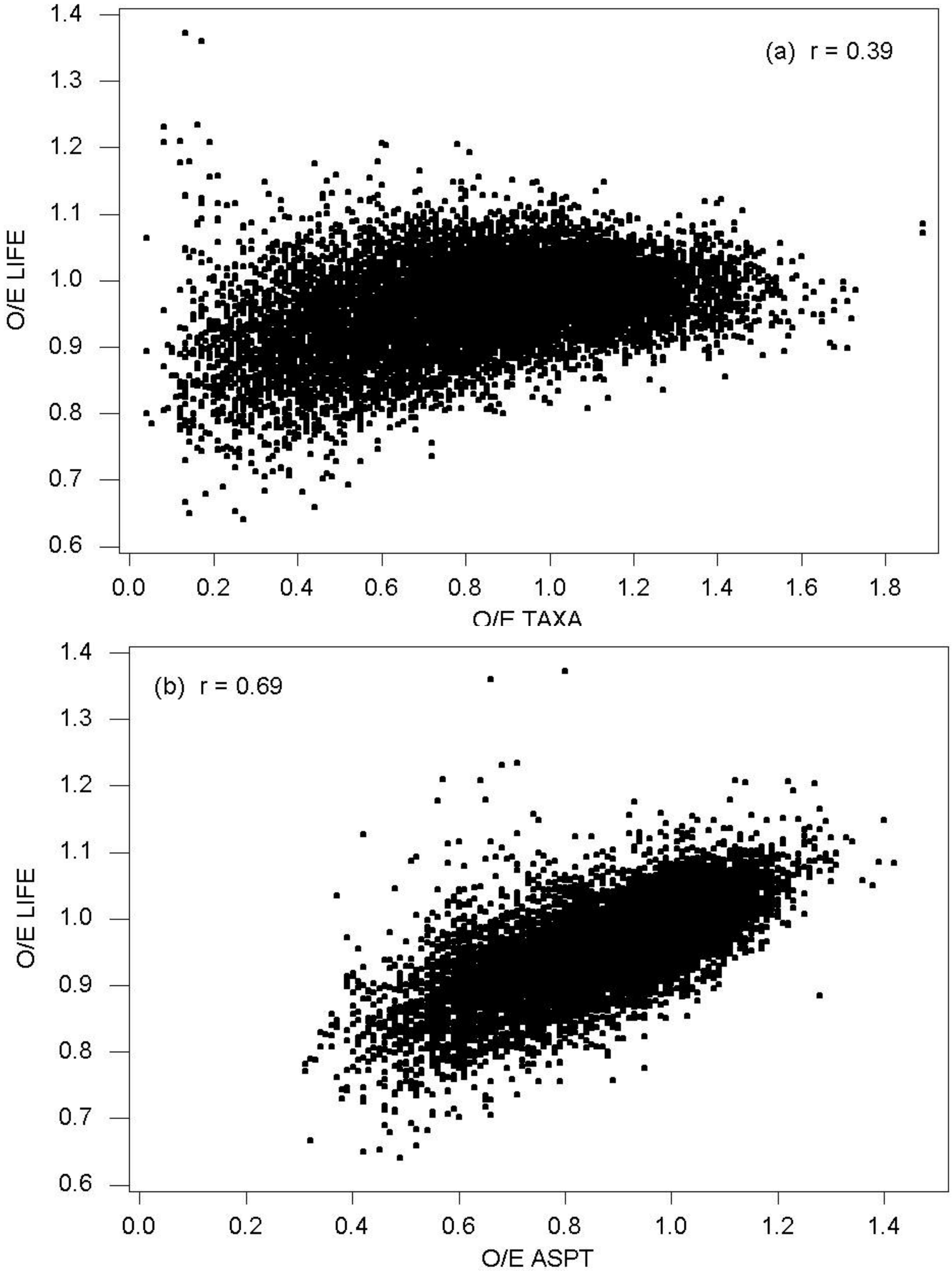


Figure 3.9 Relationship between LIFE O/E and (a) EQI_{TAXA} or (b) EQI_{ASPT} for the 6016 GQA sites in 1995 (spring and autumn samples)

There is a higher overall correlation between LIFE O/E and EQI_{ASPT}, as one might anticipate, (Figure 3.9(b)). However, such a correlation (r = 0.69) indicates that less than half of the variation in LIFE O/E is explained by, or confounded with, variation in EQI_{ASPT}. This suggests that LIFE O/E can, in practice, tells us something extra, and provide a different site assessment from that given by the information contained in the two EQIs. However, part of the apparent lack of agreement is due to the effects of sampling variation on both indices; sampling variation in observed LIFE is quantified in section 6.

3.5.4 Comparison of the LIFE O/E and biological GQA site grading systems

In section 3.4 we developed a trial grading system based on LIFE O/E, as specified in Table 3.4. Table 3.7 compares this LIFE-based grading system with the biological GQA grades assigned to the same macroinvertebrate samples based on their EQI_{TAXA} and EQI_{ASPT}.

Table 3.7 Comparison of grades for spring and autumn samples of 6016 GQA sites in 1995 based on their LIFE O/E, EQI_{TAXA} and EQI_{ASPT}. Tables show percentage of samples in each EQI-based grade, separately for samples in each LIFE grade

(a)		**grade based on EQI_{TAXA} (lower limit in brackets)**						
		(0.85)	**(0.70)**	**(0.55)**	**(0.45)**	**(0.30)**		
		a	b	c	d	e	f	Overall
grade based on LIFE O/E	a	64.1	17.7	10.1	3.3	3.2	1.6	29.5
	b	63.6	16.5	11.1	4.4	3.3	1.1	19.4
	c	53.6	17.1	14.4	6.6	6.5	1.9	23.1
	d	30.5	18.6	20.8	12.1	12.8	5.2	17.3
	e	10.3	14.4	24.4	18.9	21.2	10.8	7.4
	f	3.5	4.8	15.5	16.8	30.6	28.8	3.3
	Overall	49.8	16.8	14.4	7.4	7.9	3.8	100.0

(b)		**grade based on EQI_{ASPT} (lower limit in brackets)**						
		(1.00)	**(0.90)**	**(0.77)**	**(0.65)**	**(0.50)**		
		a	b	c	d	e	f	Overall
grade based on LIFE O/E	a	66.4	21.3	9.0	2.2	1.0	0.1	29.5
	b	42.9	35.8	15.3	4.5	1.4	0.1	19.4
	c	20.8	37.4	26.2	11.7	3.8	0.2	23.1
	d	4.8	19.9	33.8	26.1	13.9	1.7	17.3
	e	0.2	5.1	23.3	35.1	29.7	6.5	7.4
	f	0.0	1.0	7.5	23.6	47.1	20.8	3.3
	Overall	33.4	25.8	19.5	12.1	7.6	1.6	100.0

(c)		**overall biological GQA grade**						
		a	**b**	**c**	**d**	**e**	**f**	**Overall**
grade based on LIFE O/E	a	52.9	25.9	12.8	3.6	3.2	1.6	29.5
	b	37.0	35.5	17.4	5.4	3.5	1.1	19.4
	c	18.0	35.8	25.9	11.3	7.2	1.9	23.1
	d	4.0	18.5	31.9	23.3	17.1	5.2	17.3
	e	0.1	4.3	20.6	31.4	31.2	12.4	7.4
	f	0.0	0.5	6.5	19.3	40.6	33.1	3.3
	Overall	27.6	26.3	20.4	11.7	9.9	4.1	100.0

As an illustrative example of how to interpret Table 3.7, we highlight that under the proposed schemes, 29.5% of the GQA samples would be assigned to LIFE grade a. Of these sites, 66.4% would also be assigned to GQA biological grade a based on their value for EQI_{ASPT}, 2.13% to grade b, 9.0% to grade c, and so on (Table 3.7(b)). There is a much stronger relationship between LIFE grade and GQA grade based on EQI_{ASPT} than between LIFE grade and GQA grade based on EQI_{TAXA} (Table 3.7 (b) and (a)).

Remember that the overall biological GQA grade assigned to a site is the lower of its grades based on the two EQI indices. There is a general tendency for sites with high LIFE grade to have high overall biological GQA grade, and vice versa.

In Table 3.8, the shaded cells which denote the percentages of samples assigned "similar" grades by both systems, account for 79% of all the GQA sites. Two factors contribute to this. As explained in section 3.5.1, macroinvertebrate families which are susceptible to (organic) pollution also prefer medium to fast flowing water; because of this the BMWP and LIFE scoring system for taxa are naturally correlated to some extent. In addition, a large percentage of GQA sites are of high or moderate grade (i.e. a, b or c) in terms of both GQA grade (74%) and LIFE O/E grade (72%); therefore just by chance, a high proportion of sites would be expected to have similar (high) grades under both grading systems.

Table 3.8 Percentage of all spring and autumn samples for the 6016 GQA sites in 1995 given each combination of LIFE grade and overall biological GQA grade. Shaded cells denote samples given "similar" grades by both systems (i.e. differing by no more than one grade)

		Overall biological GQA grade						
		a	b	c	d	e	f	Overall
grade based on LIFE O/E	a	15.6	7.6	3.8	1.1	0.9	0.5	29.5
	b	7.2	6.9	3.4	1.0	0.7	0.2	19.4
	c	4.2	8.2	6.0	2.6	1.7	0.4	23.1
	d	0.7	3.2	5.5	4.0	3.0	0.9	17.3
	e		0.3	1.5	2.3	2.3	0.9	7.4
	f		0.0	0.2	0.6	1.4	1.1	3.3
Overall		27.6	26.3	20.4	11.7	9.9	4.1	100.0

3.6 Conclusions

The LIFE and ASPT indices are naturally correlated to some extent; macroinvertebrate families which require fast flowing conditions tend to also be susceptible to organic pollution, and vice versa.

Amongst the GQA sites the correlation between LIFE O/E and O/E based on ASPT is only 0.69. The LIFE and BMWP scoring systems do not therefore appear to be completely confounded. This suggests that LIFE O/E may often provide additional and separate information on the biological condition of a site which is not covered by the BMWP-based EQI indices. It may be possible to use the biota to at least partly differentiate flow-related stress from organic dominated stress.

However, the apparent lack of agreement in site assessments using the two scoring systems must be at least partly due to the effects of sampling variation on both sets of O/E ratios. This will be correlated variation as the O/E ratios for a site are all calculated from the same sample(s); further research is urgently needed.

4. SIMULATING FLOW-RELATED CHANGES IN EXPECTED LIFE USING RIVPACS

This section covers research in Module 4 (aims in section 1.2.4). It assesses the sensitivity of RIVPACS predictions of expected LIFE to changes in the flow-related variables involved in RIVPACS predictions.

4.1 Introduction

Simulations were used to assess the effects on expected LIFE of varying flow conditions at a site by altering stream width, depth and substratum composition, as discussed in Armitage *et al.* (1997). This approach examined the sensitivity of current RIVPACS predictions of expected LIFE to flow-related variables. Predictions of expected LIFE were based on the suite of variables in RIVPACS III+ environmental variables option 1, as described in section 1.2.2.

Expected LIFE was calculated using the methods and procedures developed in section 2.3. It is important to remember that expected LIFE for a site is based on the weighted average fauna observed at RIVPACS reference sites of similar environmental characteristics. Being an average, the expected fauna will vary less than the fauna and hence LIFE score observed in any single macroinvertebrate sample (see section 2.5.1 for a more detailed discussion). The aim of this section is to assess the extent to which the prediction of the LIFE score to be expected, on average, changes as the physical conditions at a site are altered. These predicted average responses for sites of this type will usually be less that the LIFE score response observed in any one particular scenario at a particular site.

4.2 Methods

4.2.1 Site selection

The aim was to include sites which encompassed the full spectrum of types of river sites covered by the RIVPACS reference sites. In developing RIVPACS III, the reference sites were classified into 35 groups based solely on their macroinvertebrate communities using TWINSPAN (<u>T</u>wo-<u>W</u>ay <u>In</u>dicator <u>Sp</u>ecies <u>An</u>alysis). The TWINSPAN classification of sites is hierarchical. For site selection purposes, we used the nine group TWINSPAN classification as our starting point, and referred to here as site super-groups and denoted by the range of site groups involved (e.g. super-group "15-17" in Table 4.1).

Table 4.1 The nine site super-groups in terms of the 35 site group TWINSPAN classification

site groups involved	1-4	5-9	10-14	15-17	18-20	21-24	25-28	29-32	33-35

Three to five sites were selected from each super-group to represent the range of observed environmental conditions within that group. Thus in site super-group 1-4, sites were included with (mean annual) discharge ranging from category 1 (≤ 0.31cumecs) to category 5 (5-10 cumecs). This process resulted in the selection of 31 test sites covering a representative range of rivers in the RIVPACS database (Table 4.2).

Table 4.2 The 31 RIVPACS reference sites selected for simulation studies together with their environmental characteristics .

	RIVER NAME	SITE NAME	site groups	NGR	altitude	discharge category	distance (km)	mean width (m)	mean depth (cm)	alkalinity (mg CaCO3 /l)	mean substratum
1	South Tyne	South Tyne Head	1-4	NY755361	518	3	0.8	1.7	10.8	83	-6.94
2	Pickering Beck	Levisham	1-4	SE816911	67	1	10.1	4	13.1	68	-2.33
3	Derwent	Grange-In-Borrowdale	1-4	NY255176	79	5	9	18.2	21.1	14	-4.11
4	Unnamed	Gasper	5-9	ST763335	128	1	1.2	0.8	9.9	50	-1.74
5	By Brook	Gatcombe Hill	5-9	ST834789	91	1	8	5.8	32.2	221	-2.34
6	Great Eau	Ruckland	5-9	TF332779	56	1	2	2.2	18.9	216	-3.02
7	Cowside Beck	Arncliffe	10-14	SD930719	220	3	7.5	7.5	28.2	103	-7.35
8	Ribble/Gayle Beck	Horton In Ribblesdale	10-14	SD806726	220	5	12	12.5	31.1	90	-7.16
9	Swale	Grinton	10.14	SE046985	180	6	29	20	32.8	67	-6.79
10	South Tyne	Featherstone	10.14	NY674617	120	6	33	24.3	28.9	78	-7.12
11	Clwyd	Nantclwyd Hall	15-17	SJ109519	122	2	15	4.6	17.3	112	-3.52
12	Walkham	Grenofen	15-17	SX489710	63	4	18	11.9	20.1	8	-5.35
13	Ribble/Gayle Beck	Mitton Bridge	15.17	SD715387	40	7	57.9	31.7	62.8	128	-7.12
14	Ober Water	Puttles Bridge	18-20	SU268027	23	1	10	3.4	13.5	22	-3.33
15	Lugg	Combe	18-20	SO348640	130	4	25	7.7	32.4	133	-3.30
16	Otter	Newton Poppleford	18-20	SY088900	12	5	34.6	19	28.3	100	-5.13
17	Wansbeck	Middleton	21-24	NZ053842	100	2	12	6	21.7	133	-6.35
18	Wansbeck	Bothal	21-24	NZ236862	10	5	43	16.7	27.2	170	-5.00
19	Arrow	Folly Farm	21-24	SO413588	88	5	37	17	17.8	117	-4.00
20	Usk	Llantrissant	21-24	ST386971	10	8	89.9	33.7	35	86	-5.50
21	Derwent	Ribton Hall	21-24	NY046304	30	8	46	50.7	37.6	36	-6.63
22	Perry	Rednal Mill	25-28	SJ374294	79	3	8	5.2	25.3	206	-2.21
23	Piddle	Wareham	25-28	SY919876	2	4	32	12.2	48	179	-1.65
24	Frome	East Stoke	25-28	SY866867	13	6	43	18	64.4	172	-2.23
25	Test	Skidmore	25-28	SU354178	11	7	50	22.3	107.2	221	-1.03
26	Devon	Knipton	29-32	SK822315	73	1	5	1.5	19.6	139	-2.10
27	Glen	Little Bytham	29-32	TF019177	37	1	17	4.3	19.3	197	0.70
28	Bure	Whitehouse Farm Ford	29-32	TG164305	15	2	16	9.8	49	220	3.30
29	Moors/Crane	East Moors Farm	33-35	SU101029	12	3	21	3.9	84.1	117	6.52
30	Brue	Liberty Farm	33-35	ST384446	2	4	49	10.7	115.1	270	4.90
31	Thames/Isis	Runnymede	33-35	TQ008725	18	9	202.8	56.6	238.8	213	3.49

4.2.2 Selection of environmental variables and rationale for simulations

Low flow conditions will result in changes to a number of environmental features including substratum and channel dimensions. Within RIVPACS, the macroinvertebrate fauna to be expected at a site in the absence of any pollution or stress is predicted from a suite of environmental variables. Of these, channel width and depth, substratum characteristics and discharge are features which will be altered following a prolonged low flow period. For RIVPACS, the discharge variable is the historical long-term average log discharge category (1-10) determined by hydrometric staff. Channel width, depth and substratum composition are measured in the field in each season at the time of biological sampling.

For each selected river, these four variables were altered in four steps to simulate a "realistic" change in the river environment resulting from reduced flows. The steps and details for each site are given in Appendix 1. Thus a boulder/cobble bottomed river bottom, despite prolonged low flow periods is unlikely to change to a silt dominated river (as recorded in RIVPACS survey methodology). A fine layer of organic sediment may cover the coarse substrata but this will not (and should not) be recorded for RIVPACS and the river will still be regarded as coarse bottomed. In all cases all variables were altered together, thus width, depth, discharge were altered in steps at the same time as the substratum.

It would have been possible to also simulate the effects of increased flows at these sites. However, the general effect of increasing flows can be represented to some extents by treating the most extreme simulated conditions as the starting conditions for sites and working backwards.

Occasionally the simulated change in environmental variables was sufficiently extreme to initiate a "warning" from the RIVPACS software that the site has a low probability of occurring in the RIVPACS data base. The warning is in terms of a numerical suitability code, which is based on the maximum probability of the site belonging to any of the 35 RIVPACS site groups as determined from the multiple discriminant functions based on the values of all the RIVPACS environmental variables for the site (Table 4.3; also see RIVPACS III+ User Manual, sections 3.4.2 and 6.4.1). These conditions were avoided wherever possible and rarely occurred in the first three simulation steps. Although care was taken to only simulate modified conditions which were fairly realistic for a site, the most extreme level of modification did create conditions not covered within the RIVPACS reference sites (i.e. with suitability code 5) for four of the 31 sites (Appendix 1). The estimates of expected LIFE under these particular four simulated conditions may be unreliable, but the overall sizes and directions of the trends and changes in expected LIFE for each of the sites are still informative.

Table 4.3 Suitability codes for RIVPACS predictions

Suitability code	1	2	3	4	5
Max probability of belonging to any TWINSPAN site group	≥5%	<5%	<2%	<1%	<0.1%

The full listing of test sites together with their altered environmental variables and resultant estimates of expected LIFE and suitability codes is given in Appendix 1.

4.3 Effects of simulated changes

The results of the simulations are given in full in Appendix 1 and summarised in Figure 4.1. As expected, the majority of sites showed a reduction in expected LIFE following the simulated low flow conditions.

The change in expected LIFE between the 'natural' and the most extreme simulated site conditions are shown in Figure 4.2, where the sites have been re-ordered in terms of the size and direction of the change in expected LIFE. Half of the test sites showed a reduction in expected LIFE of about 0.2, with five other sites showing a reduction of 0.28 or more. These included sites ranging from low to high discharge categories representing five separate site super-groups. Sites on three rivers, the Piddle, Moors River and the Thames at Runneymede showed a reverse trend with expected life increasing with increased simulated low flow stress.

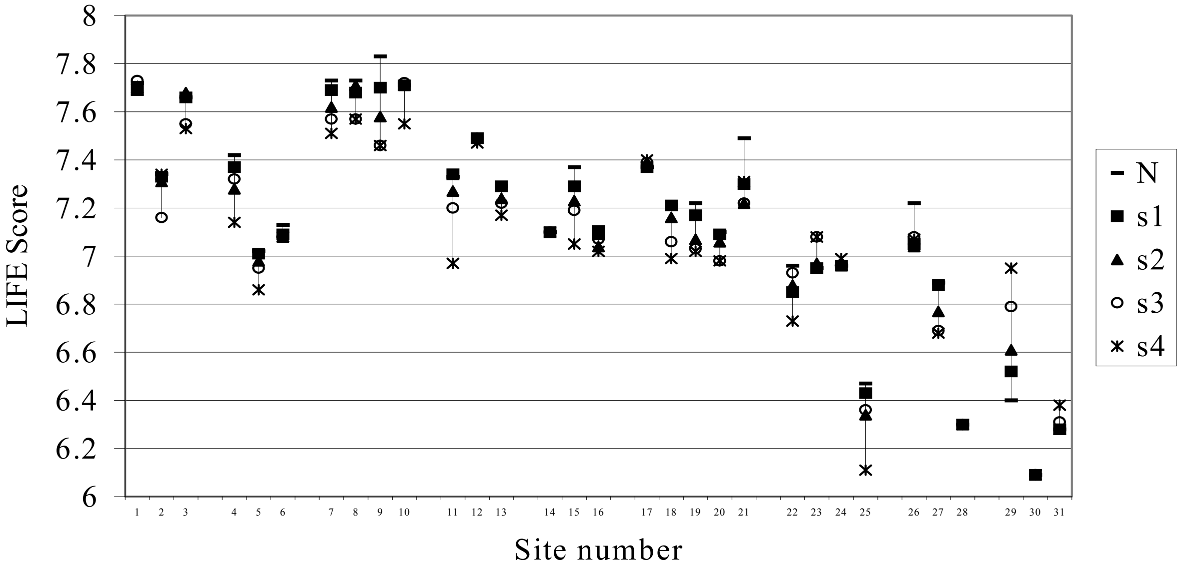


Figure 4.1 Expected LIFE for the 31 test sites used in the simulations. N = 'natural' state; s1, s2, s3, s4 = simulated flow-related change steps where s4 represents the most extreme change for each site

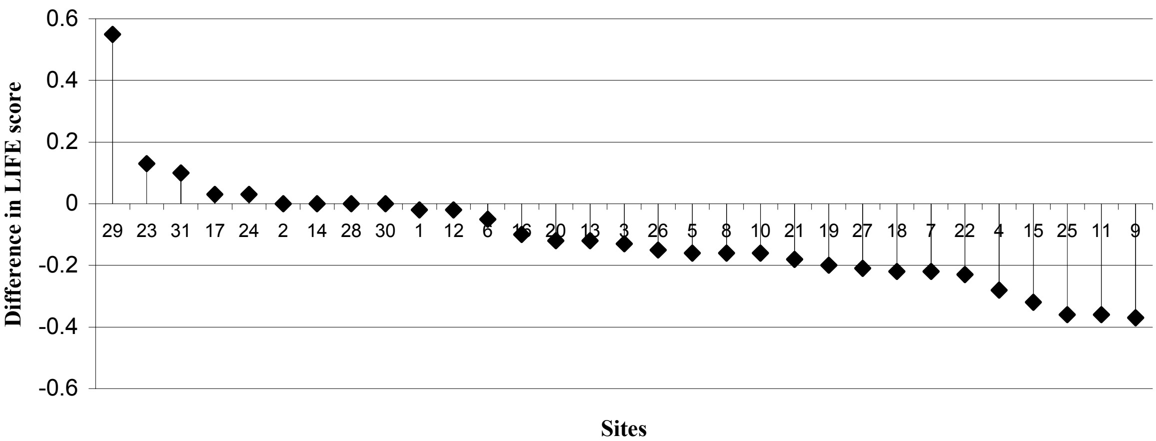


Figure 4.2 The distribution of changes in expected LIFE (s4 minus N) between 'natural' (N) and extreme simulated conditions (s4) for each of the 31 test sites

RIVPACS uses the environmental features of a site to calculate its probability of belonging to each TWINSPAN group. The opposing trends noted for some sites in our simulations may be attributable to changes in group membership in response to the altered environmental characteristics. This is illustrated in Figure 4.3 for two sites showing opposing trends.

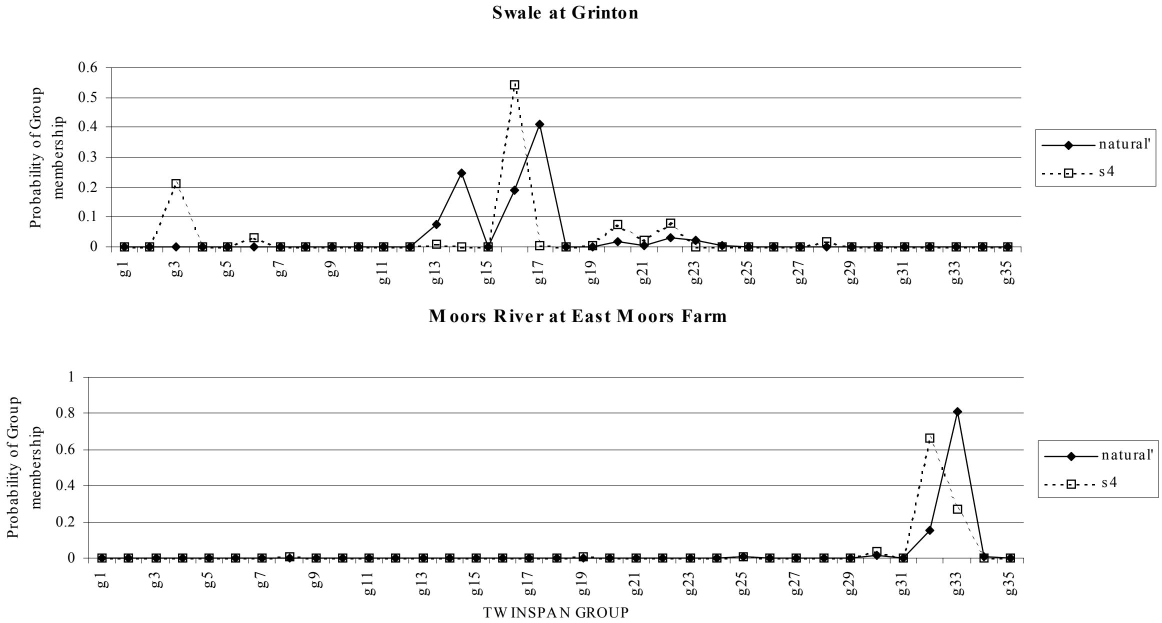


Figure 4.3 Changes in the probability of group membership from the ‘natural’ to the most extreme simulation (s4) at two sites showing contrasting responses in expected LIFE to the alteration of RIVPACS variable; see text for details

Expected LIFE at Grinton on the river Swale showed a reduction from 7.83 to 7.46 in response to the simulated reduced flow conditions whereas East Moors Farm on the Moors River increases from 6.4 to 6.95. For the Swale site, its group membership under ‘natural’ conditions was predominantly groups 17 and 14. With its most extreme simulated stress the highest probability of group membership was for group 14, followed by groups 3, 20, and 22.

For the Moors River site the ‘natural’ state has most affinity with group 33 but following simulated stresses, it was most like, and had the highest probability of group membership for, group 32. The RIVPACS reference sites in group 32 have higher expected LIFE on average than those in group 33 (Table 2.6); hence the simulated increase in expected LIFE for the Moors River site.

Thus changes in site conditions alter the RIVPACS group or groups of sites with which it is similar, which changes the expected fauna and the expected abundances at a site, which in turn alters the RIVPACS prediction of the expected LIFE.

Sites which “naturally” belong to site groups with the highest values of expected LIFE can only have their value of expected LIFE reduced or staying the same when their physical conditions are altered. Similarly sites which “naturally” belong to site groups with the lowest values of expected LIFE can only have their expected LIFE increased or staying the same when their physical conditions are altered.

The variable effects of simulated changes in substratum composition on the estimates of expected LIFE are illustrated in Figure 4.4 for the test sites in each of the nine site super-groups. There is no clear single pattern in relation to super-group and this suggests that the degree of change in expected LIFE may be site specific. All of the site super-groups except super-group “10-14” had one or more sites with a distinct lack of response to simulated effects of reduced flow (Figure 4.4).

In section 2.4 it was shown that expected LIFE as predicted from RIVPACS for any site can only vary between 5.93 and 7.92, a range of only 2.0. Thus a change of around 0.2 is not insignificant, but these simulations do show that realistic modification to the physical conditions at a site does not have a major impact on the fauna expected at the site, at least not as predicted by RIVPACS. This is because a small steeply sloping upland stream is still a small steeply sloping upland stream, even with reduced flow, and hence is still predicted by RIVPACS to belong to the same broad type of groups.

4.4 Discussion and conclusions

Simulations are useful for examining the sensitivity of RIVPACS to environmental change but changes must be severe before consistent trends are detected. Armitage (1989) has investigated the response of certain species and families to increased siltation of a stony bottomed stream using simulations. Clear trends were observed but mainly in response to very severe modifications of the substratum. The results to date, of simulations, from RIVPACS III+ predictions are at present inconclusive.

Similarly in a recent study (Armitage, 2000) the results indicated that it is possible to record faunal change by altering environmental variables to simulate potential impacts. However, the responses are relatively small and although the two validation tests carried out in that study indicate the possibility of simulating a real change, the process shows a lack of sensitivity except in the most extreme cases.

The situation in the Wool Stream (a small chalk stream) provided a good example of this insensitivity for some stream types. Despite a change from gravel substratum to one dominated by silt, the predicted family occurrence and abundance did not alter. Even the most extreme simulation did not generate a warning notice from the program and the predicted group membership did not change. The observed environmental conditions placed the site in RIVPACS III group 31 with a probability of 97.8 % and the most extreme simulation placed it in the same group with a probability of 99.9 %. This group contains small lowland streams with a high alkalinity and it is these properties which define the group despite a wide range of substratum conditions. This feature makes RIVPACS insensitive to substratum changes in streams of this type.

In the present simulations, the shift in probability of TWINSPAN group membership at East Moors Farm on the Moors Rivers from group 33 to group 32 resulted in an increase in LIFE in response to low flow stress. This is because site group 32 has higher average LIFE. Thus shifts from group to group may have minor anomalous effects on the predictions of expected LIFE.

Despite the reservations, this exercise has proved useful in demonstrating the range of changes in expected LIFE, for a wide variety of rivers, in response to extreme low flow stress.

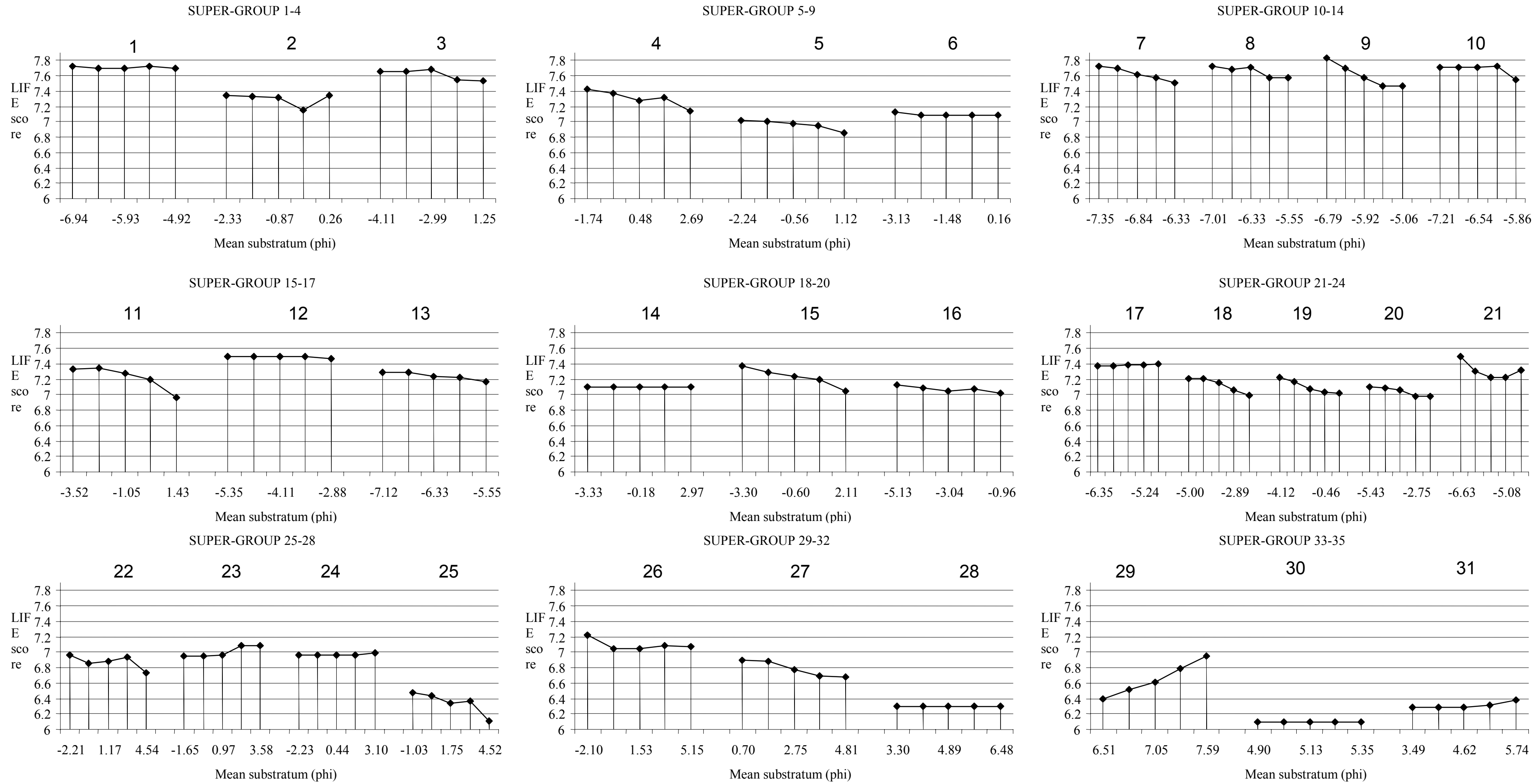


Figure 4.4 Changes in expected LIFE for each site (1-31) in the nine site super-groups following simulated effects of reduced flow. The changes in mean substratum particle size are shown for each site. Site order follows that in Table 4.2

In conclusion, simulating the effects of reductions in flow by realistic modifications to the site's discharge category, stream width and depth and substratum composition in RIVPACS, led to only limited changes in expected LIFE; the majority of changes were less than 0.3. This is because expected LIFE is based on averages across a range of broadly similar types of RIVPACS reference sites and hence, like multiple linear regression predictions, will vary much less than the observed values. Also, even with dramatic simulated reductions in flow, the broad type of a site remained unchanged and so the site was still predicted to belong to same general groups of site and hence have a broadly similar expected LIFE.

The actual changes which occur in observed LIFE rather than expected LIFE, following flow-related changes, may of course be considerably greater for individual sites.

This section has investigated the sensitivity of RIVPACS predictions of expected LIFE to changes in the flow-related variables involved in RIVPACS predictions. However, it is important to remember that actual RIVPACS predictions of expected LIFE at a site should be based on the values for stream width, stream depth and substratum composition for typical, or more specifically, healthy flow years.

5. ALTERNATIVE RIVPACS PREDICTOR OPTIONS FOR EXPECTED LIFE

This sections covers research in Module 5 (aims in section 1.2.5).

The fauna predicted by RIVPACS is intended to be the fauna expected at the test site in the absence of any pollution or environmental stress. When the principal causes of stress is organic or other forms of pollution, the current suite of RIVPACS environmental predictor variables are good predictors of the target fauna and hence the expected number of taxa and ASPT against which to compare the observed fauna and observed values of the biotic indices.

The principal aim of LIFE and LIFE O/E is to provide a measure of the possible response of the macroinvertebrate fauna to flow-related stresses. It may be inappropriate to use the substratum composition, stream width and depth at the time of sampling to predict the expected fauna and expected LIFE if the values of these variables have already been changed by the low-flow stress that we are trying to measure.

In the previous sections covering research Modules 1-4, all values of expected LIFE were predicted from the current preferred suite of RIVPACS predictor variables (option 1 in RIVPACS III+), as agreed in the objectives of this research project. In this section, we assess the effect of omitting substratum data, or substratum, stream width and depth when predicting the expected fauna and expected LIFE.

5.1 Additional GIS-based environmental variables

If variables based on stream substratum particle size measured during field sampling are not to be used for predicting expected LIFE, it may be useful if other surrogate variables could be used instead to improve the predictions.

A long-term aim of RIVPACS development is to derive fixed predictions for any one site based on time-invariant GIS-derived map-based features of the site. As part of a current CEH collaborative project (E1-007) with the Environment Agency on RIVPACS development, CEH are assessing the feasibility of measuring the current time-invariant RIVPACS variables using GIS techniques rather than from printed maps. These variables are altitude and slope at the site and its distance from stream source.

As part of this Module 5, we assessed the effect of including three new variables. Two were GIS-based, namely the altitude at the river source (referred to as 'altitude at source') and the average slope between the site and its source, defined as the drop in altitude between the source and the site divided by the site's distance from source (referred to as 'slope to source'). The slope to source, in particular may provide a surrogate measure of the erosive power upstream of the site and hence provide a predictor of sediment type at the site.

A third new variable called 'stream power' was defined as:

$$\text{stream power} = g \,.\, p.\, Q.\, S \,/\, W$$

where g = gravitational acceleration = 9.81 m s^{-2}, p = density of water = 1000 kg m^{-3}, Q = discharge (m^3s^{-1}), S = stream slope at site (m km^{-1}), W = stream width (m). Stream power is a measure of the energy within in a river system. The higher the stream power, the greater the potential to entrain large particles and to carry an increased sediment load. High stream power also increases the likelihood of an overall 'eroding' nature to the river environment (i.e. the site is a sediment source). Conversely, low stream power increases the likelihood of a 'depositing' nature to the site environment (i.e. the site is a sediment 'sink'). Stream width (W) and slope (S) at the site are already RIVPACS variables. In RIVPACS discharge is recorded in logarithmic (doubling) categories, whereby discharge category 1 = < 0.31 m^3s^{-1}, 2 = 0.31-0.62 m^3s^{-1}, 3 = 0.62-1.25 m^3s^{-1}, 4 = 1.25-2.50 m^3s^{-1}, etc. Taking the mid-point of each category as the estimated discharge Q, estimates of the variable stream power were derived for all the RIVPACS reference sites.

5.2 Relative importance of the environmental variables

The current suite of RIVPACS environmental variables is the subset of variables from a larger initial set that gave the best ability to predict the biological group of the 438 RIVPACS II reference sites using the multivariate statistical technique of multiple discriminant analysis (MDA) (Moss *et al* 1987). In the development of RIVPACS III, the extended set of 614 reference sites were re-classified in 35 biological groups, but exactly the same suite of environmental variables were used to derive the new predictive discriminant function equations.

All of the current suite of RIVPACS environmental variables are therefore expected to have some ability to discriminate between the RIVPACS biological site groups because this is the purpose for which they were originally selected. The right-hand column of Table 5.1 shows that the abilities of each of the variables, when used on their own, to discriminate between the 35 site groups were fairly similar, including for the three new trial variables.

Log alkalinity was marginally the best single variable. Table 5.1 shows the results of a stepwise multiple discrimination technique, using the SAS software (SAS 1999), which at each step added to the predictor set the variable which gave the greatest statistically significant improvement in discriminatory power, as measured by an analysis of variance F test, after allowing for the effect of the variables already included. One practical measure of the discriminatory power of a set of variables is the percentage of sites which are allocated to the correct site group using the discriminant function equations based on these variables (Moss *et al* 1987, Clarke *et al*. 1996).

The third column of Table 5.1, sub-headed "re-substitution", gives the percentage of RIVPACS reference sites which are assigned to the correct group using the discriminant functions based on the selected variables and estimated from all the RIVPACS reference sites. Using this method, known as the re-substitution method, the percentage assigned to the correct group tends to, at least slightly, increase as extra variables are included. However, once all the effective variables have been included, adding further variables can give slight reductions in the percentage allocated to correct group, as happened in Table 5.1 at steps 15 and 16 adding 'Log distance to source' and 'Log stream power'. In general, the re-substitution method, tends to over-estimate the effectiveness of the discriminant functions at each step. A better estimate of the true effectiveness is to carry out the discrimination using all the RIVPACS reference sites except one, test whether the derived discriminant functions can correctly predict the omitted site to its correct group, and then repeat this omitting each site in turn. Using this approach, referred to as the cross-validation method, the estimate of the percent allocated to the correct site group reaches an asymptote when the unused variables add no real extra discriminatory power. (Table 5.1).

Table 5.1 Stepwise discrimination showing the order of selection of environmental variables to predict the TWINSPAN biological group of the 614 RIVPACS III reference sites

Order of variable selection by stepwise multivariate ANOVA		Cumulative %classified to correct group by		% classified to correct group using single variables
		Re-substitution	Cross-validation	
1	Log alkalinity	15.6	15.6	15.6
2	Log distance from source	24.3	22.6	13.4
3	Mean substratum	30.0	28.3	13.0
4	Mean air temperature	37.5	33.9	12.7
5	Alkalinity	39.4	36.3	13.5
6	Discharge category	41.2	37.0	12.4
7	Log stream depth	43.3	37.8	11.1
8	Longitude	46.3	39.6	14.2
9	Log altitude	46.4	40.4	10.1
10	Log slope	49.5	40.6	13.0
11	Latitude	49.2	41.4	12.1
12	Air temperature range	49.7	41.0	12.2
13	Log stream width	51.3	41.2	11.2
14	Log altitude at source	52.7	39.6	13.4
15	Log slope to source	51.3	39.4	10.1
16	Log stream power	52.6	39.9	13.4

For example, after allowing for the effect of 'log alkalinity', the variable 'log distance from source' gave the greatest improvement, such that just using these two variables in the discriminant functions assigned 24.3% of the reference sites to their correct group; using the cross-validation method the percentage correctly assigned is estimated to be slightly lower at 22.6%. The difference between the discriminatory power estimates from the re-substitution and cross-validation methods increase as more variables are added and the re-substitution method is starting to "over-fit" by making use of idiosynchcracies in the dataset. (This is same type of over-fitting problem as occurs in using multiple regression with too many variables compared to the number of observations) .

The best prediction of groups, as assessed by cross-validation, occurred when all 13 of the current RIVPACS III+ preferred option 1 variables were included in the discrimination. The three new variables, although individually of reasonable discriminatory power, did not unfortunately improve the predictions compared to those based on the current standard variables (Table 5.1).

5.3 Effect of eliminating current flow-related variables

When the variable 'mean substratum' was omitted from option 1 suite of predictor variables for the discrimination of RIVPACS site groups, the percentage of sites allocated to the correct group decreased only slightly from 51.3% to 50.2% (variable sets 1 and 2 in Table 5.2). Thus, although there were obviously general differences in 'mean substratum' between the major groups, it appeared that leaving out 'mean substratum' from the predictions did not reduce their effectiveness because the other environmental variables must be sufficiently correlated with 'mean substratum' to act as good surrogates, at least for 'natural' high quality sites such as the reference sites.

If either log stream width or log stream depth are also excluded from the predictions in addition to mean substratum, the predictive ability falls further to 48.5% and 47.1% respectively (sets 3 and 4). Moreover, leaving out all three of the flow-related variables which are measured on-site at the time of biological sampling, reduces the percentage of RIVPACS reference sites assigned to their correct RIVPACS site group to 44.6% (variable set 5 in Table 5.2), a reduction of 6.7% compared to using the full RIVPACS III+ environmental option 1. Thus, in the absence of any substratum variable, stream depth appears to be important in the predictions. Water velocity and sedimentation rates are known to vary with water depth within a site.

Adding all three of the new trial variables to the standard option 1 suite of predictor variables did not improve the ability to predict the correct site group (variable set 6 in Table 5.2). More disappointingly, and surprisingly, adding these three new variables to variable set 5, which ignored 'mean substratum' stream width and stream depth, gave very little improvement to the discrimination (variable set 7).

Table 5.2 Effectiveness of different combinations of environmental variables in predicting the site group of the 614 RIVPACS reference sites

Variable	**Set of environmental variables involved**						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Latitude	x	x	x	x	x	x	x
Longitude	x	x	x	x	x	x	x
Log altitude	x	x	x	x	x	x	x
Log distance from source	x	x	x	x	x	x	x
Log width	x	x		x		x	
Log depth	x	x	x			x	
Mean substratum (phi units)	x					x	
Discharge category (1-10)	x	x	x	x	x	x	x
Alkalinity	x	x	x	x	x	x	x
Log alkalinity	x	x	x	x	x	x	x
Log slope	x	x	x	x	x	x	x
Mean air temperature	x	x	x	x	x	x	x
Air temperature range	x	x	x	x	x	x	x
Log altitude at source						x	x
Log slope to source						x	x
Log stream power						x	x
%classified to correct group by:							
Re-substitution method	51.3	50.2	48.5	47.1	44.6	52.6	45.9
Cross-validation method	41.2	40.2	41.7	37.6	37.3	39.9	37.5

5.4 Effect on prediction of expected LIFE and LIFE O/E

Although the effects of different combinations of environmental variables on site group discriminatory power is important, within this R&D project, the crucial test is their effect on the prediction of expected LIFE and hence LIFE O/E for all sites.

Determining expected LIFE from a new environmental variables option requires several steps. The multivariate discriminant functions from the MDA based on the new option must be standardised to have an average within-group standard deviation of unity. These discriminant functions are then used to calculate the probability of belonging to each RIVPACS site group, and hence to re-estimate the expected probability of occurrence and expected log abundance of each macroinvertebrate family based on their occurrence within the RIVPACS site groups (Clarke *et al* 1996). The methods described in section 2.3 are then used to re-estimate expected LIFE.

RIVPACS III+ has a total of five possible options (1-5) for the combination of environmental variables to use in predictions. Values of expected LIFE for the RIVPACS reference sites were calculated for two new options 6 and 7:

option 6: as RIVPACS III+ option 1, but excluding 'mean substratum'
option 7: as RIVPACS III+ option 1, but excluding 'mean substratum', stream width and stream depth

The correlations between observed LIFE and expected LIFE for the reference sites were, as expected, slightly lower when expected LIFE was based on the new environmental variables options 6 and 7 (Table 5.3). However, the percentage of the total variance in observed LIFE accounted for by the predictions was still high, falling from 62% for option 1 to 57% for option 7. Thus, even without using the three flow-related variables measured on-site, the RIVPACS predictor variables still explained or accounted for more than half of the total variability in observed LIFE across all types of unstressed flowing river sites in GB. This compared well with an equivalent percentage explained of 61% for ASPT and only 38% for number of BMWP taxa, both based on environmental predictor option 1.

The correlations between observed LIFE and expected LIFE within each season were similar, although, for each environmental variable option, the correlations were slightly higher in spring (Table 5.3).

Table 5.3 Correlations between observed LIFE and expected LIFE based on RIVPACS III+ standard environmental variables option 1, or new trial options 6 and 7 for the 614 RIVPACS III reference site samples (*n* = 614 sites x 3 seasons = 1842); and separately for each season

		Observed LIFE	Expected LIFE based on:		Observed LIFE in:		
			Option 1	**Option 6**	**Spring**	**Summer**	**Autumn**
Expected	Option 1	0.789			0.815	0.776	0.776
LIFE	Option 6	0.778	0.978		0.807	0.764	0.763
based on:	Option 7	0.756	0.946	0.975	0.789	0.746	0.738

Superficially, estimates of expected LIFE based on options 1, 6 and 7 were highly correlated with all correlations greater than 0.94 (Table 5.3), suggesting not much practical difference. For a large proportion of sites the changes in expected LIFE were negligible; the changes were less than 0.1 for 83% and 73% of sites under options 6 and 7 respectively (Table 5.4).

However, when the differences were examined in greater detail, variability in effects were apparent (Figure 5.1). Sites with expected LIFE greater than about 6.75 using environmental option 1 tended to have similar predictions using trial options 6 or 7, although variability about the 1:1 line was greater using option 7. However, for sites with expected LIFE less than

6.75 under option 1, there was a marked increase in the change in expected LIFE using option 6 and especially option 7 (Figure 5.1). In particular, the RIVPACS reference sites with the lowest expected LIFE (i.e. <6.25) under option 1 are all given higher expected LIFE under both option 6 and 7. These sites all had predominantly fine sediments with at least 70% cover by RIVPACS 'silt and clay' substrate type. These patterns of the differences were similar for each of the three season's samples.

Table 5.4 Difference between the estimates of expected LIFE based on trial environmental variable options 6 and 7 compared to that based on standard RIVPACS III+ environmental variable option 1 for the RIVPACS reference site samples

Difference in expected LIFE	% of samples when using:	
	option 6	option 7
≤0.01	47.4	34.7
≤0.02	54.1	42.0
≤0.03	58.6	47.3
≤0.04	62.7	51.6
≤0.05	67.7	55.9
≤0.10	82.9	73.0
≤0.15	90.7	82.3
≤0.20	93.1	87.2
≤0.30	97.0	94.5
≤0.40	98.5	96.8
≤0.50	99.1	97.6
≤0.60	99.5	98.6
≤0.80	99.9	99.5
Maximum difference	0.92	1.10

The varying importance of using mean substratum, stream width and stream depth in the predictions according to the type of river site is shown clearly in Figure 5.2. Sites in RIVPACS site groups 1-17 tended to have very similar values for expected LIFE for prediction options 1, 6 and 7. Groups 1-9 are generally small streams whilst groups 10-17 are predominantly upland streams. The greatest changes in expected LIFE occurred with sites in groups 31, 32 and especially 33-35, which are mostly large lowland river sites. Expected LIFE using option 6, and especially option 7, was nearly always increased for sites in groups 33-35, with average increases of 0.13-0.19 and a maximum increase for one site of 0.9 by environmental option 7 (Figure 5.2(b)). Sites in groups 33-35 tend to be wide, deep, slow flowing and have predominantly silt and/or clay substrates; it is these characteristics which give rise to macroinvertebrate communities which have the lowest LIFE (Table 2.2, Figure 2.2). In option 7, these key defining environmental attributes were not used in the predictions of the expected community, so it was not possible for the multiple discrimination to identify these sites accurately. Sites in these groups were therefore predicted to have significant probabilities of belonging to other RIVPACS site groups which have higher LIFE, so expected LIFE for these sites tended to be over-predicted. This will lead to lower estimates of LIFE O/E for such sites (Figure 5.3).

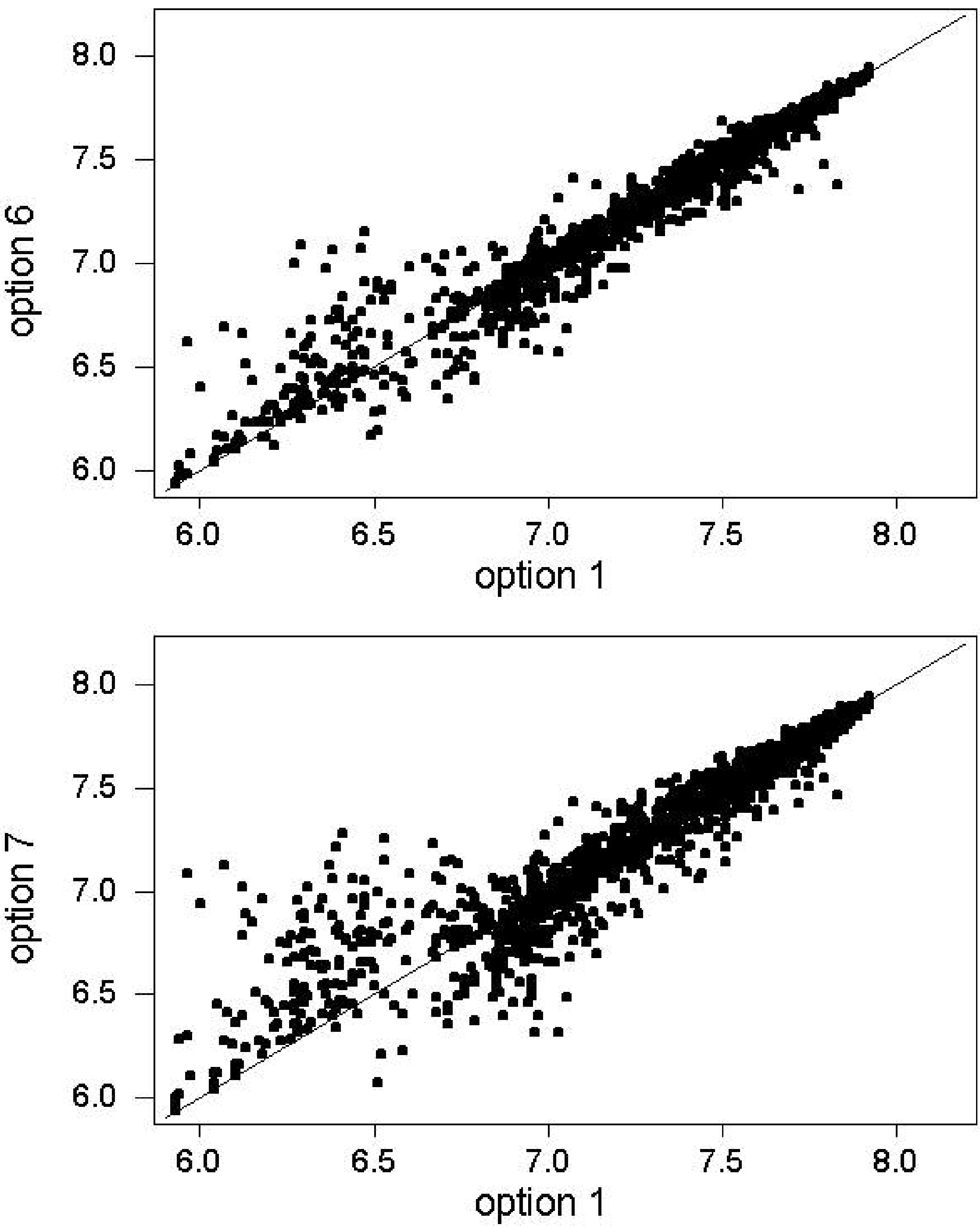


Figure 5.1 Relationship between values of expected LIFE based on new trial environmental variable options 6 and 7 compared to those based on standard RIVPACS III+ environmental variable option 1 for the RIVPACS reference sites. (*n* = 1842 = 614 sites x 3 seasons)

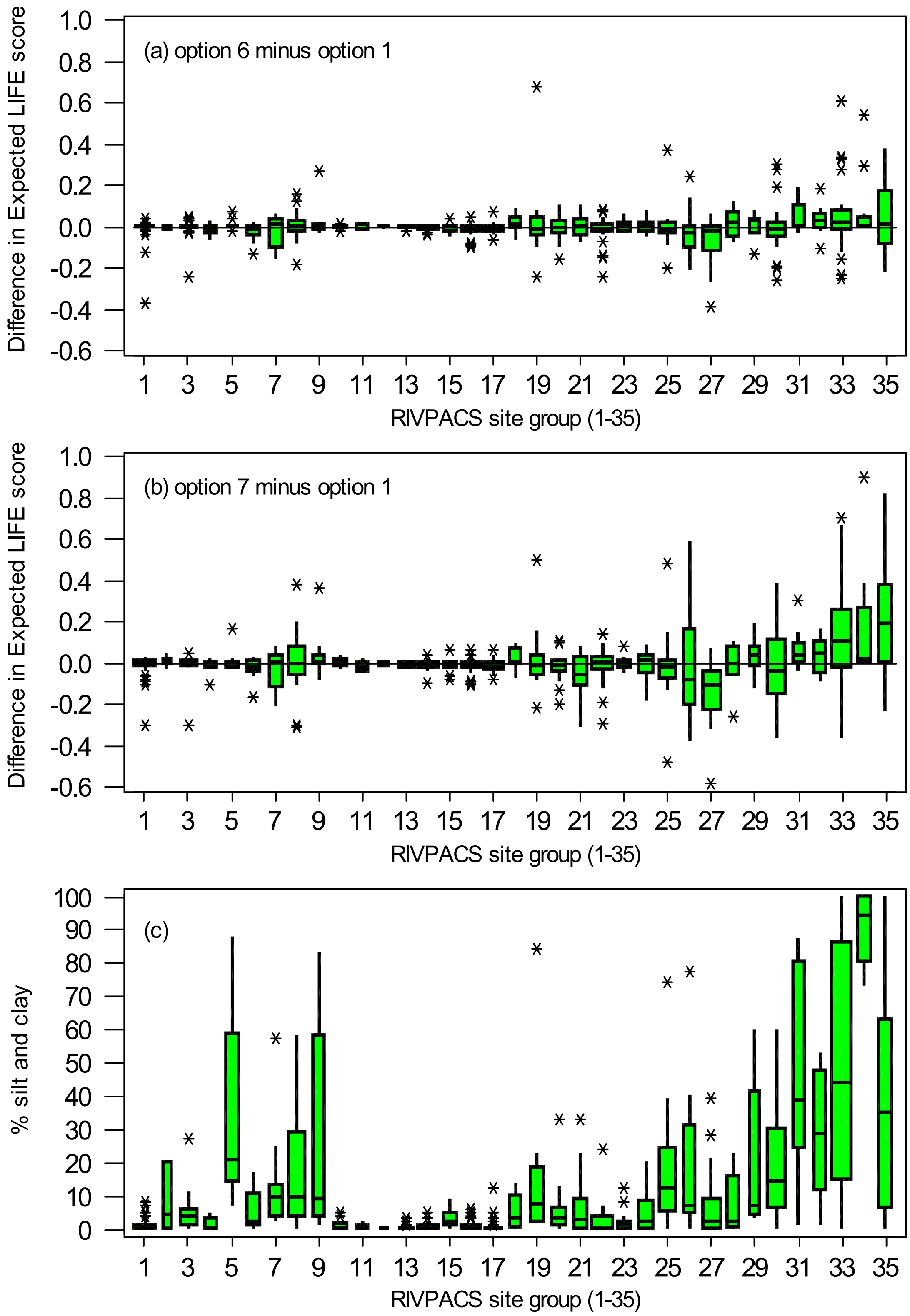


Figure 5.2 Boxplot of the differences in expected LIFE (autumn samples) using trial environmental variable options (a) 6 and (b) 7 compared to standard RIVPACS environmental variable option 1 for the RIVPACS reference sites in relation to their RIVPACS site group (1-35); (c) Boxplot of percentage cover by silt and/or clay

Table 5.5 Difference between LIFE O/E based on new trial environmental variable options 6 or 7 and that based on standard RIVPACS III+ environmental variable option 1 (LIFEExp1) for the RIVPACS reference sites

Difference in LIFE O/E	% of samples when using:	
	Option 6	Option 7
≤0.01	73.1	61.8
≤0.02	87.8	79.9
≤0.03	93.4	87.9
≤0.04	96.2	93.2
≤0.05	97.9	95.4
≤0.06	98.6	96.8
≤0.07	99.0	97.3
≤0.08	99.5	97.9
≤0.10	99.7	99.1
≤0.12	99.9	99.7
Maximum difference	0.16	0.16

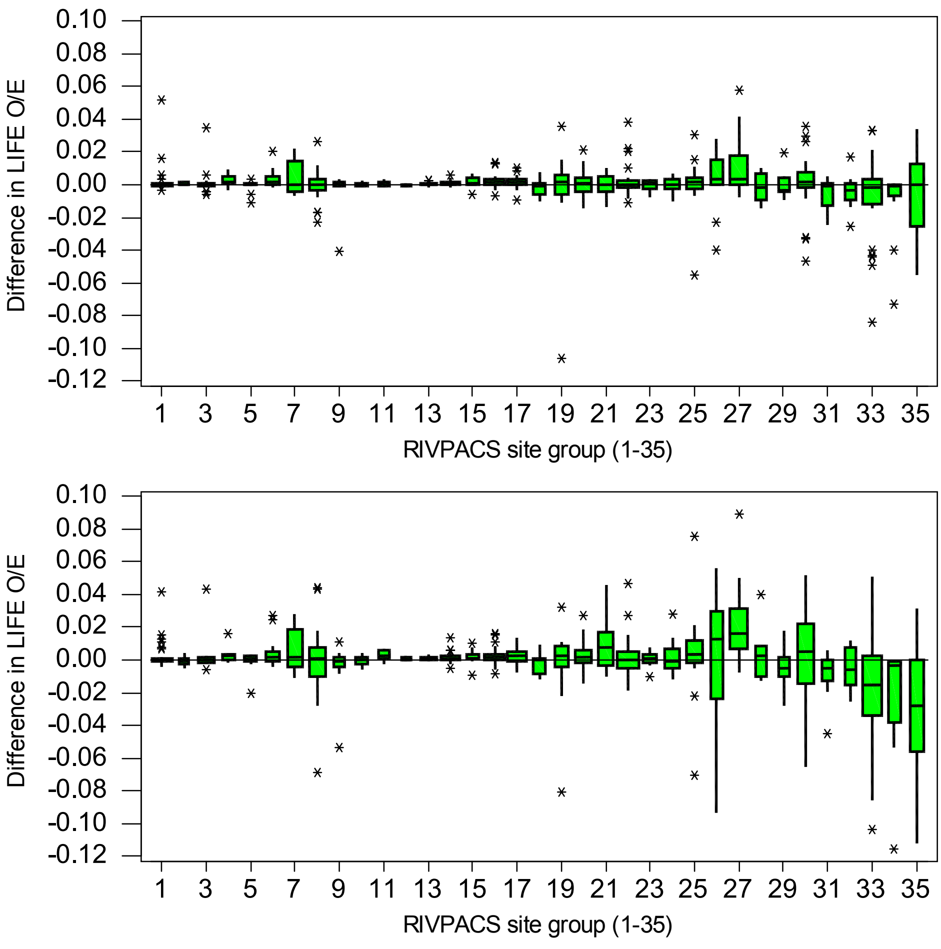


Figure 5.3 Boxplot of the differences in LIFE O/E (autumn samples) using trial environmental variable options (a) 6 and (b) 7 compared to standard RIVPACS environmental variable option 1 for the RIVPACS reference sites in relation to their RIVPACS site group (1-35)

5.5 Summary

In RIVPACS predictions of expected LIFE, it may be desirable not to involve the RIVPACS environmental predictor variables based on substratum particle size composition, stream width and stream depth. Ideally, the expected or 'target' LIFE for new test sites should not involve variables whose values may have already been altered by the flow-related stresses whose effects LIFE O/E is being used to detect.

The overall effect of not involving the RIVPACS environmental variable 'mean substratum' on estimates of expected LIFE is usually small, the change is less than 0.10 for over 80% of sites. Omitting stream width and depth in addition to mean substratum has greater effects on expected LIFE, but the change is still less than 0.10 for over 70% of sites. Moreover, the change in LIFE O/E is 0.01 or less for 73% and 62% of sites when mean substratum alone or mean substratum stream width and depth are omitted from predictions.

However, the effect is highly dependent on the type of site. In particular, excluding mean substratum from the predictions for large slow-flowing lowland river sites (RIVPACS site groups 33-35), which on average have the lowest LIFE amongst the reference sites, leads to increases in the estimates of their expected LIFE, typically of around 0.2, occasionally up to 0.5 and even 1.0 for one site. For this type of site, predictions not involving substratum composition and especially, those not involving substratum composition, stream width and depth (all measured on-site) will tend to over-estimate expected LIFE and hence under-estimate LIFE O/E for the site.

Initial trials (outside of the R&D project) of using other multivariate techniques to predict LIFE directly from the RIVPACS environmental variables, but still excluding mean substratum composition, stream width and depth, did not improve overall prediction of expected LIFE or help overcome the over-prediction problem for large slow-flowing lowland river sites.

CEH funded research has begun trying to improve predictions of expected LIFE score by including new types of additional variables which can be derived from a GIS currently being developed by CEH Dorset. This GIS is based on the Ordnance Survey 1:50000 blue-line network, but with the many breaks and errors in river line corrected. Possible new variables include upstream catchment area, Strahler (1957) stream order at site and the upstream catchment solid and drift geology composition. The latter especially might be expected to help be a surrogate predictor of river substratum type.

Further research is needed to improve predictions and the setting of targets for expected LIFE for large slow flowing lowland rivers.

It is recommended that further research be commissioned to investigate the potential to use environmental variables derived from GIS to provide temporally-invariant predictions of the expected fauna, and expected LIFE, at any test site. This may help overcome the use potential problem of using the predictor variables, stream width and depth and substratum composition, whose values may have already been modified by flow-related stress.

6. SAMPLING VARIATION IN LIFE

This sections covers research in Module 7 (aims in section 1.2.7).

6.1 Introduction

RIVPACS III+ includes assessments of the uncertainty in estimates of the ecological quality of river sites based on Ecological Quality Indices (EQI) defined as the O/E ratios of observed (O) to expected (E) values of number of BMWP taxa and ASPT (Clarke *et al*, 1997). Simulation procedures in RIVPACS III+ are used to provide confidence limits and tests for change in EQI values (Clarke *et al*. 1997, Clarke 2000).

Uncertainty in estimating the observed fauna and observed values (O) occurs because of sampling variation and, potentially, sample processing and taxonomic identification errors. The site-specific expected fauna and expected values (E) are determined by the RIVPACS prediction system from the environmental characteristics of each site. In RIVPACS III+ uncertainty assessments, errors in the expected values (E) are assumed only to arise from errors in measuring the environmental predictor variables for each site (Clarke, 2000).

Quantitative estimates for each of these sources of uncertainty in EQI values were obtained from a previous R&D project (Furse *et al*. 1995), designed specifically for this purpose. Furse *et al.* (1995) carried out a replicated sampling study covering a wide range of qualities and environmental types of site to quantify the effects of operator sampling variation and the effects of inter-operator differences in estimating the RIVPACS environmental predictor variables on EQI values. Both CEH and the Environment Agency refer to these study sites as the BAMS (Biological Assessment Methods) sites.

In this current study, we have re-analysed the BAMS dataset to quantify the effects of sampling variation on observed LIFE values. Although, not part of this R&D project, it would also be feasible to use the BAMS dataset to assess the effect of errors or inter-personnel variation in estimating the RIVPACS environmental predictor variables on RIVPACS predictions of expected LIFE.

6.2 Methods

6.2.1 BAMS study sites

The BAMS sites were selected from a listing of sites in the 1990 River Quality Survey (RQS) whose results are summarized in National Rivers Authority (1994). All the RQS sites had been classified by the National Rivers Authority (NRA) into one of four ecological quality grades (A, B, C & D) (Table 6.1a) according to their RIVPACS O/E values for BMWP score, number of taxa and ASPT (National Rivers Authority, 1994). RIVPACS II, the 25 site groups version available in 1990, was used to classify each RQS site to its most probable site group based on its environmental features (Clarke *et al*., 1996). Groups 3a, 5b, 8a and 9b (Table 6.1b) were then selected to encompass the four major site divisions within the RIVPACS II hierarchical classification (Wright, 1995). Next, within each of the four site groups, one study site was selected at random from the list of RQS sites in each of the four quality grades, giving a total of 16 sites (Table 6.1c).

6.2.2 Macroinvertebrate sampling and processing methods

Each site was sampled once in spring (March - May), summer (June - August) and autumn (September - November) during 1994, using the standard RIVPACS three-minute sampling procedures (Murray-Bligh 1999). On each sampling occasion and at each site, four macroinvertebrate samples were collected. The first sample was taken by an IFE biologist (A), the second by a local NRA regional biologist (B), the third by biologist A again and the fourth sample by a second IFE person (C). Care was taken to minimise the possibility of re-sampling the same locations within the site in order to avoid progressive depletion of the fauna. Only the three samples from biologists A and B were sorted and identified; those from biologist C were kept in reserve. At any given site, the same biologists took the samples in each of the three seasons. For continuity of experience and efficiency, the same two IFE biologists sampled at each site but varied their roles as biologist A and C at successive sites. This scheme allowed evaluation of the effects of between and within person sampling variation in both single and multiple season site assessments.

The macroinvertebrate samples were sorted and identified by experienced IFE biologists using standardised protocols (Wright *et al.*, 1984); this was done to minimise the sample processing and identification errors, which were quantified in a separate part of the R&D project report by Furse *et al*. (1995).

6.2.3 Statistical analysis

The quantitative effect of sampling variation on LIFE was assessed from the variability in values of LIFE between the three replicate samples at each site and season. Specifically, the standard deviation and mean of the three replicate sample values of LIFE were calculated separately for each of the 48 combinations of 16 sites by three seasons. The aim was to assess the pattern in these estimates of sampling SD to derive simple rules for providing estimates of the sampling SD of LIFE applicable to any site. These rules could then be used in a future version of RIVPACS which simulates uncertainty in estimates of LIFE O/E ratios.

It is common in ecology for sampling variability to increase with the sampling mean. Furse *et al.* (1995) used Taylor's Power Law regressions of log replicate variance against log replicate mean for the BMWP indices to estimate the best data transformation to equalise the replicate standard deviation for all sites (Taylor, 1961; Elliott, 1977). They found that the replicate variance in number of BMWP taxa increased with the replicate mean number of BMWP taxa and that by working with the square root of the number of BMWP taxa, the replicate variance was roughly constant and did not vary with replicate mean, site type or site quality. Furse *et* al. (1995) found no relationship between replicate variance of ASPT and replicate mean ASPT. A similar approach was used in the current study to assess whether sampling SD of LIFE values varied with the mean value and hence whether a transformation of LIFE values would help make the sampling SD more homogeneous.

Levene's (1960) general test for homogeneity of variance was used to assess whether the was general evidence of real variability in sampling SD amongst the 48 estimates, allowing for the fact that each individual estimate is only based on three replicate values. Levene's test is more robust than Bartlett's original homogeneity of variance test which is high dependent on the data being normally distributed (Minitab, 1999).

Table 6.1 Characteristics of the stratified random selection of BAMS sites in terms of (a) ecological quality grades as defined by range of O/E values for BMWP indices, (b) RIVPACS site group and (c) location of the full list of the 16 sites selected for replicate sampling

(a)	**Quality grade**			
Range of O/E values based on:	**A "best" quality**	**B**	**C**	**D "worst" quality**
BMWP score	0.91 - 1.09	0.52 - 0.62	0.29 - 0.39	< 0.18
number of taxa	0.94 - 1.06	0.64 - 0.72	0.41 - 0.53	< 0.30
ASPT	0.97 - 1.03	0.80 - 0.85	0.68 - 0.74	< 0.60

(b) RIVPACS	**Site group**			
Mean value of environmental variable	**Group 3a**	**5b**	**8a**	**9b**
distance from source (km)	15.3	8.2	11.3	33.0
width (m)	7.5	4.8	4.8	13.1
depth (cm)	19.8	21.7	32.5	77.5
altitude (m)	74	40	40	5
alkalinity (mg l^{-1} $CaCO_3$)	81	153	229	170
predominant substratum	cobbles/pebbles	gravel	gravel/sand	silt
regions of England and Wales	SW, NE, Wales	central south + midlands	east Wales to East Anglia + southern chalk streams	SE + East Anglia

	(c) RIVPACS Site group	**Quality grade**	**River name**	**Site name**	**National grid ref.**	**NRA Region**
1	3a	A	River Okement	South Dornaford	SS 600 000	South Western
2	3a	B	River Darracott	Tantons Plain	SS 494 198	South Western
3	3a	C	River Croxdale	Croxdale House	NZ 272 379	Northumbria & Yorkshire
4	3a	D	Twyzell Burn	B6313 Bridge	NZ 257 517	Northumbria & Yorkshire
5	5b	A	Petworth Brook	Haslingbourne Bridge	SU 982 204	Southern
6	5b	B	Sheppey River	Woodford	ST 537 441	South Western
7	5b	C	Sheppey River	Bowlish	ST 613 440	South Western
8	5b	D	Moss Brook	PTC Bedford Brook	SJ 676 983	North West
9	8a	A	Summerham Brook	Seend Bridge	ST 945 595	South Western
10	8a	B	Cuttle Brook	Swarkestone	SK 375 288	Severn Trent
11	8a	C	Poulshot Stream	Jenny Mill	ST 979 592	South Western
12	8a	D	Spen Beck	Dewsbury	SE 225 208	Northumbria & Yorkshire
13	9b	A	Old River Ancholme	Brigg	TA 001 065	Anglian
14	9b	B	Broad Rife	Ferry Sluice	SZ 854 963	Southern
15	9b	C	Skellingthorpe Drain	U/S Skellingthorpe	SK 937 727	Anglian
16	9b	D	Keyingham Drain	Cherry Cob	TA 219 224	Northumbria & Yorkshire

6.3 Results

Table 6.2 gives the values of observed LIFE for each of the replicate samples for each BAMS site, separately for each season, together with the number of families present upon which the value of LIFE was based in each sample.

Only 11% of the total variation in values of LIFE amongst all the BAMS samples was due to sampling variation among replicate samples from the same site in the same season. Thus sampling variation in LIFE is small relative to the range of values of LIFE which can be obtained from different sites. This suggests that sampling variation in LIFE is no so great as completely ruin the potential to detect real differences in LIFE between sites or real changes in LIFE over time.

6.3.1 LIFE in relation to number of families present

Because LIFE is a form of average score per taxon present it may be relatively more variable between replicate samples for highly stressed sites with few families present. The values of LIFE for the BAMS dataset varied from 3.00 for a summer sample from site 16 which had only Hydrobiidae present to 9.00 for a spring sample from site 4 which had only two LIFE-scoring families present (Table 6.2). Oligochaeta and Chironomidae, which are ubiquitous, are ignored in the LIFE system.

Figure 6.1 shows the relationship between the value of LIFE and the number of families in the sample on which it was based. There was some tendency for LIFE to be lower when fewer taxa were present in the sample. This pattern was made clearer when the average replicate value of LIFE is plotted against the average number of LIFE-scoring families present in those samples (Figure 6.1(b)). The correlation when based on individual samples was 0.55, which was higher than the equivalent correlation of 0.31 found between observed LIFE and number of BMWP taxa present for the 6016 sites from the 1995 GQA survey assessed in section 3 (Figure 3.7). The higher correlation occurred because the GQA sites were, in a sense, a random sample of sites which had a natural high percentage of relatively taxon-rich sites, whereas the BAMS study sites were carefully selected to provide equal representation of the full range of site qualities. The discrepancy was therefore just due to differences in site selection strategy.

6.3.2 Sampling SD of LIFE in relation to mean LIFE

The relationship between the standard deviation of the three replicate values of LIFE for each season at each site and the mean of the three replicate values is shown in Figure 6.2. Although the site by season combinations which have the highest average LIFE (i.e. > 6.8) have some tendency to have lower sampling SD than combinations with lower average values of LIFE, there is no consistent strong relationship.

Using Taylor's Power Law regressions for values of LIFE, the log variance versus log mean regression slope (standard error in brackets) was –2.96 (± 1.75) and the regression relationship, which only explained 6% of the total variation in log replicate variance, was not statistically significant ($p = 0.098$). Therefore sampling variance does not increase systematically with the mean value of LIFE and no transformation of individual values of LIFE would make the sampling variance more homogeneous.

Table 6.2 (a) Observed LIFE and (b) number of LIFE-scoring families present for each replicate sample (1-3) for each season; together with the mean and replicate standard deviation (SD), averaged across seasons, for each of the BAMS sites

(a) LIFE	Spring			Summer			Autumn			Site mean	Average replicate SD
Site	1	2	3	1	2	3	1	2	3		
1	8.00	8.05	8.00	7.67	7.74	7.63	7.56	7.75	7.41	7.76	0.085
2	6.80	6.89	7.00	7.00	7.21	7.07	6.93	6.77	7.00	6.96	0.108
3	7.00	7.11	7.00	7.22	6.27	6.64	6.33	6.73	6.31	6.73	0.260
4	9.00	7.33	7.50	7.43	7.38	7.29	7.38	7.10	6.78	7.47	0.430
5	7.00	7.50	6.82	7.47	7.16	7.50	7.20	7.28	7.45	7.26	0.223
6	7.13	7.21	7.12	6.89	6.94	7.06	7.00	7.11	6.82	7.03	0.094
7	7.22	6.82	6.86	6.92	6.36	6.90	6.60	6.60	6.10	6.71	0.276
8	6.50	6.00	6.25	5.67	5.33	5.00	6.17	6.25	6.00	5.91	0.238
9	6.90	7.00	6.93	6.84	6.82	6.83	7.22	7.18	7.33	7.01	0.046
10	5.90	5.55	5.38	5.36	5.23	5.77	5.00	5.57	5.38	5.46	0.279
11	6.50	6.18	6.44	6.25	6.23	6.55	6.25	5.70	6.18	6.25	0.216
12	6.00	4.00	5.33	6.00	5.80	6.00	5.33	5.50	5.00	5.44	0.463
13	6.09	6.33	6.07	5.95	6.00	5.75	5.94	5.85	5.95	5.99	0.111
14	6.50	6.33	6.75	5.56	5.89	5.75	5.14	5.43	4.80	5.79	0.231
15	6.10	5.54	5.91	5.82	5.57	5.85	5.75	5.47	5.57	5.73	0.193
16	4.00	3.00	5.00	4.00	4.00	4.00	4.00	5.00	5.00	4.22	0.526
Mean	6.67	6.30	6.52	6.38	6.25	6.35	6.24	6.33	6.19	6.36	0.236

(b) Families present	Spring			Summer			Autumn			Site mean
Site	1	2	3	1	2	3	1	2	3	
1	19	19	21	18	19	19	18	12	17	18.0
2	10	9	15	16	14	15	14	13	15	13.4
3	9	9	7	9	11	14	12	15	13	11.0
4	2	6	6	7	8	7	8	10	9	7.0
5	11	8	11	15	19	16	25	18	20	15.9
6	16	14	17	19	18	17	15	18	17	16.8
7	9	11	7	13	11	10	10	10	10	10.1
8	4	4	4	3	3	2	6	4	4	3.8
9	20	15	15	19	17	23	18	17	15	17.7
10	10	11	8	11	13	13	9	7	8	10.0
11	8	11	9	12	13	11	12	10	11	10.8
12	5	1	3	5	5	5	3	4	4	3.9
13	11	12	14	19	16	20	18	20	19	16.6
14	4	6	4	9	9	8	7	7	5	6.6
15	10	13	11	11	14	13	16	15	14	13.0
16	1	1	2	1	1	1	1	2	1	1.2
Mean	9.3	9.4	9.6	11.7	11.9	12.1	12.0	11.4	11.4	11.0

More generally, Levene's test for homogeneity of sampling variance across sites and seasons was not significant ($p = 0.34$). This suggests that there is no strong statistical evidence that the sampling SD for LIFE varies between sites or seasons.

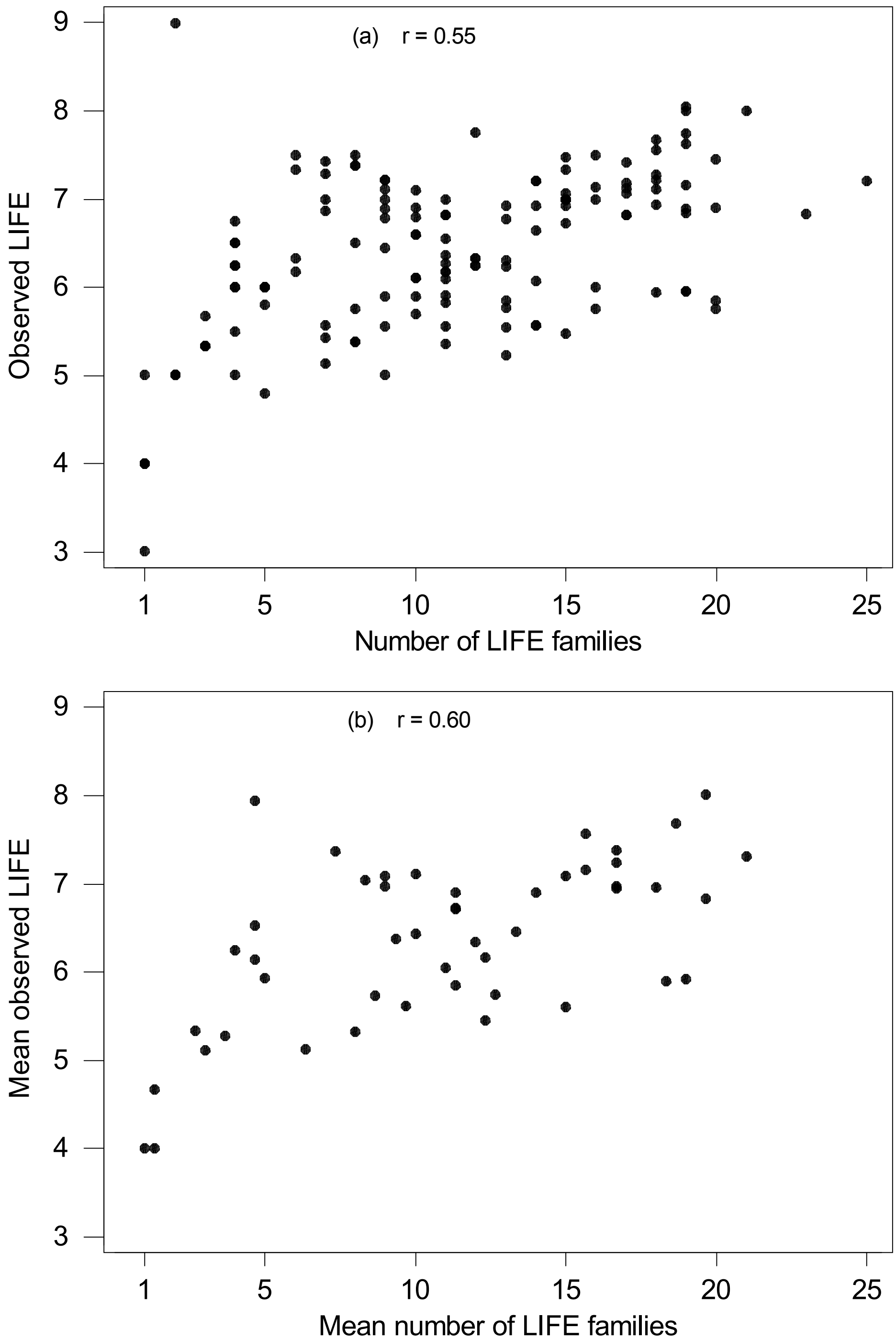


Figure 6.1 Relationship and correlation (r) between LIFE and the number of families present (a) for individual replicate samples (n = 144), (b) when averaged across the three replicate samples for each season at each site (n = 48 = 16 sites x 3 seasons)

6.3.3 Sampling SD of LIFE in relation to site type or season

The physical nature of some types of site makes it difficult to sample all their habitats appropriately. This may result in increased variability in macroinvertebrate composition between replicate samples at such sites. This could lead to the replicate sampling variability in LIFE being greater in certain types of stream. This was assessed.

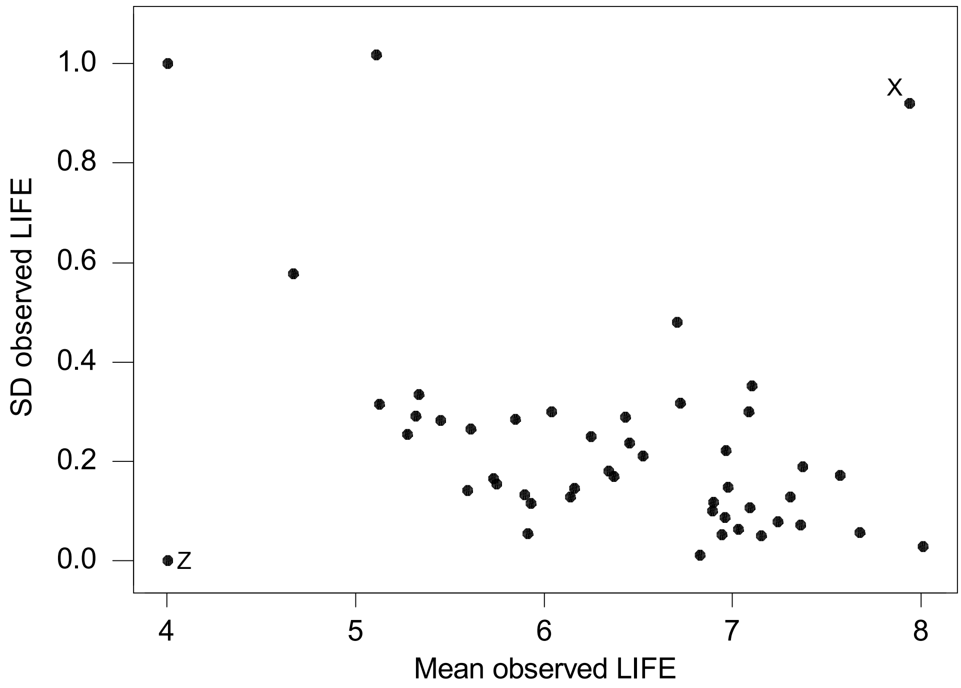


Figure 6.2 Relationship between standard deviation (SD) and mean of the three replicate values of LIFE (n = 48 = 16 sites x 3 seasons). X and Z denote outliers discussed in text

Figure 6.3 shows the sampling SD of LIFE for each of the 16 BAMS sites, classified by their TWINSPAN group. Non-parametric Kruskal-Wallis analysis of variance (ANOVA) of sampling SD showed that there were no statistically significant differences between the site groups (p = 0.77). Similar analyses showed that there were also no difference in sampling SD between the seasons (p = 0.44); nor were any site type or seasonal differences in sampling SD detected when both factors were analysed together in parametric ANOVA (both p >0.17).

We conclude that the sampling SD of LIFE does not vary systematically between different types of site or between seasons.

6.3.4 Sampling SD of LIFE in relation to number of families present

Although the sampling SD does not appear to vary with the mean of the replicate values of LIFE, some pattern emerges when sampling SD for a site by season combination is plotted against the mean number of LIFE-scoring families involved in calculating the replicate values of LIFE for that combination (Figure 6.4). The highest values of SD (i.e. >0.5) all occur when the replicate values of LIFE are based on an average of less than 5 families. At the other extreme, when the average number of LIFE-scoring families found in replicate samples is at least 15, the sampling SD is always relatively small (i.e. <0.2) (Figure 6.4(b)). The Spearman rank correlation between sampling SD and average number of families is –0.54; the correlation is still –0.54 when the observations based on an average of less than five families are ignored (Figure 6.4(b)).

This potential for increased sampling variability at sites with few families present is illustrated by the outlier point marked 'X' in Figure 6.2, which is for Site 4 in spring (Table 6.2). This example has a very high average LIFE score, but it is still very variable between replicate samples. The second and third replicate samples had similar values of LIFE (7.33 and 7.50) both based on six families, but sample 1 only had two LIFE-scoring families present, Baetidae at log abundance category 3 and Simuliidae at log abundance category 1, both in LIFE flow group II (Table 1.3), giving a value of LIFE of 9.00. This gave a SD between the three replicates of 0.92 (Figure 6.2).

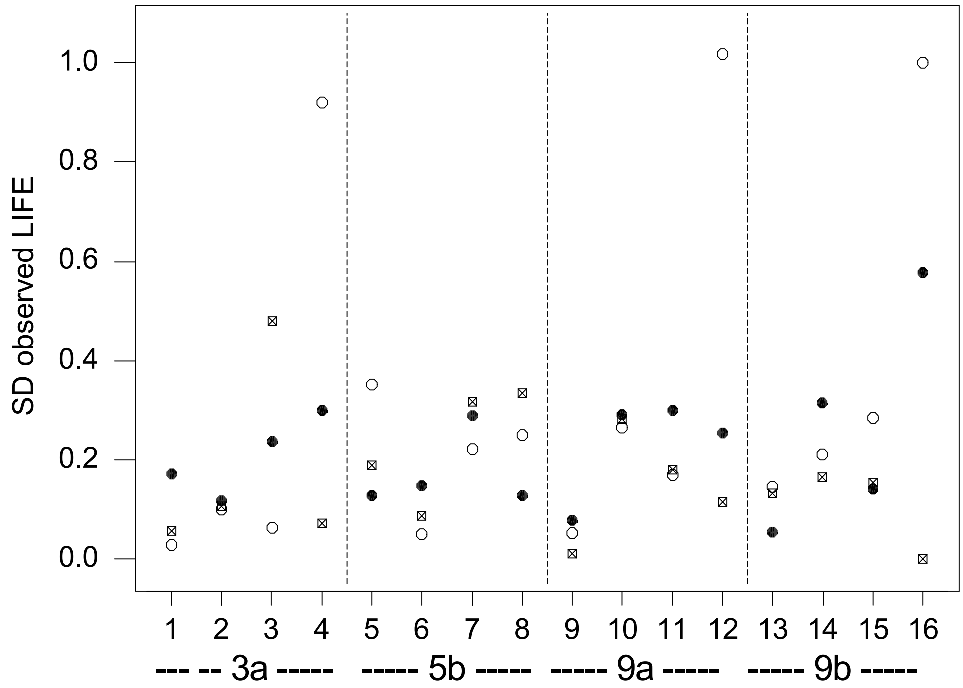


Figure 6.3 Standard deviation (SD) of LIFE for each BAMS site, grouped by TWINSPAN group (3a, 5b, 9a and 9b), shown separately for each season (o = spring, ⊠ = summer, • = autumn).

When few LIFE-scoring families are present at site, the sampling variance of LIFE is more volatile and potentially more difficult to predict. As an example of one extreme, all three replicate samples at Site 16 in summer contained only Hydrobiidae at log abundance category 3 (plus the ubiquitous Oligochaeta and Chironomidae, which are ignored in the LIFE system). All three samples therefore had values of LIFE of 4.00 and hence an estimated sampling SD of zero (outlier marked Z in Figures 6.2 and 6.4). Finding just one more family in one sample could have given a quite different value for LIFE and hence estimated SD.

Based on the BAMS dataset, we conclude that the sampling SD of LIFE does tend to decline systematically with the number (N_{LIFE}) of LIFE-scoring families present. The relationship is best estimated by a linear regression relationship between log SD and N_{LIFE}, which is statistically significant (r = -0.48; p = 0.001) and given by (standard errors of regression coefficients given underneath in brackets):

$$\log_e \text{SD} = \underset{(0.277)}{-0.910} - \underset{(0.0226)}{0.0843}\, N_{LIFE} \qquad (6.1a)$$

The back-transformed predicted relationship is:

$$\text{sampling SD} = 0.403(0.9192)^{N_{LIFE}} \qquad (6.1b)$$

which is superimposed as the solid line in Figure 6.4(b). The outlier observation Z is highly influential on the estimated regression relationship; without Z the correlation is much stronger ($r = -0.68$, $p < 0.001$) and the following equivalent relationships are obtained:

$$\text{loge SD} = \underset{(0.224)}{-0.528} - \underset{(0.0180)}{0.1154}\, N_{LIFE} \qquad (6.2a)$$

$$\text{sampling SD} = 0.590(0.8945)^{N_{LIFE}} \qquad (6.2b)$$

As the estimate of sampling SD for the outlier Z could have been quite different if just one more family had been found in any one of the three replicate samples, we conclude that it is best to ignore this point and use equation (6.2) shown as the dashed lines in Figure 6.4).

This equation can be used to provide an estimate for the unknown sampling SD for any site using just the observed number of LIFE-scoring families present in a single sample; examples are given in Table 6.3.

Table 6.3 Estimate of sampling standard deviation (SD) of observed LIFE for sites where N_{LIFE} LIFE-scoring families are present in a sample (estimates based on equation (6.2))

Number of LIFE-scoring families present (N_{LIFE})	Sampling SD
1	0.528
2	0.472
3	0.422
4	0.378
5	0.338
6	0.302
7	0.270
8	0.241
9	0.216
10	0.193
12	0.155
15	0.111
20	0.063
25	0.036

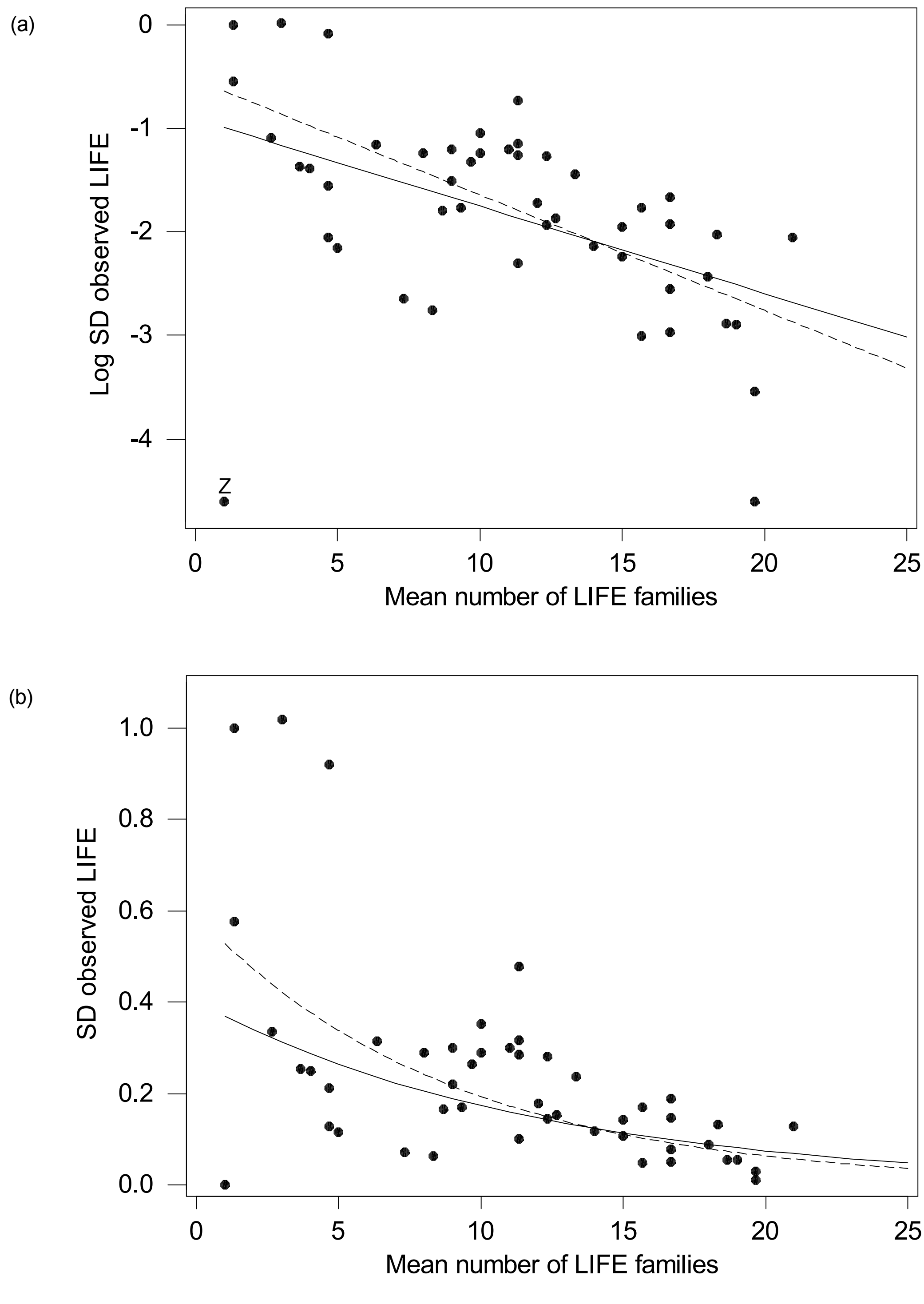


Figure 6.4 Relationship between standard deviation (SD) of the three replicate values of LIFE for each season at each site and the mean number of LIFE-scoring families present in each replicate (n = 48 = 16 sites x 3 seasons). (a) and (b) show SD on logarithmic and untransformed scales respectively. Z denotes outlier discussed in text. Solid and dashed lines denote fitted regression relationship of equations (6.1) and (6.2) with and without outlier Z respectively

In summary, the sampling SD of LIFE declines with the number of LIFE-scoring families present. A predictive equation has been derived to estimate the sampling SD at any site from the number of families present in a sample from that site. When few taxa are present, the sampling SD is greater, so a larger change in LIFE would be needed to have any confidence that it is not just due to change sampling variation.

6.3.5 Inter-operator effects on LIFE

In the BAMS sampling programme, the first and third replicate at each site were taken by one IFE biologist and second replicate by a local NRA biologist. To correctly assess whether samples taken by the same person tend to be more similar than samples taken by two different people, it is important that there is no systematic trend in values of LIFE with the order the samples were taken. A Friedman non-parametric two-way ANOVA of ranks, as used by Furse *et al*. (1995) showed no statistical significant tendency for values of LIFE to vary with sample order ($p = 0.45$).

The effect of inter-operator variability on sampling variation in LIFE was assessed using the same methods in section 2.1.6 of Furse *et al*. (1995). Let N_{more} and N_{less} denote the number of cases (out of 48 = 16 sites by 3 seasons) where the difference between replicate values for different people (samples 1 and 2) was more, and less, respectively than the difference in the two samples values from the same person (samples 1 and 3). If there were real differences between operators in their sampling technique which led to additional differences between replicate values of LIFE, then we would expect N_{more} to be greater than N_{less}. For the BAMS dataset, $N_{more} = 28$ and $N_{less} = 17$ (in the three other cases the differences were the same). Although the difference in these two numbers is not statistically significant under a null hypothesis of 50:50 (Chi-square test value = 2.69, 1 d.f., $p = 0.10$), there is a suggestion of inter-operator effects.

The size of the potential inter-operator effect was estimated by deriving three separate estimates of the replicate sampling standard deviation:

SD_O based on all three single season replicate samples
SD_{13} based on the first and third samples taken by the same person
SD_{12} based on the first and second sample taken by two different people.

In each case the sampling SD was estimated as the square root of the residual mean square in an overall ANOVA involving all the relevant replicate values of LIFE but allowing for the effects due each combination of site and season. Then

$$F_{pers} = 100(SD_{12} - SD_{13}) / SD_{12}$$

estimates the percentage of overall sampling SD due to inter-operator effects. For the BAMS dataset, $F_{pers} = 23\%$ (Table 6.4); this was a larger percentage than for either number of BMWP taxa (9%) or ASPT (4%) (Furse *et al.* 1995).

Table 6.4 Assessing inter-operator effects on sampling variation in LIFE; see text for further details.

SD_O	SD_{13}	SD_{12}	F_{pers}
0.326	0.283	0.368	23%

In summary, there was some suggestion of increases in sampling variability of observed LIFE due to differences between operators. If real, this implies that LIFE O/E ratios would be *subject to slightly greater uncertainty if different operators were used on the different occasions or at the different sites being compared. However, the evidence of any inter-operator effects on LIFE was not statistically significant. Therefore, it is best to use the same estimate of sampling variance irrespective of whether the same or different personnel took the samples.*

6.4 Summary

Sampling variation in LIFE is small relative to the range of values of LIFE which can be obtained from different sites (forming only 11% of total variation for the BAMS sites). Thus sampling variation is not necessarily so large that it completely ruins the potential to detect real differences in LIFE between sites or real changes in LIFE over time. Sampling SD needs to assessed in relation to the changes in LIFE which occur within a site when it is subjected to flow-related stress.

The sampling SD of LIFE does not vary systematically between different physical types of site or between seasons.

Sampling SD does not show any consistent tendency to either increase or decrease with the average of the replicate values of LIFE at a site.

The sampling SD of LIFE declines with the number of LIFE-scoring families present.

It is difficult to derive precise estimates of sampling SD of LIFE for sites with few families present. Ideally, estimates of sampling SD from the BAMS sites with few families present should be based on more replicates to overcome the estimate of sampling SD being sensitive to the chance occurrence of a single family in any one replicate sample.

There is no statistically significant evidence to suggestion that sampling differences between operators affect the values of LIFE of a site.

A predictive equation has been derived to estimate the sampling SD at any site from the number of families present in a sample from that site.

It would be possible to use the BAMS dataset to derive estimates of the effect of errors in measuring the RIVPACS environmental variables on predictions of expected LIFE.

In section 3, a correlation of 0.69 between LIFE O/E and EQI_{ASPT} for the 1995 GQA sites suggested that the LIFE and BMWP scoring systems are not completely confounded. However, the apparent lack of agreement in site assessments using the two systems must be at least partly due to the effects of sampling variation on both sets of O/E ratios. This will be correlated variation as the O/E ratios for a site are all calculated from the same sample(s); further research is urgently needed (this is beyond the resources available within this R&D project).

Further research is needed urgently to assess the influence of sampling variation on the observed relationship between LIFE O/E and EQI_{ASPT} and thus the extent to which they can be used to identify different forms of stress.

7. HYDROLOGICAL DATA RELATIONSHIPS

This sections covers research in Module 6 (aims in section 1.2.6).

7.1 Introduction

The typical value of LIFE in the absence of any flow-related stress will depend on the physical character of the site. In section 2.4, methods were derived which use the RIVPACS reference sites to estimate the expected LIFE for any site, in the absence of any flow-related stress, from its environmental characteristics as represented by the RIVPACS environmental variables. If the RIVPACS reference sites are to be used to set the target fauna and expected LIFE for test sites, then it is important that none (or very few) of the reference sites were subject to any flow-related stress at the time their RIVPACS reference samples were obtained in the field.

All RIVPACS reference sites (and samples) were selected because, at the time of sampling, they were considered to be of high quality and not subject to any form of environmental stress, whether from toxic or organic pollution or flow-related problems. However, this study is the first to carry out a quantitative assessment of the flow conditions in the year of sampling each reference site relative to the flows in other years at the same site.

7.2 Linking biological sites to flow gauging stations using GIS

7.2.1 Provision of gauging station details and flow data

Under a sub-contract, CEH Wallingford provided data extracted from the National Water Archive (NWA), which they manage, on the available monthly mean flows at each flow gauging station in GB for each month between 1970 and 1999 inclusive. For each gauging station CEH Wallingford extracted and provided, as requested:

river name,
site name,
station id number (within the NWA),
geographic location as easting and northing to 100m precision,
flow gauge type,
Base Flow Index (BFI, estimate by CEH Wallingford).

7.2.2 Using the GIS to link biological sites to flow gauging stations

Over the past two years, CEH Dorset has been building an intelligent GIS system, based on ArcView software, of the whole river network for GB. The starting point was the blue-line data based on the digital version of the rivers exactly as marked in blue on the Ordnance Survey's 1:50000 maps. CEH Dorset has painstakingly corrected many of the errors and breaks in the supplied river network (e.g. where rivers flowed under bridges and hence the blue line was broken on the O.S. map). Once corrected, useful additional attributes have been, and continue to be, built in the system. The CEH Dorset river network GIS groups and stores information by hydrometric areas. Further details on the development of the system are contained in Hornby *et al* (2002). This river network GIS was used to link the RIVPACS biological sites to the most appropriate flow gauging stations.
The first step was to link the locations of the gauging stations to the blue-line river network on the GIS. This was done for each hydrometric area in turn. As their locations were supplied

as National Grid references with easting and northing to 100m resolution, the stations would not generally lie exactly on the blue-line network. Each station's location was therefore automatically 'snapped' to the blue-line network, which means it was assigned to the nearest position on the blue-line network. Because we had both the river name and site name for each station, we then manually checked whether the snapped position of each station placed it on the correct river stretch by cross-referring to the name of the river stretch on standard 1:50000 Ordnance Survey maps.

The second step was to 'snap' each of the RIVPACS reference sites to its location on the blue line network. The assigned position of each biological site on the blue-line network was checked manually. By cross-referencing to the background information on the site's name, its river name and RIVPACS discharge category, it was found that some sites were snapped to the wrong nearby tributary, so these were moved to what was considered to be the correct river stretch and location.

The third step was to link each biological site to the most appropriate flow gauging station. When the river network for a hydrometric area was displayed on the screen, the blue-line locations of all the RIVPACS reference sites within the area were superimposed as green dots and the blue-line locations of the gauging stations within the area as red dots. The on-screen GIS was used to manually link each biological site to what was considered by eye to be most appropriate upstream or downstream gauging station. The nearest gauging station to a biological site "as the crow flies" could be in a different catchment. The importance of using the visual GIS at this stage is that it ensures that the assigned gauging station is in the same catchment as the biological site.

The best choice of gauging station to associate with a biological site may still not give a good representation of the flows at the site. If there are numerous tributaries or relative large tributaries joining the river between the site and the station, whether upstream or downstream, the flow regime at the gauging station may be quite different from that of the biological site. To assess the likelihood that the station provides an adequate representation of the flow regime at the biological site, several attributes were recorded using the GIS (Table 7.1).

Table 7.1 Attributes used to assess likelihood that the linked flowing gauging station provides an adequate representation of the flow regime at the biological site

Blue-line distance apart of station and site together with whether station is upstream or downstream of the site
Strahler stream order (SO) of site
Strahler stream order of station
Number of tributaries joining between site and station
Largest Strahler stream order of any tributary joining between site and station (Max SO)

Stream order was computed for the 1:50,000 scale river network as defined by Strahler (1957). The Strahler rule says that if streams of order n and m join, they become a stream of order n if $n > m$, and a stream of order $(n + 1)$ if $n = m$. An algorithm described by Lanfear (1990) for automatically computing Strahler stream order from vector networks was adapted to run in the GIS software ArcView. Each hydrometric area was processed one at a time and the stream order was attached to the arc as an attribute. The algorithm was capable of handling braided streams. However, stream orders computed for arcs in flat lowland areas, with grid-like drainage sections and some ambiguous directions of flow, were meaningless.

As these sections had already been labelled as “not traceable” within the CEH river network GIS, this was not a concern.

Stream order is a surrogate for discharge. If the stream order of the biological site and the station are the same, it is likely that the flow regime is similar at both locations. If the stream order of a downstream gauging station is more than one higher than that of the biological site, it is likely that the gauging station flow is much greater than that at the site and the flow regime could be different.

7.3 Estimating relative summer flow in year of biological sampling

Although low flows can be a problem at any time of year, low flows are much more likely to occur and be a problem in summer and especially late summer. Therefore, as agreed in the project specification (see section 1.2.6), the assessment of the flows for the year of biological sampling were based on mean summer flows, where summer is defined as the three months June, July and August. The mean summer flow at a site in the year of biological sampling was then standardised by dividing by the mean summer flow over all available years for that site to derive a relative summer flow in the year of biological sampling.

For each gauging station, the mean flow for a month was estimated as the average of the daily mean flows for all days in the month for which complete flow data was available. The number of days of complete flow data on which each monthly mean flow was based was also provided by CEH Wallingford. Initial analyses showed that over 98% of all monthly means were based on an uninterrupted record of flows. Therefore mean summer flows for a site were only calculated for those years for which the flow record was complete.

Initial analyses showed that, for most sites (87% in our datasets), the within-year mean summer flow was less than the long-term average mean summer flow for considerably more that half of all years. This is because the long-term mean summer flow is overly influenced by occasional years of, relatively, high flows during wet summers. In addition, at any site with erratic flashy and variable summer flows, the relative summer flow in the year of sampling could appear to be quite low, when, for that site, it was not an unusual or extreme low flow year.

Therefore, in addition to calculating the relative summer flows in the year of biological sampling for each site, we calculated the rank of the mean summer flow in the year of biological sampling amongst the mean summer flows for all of the available years. A year with the lowest mean summer flow was given rank 1. Because the number of years of estimable mean summer flow varied between sites, the ranks were converted into percentage ranks (%rank) by dividing the rank by the number of years available. Thus a site whose mean summer flow in the year of biological sampling was the sixth lowest out of 30 years would be given the same percentage rank (20%) as a site whose mean summer flow was ranked second out of the 10 years with complete summer flows for the site. Only sites for which there were at least five years of complete summer flows were assessed. The percentage rank was used in preference to relative flow to assess the flow in the year of biological sampling at a site.

7.4 Flow conditions and LIFE O/E for the RIVPACS reference sites

7.4.1 Linking RIVPACS reference site to gauging station flows at time of sampling

Forty one of the 614 RIVPACS reference sites were in catchments with no flow gauging stations; these sites were ignored (Table 7.2). A further 130 reference sites could be linked to a flow gauging station with the catchment, but the station did not have summer flow data for the year of biological sampling (Table 7.3).

The Slaidburn site on the river Hodder (RIVPACS site code 2703) provides a good example of the common problem of linking a biological site to an appropriate flow gauging station. The Salidburn site was only 2.6km downstream of the nearest gauging station at Stocks Reservoir (NWA id 71002) on the same river. However, the flow at this gauging site was heavily regulated with no summer flow in 19 of the 25 years available, including 1978 the year of RIVPACS sampling. Obviously this does represent the conditions at the biological site as sampling only occurred where there was flowing water. The next nearest site was 3.7 km away up the Croasdale Brook (NWA id 71003), which joins just downstream of the RIVPACS site; this may be appropriate for obtaining a relative flow but did not have any flow data in the year of sampling (Table 7.3). The next closest station was over 30km downstream on the Hodder at Hodder Place (NWA id 71008); where the flows were be much greater and the flow regime unlikely to represent that at the Slaidburn RIVPACS site.

Although it may be been possible to have linked some of the other sites listed in Table 7.3 to alternative, less appropriate, or more distant gauging stations within their catchments, this was not generally attempted and these sites were excluded from further analysis.

Each of the remaining 443 RIVPACS reference sites could be linked to a flow gauging station within the catchment that had summer flow data in the year of sampling and mean summer flow data for at least four other years. It did not seem sensible to compare the mean summer flow in the year of biological sampling with the average summer flow of less than five years data.

Appendix 2 gives, for each of these 443 reference sites, the NWA id number of the linked flow gauging station and its distance away (negative distances denotes the gauging station is upstream, positive distances indicate it is downstream of the site), together with the other attributes listed in Table 7.1 which can be used to estimate whether there are likely to have been considerable differences in the discharge volumes between the site and the station which might make the station's flow regime an unreliable surrogate for the flow regime at the biological sampling site.

For each of these reference sites, the mean summer flow in the year of biological sampling was calculated. This was then standardised into a relative mean summer flow (denoted %flow) by expressing it as a percentage of the mean summer flow averaged across all the available years. In addition the rank (1 = lowest flow) of the mean summer flow in the year of sampling relative to all that of all the available years was also calculated for each of these sites (Appendix 2).

Table 7.2 List of the 41 RIVPACS reference sites which have no NWA flow gauging station within their catchment.

RIVPACS site			NGR		RIVPACS	Distance
Code	River name	Site name	East	North	Discharge category	from source (km)
0007	Aber/Rhaeadr-fawr	ABERGWYNGREGYN	2657	3727	1	6.0
0501	Avill	WHEDDON CROSS	2925	1398	1	1.0
0503	Avill	TIMBERSCOMBE	2960	1428	3	5.0
0505	Avill	DUNSTER	2984	1432	3	10.0
0801	Avon Water	WOOTTON BRIDGE	4250	0996	1	6.0
0803	Avon Water	GORDLETON MILL	4292	0961	2	12.0
0805	Avon Water	EFFORD BRIDGE	4307	0941	2	15.0
1501	Gwendraeth Fach	GARN-LWYD	2543	2163	1	5.0
1503	Gwendraeth Fach	LLANGENDEIRNE	2460	2139	4	12.0
1505	Gwendraeth Fach	U/S KIDWELLY	2419	2077	4	23.0
4601	Durness Stream	U/S DURNESS	2403	9669	1	1.0
6501	Brue	LIBERTY FARM	3384	1446	4	49.0
7305	Strontian	ARIUNDLE OAKWOOD NNR	1843	7641	4	6.5
7311	Strontian	ANAHEILT	1816	7624	4	10.2
7505	Burn of Latheronwheel	DEN MOSS	3179	9360	3	3.5
7511	Burn of Latheronwheel	LANDHALLOW	3184	9332	3	6.5
8805	Coombevalley Stream	KILKHAMPTON	2246	1116	1	1.7
8809	Coombevalley Stream	COOMBE	2215	1116	1	5.0
9009	Laxford	D/S LOCH STACK	2259	9447	6	18.0
9903	Lusragan Burn	CLUNY VILLA	1908	7327	3	6.5
FO01	Cocklemill Burn	KILL CONQUHAR MILL	3482	7025	2	8.5
FO02	Crail Burn	A917 ROAD BRIDGE	3611	7079	1	4.5
FO03	Boghall Burn/Keil Burn	PITCRUVIE CASTLE	3413	7045	1	4.5
HI05	Unnamed	MON	1774	7830	5	10.0
HI06	Unnamed	CRAIG GHOBHAIR	1853	7817	2	2.0
HI07	Shiel	SHIEL BRIDGE	1940	8188	6	16.0
NE05	Carron Water	TEWEL FORD	3828	7853	2	9.0
NE06	Carron Water	STONEHAVEN	3874	7858	2	14.0
NH06	Kilton Beck	LODGE WOOD	4695	5160	1	4.5
NW07	Waver	WAVER BRIDGE	3223	5491	3	15.5
SO03	Southwick Burn/Boreland Burn	NR. SOUTHWICK HOUSE	2929	5574	3	8.4
SW02	Drift/Newlyn River	SKIMMEL BRIDGE	1433	0302	1	6.5
SW04	Poltesco River	POLTESCO BRIDGE	1724	0157	1	5.3
SW06	Trevaylor Stream	TRYTHOGGA	1476	0318	1	6.0
SW07	Gweek River	METHER-UNY-MILL BRIDGE	1704	0292	1	5.0
SW08	Manaccan River	POLKANOGGO	1755	0222	1	3.5
SW09	St.Keverne Stream	PORTHOUSTOCK BRIDGE	1805	0218	1	3.0
TA07	Elliot Water	ELLIOT	3620	7394	2	11.8
TA08	Kenly Water	STRAVITHIE	3537	7112	1	10.0
WE03	Afon Caseg	BRAICHMELYN	2630	3663	2	6.4
WE04	Braint	PONT MYNACH	2455	3668	3	9.5

Table 7.3 List of the 130 RIVPACS reference sites for which there is no mean summer data estimate at the matched NWA flow gauging station in the year of biological sampling. The between the site and station is shown negative/positive when the station is up/down stream of the site.

RIVPACS site			NGR		Gauging	Distance apart	Intervening Tributaries		Stream order		Sampling
Code	River name	Site name	East	North	Station	(km)	No.	Max SO	(SO) at: Site	Station	Year
0313	Exe	FLOWERPOT	2913	928	45007	1.8	0	7	7	7	1984
0381	Barle	GOAT HILL	2724	1406	45011	36.1	32	3	2	4	1988
0385	Barle	COW CASTLE	2798	1369	45011	25.3	16	3	3	4	1988
0389	Barle	SOUTH HILL	2852	1349	45011	18.1	10	3	3	4	1988
0393	Barle	PIXTON HILL	2925	1263	45011	0.6	0	4	4	4	1988
0401	Torridge	FORDMILL FARM	2324	1178	50010	31.3	43	5	4	5	1978
0403	Torridge	WOODFORD BRIDGE	2399	1126	50010	18.9	29	5	4	5	1978
0405	Torridge	KINGSLEY MILL	2470	1061	50010	5.4	10	5	5	5	1978
0407	Torridge	HELE BRIDGE	2542	1064	50010	-4.5	4	5	5	5	1978
0610	Avon	MOORTOWN	4149	1035	43001	-2.5	0	5	5	5	1979
1011	Rother	HARDHAM	5034	1178	41009	0.1	0	5	5	5	1978
1105	Brede/Line	SEDLESCOMBE STREET	5783	1177	40025	3.4	3	3	4	4	1978
1201	Evenlode	MORETON-IN-THE-MARSH	4202	2312	39060	23.2	28	5	3	5	1979
1203	Evenlode	EVENLODE	4220	2281	39060	18.6	21	5	4	5	1979
1207	Evenlode	FAWLER	4366	2173	39060	-11.1	11	5	5	5	1979
1311	Wey	BURPHAM	5005	1532	39141	-5.5	1	1	5	5	1979
2103	Smite	COLSTON BASSETT	4697	3333	28017	20.4	15	4	4	5	1978
2107	Devon	KNIPTON	4822	3315	28017	23	9	5	3	5	1978
2109	Devon	BOTTESFORD	4812	3390	28017	12.6	7	5	3	5	1978
2111	Devon	HAWTON	4785	3511	28017	-4.7	2	2	5	5	1978
2509	Glen	SOUTH OF TWENTY	5156	3190	31027	-5.3	0	1	1	1	1978
2607	Wensum	WORTHING	6005	3202	34014	3.4	2	4	4	5	1978
2609	Wensum	NORTH OF ELSING	6052	3178	34014	-4.8	2	2	5	5	1978
2703	Hodder	SLAIDBURN	3715	4524	71003	2.7	4	4	4	3	1978
2801	Dane	HUG BRIDGE	3930	3636	69044	0.1	0	5	5	5	1978
2815	Weaver	BEAM BRIDGE	3651	3536	68008	0.1	0	5	5	5	1978
3105	Derwent	YEDINGHAM	4892	4795	27087	7.1	10	5	5	6	1978
3107	Derwent	NORTON	4790	4715	27036	0.1	0	7	7	7	1978
3109	Derwent	STAMFORD BRIDGE	4710	4555	27015	-0.5	0	7	7	7	1978
3157	Holbeck	HOVINGHAM CARRS	4669	4773	27014	9.6	10	6	4	6	1991
3313	Ouse/Ure	ALDWARK TOLL BRIDGE	4467	4621	27060	6.2	9	5	7	5	1978
3393	Wharfe	OTLEY	4188	4455	27027	-10.2	17	6	6	6	1990
3405	Tees	DENT BANK	3931	5259	25002	0.2	0	5	5	5	1978
3507	South Tyne	FEATHERSTONE	3674	5617	23006	-0.7	1	2	5	5	1978
3513	Tyne/North Tyne	CORBRIDGE	3990	5641	23023	5.9	1	3	7	7	1978
3581	South Tyne	SOUTH TYNE HEAD	3755	5361	23009	13.5	24	5	2	5	1984
3609	Wansbeck	BOTHAL	4236	5862	22005	-8.3	6	2	5	5	1978
3709	Forth	ABERFOYLE BRIDGE	2507	7014	18022	-0.5	1	4	5	4	1978
3711	Forth	PARKS OF GARDEN	2599	6974	18010	22.8	16	4	5	5	1978
3713	Forth	KIPPEN BRIDGE	2669	6960	18010	11.4	5	4	5	5	1978
3715	Forth	GARGUNNOCK BRIDGE	2710	6956	18010	0.5	0	5	5	5	1978
3717	Forth	DRIP BRIDGE	2770	6955	18011	1.8	1	6	5	6	1978
3781	Caorainn Achaidh Burn	COMER	2386	7043	18019	0.3	2	1	3	3	1984
3783	Allt Tairbh	TEAPOT	2440	7032	18022	8.3	14	4	2	4	1984
3785	Green Burn	DALMARY	2515	6955	18022	14.9	15	5	3	4	1984

RIVPACS site Code	River name	Site name	NGR East	NGR North	Gauging Station	Distance apart (km)	Intervening Tributaries No.	Intervening Tributaries Max SO	Stream order (SO) at: Site	Stream order (SO) at: Station	Sampling Year
3903	Dee	BRAEMAR	3143	7915	12007	-5.6	9	6	6	6	1979
4201	Annan	ABOVE ERICSTANE	3073	6110	78006	11.4	24	5	4	5	1981
4203	Annan	MOFFAT	3079	6058	78006	5.7	8	5	4	5	1981
4205	Annan	NEWTON BRIDGE	3109	5949	78006	-7	11	4	5	5	1981
4209	Annan	WILLIAMWATH BRIDGE	3118	5760	78001	1.1	1	1	6	6	1981
4901	Tweed	FINGLAND	3055	6194	21029	2.6	6	4	4	4	1981
4903	Tweed	NETHER RIGS	3080	6230	21029	-2.5	4	3	4	4	1981
4971	Whiteadder Water	CRANSHAWS	3689	6626	21002	-3	5	3	4	4	1990
5201	Axe	WOOKEY HOLE	3531	1473	52001	1.8	0	2	2	2	1982
5203	Axe	BLEADNEY	3481	1454	52001	-5.1	0	2	2	2	1982
5207	Axe	LOWER WEARE	3406	1537	52001	-17.9	10	4	4	2	1982
5501	Stour/Great Stour	STONEBRIDGE GREEN	5917	1485	40022	14.6	12	2	3	3	1982
5503	Stour/Great Stour	LITTLE CHART FORSTAL	5958	1460	40022	8.3	4	2	3	3	1982
5505	Stour/Great Stour	WYE	6048	1469	40008	0.2	0	4	4	4	1982
5507	Stour/Great Stour	MILTON BRIDGE	6121	1561	40011	0.9	0	4	4	4	1982
5509	Stour/Great Stour	FORDWICH	6179	1597	40011	-8.7	3	2	4	4	1982
5607	Lugg	MARLBROOK	3510	2551	55021	-5.4	2	4	5	5	1982
5609	Lugg	WERGIN'S BRIDGE	3529	2446	55003	7.5	3	3	5	5	1982
5613	Wye	DOLHELFA	2921	2738	55010	-16.2	25	4	5	5	1982
5711	Usk	LLANDETTY	3127	2204	56004	0.1	0	5	5	5	1983
5887	Western Cleddau	WOLF'S CASTLE	1956	2256	61004	8.9	9	3	4	4	1990
5891	Western Cleddau	TREFFGARNE	1959	2230	61004	5.7	7	3	4	4	1990
6001	Blythe	CHESWICK GREEN	4127	2753	28094	33.9	33	3	3	4	1982
6005	Blythe	TEMPLE BALSALL	4208	2763	28094	18	19	3	4	4	1982
6009	Blythe	BLYTHE BRIDGE	4211	2898	28094	1.9	0	4	4	4	1982
6261	Reach Lode	UPWARE LOCK	5537	2698	33056	9.6	8	5	3	4	1991
6285	Wissey	LINGHILLS FARM	5834	3009	33049	8.1	2	3	3	2	1990
6701	Cannop Brook	SPECULATION	3610	2128	54085	1.4	2	1	4	4	1984
6913	Thames/Isis	BABLOCK HYTHE	4435	2042	39129	3.2	1	1	5	5	1984
6917	Thames/Isis	READING	4726	1740	39130	-1.1	3	6	6	6	1984
6921	Thames/Isis	RUNNYMEDE	5008	1725	39111	3.1	7	6	6	6	1984
7001	Conon/Bran	LEDGOWAN	2128	8553	4006	12.1	31	5	2	5	1984
7104	Moors/Crane	D/S CRANBORNE	4062	1129	43022	24.5	12	4	1	4	1985
7107	Moors/Crane	GREAT RHYMES COPSE	4077	1121	43022	22.5	12	4	1	4	1985
7110	Moors/Crane	PINNOCKS MOOR	4077	1112	43022	21.4	11	4	2	4	1985
7113	Moors/Crane	ROMFORD BRIDGE	4075	1094	43022	19.3	8	4	2	4	1985
7116	Moors/Crane	REDMANS HILL	4074	1079	43022	17.7	8	4	2	4	1985
7119	Moors/Crane	VERWOOD	4088	1075	43022	16	7	4	2	4	1985
7122	Moors/Crane	KING'S FARM	4105	1064	43022	13.3	5	4	2	4	1985
7127	Moors/Crane	EAST MOORS FARM	4101	1029	43022	8.9	4	4	3	4	1986
7143	Ed	UPPER FARM	4067	1112	43022	21.7	11	4	1	4	1985
7145	Ed	PAINS MOOR	4074	1105	43022	20.7	11	4	1	4	1985
7149	Unnamed	IN WOOD, U/S TRIBUTARY	4069	1099	43022	20.5	10	4	1	4	1985
7153	Unnamed	D/S WOOD	4074	1098	43022	19.9	10	4	1	4	1985
7189	Mannington Brook	HORTON HEATH	4054	1067	43022	16	6	4	3	4	1985
7192	Mannington Brook	NEWMAN'S LANE	4077	1042	43022	11.4	5	4	3	4	1985
7195	Mannington Brook	PENNINGSTON'S COPSE	4075	1026	43022	9.7	5	4	3	4	1986
7405	Cnocloisgte Water	U/S LOCH CALUIM	3025	9511	97001	28.6	26	4	3	3	1986
7413	Forss Water	ACHALONE	3041	9630	97001	9.2	4	4	4	3	1986
7417	Forss Water	CROSSKIRK	3029	9699	97001	-14.3	14	5	5	3	1986
8281	Clun	WHITCOTT KEYSETT	3279	2822	54056	18.1	11	5	4	5	1988

RIVPACS site			NGR		Gauging	Distance apart	Intervening Tributaries		Stream order		Sampling
Code	River name	Site name	East	North	Station	(km)	No.	Max SO	(SO) at: Site	Station	Year
8285	Clun	PURSLOW	3358	2807	54056	7.6	4	5	4	5	1988
8289	Clun	JAY	3394	2754	54056	-4.6	3	1	5	5	1988
8429	Test	SKIDMORE	4354	1178	42013	0	0	4	4	4	1987
8605	Teign	LEIGH BRIDGE	2683	879	46001	4.4	4	3	4	3	1988
8609	Teign	FINGLE BRIDGE	2745	898	46001	-12.3	10	3	4	3	1988
8905	Brora	DALNESSIE	2631	9155	2002	39.2	54	5	4	5	1989
8909	Brora	U/S BALNACOIL	2789	9106	2002	16.6	19	5	4	5	1989
8913	Brora	D/S LOCH BRORA	2870	9046	2002	3.2	1	1	5	5	1989
8921	Black Water	CREAG DHUBH	2684	9202	2002	33.1	39	5	4	5	1989
8925	Black Water	POLLIE	2747	9160	2002	24.4	30	5	4	5	1989
9109	Hull/West Beck	WANSFORD	5064	4559	26001	-0.1	0	3	3	3	1989
9581	Lathkill	ALPORT	4220	3646	28068	0.6	1	2	2	3	1990
9585	Lathkill	CONGREAVE	4242	3657	28068	-2.7	1	2	3	3	1990
9603	Coquet	CARSHOPE	3851	6109	22002	5.3	8	4	4	5	1990
9607	Coquet	LINSHIELS	3894	6062	22002	-4.3	11	4	5	5	1990
AN03	Reach Lode	HALLARDS FEN ROAD	5557	2678	33052	12	10	5	2	2	1990
AN04	Monk's Lode	ETERNITY HALL BRIDGE	5212	2858	33001	99.7	73	6	3	6	1990
AN05	Sixteen Foot Drain	HORSEWAYS CORNER	5421	2875	33035	24.6	25	6	5	6	1990
CL02	Ayr	NETHER WELLWOOD	2659	6262	83011	0.1	0	4	4	4	1992
NH01	Till/Beamish	ETAL	3926	6395	21031	0.2	0	6	6	6	1990
NH02	Till/Beamish	CHATTON	4059	6299	21031	30.4	23	5	5	6	1990
NH04	Glanton Burn	ROTHILL	4069	6126	22004	21.3	16	5	1	5	1990
NH07	Balder	U/S BALDERHEAD RESERVOIR	3899	5182	25022	-3.3	6	2	4	4	1990
NW01	Lune	OLD TEBAY	3618	5056	72010	2	1	4	4	5	1990
SN01	Ditton Stream	DITTON	5710	1585	40028	5.3	3	7	1	2	1990
SN02	Sutton Stream	ROAD BRIDGE	4986	1175	41008	3.5	5	5	2	5	1990
ST01	Severn	LLANDINAM	3025	2885	54080	-5.1	3	3	5	5	1990
ST07	Wye	ASHFORD	4195	3697	28023	1.8	0	4	4	4	1990
SW01	Bodilly Stream	BODILLY BRIDGE	1670	318	48006	6.3	2	3	2	3	1991
TA03	South Esk	STANNOCHY BRIDGE	3584	7592	13003	0.2	0	5	5	5	1992
TH04	Coln	FOSSE BRIDGE	4081	2112	39109	0.1	0	3	3	3	1990
TH05	Windrush	D/S DICKLER	4178	2177	39142	-4.9	3	3	4	3	1990
TH07	Ash	EASNEYE	5377	2133	38005	1.3	0	4	4	4	1990
WE01	Cynfal	PONT NEWYDD	2714	3409	65002	5	10	4	4	5	1990

Figure 7.1 shows the distribution of relative mean summer flows (%flow) across all the 443 reference sites. There were 31 sites whose mean summer flow in the year of biological sampling was less than 50% of the overall average summer flow across all years, of which eight sites had mean summer flows less than 40% of the overall average. However, as explained in section 7.3, the relative flow in the year of sampling at each site is usually assessed better from its percentage rank (%rank) amongst all year's summer flows. Figure 7.2 shows the frequency distribution of %rank for the reference sites. Twenty of the RIVPACS reference sites were sampled in years when the mean summer flow was amongst the lowest 10% of mean summer flows across all the available years at the site since 1970.

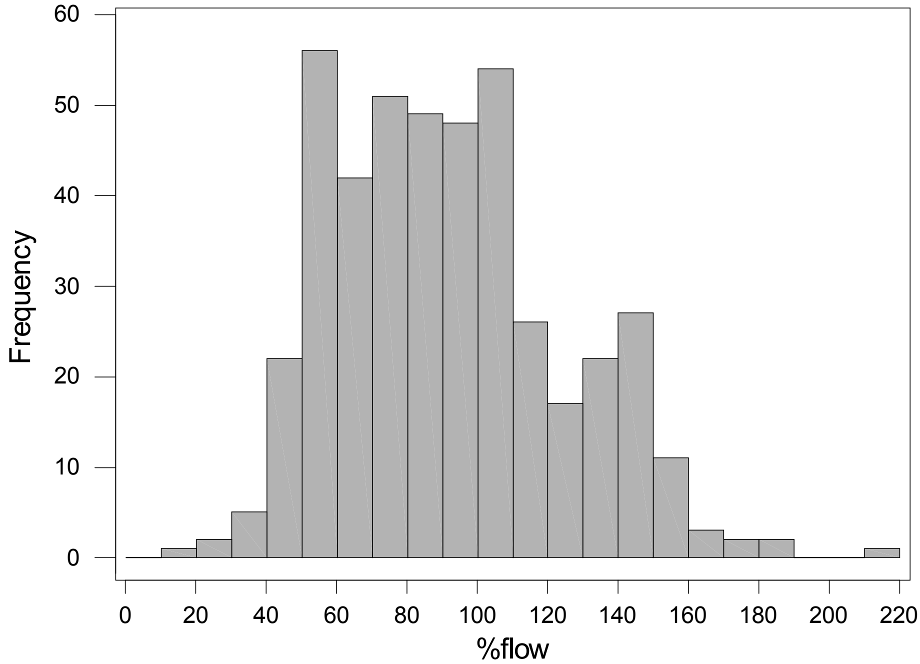


Figure 7.1 Frequency distribution of the relative mean summer flow (%flow) in the year of sampling for the RIVPACS reference sites.

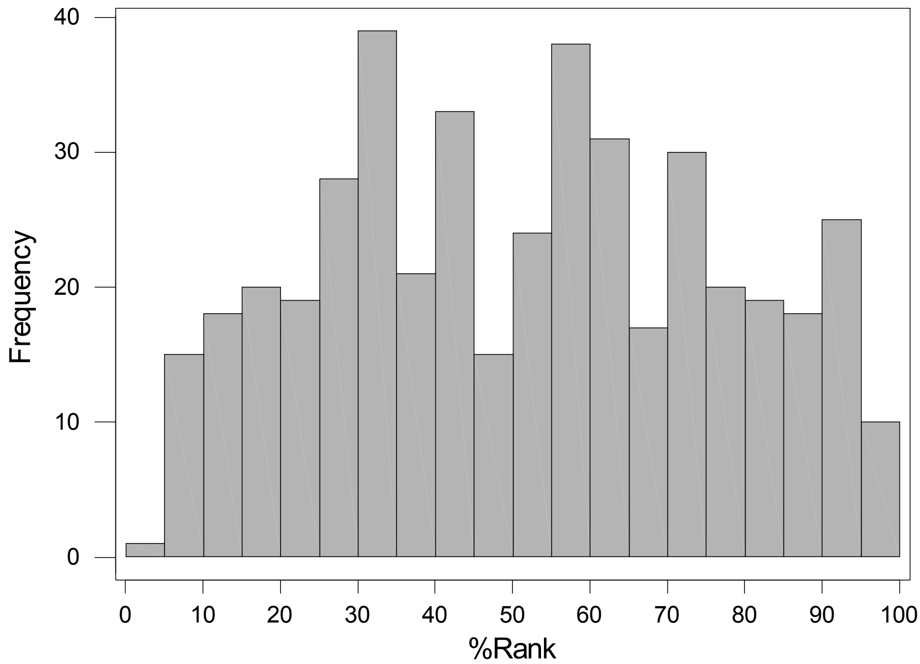


Figure 7.2 Frequency distribution of the percentage rank (%rank) of the mean summer flow in the year of sampling for the RIVPACS reference sites.

In trying to linked to as many as possible of the RIVPACS reference sites to gauging stations, some of the 443 sites listed in Appendix 2 had to be linked to a gauging station a long distance away within the catchment. Seventy one of these reference sites were linked to gauging stations over 20km downstream and a further six to stations over 20km upstream. The distance apart is not in itself important, but rather the difference in stream size and river discharge arising from intervening tributaries, abstractions or input discharges. Table 7.4 summaries the differences in Strahler stream order between the RIVPACS reference sites and the best-linking flow gauging station. Unlike some of the reference sites, none of the gauging stations were on stretches of first order streams. Three quarters of sites were best linked to a downstream flow gauging station; in many cases there was no flow gauging station upstream of the biological sampling site.

Table 7.4 Cross-classification of the Strahler stream order at the RIVPACS reference sites with the Strahler stream order at their linked flow gauging station (*n* = 443 sites).

		stream order at gauging station							Total
		1	2	3	4	5	6	7	sites
stream order at reference site	1	0	1	4	6	12	1	1	25
	2	0	5	15	10	13	4	1	48
	3	0	1	30	32	17	2	0	82
	4	0	0	6	62	28	9	2	107
	5	0	0	1	3	75	16	0	95
	6	0	1	0	1	8	60	3	73
	7	0	0	0	1	0	1	11	13
Total sites		0	8	56	115	153	93	18	443

Of the 443 sites, 242 (55%) were linked to station on stretches of the same stream order and a further 113 sites (26%) were linked to stations where the stream order was only one more (or occasional one less) than at the reference site. However, 42 sites could only be linked to downstream gauging stations situated on stretches of river at least three greater in stream order. As the flow regime at such gauging stations is likely not to be representative of the flow regime at the reference sites, these sites were eliminated from subsequent analyses, together with two further sites of stream order 6 and 7 that were links to gauging stations on streams at least threes order lower (Table 7.4). This left 399 reference sites for which there was more confidence that the linked gauging station was likely to be similar in flow regime to that of the biological sampling site.

7.4.2 Relationship between LIFE O/E and estimated relative flows

Variation in observed LIFE and LIFE O/E for the RIVPACS reference sites was assessed in section 2. If any one of the RIVPACS reference sites was sampled in a year of unusually low summer flows, then, if that site's macroinvertebrate fauna had been influenced by flow-related stress, one might expect LIFE O/E for the sites to be relatively low amongst RIVPACS reference sites. As agreed in the project's objectives (see section 1.2.6), the relative mean summer flow in the year of RIVPACS sampling was compared with the LIFE O/E for the biological sample taken in the immediately following autumn period. The relationships between LIFE O/E of autumn samples for the 443 reference sites and either the relative flow (%flow) or the percentage rank of the flow (%rank) in the summer immediately preceding the sampling are shown in Figures 7.3 and 7.4 respectively. There is some slight suggestion that some sites sampled in years of relatively low summer flow tend to have marginally lower values of LIFE O/E. Although the correlations are statistically significant ($p < 0.01$), they are very weak (0.15-0.17). In regression relationships, %flow and %rank each explain only 2-3% of the total variation in values of LIFE O/E amongst the RIVPACS reference sites, indicating there is no general relationship of any practical concern amongst the reference sites between LIFE O/E and the relative flow in the year of biological sampling. These very low correlations are unchanged when the sites with streams order greater than two different from their best matched gauging station are excluded.

We also assessed whether LIFE O/E was correlated with relative flow within streams of particular physical types. Stream types with less stable flow regimes or which are more prone to low flow problems, may have more tendency for LIFE O/E values to be lower at sites sampled in years of relatively low flow. The RIVPACS reference sites were classified according to their TWINSPAN group 1-35, but amalgamated into nine "super-groups" representing a higher level in the TWINSPAN hierarchical classification procedure used in deriving the RIVPACS system. These are the same super-groups as used in section 4 to ensure a balanced selection of sites for simulating flow-related changes in LIFE. This grouping ensured an adequate sample size upon which to assess correlations within each super-group of sites. Although the formation of the TWINSPAN groups were based only on the macroinvertebrate composition at the sites, they do correspond to different physical types of site (as shown by the multiple discriminant analysis (MDA) used in deriving RIVPACS and based on the sites' environmental characteristics). The correlations of LIFE O/E and %rank of flow within each super-group of sites are shown in Table 7.5 and the relationships plotted in Figures 7.5-7.7.

Table 7.5 Correlations between LIFE O/E and %rank of the mean summer flow in the year of sampling for the n_1 RIVPACS reference sites in each TWINSPAN super-group which could be linked to a flow gauging station with adequate flow data; n_2 = subset of the n_1 sites whose linked flow station was within ±2 stream orders of that at the site.

TWINSPAN groups	Sites in groups Total	n_1	n_2	Correlation
1-4	71	42	30	0.20
5-9	74	53	30	0.08
10-14	83	63	62	0.10
15-17	71	52	52	0.04
18-20	49	35	33	0.06
21-24	87	74	74	0.21
25-28	68	53	52	0.07
29-32	53	31	28	0.45 ($p < 0.05$)
33-35	58	40	38	0.25
Total	614	443	399	0.15 ($p < 0.01$)

Although the correlations are positive within each of the super-groups, the only statistical significant correlation ($p<0.05$) occurred amongst sites comprising TWINSPAN groups 29-32 (Figure 7.7). This super-group of lowland sites occur mainly in south and south-east England and include many of the southern chalk streams. Several sites are highlighted in Figure 7.7 and can be cross-referenced to Appendix 2. The Lyde River at Deanlands Farm (site TH03) was most extreme in its flow at the time of biological sampling in 1992, with the third lowest summer mean flow out of 29 years, but its LIFE O/E of 1.03 was not low.

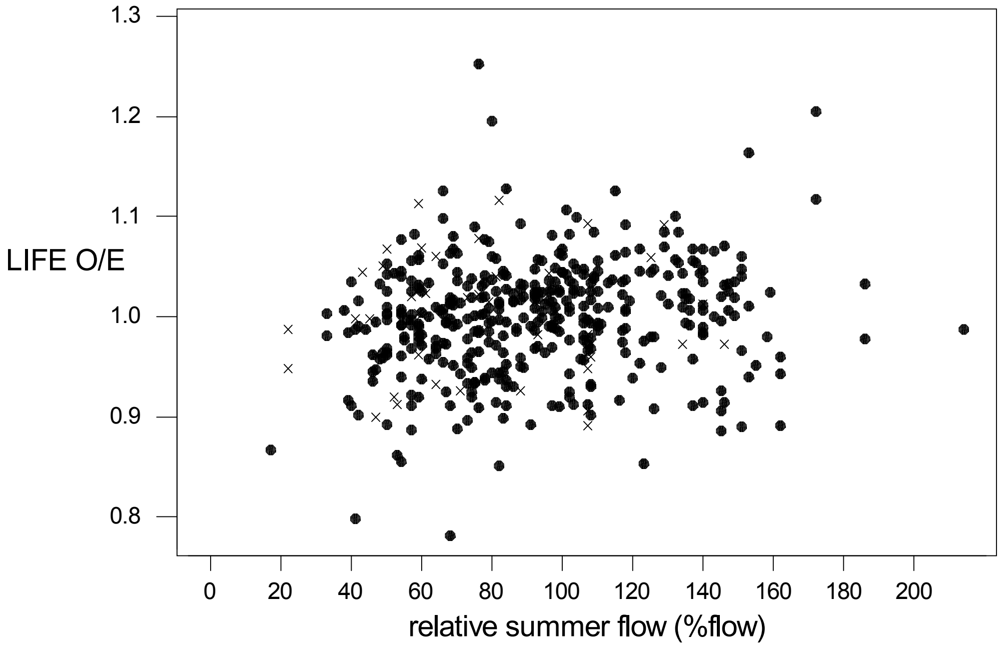


Figure 7.3 Relationship between autumn sample LIFE O/E and relative mean summer flow (%flow) in the year of sampling for 443 flow-matched RIVPACS reference sites. Crosses indicate the 44 sites whose linked flow station differs by more than two in stream order. Correlation $r = 0.16$ ($n = 443$) or $r = 0.17$ ($n = 399$ sites).

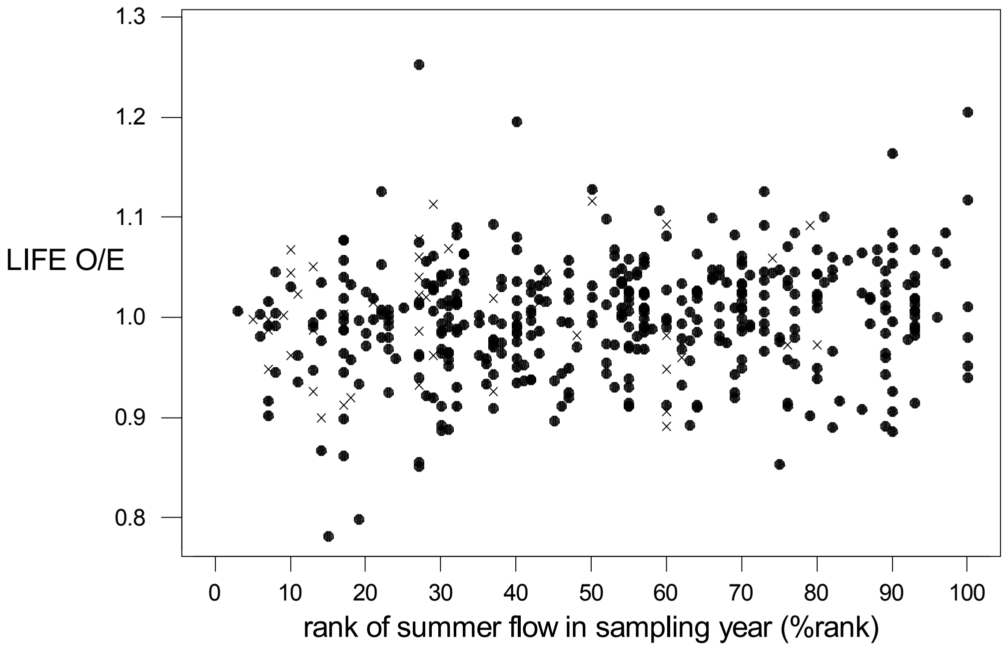


Figure 7.4 Relationship between autumn sample LIFE O/E and percentage rank (%rank) of mean summer flow in the year of sampling for 443 flow-matched RIVPACS reference sites. Crosses indicate the 44 sites whose linked flow station differs by more than two in stream order. Correlation $r = 0.15$ ($n = 443$) or $r = 0.16$ ($n = 399$ sites).

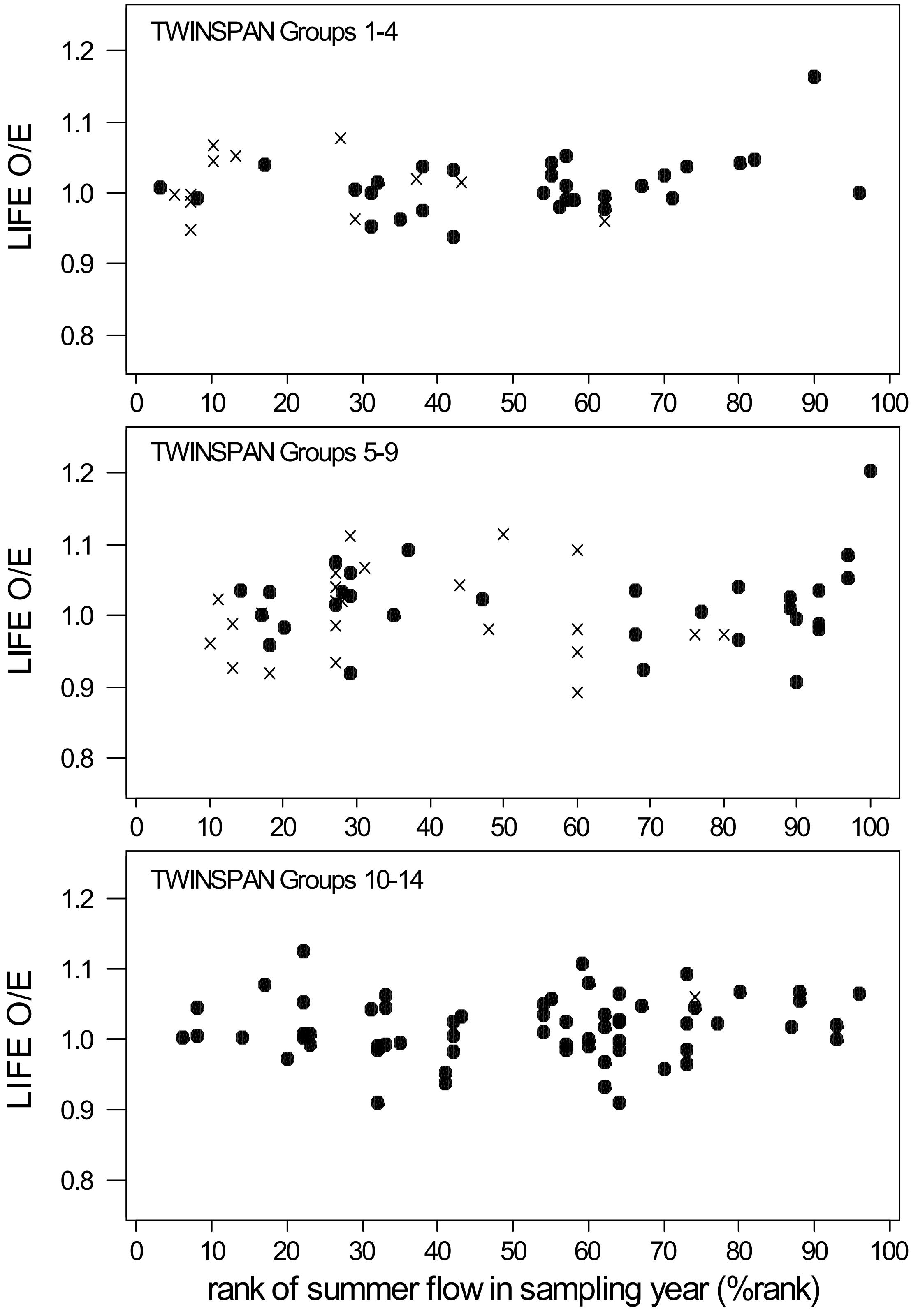


Figure 7.5 Relationship between autumn sample LIFE O/E and percentage rank (%rank) of mean summer flow in the year of sampling for the RIVPACS reference sites in TWINSPAN groups 1-4, 5-9 and 10-14. Crosses indicate the sites whose linked flow station differs by more than two in stream order.

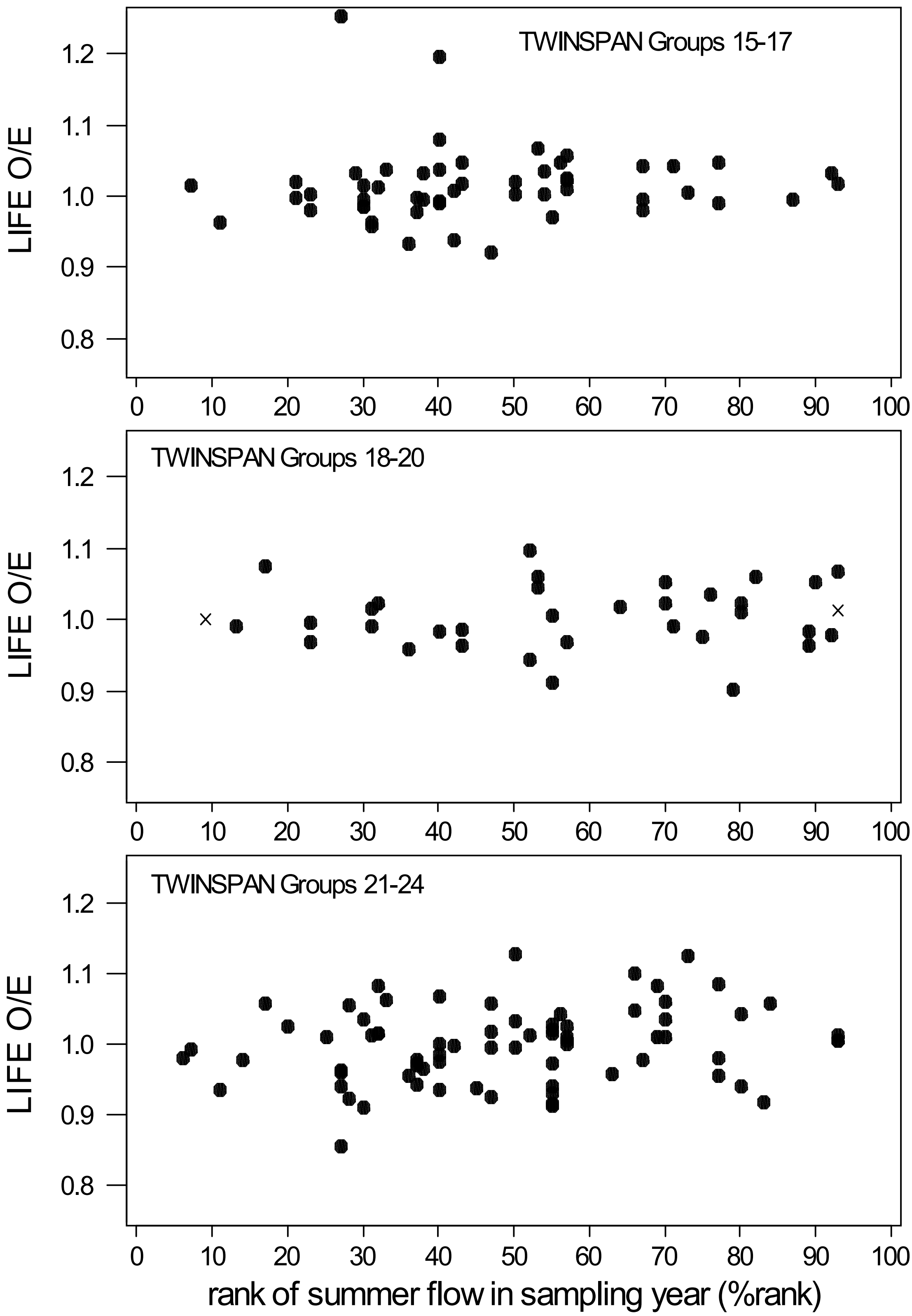


Figure 7.6 Relationship between autumn sample LIFE O/E and percentage rank (%rank) of mean summer flow in the year of sampling for the RIVPACS reference sites in TWINSPAN groups 15-17, 18-20 and 21-24. Crosses indicate the sites whose linked flow station differs by more than two in stream order.

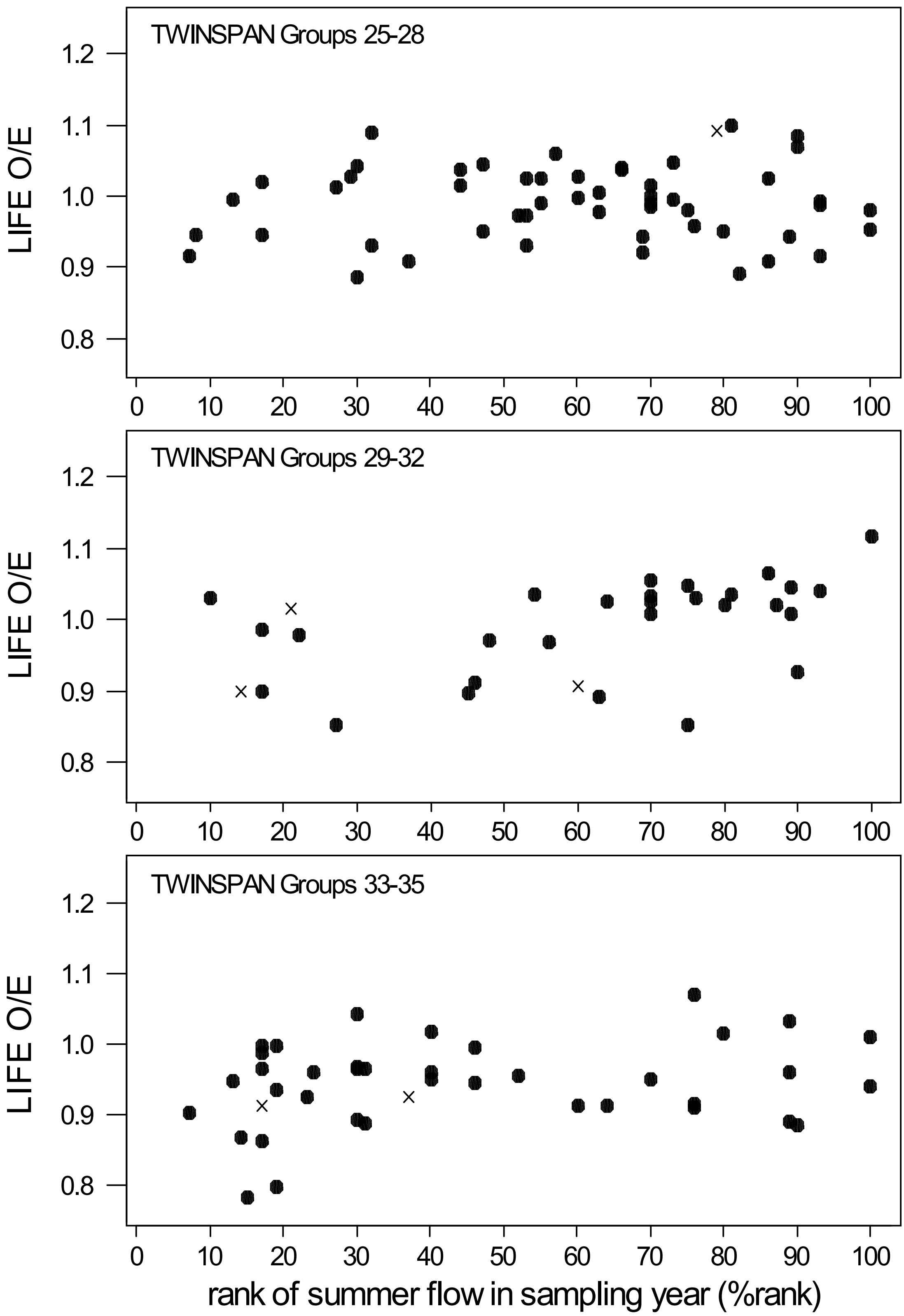


Figure 7.7 Relationship between autumn sample LIFE O/E and percentage rank (%rank) of mean summer flow in the year of sampling for the RIVPACS reference sites in TWINSPAN groups 25-28, 29-32 and 33-35. Crosses indicate the sites whose linked flow station differs by more than two in stream order.

Three sites in groups 29-32 had low relative summer flows (%rank<30%) in the year of sampling and low LIFE O/E (i.e. ≤0.90); namely the Woodlands Manor site on an unnamed tributary of the Dorset Stour (6841), the Oliver's battery site on the River Loddon (6981) and the site upstream of Brackley (code 6201) on an unnamed tributary of the Bedford Ouse. However, the Brackley site, of stream order 1, could only be linked to the flow gauging station at Thornborough Mill 27km downstream, of stream order 5, so the assigned relative flows may be quite inappropriate. Another influence on the correlation within site groups 29-32 was the site at Whitehouse Farm Ford (8309) on the upper stretches of the River Bure in Norfolk, which had the 30-year highest mean summer flow in the year of biological sampling in 1987 and a very high LIFE O/E of 1.12 (Figure 7.7).

Although the correlation of 0.25 between LIFE O/E and %rank for sites in groups 33-35 is not statistically significant ($p = 0.11$), two sites with very low LIFE O/E were sampled in years of low relative flow (Figure 7.7 bottom): the sites at Longham on the Dorset Stour (code 6811) and Corpslanding on the Hull river drainage system (code 9113). These two sites are both in the same TWINSPAN group (33), so there may be implications for determining expected LIFE for test sites with high probabilities of belonging to this group type. These two sites are examined further in section 7.4.3 below.

Overall, it is concluded that, amongst the RIVPACS reference sites, there are no groups (i.e. types) of sites for which several sites had both relatively low flow prior to sampling and low LIFE O/E. Thus there is no major systematic problem in using RIVPACS to set the expected LIFE for any type of river site.

However, there may be individual reference sites which perhaps should be excluded from setting the expected LIFE; this is examined further below.

7.4.3 Reference Sites with atypical flows and LIFE O/E

Table 7.6 lists the 20 RIVPACS reference sites which were sampled in years where the mean summer flow at the linked flow gauging station was either less than 40% of the long-term average summer flow or within the lowest 10% of mean summer flows amongst the years available. Table 7.6 also includes two sites for which the autumn LIFE O/E was less than 0.85.

The three RIVPACS reference sites furthest up the Spey catchment in NE Scotland were linked to the flow gauging station at Invertruim on the Spey; they were sampled for RIVPACS in 1978, following the second lowest mean summer flow during the available period 1970-1995 (54% of long-term average, Figure 7.8). However, all three sites had LIFE O/E close to unity, so no major flow-related effects on the macroinvertebrate community are thought be present at the time of sampling.

The reference site at Redbrook on the River Wye had a relatively low LIFE O/E of 0.917 when sampled in autumn 1984. The mean summer flow in 1984 at the gauging station 1km away was 10.4 cumecs, only 39% of the long-term average summer flow and also the second lowest since 1970 (Figure 7.9).

The RIVPACS reference site with the lowest relative flow was at Hildersham (id 6259) on the river Granta where %flow was 17 and %rank was 14. This was based on the nearest gauging station, 4.9km downstream at Babraham on the same river (NWA id 33055) where the mean summer flow in the 1991, the year of biological sampling, was 0.021 m^3s^{-1} compared to the long-term average of 0.123 m^3s^{-1} (Figure 7.10). Closer examination of the flow record showed that mean summer flows decreased at the end of the 1980s just before the site was selected as a new reference site in 1991 for inclusion in the upgrade of RIVPACS II to RIVPACS III. There was a natural drought during 1990-92, but groundwater abstraction also had a major impact (Extence, *pers. comm.*). Although the summer flow in 1991 was lower than in all previous years since 1977 when regular recording began, it was slightly higher than the mean summer flow in 1992 and 1997 (Figure 7.10). The LIFE O/E for the autumn sample in 1991 was 0.867. Moreover, for the spring and summer samples, LIFE O/E was also low at 0.868 and 0.862 respectively, suggesting persistent long-term problems of flow-related stress.

In retrospect, the reference site at Hildersham on the river Granta should perhaps be removed from the RIVPACS reference site data set.

Table 7.6 List of the 24 RIVPACS reference sites for which %flow <40% or %rank ≤10% or LIFE O/E <0.85. The distance between the site and station is shown negative/positive when the station is up/down stream of the site; n/a indicates adequate flow data not available at linked gauging station.

RIVPACS site			NGR		Flow	Distance apart	Stream order (SO) at:					LIFE
Code	River name	Site name	East	North	Station	(km)	Site	Station	Year	%flow	%rank	O/E
4001	Spey	GARVA BRIDGE	2522	7947	8007	22.1	4	6	1978	54	8	0.992
4003	Spey	LAGGAN BRIDGE	2614	7943	8007	11.2	5	6	1978	54	8	1.004
4005	Spey	NEWTONMORE	2708	7980	8007	-3.1	6	6	1978	54	8	1.046
4381	Carron	U/S LOCH SGAMHAIN	2116	8537	93001	23.9	2	6	1984	45	5	0.998
4881	Unnamed	ACHAVANICH	3180	9408	97002	28	1	5	1984	22	7	0.948
4885	Unnamed	WESTERDALE	3123	9517	97002	11.8	2	5	1984	22	7	0.988
5623	Wye	REDBROOK	3534	2100	55023	-1.3	7	7	1984	39	7	0.917
5681	Lugg	CRUG	3184	2730	55014	27.6	2	5	1984	50	10	1.068
5881	Wern	MYNACHLOG-DDU	2118	2307	61002	22.4	1	4	1984	41	7	0.998
6259	Babraham/Granta	HILDERSHAM	5545	2485	33055	4.9	3	3	1991	17	14	0.867
6801	Middlemarsh Stream	GRANGE WOOD	3665	1073	43009	32.2	1	5	1984	47	10	0.962
6811	Stour	LONGHAM	4065	973	43007	9.1	5	5	1984	68	15	0.782
6993	Enborne	BRIMPTON	4568	1648	39025	0	5	5	1990	42	7	0.902
9105	Hull/West Beck	LITTLE DRIFFIELD	5010	4576	26006	0.2	2	2	1989	39	20	0.984
9113	Hull/West Beck	CORPSLANDING	5066	4529	26002	4.8	3	4	1989	41	19	0.798
9205	MillburnBk/Knock Ore Gill	GREEN CASTLE	3711	5306	76005	14.7	2	6	1989	43	10	1.044
AN02	Cringle Brook	THUNDERBRIDGE	4920	3287	30015	1.5	2	2	1990	46	8	0.945
NE02	Lossie	U/S BLACKBURN	3185	8620	7003	1.4	5	5	1992	42	7	1.016
NH03	Glen	EWART	3955	6302	21032	-4.3	5	5	1990	33	6	0.981
NH09	Wooler W/Harthope Burn	CORONATION WOOD	3973	6248	21032	24.2	3	5	1990	33	6	1.003
ST04	Sence	NEWTON LINFORD	4523	3098	28093	13.6	2	5	1990	60	9	1.002
ST05	Derwent	BASLOW	4252	3722	28043	4.3	6	6	1990	57	7	0.992
SW05	Stithians Stream	SEARAUGH MOOR	1734	374	48007	3.8	3	4	1990	38	3	1.007
TH03	Lyde River	DEANLANDS FARM	4696	1542	39022	16.6	2	4	1992	77	10	1.031

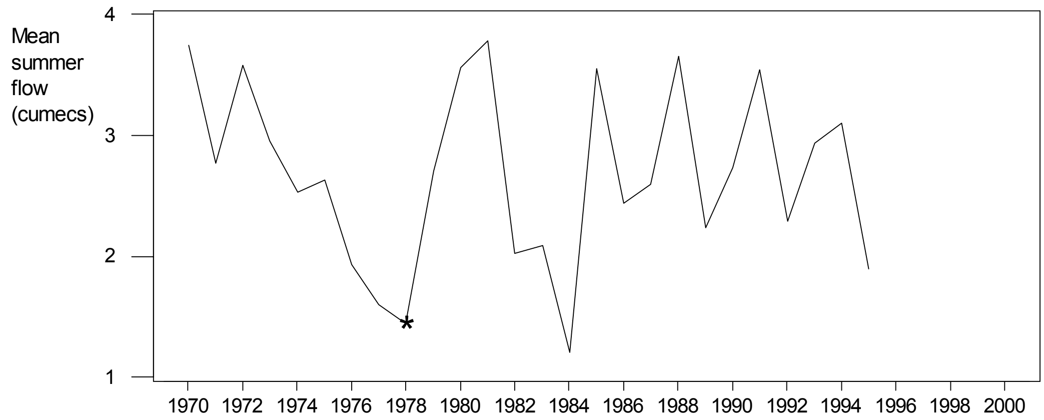


Figure 7.8 Mean summer (June-August) flow (m^3s^{-1}) on the river Spey at the Invertruim gauging station (NWA id 8007) since 1970. The three linked RIVPACS reference sites on the Spey were sampled in 1978 (marked *).

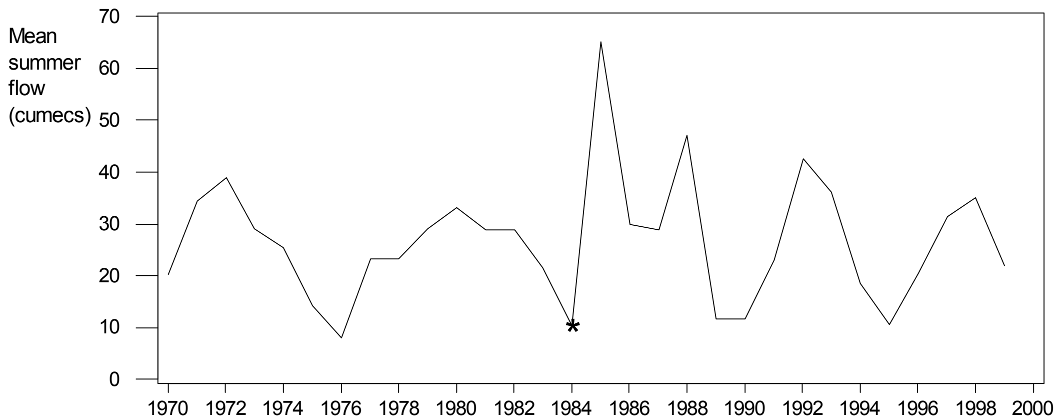


Figure 7.9 Mean summer (June-August) flow (m^3s^{-1}) on the river Wye at the Redbrook gauging station (NWA id 55023). * denotes year of sampling at the nearby RIVPACS reference site (code 5623).

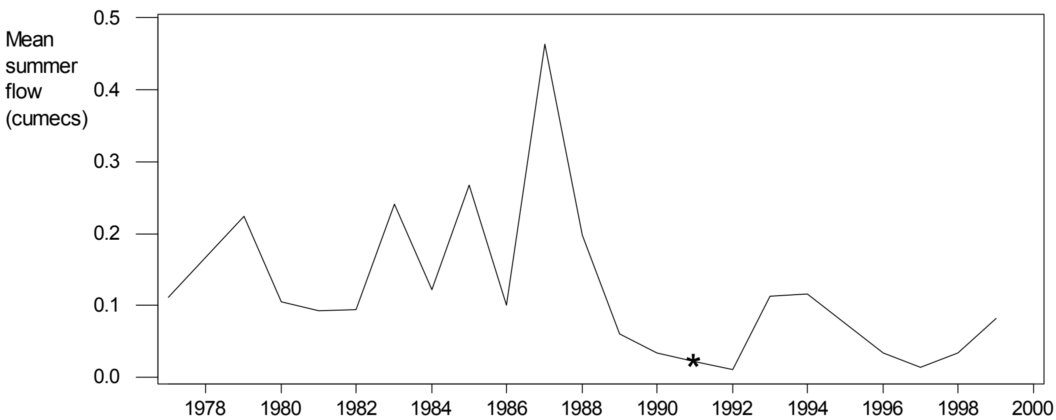


Figure 7.10 Mean summer (June-August) flow (m^3s^{-1}) on the river Granta at the Babraham gauging station (NWA id 33055) since 1977. * denotes year of sampling at the nearby RIVPACS reference site (code 6259).

The second lowest %flow was 22, which was based on the flow conditions at the Halkirk gauging station on the Thurso in northern Scotland (id 97002). This station was the nearest available station to two much smaller headwater sites, Achavanich (code 4881) and Westerdale (code 4885), 28.0 and 11.7 km upstream respectively; both within 1.5km of their source. The mean summer flow at the time of biological sampling of these two sites in 1984 was the second lowest of the 28 years summer flow data. Neither of these two reference sites had unusually low LIFE O/E.

The only two RIVPACS reference sites with autumn LIFE O/E less than 0.85 were the sites at Longham (code 6811) in the Dorset Stour and at Corpslanding (code 9113) on the Hull/West Beck (Table 7.6).

The Corpslanding site is on the partly canalised River Hull system flowing into the Humber estuary. The LIFE O/E was 0.798 for the autumn sample in 1989. It was best linked to the gauging station at Hempholme Lock (NWA id 26002) 5km downstream, where the mean summer flow in 1989, the year of sampling for RIVPACS, was 0.838 m^3s^{-1} , which was 41% of the long-term average and fifth lowest over the available period 1970-1996 (Figure 7.11). The summer flow was even lower in 1990 suggesting that any problems of low flow were increasing at the time of the autumn sampling. This is supported by the observation that the LIFE O/E at the Corpslanding site was 0.929 for the summer sample (although the spring 1989 sample value of LIFE O/E was only 0.865).

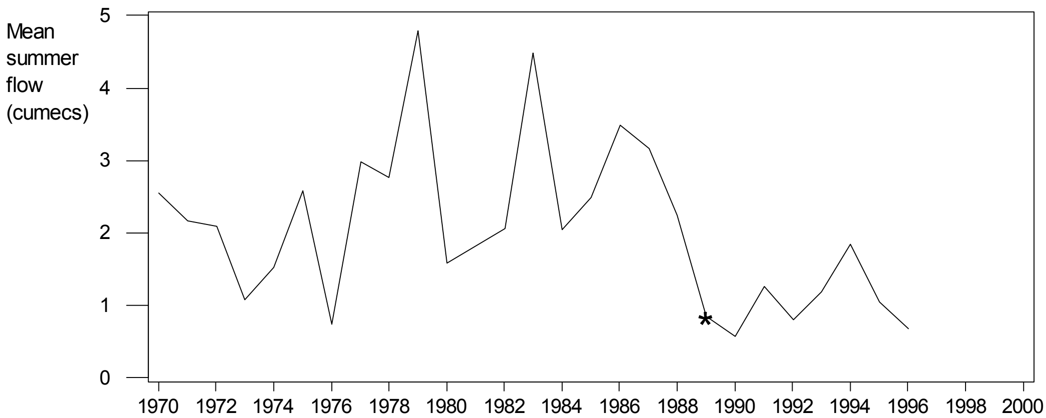


Figure 7.11 Mean summer (June-August) flow (m^3s^{-1}) on the river Hull at the Hempholme Lock gauging station (NWA id 33055). * denotes year of sampling at the linked RIVPACS reference site at Corpslanding (code 9113).

In retrospect, the reference site at Corpslanding on the river Hull should perhaps be removed from the RIVPACS reference site data set.

The site at Longham (code 6811) on the River Stour in Dorset had the lowest LIFE O/E (0.782) of any sample in any of the three seasons (spring, summer or autumn) for any of the 614 RIVPACS reference sites. The LIFE O/E for the spring and summer samples in 1984 were 0.942 and 0.847 respectively, suggesting any flow-related stresses may have been increasing throughout the year. The nearest gauging station with adequate flow data was at Throop (NWA id 43007), 9km downstream on the Stour but with no significant intervening tributaries. The mean summer flow in 1984 was only 68% of the long-term average, but it was not particularly exceptional (Figure 7.12). The EQI_{ASPT} for the autumn 1984 sample at Longham was 0.95, surprisingly high compared to the LIFE O/E for the same sample. The reason for the discrepancy was that the BMWP families present were roughly as expected, but many families classed as being tolerant of slow flows (i.e in LIFE flow groups III and IV in Table 1.4-1.5) were found at higher abundances than expected (e.g. Asellidae, Sphaeriidae, Valvatidae and Planorbidae observed at abundance category 4 but with expected abundance values of 1.88, 1.11, 2.57 and 1.48 respectively. This made the observed LIFE considerably less than the expected LIFE.

None of the other reference sites listed in Table 7.6 (because of their relatively low flows in the year of RIVPACS sampling) had LIFE O/E values significantly different from unity (the overall average for the RIVPACS reference sites). Therefore, there was no reason to suspect any flow-related impacts on the macroinvertebrate fauna observed at these sites.

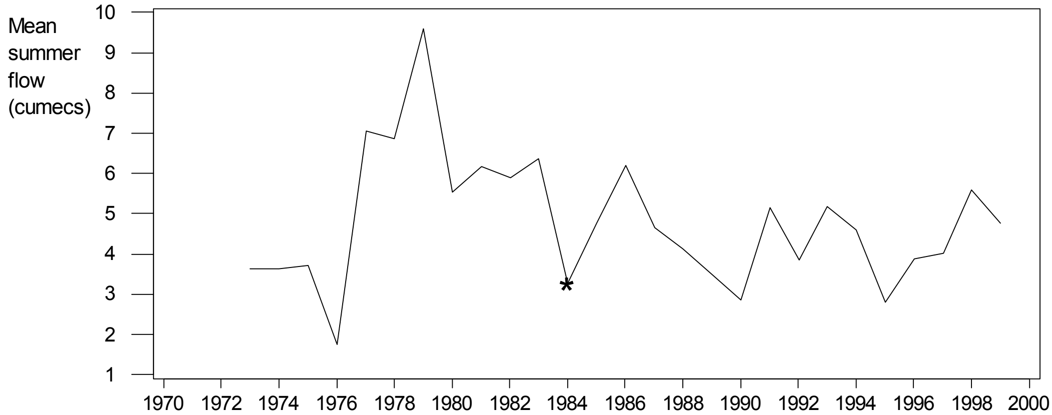


Figure 7.12 Mean summer (June-August) flow (m^3s^{-1}) on the river Stour in Dorset at the Throop gauging station (NWA id 43007). * denotes year of sampling at the linked upstream RIVPACS reference site at Longham (code 6811).

7.4.4 Reference sites to be excluded from prediction of expected LIFE

We concluded that there were three reference sites which perhaps should be excluded from the RIVPACS prediction of expected LIFE (Table 7.7). All three reference sites were assigned to RIVPACS site group 33 in the TWINSPAN biological classification of the sites used in the development of RIVPACS III (and RIVPACS III+). Therefore, in the RIVPACS software, it would only be necessary to modify the probabilities of occurrence and average abundances of the families for the reference sites in this group based on excluding the three sites above. There are currently 31 reference sites in group 33. Therefore, the removal of three sites will not radically change the overall probabilities of taxon occurrence and average abundance for the site group, nor grossly affect the predictions of expected number of BMWP taxa or expected ASPT. At this stage, it is not recommended that the RIVPACS system for determining EQIs be modified because it would slightly alter the prediction of expected number of BMWP taxa and expected ASPT for many lowland river sites whose environmental characteristics gave them a probability of belonging to RIVPACS sites group 33. The changes would usually be trivial and hence of no practical importance, but it would give incompatibility with previous assessment of EQIs, which may be important in national monitoring surveys such the quinquennial GQA.

Table 7.7 Details of reference sites which should be excluded from the RIVPACS prediction of expected LIFE.

Season	Site name	Hildersham	Longham	Corpslanding
	River	River Granta	River Stour (Dorset)	River Hull / West Beck
	RIVPACS code	6259	6811	9113
EQI_{TAXA}	Spring	0.83	1.19	0.99
	Summer	0.81	1.00	1.15
	Autumn	0.94	1.06	0.77
EQI_{ASPT}	Spring	0.93	1.00	0.91
	Summer	0.87	0.93	0.97
	Autumn	0.90	0.95	0.81
LIFE O/E	Spring	0.868	0.942	0.865
	Summer	0.862	0.897	0.929
	Autumn	0.867	0.782	0.798

Our conclusions on this analysis of LIFE O/E and flow conditions at the RIVPACS reference sites are summarised in section 7.6.

7.5 Flow conditions and LIFE O/E for the 1995 GQA sites

The LIFE O/E for the GQA sites based on their autumn macroinvertebrate samples in 1995 were related to the flow conditions in the immediately preceding summer. The initial dataset consisted the same large set of 6016 sites described and analysed in section 3.

7.5.1 Linking the GQA sites to flow gauging stations

The first stage was determine the subset of 1325 National Water Archive (NWA) flow gauging stations for which complete summer (June-August) flow data were available for at least five years since 1970 (Appendix 3). Of these, 235 did not have complete summer flow data for 1995, the year of GQA sampling, and so were excluded, leaving 1090 gauging stations. Five years may not always be long enough to get an adequate estimate of the long-term average flow. However the mean flows for all except 66 of the 1090 gauging stations were actually based on 10 or more years flow data, and there were more than 20 years of flow data for over 70% of these gauging stations.

The second stage was to link each of the GQA sites to the geographically nearest (i.e. shortest straight line distance) of the 1090 flow gauging stations with at least five years complete summer flow data, including for 1995. Interestingly, only 800 of the 1090 gauging stations were linked to any of the 6016 GQA sites.

Then specially written procedures within the CEH Dorset blue-line network GIS were used to assess whether the flow station linked to a GQA site was likely to adequately represent the flow conditions at the GQA site. For 1056 of the GQA sites, the linked gauging station was not in the same catchment. For each of the remaining 4960 sites, the GIS was used to determine the blue-line distance between the GQA site and the linked gauging station, the Strahler stream order of the site and of the linked station and the other attributes listed in Table 7.1, as per the RIVPACS reference sites.

The further a gauging station is from a GQA site, the less likely it is that the flow record will adequately represent the flow regime at the GQA site. For the vast majority (85%) of GQA sites, the nearest gauging station was downstream. Consequently, most GQA sites are linked to a gauging station on a downstream river stretch of higher Strahler stream order (53%) or the same stream order (34%) (Table 7.8).

Table 7.8 Cross-classification of the Strahler stream order at the 1995 GQA sites with the Strahler stream order at the linked flow gauging station (n = 4960 sites). Site and station stream orders within ±1 are highlighted

		stream order at gauging station							Total
		1	2	3	4	5	6	7	sites
stream order at reference site	1	22	20	86	142	106	25	12	413
	2	16	71	205	277	199	81	25	874
	3	36	50	419	487	347	118	43	1500
	4	13	23	110	628	309	95	20	1198
	5	2	6	63	98	404	44	5	622
	6	0	7	33	60	46	135	7	288
	7	0	0	14	8	4	11	28	65
Total sites		89	177	930	1700	1415	509	140	4960

Stations on river stretches of similar stream order to the GQA site are mostly likely to have flow regimes similar to that of the GQA site. (As mentioned before, the flows do not need to be the same at the station and site, only the relative flows from one year to the next.) Therefore, within this large dataset, we have selected those GQA sites which were linked to a gauging station differing by no more than one in stream order. This gave a subset of 3109 GQA sites.

Unfortunately, a linked gauging station identified within the GIS as being downstream of a GQA site may occasionally be downstream and then up another branch of the river system within the catchment. It was not feasible to manually check for such cases. However, GIS procedures developed by CEH calculated the highest stream order of any tributary joining the river between a GQA site and its nearest gauging station. If the stream order was greater than the stream orders of both the site and the gauging station, then the gauging station must have been downstream of the site, but then up another branch of the river system.

There were 296 cases where an intervening tributary was one stream order higher than the stream order at both the site and linked station, together with a further 290 cases with an intervening tributary at least two stream orders higher. In most of these cases, the nearest gauging station was at least 10km from the GQA site. All these cases were excluded from further analyses, leaving 2523 GQA sites with suitably matched flow gauging stations.

Amongst these GQA sites linked to gauging stations on similar ‘sized’ river stretches, just over four-fifths (79%) were within 10km up- or down-stream of the linked flow gauging station (Table 7.9). The comparison of LIFE O/E and relative flow has been restricted to this subset of 2005 ‘well-matched’ GQA sites which have a gauging station within 10km.

Table 7.9 Frequency distribution of the distance to the linked flow gauging station for the 2524 GQA sites whose linked gauging station is on a river stretch within one stream order of that of the site.

Blue-line river distance between GQA sites and linked gauging station (km)	Number of sites	Cumulative number of sites	% of sites	Cumulative %of sites
< 1.0	413	413	16.4	16.4
1 - 2	257	670	10.1	26.5
2 - 3	247	917	9.8	36.3
3 - 5	424	1341	16.8	53.1
5 - 10	664	2005	26.4	79.5
10 - 20	409	2414	16.2	95.7
20 - 50	103	2518	4.1	99.8
> 50	6	2524	0.2	100.0

7.5.2 Overall relationship between LIFE O/E and relative flows

Several of these 2005 ‘well matched’ GQA sites were linked to the same gauging station. Of the 725 gauging stations linked to at least one of these GQA sites, 27% were linked to only one GQA site, 29% to two sites, 29% to three or four sites and the remaining 15% to between five and 11 GQA sites. It might be worthwhile to examine the variation in LIFE O/E between all the GQA sites linked to the same gauging station or to profile the joint pattern of LIFE O/E and flow with progression down individual catchments, but this was beyond the scope of this initial investigation.

The relationships between LIFE O/E and the two measures of relative flow for the GQA sites are shown in Figures 7.13 and 7.14. The overall correlations between LIFE O/E and relative mean summer flow (%flow) and rank of summer flow in 1995 (%rank) amongst these 2005 ‘well-matched’ GQA were only 0.12 and 0.18 respectively; although the correlations were highly statistically significant ($p<0.001$) because of the very large sample sizes. This suggests a lack of any strong, consistent simple relationship between LIFE O/E in autumn 1995 and the preceding summer’s average flow that is applicable across the whole range of GQA sites.

One very important factor in the analyses was that summer 1995 was relatively dry, so that the summer flows in 1995 were low relative to the long term average across most areas of England and Wales. Thus there was a predominance of low values of relative flow (%flow) and flow rank (%rank) amongst the GQA sites in all Regions in 1995 (Table 7.10).

Just over 90% of GQA sites were linked to flow stations whose mean summer flow in 1995 was less than the long-term summer average at each site. This means that, just by chance, most of the low values of LIFE O/E will also be expected to occur in association with relatively low summer flows (because low flows were so widespread). Thus the relationships observed in Figures 7.13 and 7.14 between LIFE O/E and the two measures of relative flows need to be interpreted with caution; they might be expected by chance with no due underlying association. As an alternative approach, the sites were grouped into classes according to their value of %rank and assessed in terms of their distribution of values of LIFE O/E within each class (Table 7.11).

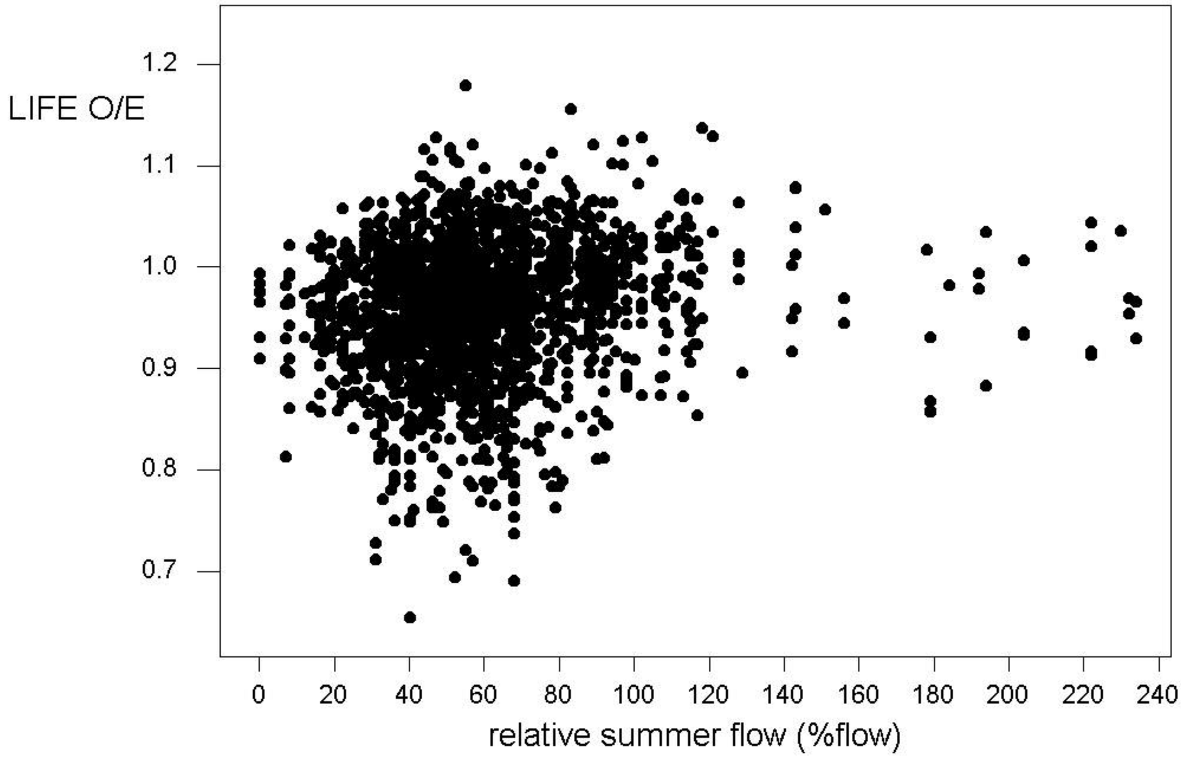


Figure 7.13 Relationship between autumn sample LIFE O/E and relative mean summer flow (%flow) for the 'well-matched' GQA sites in 1995 (*n* = 2005).

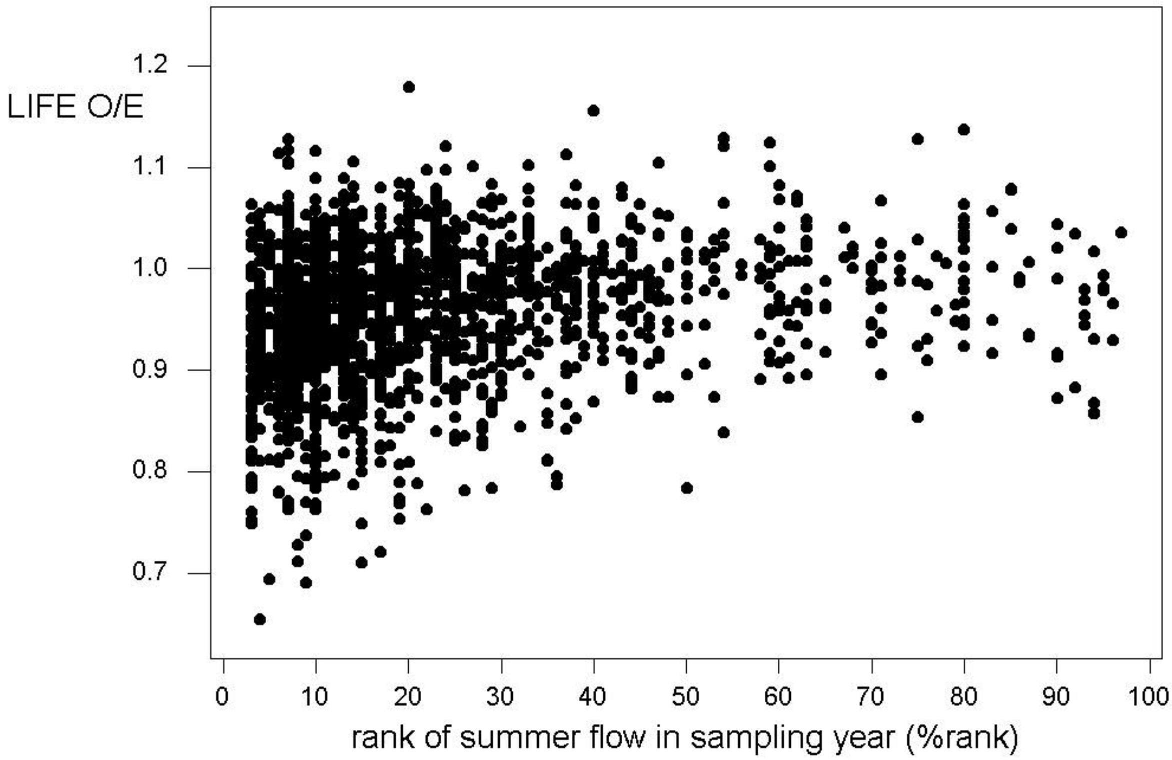


Figure 7.14 Relationship between autumn sample LIFE O/E and percentage rank (%rank) of mean summer flow for the 'well-matched' GQA sites in 1995 (*n* = 2005).

Table 7.10 Median and lower and upper quartile values of percentage rank (%rank) of the mean summer flow in 1995 for the 2005 'well-matched' GQA sites.

Region	number of GQA sites	Values of %rank		
		median	lower quartile	upper quartile
Anglian	252	30	21	41
North East	250	7	5	15
North West	234	10	7	20
Midlands	246	15	8	22
Southern	171	24	14	47
South West	375	13	10	20
Thames	189	23	13	44
Welsh	288	14	10	20
Overall	2005	15	10	27

Table 7.11 Classification of 'well matched' GQA sites by (a) LIFE O/E and rank of mean summer flow (%rank), (b) %rank within each class of LIFE O/E and (c) LIFE O/E within each class of %rank (n = 2005 sites).

(a)

		LIFE O/E					
		≤ 0.8	0.801 - 0.9	0.901 - 1.0	1.001 -1.1	>1.1	total
%rank	1-10	28	133	386	112	6	665
	11-20	11	88	370	167	2	638
	21-30	4	39	157	94	2	296
	31-50	3	18	144	75	4	244
	51-100	0	12	83	61	6	162
	total	46	290	1140	509	20	2005

(b)

		LIFE O/E					
		≤ 0.8	0.801 - 0.9	0.901 - 1.0	1.001 -1.1	>1.1	total
%rank	1-10	61	46	34	22	30	33
	11-20	24	30	32	33	10	32
	21-30	9	13	14	18	10	15
	31-50	7	6	13	15	20	12
	51-100	0	4	7	12	30	8
	total	100	100	100	100	100	100

(c)

		LIFE O/E					
		≤ 0.8	0.801 - 0.9	0.901 - 1.0	1.001 -1.1	>1.1	total
%rank	1-10	4.2	20.0	58.1	16.8	0.9	100
	11-20	1.7	13.8	58.0	26.2	0.3	100
	21-30	1.4	13.2	53.0	31.8	0.7	100
	31-50	1.2	7.4	59.0	30.7	1.6	100
	51-100	0.0	7.4	51.2	37.7	3.7	100
	total	2.3	14.5	56.9	25.4	1.0	100

Of the 46 GQA sites with autumn sample LIFE O/E less than or equal to 0.8, 61% had relative mean summer flows in 1995 ranked amongst the lowest 10% of all available years, even though only 33% of all the GQA sites had %rank of 10% or less (Table 7.10). A Chi-square test for association between class of LIFE O/E and class of %rank within Table 7.10(a) was highly statistically significant (Chi-square = 101.1, degrees of freedom = 16, $p < 0.001$). Sites with low relative flows were more than twice as likely as other sites to have LIFE O/E values less than or equal to 0.8 (Table 7.10(c)). Also the few sites with higher than normal summer flow in 1995 (i.e. %rank 51-100%) were more than twice as other sites to have LIFE O/E values greater than 1.1. However, the vast majority of GQA sites showed no distinct relationship between LIFE O/E in autumn 1995 with the preceding summer's mean flow.

7.5.3 Relationship between LIFE O/E and relative flows within site type

In section 7.5.2, we did not find a strong overall relationship between LIFE O/E for the autumn 1995 samples and the relative mean summer flow in 1995 amongst the GQA sites. However, some types of river are more prone to flow-related stress than others. In some rivers flowing over impervious rocks or prone to spates, low summer flows are both natural and common and the fauna may be partially adapted to such conditions.

The relationship between LIFE O/E and relative flow was therefore assessed separately for the GQA sites in each major type of river site. Sites were assigned to the same set of nine super-groups used to assess the RIVPACS reference sites (see section 7.4.2). RIVPACS predictions for the GQA sites gave their probability of belonging to each of the 35 RIVPACS site groups based on their environmental characteristics. For this specific analysis, the GQA sites were assigned to their most probable group and then combined into nine super-groups (Table 7.12). It is important to understand that this classification of the GQA sites is based solely on their environmental characteristics, whereas that for the RIVPACS reference sites was based solely on their macroinvertebrate composition.

Table 7.12 Correlations between LIFE O/E and %rank of the mean summer flow in the year of sampling for the n_1 RIVPACS reference sites in each TWINSPAN super-group which could be linked to a flow gauging station with adequate flow data and with a stream order within ±2 of that at the site ; n_2 = subset of the n_1 sites whose linked flow station was within 10km of the site

TWINSPAN groups	Sites in groups Total	n_1	n_2	Correlation
1-4	442	108	85	0.14
5-9	1052	175	134	0.19
10-14	97	51	40	0.00
15-17	564	300	231	0.18 ($p < 0.01$)
18-20	581	319	247	0.20 ($p < 0.01$)
21-24	399	265	229	0.30 ($p < 0.001$)
25-28	621	409	348	0.21 ($p < 0.001$)
29-32	1489	532	408	0.12 ($p < 0.01$)
33-35	771	365	284	0.14 ($p < 0.05$)
Total	6016	2524	2006	0.12 ($p < 0.001$)

The correlations between LIFE O/E and relative mean summer flow within each super-group site type range from 0.00 to 0.30 (Table 7.12, Figure 7.15-7.17). The relationship is strongest amongst sites in groups 21-24, which are intermediate size non-lowland streams mainly in northern and south-west England and Wales; all sites with LIFE O/E less than 0.9 occur at sites whose mean summer flow in 1995 was amongst the lowest 25% recorded at each site (Figure 7.16). This may be because sites in these groups are generally flashy rivers with the macroinvertebrates being more dependent on recent flows.

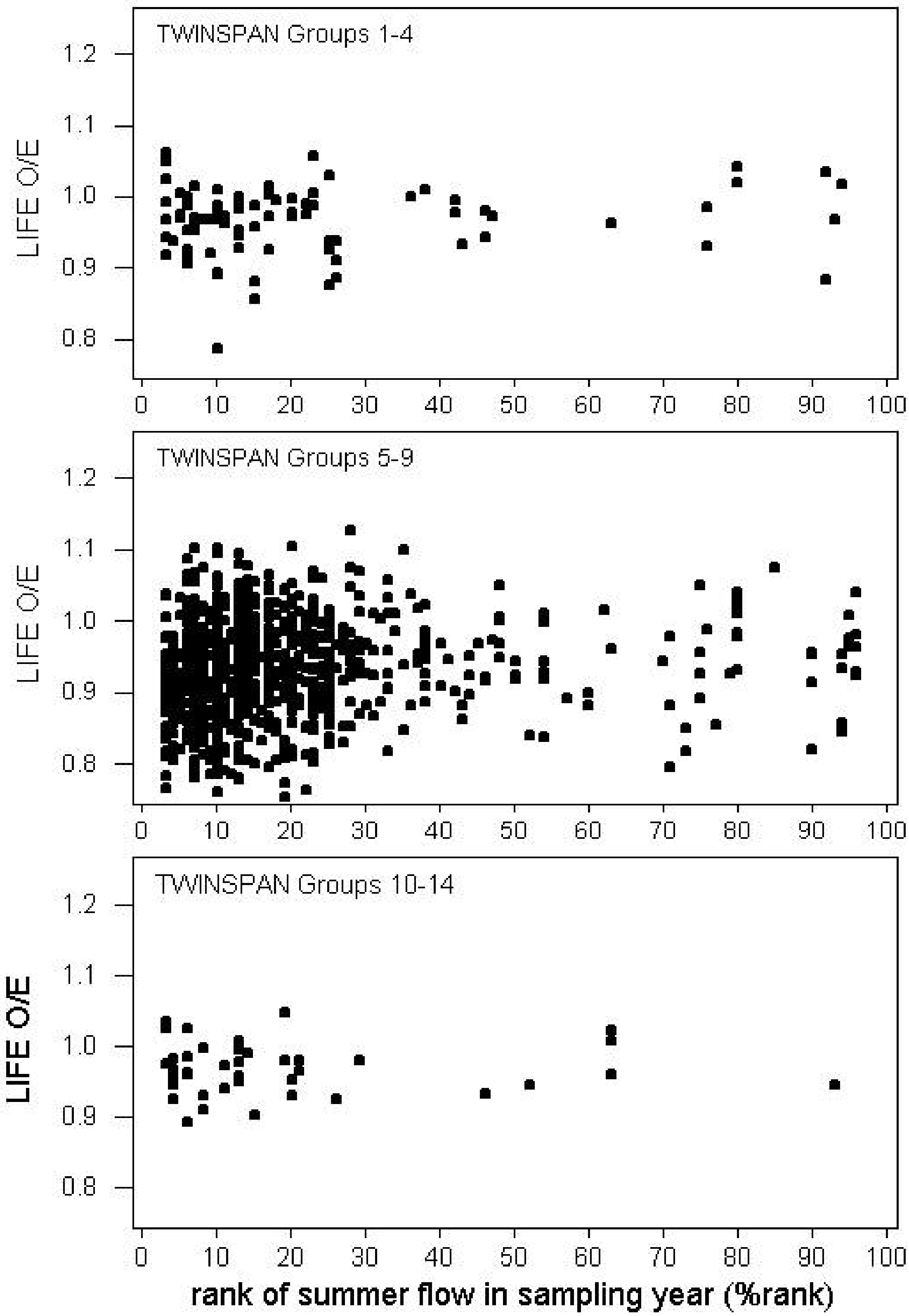


Figure 7.15 Relationship between autumn sample LIFE O/E and percentage rank (%rank) of mean summer flow in 1995 for GQA sites in TWINSPAN groups 1-4, 5-9 and 10-14.

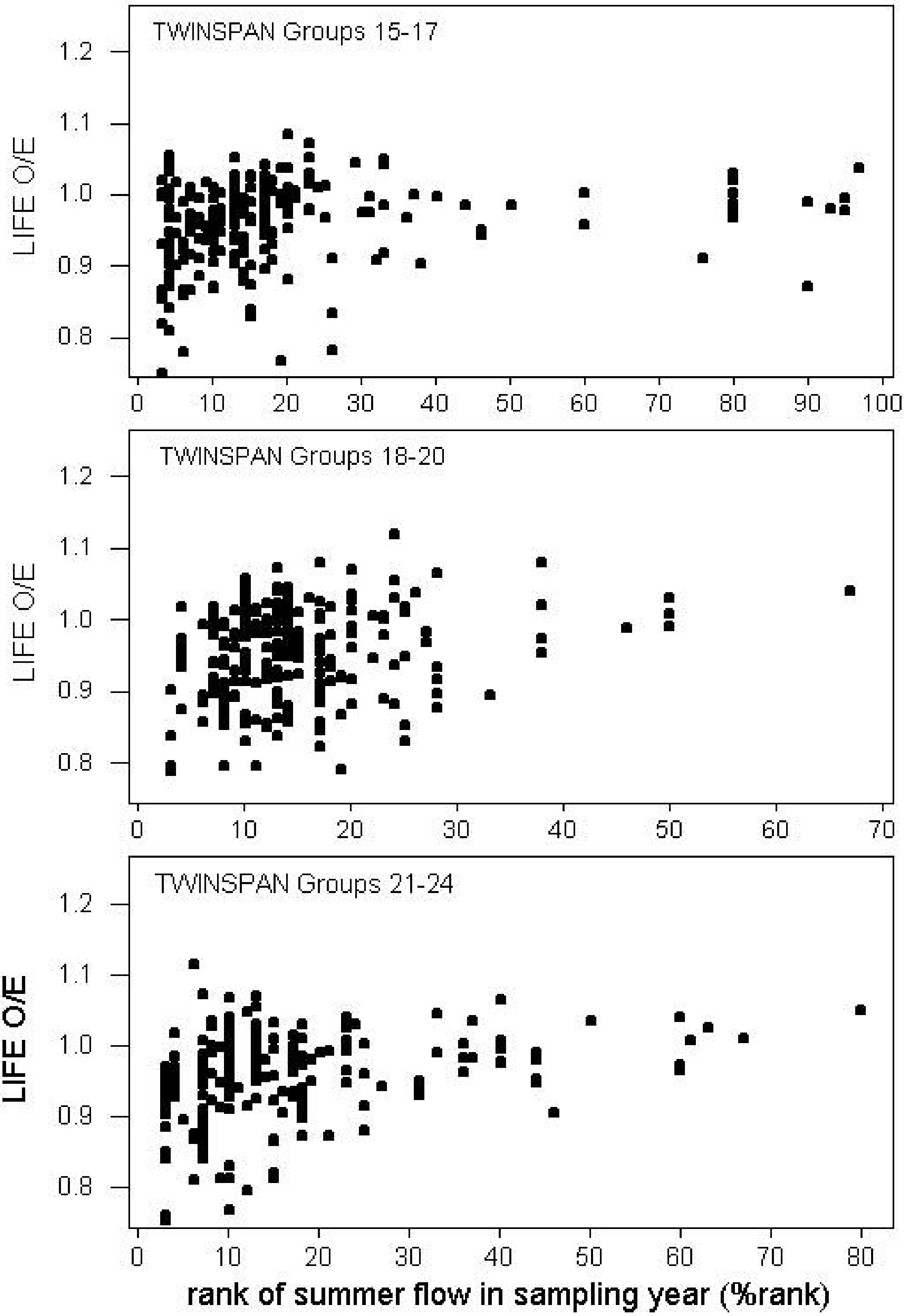


Figure 7.16 Relationship between autumn sample LIFE O/E and percentage rank (%rank) of mean summer flow in 1995 for GQA sites in TWINSPAN groups 15-17, 18-20 and 21-24.

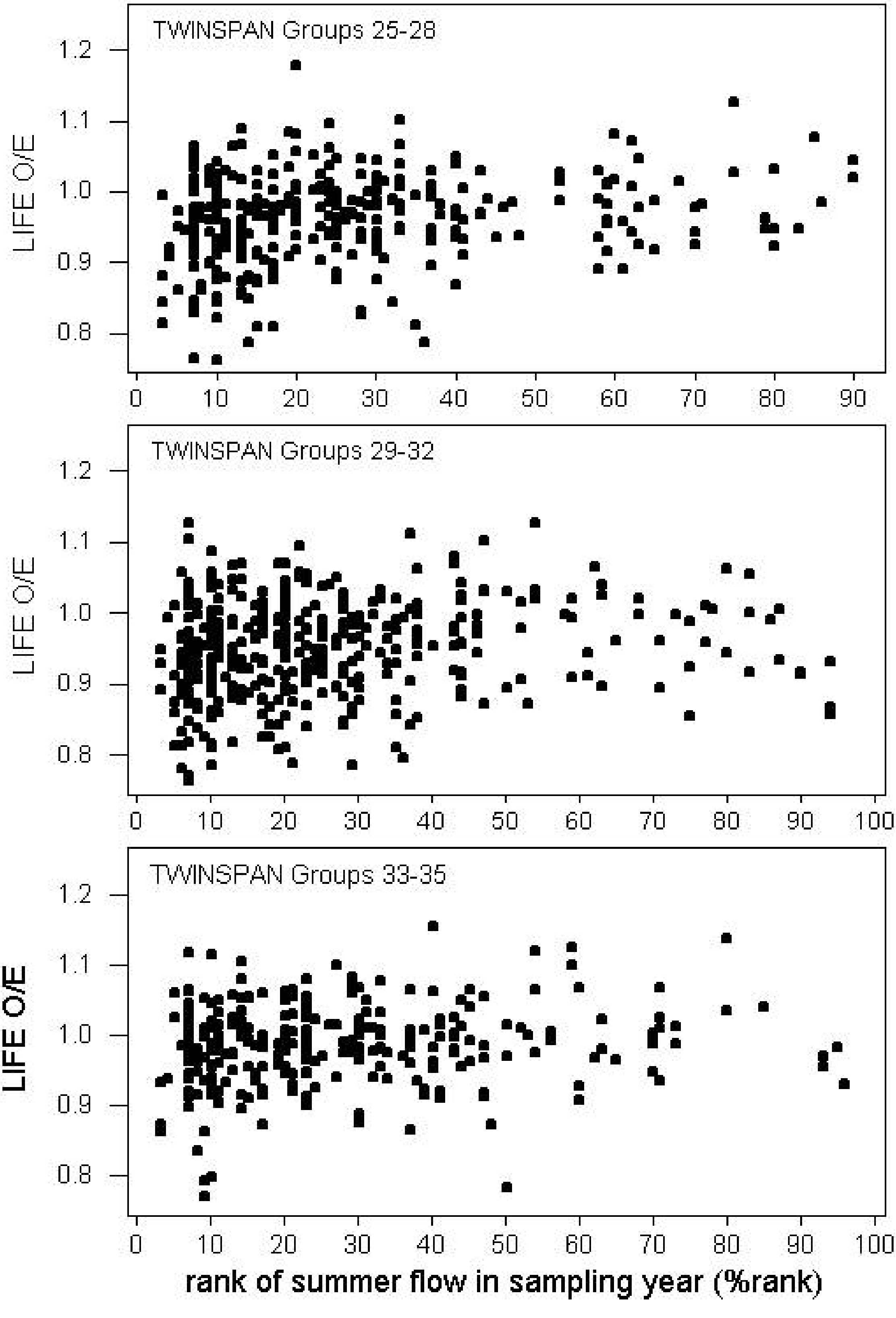


Figure 7.17 Relationship between autumn sample LIFE O/E and percentage rank (%rank) of mean summer flow in 1995 for GQA sites in TWINSPAN groups 25-28, 29-32 and 33-35.

In contrast large rivers, or rivers with high baseflow draining permeable catchments will be more dependent on flow conditions over a longer period. This may explain why autumn 1995 LIFE O/E values for such sites seem to be less dependent and only poorly correlated with the relatively recent flows of the previous summer. Sear *et al*. (1999) examined groundwater dominated sites which occurred in RIVPACS site groups 8, 25, 27, 32 and 33.

7.6 Summary

The locations of the flow gauging stations in the National Water Archive were carefully positioned on the CEH national river network GIS derived from the Ordnance Survey 1:50000 blue line network.

Forty one of the 614 RIVPACS reference sites were in catchments with no gauging station and a further 130 sites were closest to gauging stations which had no flow data in the year of sampling macroinvertebrates for RIVPACS. The remaining 443 reference sites were carefully positioned on the blue-line network within the GIS and the Strahler stream order at the site and gauging station determined using GIS algorithms to assess compatibility of station and site.

There does not appear to be any systematic tendency for the RIVPACS reference sites of any particular type to have been sampled during years of relatively low flows. Therefore the predictions of expected LIFE are not systematically biased for any particular type of site.

There are a very small number of reference sites which were sampled in years of relatively low flow and had low LIFE O/E values.

In particular the sites at:

Hilersham (code 6259) on the river Granta,
Longham (code 6811) on the river Stour in Dorset
and Corpslanding (code 9113) on the river Hull drainage system.

These three reference sites were all assigned to TWINSPAN group 33 in the original biological classification used in the development of RIVPACS III. Site group 33 is a relative large group containing 31 reference sites; mostly lowland slow-flowing river sites.

It is recommended that these three sites are eliminated from the RIVPACS estimation of expected LIFE. (This will require revisions to the predictive equations and RIVPACS software to provide new estimates of the probabilities of occurrence and average (log) abundance categories based on the remaining reference sites in this group.)

It was possible to link 2005 of the biological GQA sites surveyed in 1995 to suitable gauging stations of similar stream order within 10km which had complete summer flow data in 1995 and in at least four other years. One very important factor in the analyses was that summer 1995 was relatively dry, so that the summer flows in 1995 were low relative to the long term average across most areas of England and Wales. This made it more difficult to detect relationships between LIFE O/E and relative flows.

The vast majority of such GQA sites with very low values of LIFE O/E (i.e. <0.8) had mean summer flows in 1995 which were ranked amongst the lowest 20% of all years with flow data available. Sites whose flows in summer 1995 were amongst the lowest recorded (for each site) were more than twice as likely as other sites to have LIFE O/E values less than or equal to 0.8. Also the few sites with higher than normal summer flow in 1995 (i.e. %rank 51-100%) were more than twice as likely as other sites to have very high LIFE O/E values (i.e. >1.1).

However, the general correlations between autumn sample LIFE O/E and relative summer flows in the preceding summer for the 1995 GQA sites were statistically significant, but weak, both overall and for sites within each environmental type. Correlations were strongest for intermediate size non-lowland streams occurring mainly in northern and south-west England and Wales, which include flashy rivers where the macroinvertebrates are more likely to be dependent on recent flows.

It must be pointed out that although this simple analysis of a large number of GQA sites is useful, it is far from ideal. Autumn LIFE O/E values were only assessed in relation to relative mean flows in the immediately preceding summer. Extence *et al*. (1999) have shown that LIFE scores for sites on many types of rivers tend to be most highly correlated with preceding flows over a much longer period that just the preceding three or four months.

More research is needed on developing relationships between LIFE O/E and flow parameters whose time period and form vary with the type of site.

Time series of linked flow and LIFE data for a range of sites are currently being analysed within a separate collaborative R&D project between the CEH and the Environment Agency titled ‘Generalised LIFE response curves’.

8. CONCLUSIONS AND RECOMMENDATIONS

This final section collates and summarises the conclusions and recommendations (highlighted in italics) derived from the various components of this R&D project. Where appropriate, a conclusion or recommendation is cross-referenced to the report section where further details may be obtained.

Over 70% of the total variation in observed LIFE amongst the 614 RIVPACS reference sites can be explained by differences between the 35 biological site groups into which the RIVPACS reference sites are classified (section 2.2).

The methods prescribed in Murray-Bligh (1999) for estimating the values for all the environmental RIVPACS predictor variables for a site should be used in any prediction of expected LIFE for a site (section 2.3.2).

LIFE was positively correlated with site altitude and slope and the percentage substratum cover of boulders and cobbles; it was negatively correlated with stream depth and in-stream alkalinity and the percentage cover of sand and fine silt or clay sediment.

CEH have derived a numerical algorithm to provide predictions of the expected LIFE for any river site based on its values for the standard RIVPACS environmental predictor variables (section 2.3). This algorithm is compatible with the derivation of expected ASPT, gives appropriate lower weighting to taxa with lower expected probabilities of occurrence and hence should be used in preference to the current LIFECALCULATOR method.

It is recommended that this new algorithm for calculating expected LIFE is incorporated into an updated Windows version of the RIVPACS software system to provide automatic calculation of observed LIFE, expected LIFE and hence LIFE O/E for any macroinvertebrate sample and river site.

It is recommended that LIFE O/E be calculated, stored and presented to an accuracy of 3 decimal places. The observed (O) and expected (E) LIFE need only be calculated, stored and presented to an accuracy of 2 decimal places, so that O, E and O/E values are all stored to 3 significant figures.

When based on its standard suite of environmental predictor variables, RIVPACS predictions of expected LIFE were very effective overall, with correlations between observed life and expected LIFE of 0.78 for the 614 RIVPACS reference sites. Expected LIFE can vary between 5.93 and 7.92.

A provisional six grade system for LIFE O/E was developed based on the frequency distributions of values of LIFE O/E for the high quality RIVPACS reference sites and the wide ranging GQA sites.

The LIFE and ASPT indices are naturally correlated to some extent; macroinvertebrate families which require fast flowing conditions tend to also be susceptible to organic pollution, and vice versa.

Amongst the GQA sites the correlation between LIFE O/E and O/E based on ASPT is only 0.69. The LIFE and BMWP scoring systems do not therefore appear to be completely confounded. This suggests that LIFE O/E may often provide additional and separate information on the biological condition of a site which is not covered by the BMWP-based EQI indices. It may be possible to use the biota to help differentiate flow-related stress from organic dominated stress.

However, the apparent lack of agreement in site assessments using the two scoring systems must be at least partly due to the effects of sampling variation on both sets of O/E ratios. This will be correlated variation as the O/E ratios for a site are all calculated from the same sample(s).

Further research is needed urgently to assess the influence of sampling variation on the observed relationship between LIFE O/E and EQI_{ASPT} and the extent to which they can be used to identify different forms of stress.

The sensitivity of RIVPACS predictions of expected LIFE to flow related characteristics at a site was assessed by simulating alterations to stream width, depth, discharge category and substratum composition (section 4). Within a site type, realistic changes led to relatively small changes, usually less than 0.3, in expected LIFE. This suggests that RIVPACS predictions of expected LIFE are robust and mostly vary with the major physical types of site. (This simulation approach using only the reference sites cannot be used to predict the biological impact of a flow-related stress.)

Ideally, the RIVPACS predictions of the 'target' or expected LIFE, should not involve variables whose values when measured in the field may have already been altered by the flow-related stresses whose effects LIFE O/E is being used to detect. Using new predictions not involving the RIVPACS variables based on substratum particle size composition, stream width and depth, the change in expected LIFE is less than 0.10 for over 70% of sites and the change in LIFE O/E is less than 0.02 for 80% of sites (section 5).

However, omitting these variables, especially mean substratum particle size, lead to significant increases and hence over-predictions of expected LIFE for large and/or slow-flowing lowland river sites (in RIVPACS sites groups 33-35), which then under-estimated LIFE O/E for this type of site (section 5.4). This problem needs resolving.

Further research is needed to improve predictions and the setting of targets for expected LIFE for large slow flowing lowland rivers without using the flow-related predictor variables, stream width and depth and substratum composition.

It is recommended that further research be commissioned to investigate the potential to use environmental variables derived from GIS, to provide temporally-invariant predictions of the expected fauna, and expected LIFE, at any test site. Using GIS-derived variables, such as upstream catchment or river corridor geological composition, may help overcome the potential problem of using the predictor variables, stream width and depth and substratum composition, whose values may have already been modified by flow-related stress.

Sampling variation in observed LIFE was assessed using the replicated sampling study sites involved in quantifying sampling variation of ASPT and number of BMWP taxa as used in the uncertainty assessment of EQIs in RIVPACS III+. Sampling variation in LIFE was found to be small relative to differences between physical types of site. There was no evidence that sampling differences between operators affected LIFE.

The sampling standard deviation of LIFE decreased with the number of LIFE-scoring families present at a site; a predictive equation has been derived. It is recommended that this relationship is used in any future assessment of uncertainty in values of LIFE O/E.

The current study included the first quantitative assessment of the flow conditions in the year of sampling each reference site relative to the flows in other years at the same site. Reference sites were carefully linked to the most appropriate national flow gauging station using the CEH national river network GIS. For most types of site there was no relationship between autumn sample LIFE O/E and the relative mean summer (June-August) flow in the immediately preceding summer.

Three lowland river reference sites of the same biological type were identified as having low LIFE O/E and sampled in years of relatively low summer flows. It is recommended that these three sites are not involved in RIVPACS predictions of expected LIFE.

Removing these three sites, which are all from RIVPACS site group 33, may also reduce the problem, discussed above, of over-predicting expected LIFE for lowland sites in RIVPACS site groups 33-35 when flow-related variables are excluded from the predictions.

Around 2000 of the biological GQA sites sampled in 1995 were linked, using the GIS, to suitable gauging stations of similar Strahler stream order within 10km which had complete summer flow data in 1995 and in at least four other years. One important factor influencing the ability to detect relationships between LIFE and flows was that river flows were less, often much less, than average in all regions of England and Wales in 1995.

Correlations between autumn sample LIFE O/E and relative summer flows in the preceding summer were statistically significant, but weak, both overall and for sites within each biological type. Correlations were strongest for intermediate size non-lowland streams occurring mainly in northern and south-west England and Wales, which include flashy rivers where the macroinvertebrates are more likely to be dependent on recent flows.

However, the vast majority of the GQA sites with very low values of LIFE O/E (i.e. less than 0.8) had mean summer flows in 1995 which were ranked amongst the lowest 20% of all years with flow data available. These GQA sites are likely to have been suffering from flow related stress in 1995. In contrast, a large proportion of GQA sites with relatively low flows had relatively high values of LIFE O/E in autumn 1995. The autumn 1995 macroinvertebrate fauna at many of these sites may be dependent on flow conditions over longer or earlier periods than just the preceding summer.

In this study, the only flow variable considered was relative mean summer flow and this was correlated with autumn sample LIFE O/E across all GQA sites. The correlations were less than those found by Extence *et al* (1999) within individual sites between observed LIFE and the best of a large range of flow variables measured over a period of years.

More research is needed on developing relationships between LIFE O/E and flow parameters whose time period and form vary with the type of site.

Autumn 2000 was a period of very high flows in many regions, which contrast with the generally low flows in 1995. It may be useful to compare differences in LIFE O/E with *differences in flows between the two years amongst those sites with matched flow data that were surveyed in both the 1995 and 2000 GQA surveys.*

LIST OF FIGURES

LIST OF TABLES

REFERENCES

Armitage, P.D. (1989) The application of a classification and prediction technique based on macroinvertebrates to assess the effects of river regulation. In*: Alternatives in Regulated River Management* (eds Gore, J.A. & Petts, G.E.), 267-293. CRC Press Inc., Boca Raton, Florida.

Armitage, P.D., Cannan, C.A. & Symes, K.L. (1997) Appraisal of the use of ecological information in the management of low flows in rivers. Environment Agency R&D Technical Report W72, 97pp.

Armitage, P.D. (2000) The potential of RIVPACS for predicting the effects of environmental change. In Assessing the biological quality of freshwaters – RIVPACS and other techniques. Wright, J.F., Sutcliffe, D.W. and Furse, M..T.(eds), 93-111. Freshwater Biological Association, Ambleside.

Clarke, R.T. (2000) Uncertainty in estimates of river quality based on RIVPACS. In: Assessing the biological quality of fresh waters: RIVPACS and other techniques. Wright, J.F., Sutcliffe, D.W. and Furse, M..T.(eds),39-54. Freshwater Biological Association, Ambleside.

Clarke R.T., Furse M.T., Wright J.F. & Moss D. (1996) Derivation of a biological quality index for river sites: comparison of the observed with the expected fauna. *Journal of Applied Statistics*, **23**, 311-332.

Clarke, R.T., Cox, R., Furse, M.T., Wright, J.F. & Moss, D (1997). RIVPACS III+ User Manual. (River Invertebrate Prediction and Classification System with error assessments.) July 1997. Environment Agency. R&D Technical Report E26, 64pp + appendices.

Clarke, R.T., Furse, M.T. & Bowker, J. (1999) Analysis of the 1995 survey data. Phase 2 Post-survey appraisal. Unit II: Post-survey appraisal. Environment Agency R&D Technical Report E101, 130pp, Bristol: Environment Agency.

Clarke, R.T. & Wright, J.F. 2000. Testing and Further development of RIVPACS Phase 3. Development of new RIVPACS Methodologies. Stage 2. Environment Agency R&D Technical Report E124, 95pp, Bristol: Environment Agency.

Council of the European Communities (2000) Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, *Official Journal of the European Communities* L327 (43), 1-72.

Cox, R., Wright, J.F., Furse, M.T. & Moss, D. (1995) *RIVPACS III (River Invertebrate Prediction and Classification System). User Manual*. R&D Note 454, National Rivers Authority, Bristol.

Davy-Bowker, J., Furse, M.T., Clarke, R.T. & Gravelle, M.J. 2000. Analysis of the 1995 survey data. Phase 2 Post-survey appraisal. Unit I: Taxon distribution studies. Environment Agency R&D Technical Report E103, 552pp, Bristol: Environment Agency.

Elliott J.M. (1977) *Some methods for the statistical analysis of samples of benthic invertebrates*. Scientific Publication No. 25, 2nd edition. pp 160. Freshwater Biological Association, Ambleside.

Extence, C.A., Balbi, D.M. & Chadd, R.P. (1999). River flow indexing using British benthic macroinvertebrates: a framework for setting hydroecological objectives. *Regulated River: Research and Management*, **15**, 543-574.

Furse, M.T., Clarke, R.T., Winder, J.M., Symes, K.L., Blackburn, J.H., Grieve, N.J. and Gunn, R.J.M. (1995) *Biological assessment methods: controlling the quality of biological data. package 1: The variability of data used for assessing the biological condition of rivers.* R&D Note 412, National Rivers Authority, Bristol. 139pp.

Furse, M.T., Clarke, R.T. , Davy-Bowker, J. & Vowles, K. 2000. Analysis of the 1995 survey data. Phase 2 Post-survey appraisal. Unit III: Post-survey appraisal. Environment Agency R&D Technical Report E102, 145pp, Bristol: Environment Agency.

Hornby D.D., Clarke R.T., Wright J.F. & Dawson F.H. (2002). Testing and further development of RIVPACS. Phase 3 An evaluation of procedures for acquiring environmental variables for use in RIVPACS from a GIS. Environment Agency R&D Technical Report, Bristol: Environment Agency.

Lanfear, K. J., 1990. A fast algorithm for automatically computing Strahler stream order. Water Resources Bulletin, 26, 6: 977-981.

Levene, H. 1960. Contributions to probability and statistics, pp. 278-292. Stamford University Press, California.

Minitab 1999. Minitab 13.1 User Guide, State College, Pennsylvania.

Moss, D., Furse, M.T., Wright, J.F. & Armitage, P.D. (1987) The prediction of the macroinvertebrate fauna of unpolluted running-water sites in Great Britain using environmental data. *Freshwater Biology*, 17, pp. 41-52.

Murray-Bligh, J.A.D. 1999. Procedure for collecting and analysing macroinvertebrate samples for RIVPACS. Quality Management Systems for Environmental Monitoring: Biological Techniques BT001. (Version 2.0 30 July 1999) Bristol, Environment Agency.

National Rivers Authority (1994) *The quality of rivers and canals in England and Wales (1990 to 1992)*, Water Quality Series, 19. National Rivers Authority, Bristol.

SAS (1989) SAS/STAT User's Guide, Version 6, 4th edition, Vol.2., SAS Institute, Cary.

Sear, D.A., Armitage, P.D. & Dawson, F.H. (1999) Groundwater dominated rivers. *Hydrological Processes*, 13, 255-276.

Strahler, A. N., 1957. Quantitative analysis of watershed geomorphology. Transactions of the American Geophysical Union 38: 913 – 920.

Taylor, L.R. (1961) Aggregation, variance and the mean. *Nature*, **189**, 732-735.

Walley, W.J. & Hawkes, H.A. (1996) A computer-based reappraisal of the Biological Monitoring Working Party score system using data from the 1990 river quality survey of England and Wales. *Water Research*, **30,** 2086-2094.

Walley, W.J. & Hawkes, H.A. (1997) A computer-based development of the Biological Monitoring Working Party score system incorporating abundance rating, site type and indicator value. *Water Research*, **31,** 201-210.

Wright, J.F., Furse, M.T., Clarke, R.T. & Moss, D. 1991. *Testing And Further development of RIVPACS*. For National Rivers Authority. 141pp.

Wright J.F. (1995) Development and use of a system for predicting the macroinvertebrate fauna in flowing waters. *Australian Journal of Ecology*, **20**, 181-197.

Wright J.F. (2000) An introduction to RIVPACS. In: *Assessing the biological quality of fresh waters: RIVPACS and other techniques*. (eds J.F.Wright, D.W. Sutcliffe & M.T. Furse), pp 1-24. Freshwater Biological Association, Ambleside.

Wright J.F., Moss D., Armitage P.D. & Furse M.T. (1984) A preliminary classification of running-water sites in Great Britain based on macroinvertebrate species and the prediction of community type using environmental data. *Freshwater Biology*, **14**, 221-256.

Wright, J.F., Furse, M.T., Clarke, R.T., Moss, D., Gunn, R.J.M., Blackburn, J.H., Symes, K.L., Winder, J.M., Grieve, N.J. & Bass, J.A.B. (1995). Testing And Further Development Of RIVPACS. R&D Note 453 for National Rivers Authority. (2 Vols.: 77pp & 110pp)

Wright, J.F., Clarke, R.T., Gunn, R.J.M., Blackburn, J.H. & Davy-Bowker, J. (1999). Testing and further development of RIVPACS Phase 3. Development of new RIVPACS Methodologies. Stage 1. Environment Agency R&D Technical Report E71. 138pp.

APPENDIX 1

The 31 sites used in section 4 (Module 4) in the simulation of the effects on expected LIFE of flow-related changes to site characteristics, together with the current and step-wise altered conditions, expected LIFE and the RIVPACS suitability code in each case.

River name	Site number	Major TWINSPAN group (1-9)	Site Name	Discharge category	Width	Depth	%Boulders/cobbles	%Pebbles/gravel	%Sand	%Silt/clay	Mean substratum (phi units)	Expected LIFE	Suitability code
South Tyne	1	1	South Tyne Head	3	1.70	10.80	82.0	18.0	0.0	0.0	-6.94	7.72	2
South Tyne	1	1	South Tyne Head	2	1.40	8.00	82.0	14.0	0.0	4.0	-6.49	7.69	1
South Tyne	1	1	South Tyne Head	2	1.10	7.50	82.0	9.0	0.0	9.0	-5.93	7.69	1
South Tyne	1	1	South Tyne Head	1	0.80	6.00	82.0	6.0	0.0	12.0	-5.59	7.73	1
South Tyne	1	1	South Tyne Head	1	0.50	5.00	82.0	0.0	0.0	18.0	-4.92	7.7	3
Pickering Beck	2	1	Levisham	1	4.00	13.10	47.0	26.0	0.0	27.0	-2.33	7.34	1
Pickering Beck	2	1	Levisham	1	3.00	11.00	47.0	21.0	0.0	32.0	-1.77	7.33	1
Pickering Beck	2	1	Levisham	1	2.50	9.50	47.0	13.0	0.0	40.0	-0.87	7.31	1
Pickering Beck	2	1	Levisham	1	1.80	4.50	47.0	6.0	0.0	47.0	-0.08	7.16	4
Pickering Beck	2	1	Levisham	1	1.00	6.00	47.0	3.0	0.0	50.0	0.26	7.34	4
Derwent	3	1	Grange-In-Borrowdale	5	18.20	21.10	25.0	70.0	5.0	0.0	-4.11	7.66	1
Derwent	3	1	Grange-In-Borrowdale	4	16.00	18.00	25.0	65.0	5.0	5.0	-3.55	7.66	1
Derwent	3	1	Grange-In-Borrowdale	3	12.00	15.00	25.0	60.0	5.0	10.0	-2.99	7.68	1
Derwent	3	1	Grange-In-Borrowdale	2	8.00	12.00	25.0	50.0	0.0	25.0	-1.56	7.55	1
Derwent	3	1	Grange-In-Borrowdale	1	4.00	10.00	25.0	25.0	0.0	50.0	1.25	7.53	2
Unnamed	4	2	Gasper	1	0.80	9.90	8.0	70.0	10.0	12.0	-1.74	7.42	1
Unnamed	4	2	Gasper	1	0.80	8.00	8.0	55.0	12.0	25.0	-0.17	7.37	1
Unnamed	4	2	Gasper	1	0.70	7.00	8.0	45.0	20.0	27.0	0.48	7.28	1
Unnamed	4	2	Gasper	1	0.60	6.00	8.0	30.0	25.0	37.0	1.87	7.32	1
Unnamed	4	2	Gasper	1	0.50	4.00	8.0	20.0	30.0	42.0	2.69	7.14	1
By Brook	5	2	Gatcombe Hill	1	5.80	32.20	18.0	53.0	24.0	5.0	-2.24	7.02	1
By Brook	5	2	Gatcombe Hill	1	4.70	25.00	18.0	44.8	25.5	11.8	-1.40	7.01	1
By Brook	5	2	Gatcombe Hill	1	3.70	20.00	18.0	36.5	27.0	18.5	-0.56	6.98	1
By Brook	5	2	Gatcombe Hill	1	2.60	15.00	18.0	28.3	28.5	25.3	0.28	6.95	1
By Brook	5	2	Gatcombe Hill	1	1.50	10.00	18.0	20.0	30.0	32.0	1.12	6.86	1
Great Eau	6	2	Ruckland	1	2.20	18.90	41.0	41.0	1.0	17.0	-3.13	7.13	1
Great Eau	6	2	Ruckland	1	1.70	16.00	41.0	32.8	2.8	23.5	-2.31	7.09	1
Great Eau	6	2	Ruckland	1	1.40	14.00	41.0	24.5	4.5	30.0	-1.48	7.08	1
Great Eau	6	2	Ruckland	1	1.00	12.00	41.0	16.3	6.3	36.5	-0.66	7.08	1
Great Eau	6	2	Ruckland	1	0.80	10.00	41.0	8.0	8.0	43.0	0.16	7.08	1
Cowside Beck	7	3	Arncliffe	3	7.50	28.20	91.0	9.0	0.0	0.0	-7.35	7.73	1
Cowside Beck	7	3	Arncliffe	2	6.25	23.65	91.0	6.8	0.0	2.3	-7.09	7.69	1
Cowside Beck	7	3	Arncliffe	2	5.00	19.10	91.0	4.5	0.0	4.5	-6.84	7.62	1
Cowside Beck	7	3	Arncliffe	1	3.75	14.55	91.0	2.3	0.0	6.8	-6.59	7.57	1
Cowside Beck	7	3	Arncliffe	1	2.50	10.00	91.0	0.0	0.0	9.0	-6.33	7.51	1
Ribble/Gayle Beck	8	3	Horton In Ribblesdale	5	12.50	31.10	86.0	13.0	0.0	1.0	-7.01	7.73	1
Ribble/Gayle Beck	8	3	Horton In Ribblesdale	4	10.13	25.83	86.0	10.0	0.0	4.0	-6.67	7.68	1
Ribble/Gayle Beck	8	3	Horton In Ribblesdale	3	7.75	20.55	86.0	7.0	0.0	7.0	-6.33	7.71	1
Ribble/Gayle Beck	8	3	Horton In Ribblesdale	2	5.38	15.28	86.0	4.0	0.0	10.0	-6.00	7.57	1
Ribble/Gayle Beck	8	3	Horton In Ribblesdale	1	3.00	10.00	86.0	0.0	0.0	14.0	-5.55	7.57	1
Swale	9	3	Grinton	6	20.00	32.80	81.0	17.0	2.0	0.0	-6.79	7.83	1
Swale	9	3	Grinton	5	16.25	27.10	81.0	12.8	2.8	3.5	-6.36	7.7	1
Swale	9	3	Grinton	4	12.50	21.40	81.0	8.5	3.5	7.0	-5.92	7.58	1
Swale	9	3	Grinton	2	10.63	18.55	81.0	6.4	3.9	8.8	-5.71	7.46	1
Swale	9	3	Grinton	1	5.00	10.00	81.0	0.0	5.0	14.0	-5.06	7.46	2
South Tyne	10	3	Featherstone	6	24.30	28.90	88.0	12.0	0.0	0.0	-7.21	7.71	1
South Tyne	10	3	Featherstone	5	19.48	24.18	88.0	9.0	0.0	3.0	-6.87	7.71	1

River name	Site number	Major TWINSPAN group (1-9)	Site Name	Discharge category	Width	Depth	%Boulders/cobbles	%Pebbles/gravel	%Sand	%Silt/clay	Mean substratum (phi units)	Expected LIFE	Suitability code
South Tyne	10	3	Featherstone	4	14.65	19.45	88.0	6.0	0.0	6.0	-6.54	7.71	1
South Tyne	10	3	Featherstone	2	12.24	17.09	88.0	4.0	0.0	8.0	-6.31	7.72	1
South Tyne	10	3	Featherstone	1	5.00	10.00	88.0	0.0	0.0	12.0	-5.86	7.55	4
Clwyd	11	4	Nantclwyd Hall	2	4.60	17.30	12.0	84.0	3.0	1.0	-3.52	7.33	1
Clwyd	11	4	Nantclwyd Hall	2	3.95	15.48	12.0	73.0	3.0	12.0	-2.28	7.34	1
Clwyd	11	4	Nantclwyd Hall	1	3.30	13.65	12.0	62.0	3.0	23.0	-1.05	7.27	1
Clwyd	11	4	Nantclwyd Hall	1	2.98	12.74	12.0	56.5	3.0	28.5	-0.43	7.2	1
Clwyd	11	4	Nantclwyd Hall	1	2.00	10.00	12.0	40.0	3.0	45.0	1.43	6.97	2
Walkham	12	4	Grenofen	4	11.90	20.10	66.0	22.0	8.0	4.0	-5.35	7.49	1
Walkham	12	4	Grenofen	3	9.43	17.58	66.0	16.5	8.0	9.5	-4.73	7.49	1
Walkham	12	4	Grenofen	2	6.95	15.05	66.0	11.0	8.0	15.0	-4.11	7.49	1
Walkham	12	4	Grenofen	1	5.71	13.79	66.0	8.3	8.0	17.8	-3.80	7.49	1
Walkham	12	4	Grenofen	1	2.00	10.00	66.0	0.0	8.0	26.0	-2.88	7.47	1
Ribble/Gayle Beck	13	4	Mitton Bridge	7	31.70	62.80	86.0	14.0	0.0	0.0	-7.12	7.29	1
Ribble/Gayle Beck	13	4	Mitton Bridge	5	25.03	52.10	86.0	10.5	0.0	3.5	-6.73	7.29	1
Ribble/Gayle Beck	13	4	Mitton Bridge	4	18.35	41.40	86.0	7.0	0.0	7.0	-6.33	7.24	1
Ribble/Gayle Beck	13	4	Mitton Bridge	2	15.01	36.05	86.0	5.3	0.0	8.8	-6.14	7.22	1
Ribble/Gayle Beck	13	4	Mitton Bridge	1	5.00	20.00	86.0	0.0	0.0	14.0	-5.55	7.17	2
Ober Water	14	5	Puttles Bridge	1	3.40	13.50	9.0	86.0	4.0	1.0	-3.33	7.1	1
Ober Water	14	5	Puttles Bridge	1	2.80	11.63	9.0	72.0	4.0	15.0	-1.76	7.1	1
Ober Water	14	5	Puttles Bridge	1	2.20	9.75	9.0	58.0	4.0	29.0	-0.18	7.1	1
Ober Water	14	5	Puttles Bridge	1	1.90	8.81	9.0	51.0	4.0	36.0	0.61	7.1	1
Ober Water	14	5	Puttles Bridge	1	1.00	6.00	9.0	30.0	4.0	57.0	2.97	7.1	2
Lugg	15	5	Combe	4	7.70	32.40	22.0	68.0	3.0	7.0	-3.30	7.37	1
Lugg	15	5	Combe	3	6.28	26.80	22.0	56.0	3.0	19.0	-1.95	7.29	1
Lugg	15	5	Combe	2	4.85	21.20	22.0	44.0	3.0	31.0	-0.60	7.23	1
Lugg	15	5	Combe	2	4.14	18.40	22.0	38.0	3.0	37.0	0.08	7.19	1
Lugg	15	5	Combe	1	2.00	10.00	22.0	20.0	3.0	55.0	2.11	7.05	3
Otter	16	5	Newton Poppleford	5	19.00	28.30	49.0	47.0	2.0	2.0	-5.13	7.12	1
Otter	16	5	Newton Poppleford	4	15.25	23.73	49.0	37.8	2.0	11.3	-4.08	7.09	1
Otter	16	5	Newton Poppleford	3	11.50	19.15	49.0	28.5	2.0	20.5	-3.04	7.04	1
Otter	16	5	Newton Poppleford	2	9.63	16.86	49.0	23.9	2.0	25.1	-2.52	7.07	1
Otter	16	5	Newton Poppleford	1	4.00	10.00	49.0	10.0	2.0	39.0	-0.96	7.02	1
Wansbeck	17	6	Middleton	2	6.00	21.70	77.0	16.0	7.0	0.0	-6.35	7.37	1
Wansbeck	17	6	Middleton	2	5.00	18.78	77.0	13.0	5.3	4.8	-5.91	7.37	1
Wansbeck	17	6	Middleton	1	4.00	15.85	77.0	10.0	3.5	9.5	-5.46	7.39	1
Wansbeck	17	6	Middleton	1	3.50	14.39	77.0	8.5	2.6	11.9	-5.24	7.39	1
Wansbeck	17	6	Middleton	1	2.00	10.00	77.0	4.0	0.0	19.0	-4.58	7.4	1
Wansbeck	18	6	Bothal	5	16.70	27.20	56.0	35.0	4.0	5.0	-5.00	7.21	1
Wansbeck	18	6	Bothal	4	13.03	22.90	56.0	27.5	4.0	12.5	-4.15	7.21	1
Wansbeck	18	6	Bothal	3	9.35	18.60	56.0	20.0	4.0	20.0	-3.31	7.16	1
Wansbeck	18	6	Bothal	2	7.51	16.45	56.0	16.3	4.0	23.8	-2.89	7.06	1
Wansbeck	18	6	Bothal	1	2.00	10.00	56.0	5.0	4.0	35.0	-1.62	6.99	5
Arrow	19	6	Folly Farm	5	17.00	17.80	24.0	72.0	4.0	0.0	-4.12	7.22	1
Arrow	19	6	Folly Farm	4	13.25	15.85	24.0	59.0	4.0	13.0	-2.66	7.17	1
Arrow	19	6	Folly Farm	3	9.50	13.90	24.0	46.0	4.0	26.0	-1.20	7.07	1
Arrow	19	6	Folly Farm	2	7.63	12.93	24.0	39.5	4.0	32.5	-0.46	7.03	1
Arrow	19	6	Folly Farm	1	2.00	10.00	24.0	20.0	4.0	52.0	1.73	7.02	4
Usk	20	6	Llantrissant	8	33.70	35.00	53.0	43.0	4.0	0.0	-5.43	7.1	1
Usk	20	6	Llantrissant	5	26.53	30.00	53.0	33.5	4.0	9.5	-4.36	7.09	2
Usk	20	6	Llantrissant	4	19.35	25.00	53.0	24.0	4.0	19.0	-3.29	7.06	3
Usk	20	6	Llantrissant	3	15.76	22.50	53.0	19.3	4.0	23.8	-2.75	6.98	4
Usk	20	6	Llantrissant	2	5.00	15.00	53.0	5.0	4.0	38.0	-1.15	6.98	5
Derwent	21	6	Ribton Hall	8	50.70	37.60	75.0	25.0	0.0	0.0	-6.63	7.49	1
Derwent	21	6	Ribton Hall	5	40.53	31.95	75.0	19.5	0.0	5.5	-6.01	7.3	1
Derwent	21	6	Ribton Hall	4	30.35	26.30	75.0	14.0	0.0	11.0	-5.39	7.22	1
Derwent	21	6	Ribton Hall	3	25.26	23.48	75.0	11.3	0.0	13.8	-5.08	7.22	1

River name	Site number	Major TWINSPAN group (1-9)	Site Name	Discharge category	Width	Depth	%Boulders/cobbles	%Pebbles/gravel	%Sand	%Silt/clay	Mean substratum (phi units)	Expected LIFE	Suitability code
Derwent	21	6	Ribton Hall	2	10.00	15.00	75.0	3.0	0.0	22.0	-4.15	7.31	1
Perry	22	7	Rednal Mill	3	5.20	25.30	11.0	70.0	10.0	9.0	-2.21	6.96	1
Perry	22	7	Rednal Mill	2	4.90	21.48	11.0	55.0	10.0	24.0	-0.52	6.85	1
Perry	22	7	Rednal Mill	2	4.60	17.65	11.0	40.0	10.0	39.0	1.17	6.88	1
Perry	22	7	Rednal Mill	1	4.45	15.74	11.0	32.5	10.0	46.5	2.01	6.93	1
Perry	22	7	Rednal Mill	1	4.00	10.00	11.0	10.0	10.0	69.0	4.54	6.73	1
Piddle	23	7	Wareham	4	12.20	48.00	10.0	60.0	22.0	8.0	-1.65	6.95	1
Piddle	23	7	Wareham	3	11.65	39.75	10.0	50.0	19.0	21.0	-0.34	6.95	1
Piddle	23	7	Wareham	2	11.10	31.50	10.0	40.0	16.0	34.0	0.97	6.97	1
Piddle	23	7	Wareham	1	10.83	27.38	10.0	35.0	14.5	40.5	1.62	7.08	2
Piddle	23	7	Wareham	1	10.00	15.00	10.0	20.0	10.0	60.0	3.58	7.08	4
Frome	24	7	East Stoke	6	18.00	64.40	13.0	61.0	22.0	4.0	-2.23	6.96	1
Frome	24	7	East Stoke	5	17.50	53.30	13.0	50.8	19.0	17.3	-0.90	6.96	1
Frome	24	7	East Stoke	4	17.00	42.20	13.0	40.5	16.0	30.5	0.44	6.96	1
Frome	24	7	East Stoke	3	16.75	36.65	13.0	35.4	14.5	37.1	1.10	6.96	1
Frome	24	7	East Stoke	2	16.00	20.00	13.0	20.0	10.0	57.0	3.10	6.99	4
Test	25	7	Skidmore	7	22.30	107.20	4.0	64.0	20.0	12.0	-1.03	6.47	1
Test	25	7	Skidmore	5	21.73	100.40	4.0	53.0	17.5	25.5	0.36	6.43	1
Test	25	7	Skidmore	4	21.15	93.60	4.0	42.0	15.0	39.0	1.75	6.34	1
Test	25	7	Skidmore	3	20.86	90.20	4.0	36.5	13.8	45.8	2.44	6.36	2
Test	25	7	Skidmore	2	20.00	80.00	4.0	20.0	10.0	66.0	4.52	6.11	3
Devon	26	8	Knipton	1	1.50	19.60	0.0	78.0	22.0	0.0	-2.10	7.22	1
Devon	26	8	Knipton	1	1.38	17.20	0.0	63.5	19.0	17.5	-0.28	7.05	1
Devon	26	8	Knipton	1	1.25	14.80	0.0	49.0	16.0	35.0	1.53	7.04	1
Devon	26	8	Knipton	1	1.19	13.60	0.0	41.8	14.5	43.8	2.43	7.08	1
Devon	26	8	Knipton	1	1.00	10.00	0.0	20.0	10.0	70.0	5.15	7.07	1
Glen	27	8	Little Bytham	1	4.30	19.30	5.0	43.0	28.0	24.0	0.70	6.89	1
Glen	27	8	Little Bytham	1	3.98	16.98	5.0	36.0	24.0	35.0	1.72	6.88	1
Glen	27	8	Little Bytham	1	3.65	14.65	5.0	29.0	20.0	46.0	2.75	6.77	1
Glen	27	8	Little Bytham	1	3.49	13.49	5.0	25.5	18.0	51.5	3.26	6.69	1
Glen	27	8	Little Bytham	1	3.00	10.00	5.0	15.0	12.0	68.0	4.81	6.68	1
Bure	28	8	Whitehouse Farm	2	9.80	49.00	1.0	34.0	12.0	53.0	3.30	6.3	1
Bure	28	8	Whitehouse Farm	2	8.85	41.75	1.0	28.0	10.0	61.0	4.09	6.3	1
Bure	28	8	Whitehouse Farm	1	7.90	34.50	1.0	22.0	8.0	69.0	4.89	6.3	1
Bure	28	8	Whitehouse Farm	1	7.43	30.88	1.0	19.0	7.0	73.0	5.29	6.3	1
Bure	28	8	Whitehouse Farm	1	6.00	20.00	1.0	10.0	4.0	85.0	6.48	6.3	1
Moors/Crane	29	9	East Moors Farm	3	3.90	84.10	0.0	1.0	23.0	76.0	6.51	6.4	1
Moors/Crane	29	9	East Moors Farm	2	3.55	68.08	0.0	1.0	18.5	80.5	6.78	6.52	1
Moors/Crane	29	9	East Moors Farm	2	3.20	52.05	0.0	1.0	14.0	85.0	7.05	6.61	1
Moors/Crane	29	9	East Moors Farm	1	3.03	44.04	0.0	1.0	11.8	87.3	7.18	6.79	1
Moors/Crane	29	9	East Moors Farm	1	2.50	20.00	0.0	1.0	5.0	94.0	7.59	6.95	2
Brue	30	9	Liberty Farm	4	10.70	115.10	15.0	6.0	1.0	78.0	4.90	6.09	1
Brue	30	9	Liberty Farm	3	10.03	93.83	15.0	5.0	1.0	79.0	5.02	6.09	1
Brue	30	9	Liberty Farm	2	9.35	72.55	15.0	4.0	1.0	80.0	5.13	6.09	2
Brue	30	9	Liberty Farm	1	9.01	61.91	15.0	3.5	1.0	80.5	5.18	6.09	4
Brue	30	9	Liberty Farm	1	8.00	30.00	15.0	2.0	1.0	82.0	5.35	6.09	5
Thames/Isis	31	9	Runnymede	9	56.60	238.80	10.0	25.0	2.0	63.0	3.49	6.28	1
Thames/Isis	31	9	Runnymede	7	55.45	191.60	10.0	20.0	2.0	68.0	4.06	6.28	1
Thames/Isis	31	9	Runnymede	5	54.30	144.40	10.0	15.0	2.0	73.0	4.62	6.28	4
Thames/Isis	31	9	Runnymede	4	53.73	120.80	10.0	12.5	2.0	75.5	4.90	6.31	5
Thames/Isis	31	9	Runnymede	3	52.00	50.00	10.0	5.0	2.0	83.0	5.74	6.38	5

APPENDIX 2

Flow-related details of the 443 RIVPACS reference sites for which relative mean summer flows in the year of biological sampling were available for an appropriate "nearby" NWA flow gauging station The distance apart of the site and station is shown negative/positive when the station is up/down stream of the site. [1] denotes station downstream of site but then up tributary; [2] denotes station upstream of site but not on main channel. %flow = mean summer flow in year of sampling relative to that averaged over all available years.

RIVPACS site			NGR		Flow	Distance apart	Intervening Tributaries		Stream order (SO) at:		Mean summer flow :				Flow rank of	out of		LIFE
Code	River name	Site name	East	North	Station	(km)	No.	Max SO	Site	Station	in sampling year		over all years	%flow	sampling year	n years	%rank	O/E
101	Camel	PENCARROW BRIDGE	2104	0827	49001	24.3	25	4	4	5	1978	2.198	2.376	92	17	30	57	0.969
103	Camel	TUCKINGMILL	2088	0778	49001	18.2	21	4	4	5	1978	2.198	2.376	92	17	30	57	1.022
105	Camel	HELLAND BRIDGE	2065	0715	49001	8.7	12	4	4	5	1978	2.198	2.376	92	17	30	57	1.024
107	Camel	BROCTON	2015	0685	49001	0.5	0	5	5	5	1978	2.198	2.376	92	17	30	57	1.009
181	DeLank River	BRADFORD	2114	0758	49003	-2.7	2	2	3	3	1990	0.203	0.327	62	9	29	31	1.000
185	DeLank River	KEYBRIDGE	2089	0739	49003	-6.9	5	2	3	3	1990	0.203	0.327	62	9	29	31	0.958
201	Axe	MOSTERTON	3457	1053	45004	33.8	31	5	3	5	1978	2.021	2.176	93	14	30	47	1.024
203	Axe	OATHILL FARM	3402	1060	45004	26.9	25	5	4	5	1978	2.021	2.176	93	14	30	47	1.057
205	Axe	BROOM	3326	1025	45004	14.4	15	5	4	5	1978	2.021	2.176	93	14	30	47	1.018
207	Axe	WHITFORD BRIDGE	3262	953	45004	0.1	0	5	5	5	1978	2.021	2.176	93	14	30	47	0.995
221	Synderford	VENN HILL	3383	1037	45004	26	25	5	3	5	1986	3.036	2.176	140	28	30	93	0.982
223	Blackwater	BEERHALL	3358	1010	45004	18.2	17	5	3	5	1986	3.036	2.176	140	28	30	93	0.990
225	Kit Brook	KIT BRIDGE	3308	1039	45004	15.8	16	5	3	5	1986	3.036	2.176	140	28	30	93	1.035
227	Yarty	CRAWLEY BRIDGE	3256	1080	45004	18	16	5	3	5	1986	3.036	2.176	140	28	30	93	1.068
229	Yarty	GAMMONS HILL	3283	0983	45004	6	6	5	3	5	1986	3.036	2.176	140	28	30	93	1.006
231	Corry Brook	CORYTON	3270	0991	45004	7.8	6	5	3	5	1986	3.036	2.176	140	28	30	93	0.915
233	Umbourne Brook	EASY BRIDGE	3240	0969	45004	10.7[1]	10	5	2	5	1986	3.036	2.176	140	28	30	93	1.013
301	Exe	WARREN FARM	2791	1407	45009	30.4	18	3	1	4	1978	1.111	1.528	73	11	30	37	1.019
303	Exe	EXFORD	2853	1383	45009	22.9	12	3	3	4	1978	1.111	1.528	73	11	30	37	0.978
305	Exe	EDBROOKE	2912	1342	45009	12.1	6	3	3	4	1978	1.111	1.528	73	11	30	37	0.998
307	Exe	EXEBRIDGE	2930	1245	45011	-1.7	1	2	5	4	1978	1.605	1.796	89	3	6	50	1.020
309	Exe	LYTHECOURT	2948	1153	45002	-3	3	3	5	5	1978	3.151	4.453	71	9	30	30	1.014
311	Exe	BRAMFORD SPEKE	2929	984	45001	-4.9	1	1	5	5	1978	3.609	5.270	68	10	30	33	1.063

RIVPACS site Code	River name	Site name	NGR East	NGR North	Flow Station	Distance apart (km)	Intervening Tributaries No.	Intervening Tributaries Max SO	Stream order (SO) at: Site	Stream order (SO) at: Station	Mean summer flow: in sampling year		Mean summer flow: over all years	%flow	Flow rank of sampling year	out of n years	%rank	LIFE O/E
409	Torridge	BEAFORD BRIDGE	2543	1143	50002	14.3	9	6	6	6	1978	2.872	4.164	69	12	30	40	1.080
411	Torridge	GREAT TORRINGTON TOWN MILL	2499	1185	50002	0.1	0	6	6	6	1978	2.872	4.164	69	12	30	40	1.068
601	Avon	PATNEY	4071	1585	43017	71	19	4	3	5	1978	0.327	0.260	126	21	28	75	1.048
603	Avon	RUSHALL	4132	1558	43017	61.7	18	4	3	5	1978	0.327	0.260	126	21	28	75	0.980
605	Avon	BULFORD	4163	1437	43005	4.9	4	1	4	4	1978	2.606	2.021	129	27	30	90	1.070
607	Avon	STRATFORD-SUB-CASTLE	4129	1330	43005	-15.1	4	1	4	4	1978	2.606	2.021	129	27	30	90	1.085
609	Avon	BREAMORE	4163	1174	43003	5.2	3	2	5	5	1978	12.446	9.160	136	27	29	93	0.992
613	Avon	CHRISTCHURCH	4158	933	43021	-1.5	0	5	5	5	1979	17.078	10.789	158	23	23	100	0.980
701	Avon	EASTON GREY	3880	1873	53023	1.8	0	3	3	3	1978	0.227	0.285	80	13	23	57	1.060
703	Tetbury Avon	BROCKENBOROUGH	3915	1893	53024	0.1	0	2	2	2	1978	0.147	0.198	74	14	22	64	1.019
705	Avon	COW BRIDGE	3943	1862	53019	-0.6[2]	2	3	4	3	1978	0.116	0.157	74	14	30	47	0.950
707	Avon	GREAT SOMERFORD	3965	1831	53008	0.1	0	4	4	4	1978	1.036	0.953	109	23	30	77	1.085
709	Avon	KELLAWAY'S WEIR	3947	1758	53008	-12.4	9	4	4	4	1979	2.04	0.953	214	28	30	93	0.988
711	Avon	LACOCK	3922	1681	53001	5.9	4	3	5	5	1978	3.172	3.597	88	6	10	60	1.028
713	Avon	STAVERTON WEIR	3856	1609	53001	-7.3	7	5	6	5	1979	4.271	3.597	119	8	10	80	1.016
771	By Brook	GATCOMBE HILL	3834	1789	53028	17.7	8	3	2	3	1988	0.726	0.519	140	16	18	89	1.012
773	By Brook	SLAUGHTERFORD	3837	1738	53028	9.4	4	2	3	3	1988	0.726	0.519	140	16	18	89	0.984
775	By Brook	ASHLEY	3815	1687	53028	0.3	0	3	3	3	1988	0.726	0.519	140	16	18	89	1.047
781	Avon	WASHPOOL BRIDGE	3841	1860	53023	7.6	1	3	1	3	1984	0.156	0.285	55	5	23	22	0.980
901	Candover Brook	ABBOTSTONE	4565	1345	42009	3.8	2	1	2	2	1978	0.499	0.423	118	25	29	86	1.065
903	Itchen	CHILLAND	4523	1325	42016	1.2	0	4	4	4	1978	4.156	3.511	118	17	19	89	0.964
905	Itchen	ITCHEN ST.CROSS	4481	1282	42016	-6.5	3	1	4	4	1978	4.156	3.511	118	17	19	89	1.008
907	Itchen	OTTERBOURNE WATERWORKS	4470	1233	42010	3	1	1	4	4	1978	4.39	4.000	110	22	30	73	1.046
909	Itchen	D/S CHICKENHALL SDW	4466	1175	42010	-5.2	1	1	4	4	1978	4.39	4.000	110	22	30	73	0.994
1001	Rother	U/S LISS STW	4773	1273	41027	0.4	1	2	3	3	1978	0.227	0.221	103	19	27	70	1.053
1003	Rother	STODHAM PARK	4769	1260	41027	-1.3	1	1	3	3	1978	0.227	0.221	103	19	27	70	1.023
1005	Rother	DURFORD BRIDGE	4783	1233	41027	-7.1	6	4	4	3	1978	0.227	0.221	103	19	27	70	1.033
1007	Rother	STEDHAM	4863	1226	41011	-1.6	1	2	5	5	1978	0.959	0.925	104	19	29	66	1.048
1009	Rother	SELHAM	4935	1213	41011	-13.9	9	3	5	5	1978	0.959	0.925	104	19	29	66	1.099
1013	Arun	MAGPIE BRIDGE	5187	1292	41019	13.1	14	5	4	5	1978	0.315	0.432	73	13	29	45	0.897
1081	Hammer's Pond Tributary	CARTER'S LODGE	5242	1293	41019	20.1	21	5	2	5	1984	0.258	0.432	60	9	29	31	1.069

RIVPACS site Code	River name	Site name	NGR East	NGR North	Flow Station	Distance apart (km)	Intervening Tributaries No.	Intervening Tributaries Max SO	Stream order (SO) at: Site	Stream order (SO) at: Station	Mean summer flow : in sampling year		Mean summer flow : over all years	%flow	Flow rank of sampling year	out of n years	%rank	LIFE O/E
1083	Rother	HAWKLEY MILL	4749	1307	41027	6.7	9	3	2	3	1984	0.195	0.221	88	10	27	37	1.093
1101	Dudwell	BURWASH WEALD	5655	1224	40017	3.6	4	2	4	4	1978	0.092	0.102	91	15	21	71	0.991
1109	Rother	ETCHINGHAM	5720	1262	40004	8.1	9	5	5	5	1978	0.399	0.604	66	14	27	52	1.098
1111	Rother	UDIAM	5771	1243	40004	0.3	1	2	5	5	1978	0.399	0.604	66	14	27	52	0.974
1113	Rother	D/S NEWENDEN	5850	1270	40004	-9.4	12	4	5	5	1978	0.399	0.604	66	14	27	52	0.955
1209	Evenlode	CASSINGTON	4448	2102	39034	0.3	0	5	5	5	1979	2.568	1.619	159	25	29	86	1.024
1301	Tilling Bourne	WOTTON	5130	1470	39029	15.9	5	2	2	3	1979	0.577	0.433	133	29	30	97	1.054
1303	Tilling Bourne	U/S ALBURY VILLAGE	5053	1479	39029	6.9	3	2	2	3	1979	0.577	0.433	133	29	30	97	1.085
1305	Wey	WYCK	4756	1417	39078	12.4	6	3	3	4	1979	0.601	0.388	155	21	21	100	0.952
1307	Wey	TILFORD	4873	1437	39011	0.5	1	5	4	5	1979	2.442	1.873	130	28	30	93	1.041
1309	Wey	EASHING	4947	1438	39011	-11.7	10	5	5	5	1979	2.442	1.873	130	28	30	93	1.013
1403	Mimram	CODICOTE BOTTOM	5208	2180	38011	3	0	3	3	3	1978	0.288	0.194	149	13	16	81	1.035
1405	Mimram	PANSHANGER	5282	2134	38003	0.1	0	3	3	3	1978	0.667	0.461	145	26	30	87	1.020
1407	Lee	WARE WEIR	5365	2143	38018	-9.8	13	6	6	4	1978	1.263	1.000	126	24	28	86	0.908
1409	Lee	MEADGATE	5384	2076	38001	-2.3	1	1	6	6	1978	3.915	2.419	162	25	28	89	0.960
1411	Lee	FISHER'S GREEN	5374	2044	38001	-6.8	4	3	6	6	1978	3.915	2.419	162	25	28	89	0.943
1413	Lee	ENFIELD WEIR	5374	1983	38001	-14.1	10	4	6	6	1978	3.915	2.419	162	25	28	89	0.891
1601	Teifi	STRATA FLORIDA	2749	2659	62002	66.1	63	5	4	5	1978	5.398	5.541	97	6	11	55	0.970
1603	Teifi	TREGARON BOG	2684	2628	62002	55.2	50	4	4	5	1978	5.398	5.541	97	6	11	55	0.911
1605	Teifi	PONT GOGOYAN	2642	2547	62002	39.6	35	4	5	5	1978	5.398	5.541	97	6	11	55	1.027
1607	Teifi	ALLTYBLACCA	2523	2454	62002	17.9	12	3	5	5	1978	5.398	5.541	97	6	11	55	1.006
1609	Teifi	BANGOR TYFI	2373	2403	62002	-11.5	10	4	5	5	1978	5.398	5.541	97	6	11	55	1.015
1611	Teifi	LLECHRYD	2217	2437	62001	-4.4	6	3	5	5	1978	8.988	10.988	82	16	31	52	0.944
1701	Clwyd	MELIN-Y-WIG	3040	3488	66005	18.2	14	3	3	4	1979	0.27	0.325	83	14	25	56	0.981
1703	Clwyd	NANTCLWYD HALL	3109	3519	66005	9.1	9	3	3	4	1979	0.27	0.325	83	14	25	56	1.046
1705	Clwyd	ABOVE RUTHIN	3124	3571	66005	2.4	2	2	4	4	1979	0.27	0.325	83	14	25	56	1.042
1707	Clwyd	GLAN-Y-WERN	3091	3658	66001	7.6	12	5	5	5	1979	2.056	2.182	94	17	30	57	1.005
1709	Clwyd	PONT LLANERCH	3060	3719	66001	-2	3	2	5	5	1979	2.056	2.182	94	17	30	57	1.024
1807	Leadon	KETFORD	3730	2307	54017	13.5	9	3	4	4	1978	0.705	0.685	103	18	28	64	1.027
1809	Leadon	UPLEADON	3770	2270	54017	4.6	4	3	4	4	1978	0.705	0.685	103	18	28	64	0.913
1901	Perry	PERRY FARM	3347	3302	54045	0.1	0	3	3	3	1978	0.386	0.302	128	4	5	80	1.021

RIVPACS site Code	River name	Site name	NGR East	NGR North	Flow Station	Distance apart (km)	Intervening Tributaries No.	Intervening Tributaries Max SO	Stream order (SO) at: Site	Stream order (SO) at: Station	Mean summer flow : in sampling year		Mean summer flow : over all years	%flow	Flow rank of sampling year	out of n years	%rank	LIFE O/E
1903	Perry	REDNAL MILL	3374	3294	54045	-3.3	4	2	3	3	1978	0.386	0.302	128	4	5	80	0.950
1907	Perry	MILFORD	3422	3210	54020	2.9	2	3	4	4	1978	0.746	0.693	108	16	30	53	0.931
1909	Perry	MYTTON	3439	3171	54020	-3.3	1	1	4	4	1978	0.746	0.693	108	16	30	53	1.026
2001	Blithe	COOKSHILL	3942	3435	28002	35.4	42	4	3	4	1978	0.492	0.483	102	9	13	69	0.925
2003	Blithe	CRESSWELL	3975	3393	28002	29.4	37	4	3	4	1978	0.492	0.483	102	9	13	69	1.010
2005	Blithe	FIELD	4024	3334	28002	20.4	20	4	3	4	1978	0.492	0.483	102	9	13	69	0.920
2007	Blithe	NEWTON	4048	3259	28002	10.4	10	4	4	4	1978	0.492	0.483	102	9	13	69	1.082
2009	Blithe	HAMSTALL RIDWARE	4109	3190	28002	0.3	0	4	4	4	1978	0.492	0.483	102	9	13	69	0.943
2201	Dove	GLUTTON BRIDGE	4084	3665	28033	-2.6	4	1	3	3	1979	0.104	0.126	83	4	13	31	0.964
2203	Dove	HARTINGTON	4121	3598	28046	12.7	6	2	3	3	1979	1.438	1.058	136	28	30	93	1.006
2205	Dove	DOVE DALE	4146	3504	28046	-0.6	0	3	3	3	1979	1.438	1.058	136	28	30	93	1.018
2207	Dove	U/S ROCESTER	4115	3392	28008	-0.6	1	3	5	5	1979	4.262	3.694	115	21	30	70	1.061
2209	Dove	SUDBURY	4163	3312	28018	12.8	7	3	6	6	1979	7.737	6.819	113	21	30	70	1.034
2211	Dove	MONK'S BRIDGE	4268	3270	28018	-4.8	4	4	6	6	1979	7.737	6.819	113	21	30	70	1.010
2301	Stambourne Brook	GREAT YELDHAM	5759	2384	37012	3	3	4	2	4	1978	0.025	0.063	40	13	28	46	0.912
2303	Colne	D/S HEDINGHAM STW	5798	2323	37024	8.2	8	3	4	4	1978	0.248	0.280	89	19	27	70	0.949
2305	Colne	EARL'S COLNE	5867	2289	37024	-1.9	3	2	4	4	1978	0.248	0.280	89	19	27	70	0.999
2307	Colne	FORDSTREET BRIDGE	5921	2272	37005	6.1	6	3	4	4	1978	0.409	0.403	101	21	30	70	1.016
2401	Great Eau	RUCKLAND	5332	3779	29002	12.1	5	2	2	3	1978	0.728	0.504	145	26	29	90	0.996
2403	Great Eau	SWABY	5370	3768	29002	7.5	4	2	2	3	1978	0.728	0.504	145	26	29	90	0.906
2405	Great Eau	BELLEAU	5403	3777	29002	2.4	2	2	3	3	1978	0.728	0.504	145	26	29	90	0.926
2409	Great Eau	THEDDLETHORPE-ALL-SAINTS	5452	3867	29002	-10.5	2	2	3	3	1978	0.728	0.504	145	26	29	90	0.886
2505	Glen	LITTLE BYTHAM	5019	3177	31024	4.3	2	2	3	2	1978	0.105	0.103	102	13	24	54	1.036
2507	Glen	BANTHORPE LODGE	5068	3112	31009	0.8	0	3	3	3	1978	0.162	0.153	106	12	19	63	0.957
2513	Welland	MARSTON TRUSSEL	4697	2864	31022	6.6[1]	6	3	2	2	1978	0.01	0.016	64	10	18	56	0.969
2521	Welland	TINWELL	5007	3063	31004	10.3	3	4	4	5	1978	2.786	2.032	137	22	29	76	0.958
2523	Welland	CROWLAND	5228	3106	31004	-14.8	7	5	6	5	1978	2.786	2.032	137	22	29	76	0.911
2601	Wensum	SOUTH RAYNHAM	5885	3240	34011	11.5	4	3	3	4	1978	0.781	0.533	147	24	27	89	1.025
2605	Wensum	GREAT RYBURGH	5964	3273	34011	-6.1	6	4	4	4	1978	0.781	0.533	147	24	27	89	1.033
2611	Wensum	TAVERHAM	6161	3137	34004	3.9	1	1	5	5	1978	2.947	2.231	132	22	27	81	1.100
2619	Yare/Blackwater	NORTH OF BARFORD	6108	3084	34001	12.7	3	3	4	4	1978	0.612	0.601	102	19	30	63	1.005

RIVPACS site Code	River name	Site name	NGR East	NGR North	Flow Station	Distance apart (km)	Intervening Tributaries No.	Intervening Tributaries Max SO	Stream order (SO) at: Site	Stream order (SO) at: Station	Mean summer flow : sampling year	Mean summer flow : in sampling year	Mean summer flow : over all years	%flow	Flow rank of sampling year	out of n years	%rank	LIFE O/E
2621	Yare/Blackwater	EARLHAM	6190	3082	34001	-1.5	0	4	4	4	1978	0.612	0.601	102	19	30	63	0.977
2703	Hodder	SLAIDBURN	3715	4524	71008	27.5	5	3	4	4	1978	3.16	4.065	78	13	24	54	1.016
2705	Hodder	D/S LANGDEN BROOK	3658	4479	71008	15.7	37	6	6	6	1978	3.16	4.065	78	13	24	54	1.003
2707	Hodder	HIGHER HODDER BRIDGE	3697	4411	71008	2.1	6	6	6	6	1978	3.16	4.065	78	13	24	54	1.034
2709	Ribble/Gayle Beck	CAM END	3785	4803	71011	35	54	4	4	5	1978	2.69	3.317	81	16	29	55	1.026
2711	Ribble/Gayle Beck	HORTON IN RIBBLESDALE	3806	4726	71011	24	33	4	5	5	1978	2.69	3.317	81	16	29	55	1.058
2713	Ribble/Gayle Beck	CLEATOP BARNS	3806	4614	71011	10	12	4	5	5	1978	2.69	3.317	81	16	29	55	0.972
2715	Ribble/Gayle Beck	HALTON BRIDGE	3851	4551	71011	-1.5	2	2	5	5	1978	2.69	3.317	81	16	29	55	0.915
2717	Ribble/Gayle Beck	SAWLEY BRIDGE	3775	4466	71006	12.6	18	4	5	5	1978	4.258	5.789	74	14	30	47	0.925
2719	Ribble/Gayle Beck	MITTON BRIDGE	3715	4387	71006	-1	2	3	5	5	1978	4.258	5.789	74	14	30	47	0.920
2721	Ribble/Gayle Beck	RIBCHESTER BRIDGE	3662	4356	71001	14.9	19	6	6	6	1978	11.816	15.240	78	13	29	45	0.937
2901	Derwent	GRANGE-IN-BORROWDALE	3255	5176	75005	7.8	9	5	5	6	1978	4.08	5.550	74	10	26	38	1.038
2903	Derwent	HIGH STOCK BRIDGE	3243	5260	75005	-2.5	1	3	6	6	1978	4.08	5.550	74	10	26	38	0.964
2905	Derwent	OUSE BRIDGE	3200	5321	75003	0.1	0	6	6	6	1978	5.422	7.590	71	11	30	37	0.943
2907	Derwent	COCKERMOUTH	3116	5307	75002	11	14	4	6	6	1978	8.606	11.427	75	12	30	40	0.935
2909	Derwent	RIBTON HALL	3046	5304	75002	1.4	3	2	6	6	1978	8.606	11.427	75	12	30	40	1.001
2911	Derwent	WORKINGTON	3009	5293	75002	-4.8	2	1	6	6	1978	8.606	11.427	75	12	30	40	0.985
3001	Ehen/Liza	ENNERDALE BRIDGE	3068	5159	74003	-3.5	6	3	4	4	1978	1.015	1.317	77	13	26	50	1.002
3003	Ehen/Liza	U/S KEEKLE	3014	5130	74005	9.5	9	4	4	4	1978	2.238	2.745	82	11	26	42	1.008
3005	Ehen/Liza	D/S KEEKLE	3012	5125	74005	8.8	5	4	4	4	1978	2.238	2.745	82	11	26	42	0.938
3007	Ehen/Liza	BRAYSTONES	3007	5061	74005	0.4	0	4	4	4	1978	2.238	2.745	82	11	26	42	0.997
3101	Derwent	LANGDALE END	4942	4910	27048	10.1	9	4	4	5	1978	0.256	0.208	123	21	28	75	0.976
3103	Derwent	WEST AYTON	4988	4848	27048	-0.6	0	5	5	5	1978	0.256	0.208	123	21	28	75	0.853
3111	Derwent	THORGANBY	4697	4424	27044	-7.5[2]	6	7	7	4	1978	0.134	0.104	129	19	24	79	1.092
3141	Mill Beck	BATHINGWELL WOOD	4822	4638	27041	25.2	23	7	1	7	1991	5.118	8.048	64	7	26	27	0.933
3144	Long Gill	NEWGATE FOOT	4866	4935	27048	20.8	24	5	2	5	1991	0.108	0.208	52	5	28	18	0.920
3145	Halleykeld Spring Stream	HALLEYKELD RIGG	4939	4860	27073	10.2	7	5	1	2	1991	0.089	0.143	62	5	18	28	1.034
3150	Cowhouse Beck	SNAPER HOUSE	4598	4912	27058	15.1	8	3	2	3	1991	0.218	0.248	88	10	24	42	1.033
3151	Mire Falls Gill	REINS WOOD	4566	4853	27049	22.6	19	5	1	5	1991	1.011	1.761	57	7	25	28	1.020
3152	Sledhill Gill	YOWLASS WOOD	4531	4870	27055	6.3[1]	4	5	1	5	1991	0.674	1.135	59	7	24	29	1.113
3153	Wheat Beck	DALE HEAD	4496	4950	27055	12.2	20	5	2	5	1991	0.674	1.135	59	7	24	29	0.962

RIVPACS site Code	River name	Site name	NGR East	NGR North	Flow Station	Distance apart (km)	Intervening Tributaries No.	Intervening Tributaries Max SO	Stream order (SO) at: Site	Stream order (SO) at: Station	Mean summer flow: in sampling year		Mean summer flow: over all years	%flow	Flow rank of sampling year	out of n years	%rank	LIFE O/E
3160	Pickering Beck	LEVISHAM	4816	4911	27056	13.9	2	4	3	4	1991	0.291	0.450	65	7	24	29	1.006
3162	Seph	LASKILL	4563	4907	27055	3.8	7	4	4	5	1991	0.674	1.135	59	7	24	29	1.032
3163	Menethorpe Beck	MENETHORPE	4768	4676	27041	15.9	15	7	4	7	1991	5.118	8.048	64	7	26	27	1.060
3166	Rye	NUNNINGTON	4664	4794	27049	3.4	0	5	5	5	1991	1.011	1.761	57	7	25	28	1.056
3205	Esk	LEALHOLM	4762	5076	27050	18.7	25	5	5	5	1978	4.097	2.200	186	23	25	92	0.978
3207	Esk	BRIGGSWATH	4869	5082	27050	-0.5	1	4	5	5	1978	4.097	2.200	186	23	25	92	1.033
3301	Swale	KELD	3885	5015	27024	35.2	42	5	5	6	1978	2.86	4.358	66	2	9	22	1.008
3303	Swale	OXNOP	3933	4978	27024	27.6	30	5	5	6	1978	2.86	4.358	66	2	9	22	1.003
3305	Swale	GRINTON	4046	4985	27024	14.5	15	4	6	6	1978	2.86	4.358	66	2	9	22	1.053
3307	Swale	U/S RICHMOND	4146	5007	27024	0.1	0	6	6	6	1978	2.86	4.358	66	2	9	22	1.126
3309	Swale	MORTON-ON-SWALE	4319	4918	27008	30.6	16	5	6	6	1978	8.487	10.128	84	4	8	50	1.128
3311	Swale	TOPCLIFFE	4398	4759	27008	2.5	1	5	6	6	1978	8.487	10.128	84	4	8	50	0.995
3315	Ouse/Ure	NETHER POPPLETON	4556	4552	27009	1.3	2	2	7	7	1978	15.788	19.761	80	13	28	46	0.996
3317	Ouse/Ure	ACASTER MALBIS	4591	4455	27009	-14.1	13	5	7	7	1978	15.788	19.761	80	13	28	46	0.944
3372	Cowside Beck	NAB END	3903	4700	27032	22.9[1]	25	6	4	4	1989	0.038	0.077	50	4	29	14	1.003
3376	Cowside Beck	ARNCLIFFE	3930	4719	27043	36.1	53	6	4	6	1989	3.402	5.658	60	5	25	20	0.972
3381	Wharfe	HUBBERHOLME	3933	4783	27043	41.7	61	5	4	6	1990	3.845	5.658	68	8	25	32	0.911
3385	Wharfe	GRASSINGTON	3997	4639	27043	23	38	4	6	6	1990	3.845	5.658	68	8	25	32	1.013
3389	Wharfe	ADDINGHAM	4084	4499	27043	1	2	3	6	6	1990	3.845	5.658	68	8	25	32	1.015
3391	Gordale Beck	SEATY HILL	3912	4654	27070	24.7	33	6	3	4	1989	0.194	0.388	50	6	17	35	1.002
3395	Gordale Beck	GORDALE BRIDGE	3914	4636	27070	22.7	33	6	3	4	1989	0.194	0.388	50	6	17	35	0.962
3397	Wharfe	WETHERBY	4406	4477	27002	2.2	0	6	6	6	1990	4.682	7.282	64	8	30	27	0.963
3401	Tees	MOORHOUSE	3762	5338	25023	8.8	20	3	4	4	1978	2.518	2.901	87	7	22	32	0.989
3403	Tees	CAULDRON SNOUT	3814	5288	25023	0.1	0	4	4	4	1978	2.518	2.901	87	7	22	32	0.985
3407	Tees	BARNARD CASTLE	4042	5172	25008	0.9	2	4	5	5	1978	5.551	7.119	78	4	24	17	1.077
3409	Tees	GAINFORD	4178	5163	25001	11.9	8	6	6	6	1978	4.962	7.358	67	9	30	30	0.994
3413	Tees	OVER DINSDALE	4346	5114	25009	4.3	3	1	6	6	1978	4.684	8.258	57	6	30	20	1.025
3501	South Tyne	DIPPER BRIDGE	3758	5372	23009	12.4	21	5	3	5	1978	1.299	1.851	70	6	18	33	1.044
3503	South Tyne	ALSTON	3717	5459	23009	0.7	0	5	5	5	1978	1.299	1.851	70	6	18	33	1.063
3505	South Tyne	D/S KNARSDALE	3683	5554	23009	-11.5	16	5	5	5	1978	1.299	1.851	70	6	18	33	0.993
3509	South Tyne	BARDON MILL	3781	5643	23004	8.9	15	5	5	6	1978	4.355	8.069	54	7	30	23	1.008

RIVPACS site Code	River name	Site name	NGR East	NGR North	Flow Station	Distance apart (km)	Intervening Tributaries No.	Intervening Tributaries Max SO	Stream order (SO) at: Site	Stream order (SO) at: Station	Mean summer flow :	in sampling year	over all years	%flow	Flow rank of sampling year	out of n years	%rank	LIFE O/E
3511	South Tyne	WARDEN BRIDGE	3910	5659	23004	-7.8	6	3	6	6	1978	4.355	8.069	54	7	30	23	0.992
3515	Tyne/North Tyne	WYLAM	4111	5643	23001	-9.4	17	7	7	7	1978	13.163	19.611	67	11	30	37	0.973
3601	Wansbeck	KIRKWHELPINGTON	3996	5844	22007	26.4	24	4	4	5	1978	0.585	0.984	59	12	30	40	0.993
3603	Wansbeck	MIDDLETON	4053	5842	22007	18.2	17	4	4	5	1978	0.585	0.984	59	12	30	40	0.976
3605	Wansbeck	MELDON	4119	5850	22007	8.2	11	4	5	5	1978	0.585	0.984	59	12	30	40	0.991
3607	Wansbeck	MITFORD GAUGING STATION	4174	5858	22007	0.1	0	5	5	5	1978	0.585	0.984	59	12	30	40	0.984
3701	Teith	TEITH BRIDGE, CALLANDER	2628	7078	18008	-5.9	9	5	6	5	1978	3.078	5.205	59	6	26	23	0.980
3703	Teith	LAIGHLANDS	2668	7045	18003	7.2	8	6	6	6	1978	7.902	10.333	76	9	30	30	0.986
3704	Teith	BLACKDUB	2763	6966	18011	2	3	5	6	6	1986	20.683	19.121	108	15	19	79	0.902
3705	Teith	BRIDGE OF TEITH, DOUNE	2723	7013	18003	0.3	0	6	6	6	1978	7.902	10.333	76	9	30	30	0.984
3791	Balvag/Larig	BLAIRCREICH	2437	7181	18018	12.8[1]	27	3	3	3	1986	0.229	0.206	111	10	14	71	0.993
3801	Tyne	CRICHTON	3378	6618	20003	13.7	15	4	2	4	1978	0.481	0.616	78	16	29	55	1.041
3803	Tyne	ORMISTON	3413	6689	20003	4.9	6	4	3	4	1978	0.481	0.616	78	16	29	55	1.020
3805	Tyne	EASTER PENCAITLAND	3459	6690	20003	0.4	0	4	4	4	1978	0.481	0.616	78	16	29	55	0.939
3807	Tyne	HADDINGTON WEIR	3513	6733	20001	10.4	4	3	5	5	1978	1.054	1.258	84	16	29	55	0.912
3809	Tyne	EAST LINTON	3593	6772	20001	0.5	0	5	5	5	1978	1.054	1.258	84	16	29	55	0.931
3905	Dee	BALMORAL	3271	7944	12003	8.9	6	2	6	6	1979	16.168	11.802	137	21	24	88	1.056
3907	Dee	D/S BALLATER	3385	7965	12003	-6.6	5	4	6	6	1979	16.168	11.802	137	21	24	88	1.068
3909	Dee	D/S ABOYNE	3557	7980	12001	12.9	9	6	6	6	1979	25.95	19.231	135	26	30	87	0.994
3911	Dee	POTARCH BRIDGE	3608	7973	12001	3.7	4	6	6	6	1979	25.95	19.231	135	26	30	87	1.018
3913	Dee	D/S BANCHORY	3719	7964	12002	9.1	8	6	6	6	1979	33.044	22.166	149	25	27	93	1.001
3915	Dee	CULTS	3904	8023	12002	-14	7	6	6	6	1979	33.044	22.166	149	25	27	93	1.019
4001	Spey	GARVA BRIDGE	2522	7947	8007	22.1	35	5	4	6	1978	1.439	2.672	54	2	26	8	0.992
4003	Spey	LAGGAN BRIDGE	2614	7943	8007	11.2	15	5	5	6	1978	1.439	2.672	54	2	26	8	1.004
4005	Spey	NEWTONMORE	2708	7980	8007	-3.1	2	6	6	6	1978	1.439	2.672	54	2	26	8	1.046
4009	Spey	BOAT OF GARTEN	2946	8188	8005	0.4	0	6	6	6	1978	15.226	15.634	97	18	30	60	0.991
4011	Spey	GRANTOWN	3038	8264	8010	0.7	0	6	6	6	1978	22.108	20.932	106	18	30	60	0.999
4013	Spey	MARYPARK	3183	8388	8004	-4.9[2]	5	6	7	6	1978	13.249	9.781	135	23	30	77	1.023
4017	Spey	GARMOUTH	3343	8610	8006	-10.9	9	4	7	7	1978	46.188	39.119	118	22	30	73	1.092
4101	Stinchar	HIGHBRIDGE	2395	5956	82003	43.8	100	4	3	5	1979	4.671	4.415	106	18	27	67	1.011
4103	Stinchar	D/S DALQUHAIRN	2321	5957	82003	33.3	82	4	5	5	1979	4.671	4.415	106	18	27	67	0.994

RIVPACS site			NGR		Flow	Distance apart	Intervening Tributaries		Stream order (SO)		Mean summer flow :				Flow rank of	out of		LIFE
Code	River name	Site name	East	North	Station	(km)	No.	Max SO	at: Site	Station	in sampling year		over all years	%flow	sampling year	n years	%rank	O/E
4105	Stinchar	D/S BARR	2272	5937	82003	25.5	57	4	5	5	1979	4.671	4.415	106	18	27	67	1.048
4107	Stinchar	PINMORE BRIDGE	2204	5899	82003	15.8	30	4	5	5	1979	4.671	4.415	106	18	27	67	1.042
4109	Stinchar	D/S COLMONELL	2140	5858	82003	5.4	8	4	5	5	1979	4.671	4.415	106	18	27	67	0.977
4111	Stinchar	BALLANTRAE	2089	5825	82003	-2.2	1	3	5	5	1979	4.671	4.415	106	18	27	67	0.981
4207	Annan	MILLHOUSE BRIDGE	3105	5854	78005	3.9[1]	3	6	5	6	1981	3.885	3.839	101	15	21	71	1.042
4211	Annan	BRYDEKIRK	3187	5707	78003	0.7	1	1	6	6	1981	15.708	13.661	115	22	30	73	1.126
4301	Allt Coire Crubaidh	ALLT COIRE CRUBAIDH	2086	8531	93001	21.1	75	6	3	6	1981	6.487	6.015	108	13	21	62	0.960
4303	Lair	ACHNASHELLACH LODGE	2002	8481	93001	9.9	27	6	4	6	1981	6.487	6.015	108	13	21	62	0.979
4305	Fionn Abhainn	FIONN-ABHAINN	1957	8453	93001	3.5	4	6	5	6	1981	6.487	6.015	108	13	21	62	1.017
4307	Carron	D/S LOCH DAMHAIN	2081	8520	93001	19.4	69	6	4	6	1981	6.487	6.015	108	13	21	62	0.968
4309	Carron	CRAIG	2023	8488	93001	11.9	34	6	5	6	1981	6.487	6.015	108	13	21	62	0.994
4311	Carron	BALNACRA	1978	8458	93001	6.3	11	6	5	6	1981	6.487	6.015	108	13	21	62	0.933
4313	Carron	NEW KELSO	1940	8425	93001	-0.7	1	2	6	6	1981	6.487	6.015	108	13	21	62	1.034
4381	Carron	U/S LOCH SGAMHAIN	2116	8537	93001	23.9	91	6	2	6	1984	2.728	6.015	45	1	21	5	0.998
4401	Traligill	GLENBAIN	2250	9218	95001	13.2	26	5	4	5	1981	5	5.053	99	14	22	64	1.027
4403	Loanan	D/S LOCH AWE	2250	9162	95001	20.2	42	4	3	5	1981	5	5.053	99	14	22	64	1.024
4405	Loanan	INCHNADAMPH	2246	9216	95001	13.2	26	4	3	5	1981	5	5.053	99	14	22	64	0.998
4407	Inver	LITTLE ASSYNT	2154	9250	95001	1.1	3	3	5	5	1981	5	5.053	99	14	22	64	0.985
4409	Inver	LOCHINVER	2097	9232	95001	-6.4	10	4	5	5	1981	5	5.053	99	14	22	64	0.910
4701	Halladale	FORSINARD LODGE	2893	9438	96001	13.8	32	4	4	5	1981	1.282	2.147	60	10	24	42	0.938
4703	Halladale	FORSINAIN	2903	9486	96001	8.2	22	4	4	5	1981	1.282	2.147	60	10	24	42	0.982
4705	Halladale	MILLBURN	2890	9560	96001	0.1	0	5	5	5	1981	1.282	2.147	60	10	24	42	1.004
4707	Halladale	GOLVAL	2896	9618	96001	-7.6	12	3	5	5	1981	1.282	2.147	60	10	24	42	1.026
4801	Burn of Aultachleven	U/S LOCH RANGAG	3180	9420	97002	27.6	23	5	3	5	1981	3.132	3.184	98	15	28	54	1.000
4803	Little River	TACHER	3170	9469	97002	21.1	18	5	4	5	1981	3.132	3.184	98	15	28	54	1.049
4805	Thurso	WESTERDALE	3130	9518	97002	11.9	12	4	5	5	1981	3.132	3.184	98	15	28	54	1.035
4807	Thurso	SORDALE	3143	9621	97002	-3.6	4	3	5	5	1981	3.132	3.184	98	15	28	54	1.010
4881	Unnamed	ACHAVANICH	3180	9408	97002	28	25	5	1	5	1984	0.693	3.184	22	2	28	7	0.948
4885	Unnamed	WESTERDALE	3123	9517	97002	11.8	11	5	2	5	1984	0.693	3.184	22	2	28	7	0.988
4905	Tweed	KINGLEDORES	3109	6285	21014	0	0	5	5	5	1981	2.104	1.960	107	22	30	73	0.966
4907	Tweed	CROWNHEAD BRIDGE	3165	6355	21005	6.8	8	3	5	5	1981	4.789	4.129	116	25	30	83	0.917

RIVPACS site Code	River name	Site name	NGR East	NGR North	Flow Station	Distance apart (km)	Intervening Tributaries No.	Intervening Tributaries Max SO	Stream order (SO) at: Site	Stream order (SO) at: Station	Mean summer flow : in sampling year		Mean summer flow : over all years	%flow	Flow rank of sampling year	out of n years	%rank	LIFE O/E
4909	Tweed	PEEBLES GAUGE	3258	6400	21003	0.1	0	6	6	6	1981	7.084	6.741	105	21	30	70	0.958
4911	Tweed	OLD TWEED BRIDGE	3488	6323	21006	1.6	1	6	6	7	1981	20.06	16.477	122	23	30	77	0.954
4913	Tweed	DRY GRANGE BRIDGE	3576	6347	21006	-9.9	6	7	7	7	1981	20.06	16.477	122	23	30	77	1.046
4915	Tweed	D/S BIRGHAM	3814	6393	21021	-9.2	7	7	7	7	1981	34.071	28.336	120	24	30	80	0.939
4917	Tweed	CANNY ISLAND	3893	6465	21009	1.8	0	7	7	7	1981	42.801	34.260	125	23	30	77	0.980
4975	Whiteadder Water	PRESTON HAUGH	3774	6577	21022	17.1	12	5	5	6	1990	1.692	2.957	57	9	30	30	1.036
4979	Whiteadder Water	U/S ALLANTON	3864	6547	21022	2.4	3	5	5	6	1990	1.692	2.957	57	9	30	30	0.887
4983	Whiteadder Water	CHESTERFIELD FORD	3937	6536	21022	-8.9	5	2	6	6	1990	1.692	2.957	57	9	30	30	0.911
4987	Blackadder Water	HALLIBURTON BRIDGE	3677	6478	21027	22.5	8	4	4	5	1990	0.39	0.729	54	7	26	27	0.940
4991	Blackadder Water	FOGO	3770	6491	21027	9.2	3	4	4	5	1990	0.39	0.729	54	7	26	27	0.961
4995	Blackadder Water	BLACKADDER WATER FOOT	3864	6545	21027	-5.9	4	1	5	5	1990	0.39	0.729	54	7	26	27	0.856
5001	Otter	FAIRHOUSE FARM	3223	1122	45008	21.7	26	3	2	4	1982	0.759	0.879	86	8	25	32	1.016
5003	Otter	BIDWELL FARM	3203	1073	45008	15.8	20	3	3	4	1982	0.759	0.879	86	8	25	32	1.023
5005	Otter	MONKTON	3184	1030	45008	10.3	11	3	3	4	1982	0.759	0.879	86	8	25	32	1.015
5007	Otter	COLHAYES FARM	3123	0993	45008	1.3	1	1	4	4	1982	0.759	0.879	86	8	25	32	0.930
5009	Otter	NEWTON POPPLEFORD	3088	0900	45005	2.3	2	3	4	4	1982	1.374	1.449	95	13	30	43	0.964
5101	Frome	CHANTMARLE	3589	1023	44004	21.4	8	4	1	4	1982	1.543	1.613	96	12	27	44	1.043
5103	Frome	FRAMPTON	3623	0949	44004	11.1	3	1	4	4	1982	1.543	1.613	96	12	27	44	1.036
5105	Frome	LOWER BOCKHAMPTON	3721	0904	44004	-1.6	0	4	4	4	1982	1.543	1.613	96	12	27	44	1.016
5107	Frome	MORETON	3806	0895	44001	8	2	1	4	4	1982	3.469	3.601	96	16	29	55	0.991
5109	Frome	EAST STOKE	3866	0867	44001	0.1	0	4	4	4	1982	3.469	3.601	96	16	29	55	1.026
5183	Wool Stream	WOOL	3848	0869	44001	2.6	2	4	1	4	1984	2.846	3.601	79	6	29	21	1.015
5301	Ober Water	MILL LAWN	4227	1036	42003	12.6	11	4	3	4	1982	0.382	0.254	151	23	28	82	0.966
5303	Ober Water	PUTTLES BRIDGE	4268	1027	42003	7.5	8	4	3	4	1982	0.382	0.254	151	23	28	82	1.060
5305	Highland Water	MILLYFORD BRIDGE	4268	1079	42003	9.7	16	4	3	4	1982	0.382	0.254	151	23	28	82	1.048
5307	Lymington	BALMER LAWN	4297	1036	42003	3.6	5	3	4	4	1982	0.382	0.254	151	23	28	82	1.040
5309	Lymington	BOLDRE BRIDGE	4320	0984	42003	-4.7	6	2	4	4	1982	0.382	0.254	151	23	28	82	0.890
5381	Ober Water	VERELEY	4205	1050	42003	15.7	14	4	3	4	1984	0.15	0.254	59	8	28	29	1.029
5383	Bratley Water	BRATLEY	4231	1098	42003	15.6	15	4	2	4	1984	0.15	0.254	59	8	28	29	1.061
5385	Highland Water	OCKNELL	4245	1112	42003	14.5	23	4	2	4	1984	0.15	0.254	59	8	28	29	0.920
5401	Beult	HADMAN'S PLACE	5865	1425	40005	16	14	4	4	5	1982	0.147	0.292	50	9	30	30	0.968

RIVPACS site Code	River name	Site name	NGR East	NGR North	Flow Station	Distance apart (km)	Intervening Tributaries No.	Intervening Tributaries Max SO	Stream order (SO) at: Site	Stream order (SO) at: Station	Mean summer flow :	in sampling year	over all years	%flow	Flow rank of sampling year	out of n years	%rank	LIFE O/E
5403	Beult	SLANEY PLACE	5798	1445	40005	7.1	8	2	5	5	1982	0.147	0.292	50	9	30	30	0.892
5405	Beult	STILE BRIDGE	5759	1477	40005	0.1	0	5	5	5	1982	0.147	0.292	50	9	30	30	0.964
5407	Beult	HUNTON	5706	1495	40005	-7.3	4	5	6	5	1982	0.147	0.292	50	9	30	30	1.042
5601	Lugg	MONAUGHTY	3238	2681	55014	18.6	17	4	3	5	1982	1.404	1.404	100	16	30	53	1.068
5603	Lugg	COMBE	3348	2640	55014	3.5	5	4	4	5	1982	1.404	1.404	100	16	30	53	1.061
5605	Lugg	MORTIMER'S CROSS	3427	2637	55014	-10	3	3	5	5	1982	1.404	1.404	100	16	30	53	1.045
5615	Wye	LLANWRTHWL	2976	2640	55026	-4.7	4	5	6	5	1982	2.475	2.691	92	13	30	43	1.032
5617	Wye	HAFODYGARREG	3115	2414	55007	-5.6	5	4	6	6	1982	11.929	12.727	94	17	30	57	0.999
5619	Wye	BREDWARDINE	3336	2446	55002	23.1	10	3	6	6	1982	16.048	18.062	89	15	30	50	1.032
5621	Wye	HUNTSHAM BRIDGE	3567	2182	55023	15	10	6	6	7	1982	28.677	26.701	107	16	30	53	0.973
5623	Wye	REDBROOK	3534	2100	55023	-1.3	2	2	7	7	1984	10.366	26.701	39	2	30	7	0.917
5671	Monnow	LLANVEYNOE	3309	2318	55029	-23.6	36	6	3	6	1988	2.483	1.851	134	24	30	80	0.973
5673	Monnow	CLODOCK	3327	2278	55029	18.1	30	6	4	6	1988	2.483	1.851	134	24	30	80	1.023
5675	Monnow	GREAT GOYTRE	3365	2245	55029	8.7	13	5	5	6	1988	2.483	1.851	134	24	30	80	1.010
5677	Monnow	ROCKFIELD	3483	2153	55029	-19.6	20	3	6	6	1988	2.483	1.851	134	24	30	80	1.043
5681	Lugg	CRUG	3184	2730	55014	27.6	29	4	2	5	1984	0.707	1.404	50	3	30	10	1.068
5691	Arrow	KESTY	3179	2539	55013	24.5	20	4	2	4	1987	0.512	0.738	69	9	29	31	0.952
5693	Arrow	KINGTON URBAN	3288	2561	55013	6.1	3	3	4	4	1987	0.512	0.738	69	9	29	31	1.017
5695	Arrow	FOLLY FARM	3413	2588	55013	-12.8	5	4	4	4	1987	0.512	0.738	69	9	29	31	1.012
5697	Arrow	IVINGTON	3477	2572	55013	-22.1	9	4	4	4	1987	0.512	0.738	69	9	29	31	0.991
5701	Usk	U/S USK RESERVOIR	2820	2271	56014	4.5	6	2	3	3	1983	0.152	0.301	50	8	14	57	1.010
5703	Usk	D/S USK RESERVOIR	2839	2291	56014	0.1	0	3	3	3	1983	0.152	0.301	50	8	14	57	1.053
5705	Usk	TRECASTLE	2882	2287	56014	-5.5	9	3	4	3	1983	0.152	0.301	50	8	14	57	1.026
5707	Usk	TRALLONG	2948	2296	56006	0.1	0	5	5	5	1983	1.574	2.323	68	3	14	21	1.019
5709	Usk	BRECON TOWN BRIDGE	3043	2285	56006	-11.8	14	4	5	5	1983	1.574	2.323	68	3	14	21	0.998
5713	Usk	CRICKHOWELL	3229	2169	56012	3.4[1]	1	4	5	4	1983	0.667	0.832	80	8	24	33	1.037
5715	Usk	LLANELLEN BRIDGE	3306	2110	56001	13	13	5	5	5	1983	7.526	9.421	80	12	30	40	1.196
5717	Usk	LLANTRISSANT	3386	1971	56015	-4.7[2]	6	5	6	5	1983	0.442	0.335	132	21	25	84	1.057
5801	Eastern Cleddau	PLASYMEIBION	2129	2274	61002	17.5	17	4	3	4	1982	1.427	2.483	57	7	30	23	1.002
5803	Eastern Cleddau	WEST OF LLANDISSILIO	2106	2224	61002	10.4	11	4	3	4	1982	1.427	2.483	57	7	30	23	0.969
5805	Eastern Cleddau	LLAWHADEN	2075	2172	61002	2.3	2	2	4	4	1982	1.427	2.483	57	7	30	23	0.997

RIVPACS site Code	River name	Site name	NGR East	NGR North	Flow Station	Distance apart (km)	Intervening Tributaries No.	Intervening Tributaries Max SO	Stream order (SO) at: Site	Stream order (SO) at: Station	Mean summer flow: in sampling year		Mean summer flow: over all years	%flow	Flow rank of sampling year	out of n years	%rank	LIFE O/E
5841	Unnamed	BREDENBURY	3603	2558	55018	19.4	14	4	1	4	1991	0.234	0.395	59	4	30	13	0.988
5844	Unnamed	DUNHAMPTON FARM	3586	2603	55021	23.6[1]	13	5	1	5	1991	2.062	2.210	93	13	27	48	0.982
5845	Unnamed	DINMORE MANOR	3490	2503	55003	18.1	7	5	1	5	1991	2.353	4.018	59	4	23	17	1.003
5848	Unnamed	GLASNANT	3182	2508	55013	23.2	17	4	2	4	1991	0.399	0.738	54	5	29	17	1.040
5850	Unnamed	CRINFYNYDD	3176	2602	55014	25.9	19	5	2	5	1991	1.064	1.404	76	8	30	27	1.078
5851	Unnamed	HILL HOUSE DINGLE	3303	2685	55014	12.7	14	5	2	5	1991	1.064	1.404	76	8	30	27	0.986
5852	Unnamed	PEN-TWYN	3187	2729	55014	27.7	29	5	1	5	1991	1.064	1.404	76	8	30	27	1.022
5854	Back Brook	KINGTON	3303	2570	55013	3.7	2	4	3	4	1991	0.399	0.738	54	5	29	17	1.002
5855	Curl Brook	PEMBRIDGE	3390	2585	55013	9.6	5	4	3	4	1991	0.399	0.738	54	5	29	17	1.077
5856	Main Ditch	LEOMINSTER	3501	2597	55021	0.9	3	5	3	5	1991	2.062	2.210	93	13	27	48	0.971
5861	Hindwell Brook/Summergil Brook	COMBE	3345	2635	55014	3.5	5	5	4	5	1991	1.064	1.404	76	8	30	27	1.252
5864	Lugg	MORDIFORD	3570	2375	55003	-5	2	4	5	5	1991	2.353	4.018	59	4	23	17	1.057
5881	Wern	MYNACHLOG-DDU	2118	2307	61002	22.4	21	4	1	4	1984	1.019	2.483	41	2	30	7	0.998
5895	Western Cleddau	CROW HILL	1954	2177	61001	0.1	0	4	4	4	1990	0.825	1.958	42	4	30	13	0.991
5901	Dwyfach	PANT GLAS	2468	3472	65007	18.2[1]	14	4	3	4	1982	1.076	1.466	73	9	25	36	0.959
5903	Dwyfach	PONT Y FELIN	2481	3435	65007	14.5[1]	11	4	4	4	1982	1.076	1.466	73	9	25	36	0.954
5905	Dwyfach	BONT FECHAN	2460	3380	65007	8.3[1]	3	4	4	4	1982	1.076	1.466	73	9	25	36	0.934
6101	Thet	RED BRIDGE, SHROPHAM	5996	2924	33046	0.1	0	4	4	4	1982	0.3	0.329	91	19	30	63	0.892
6103	Thet	EAST HARLING	5989	2867	33044	4.8	3	2	4	4	1982	0.572	0.749	76	11	30	37	0.909
6105	Thet	NUNS BRIDGE, THETFORD	5875	2826	33019	0.9	0	4	4	4	1982	0.749	0.981	76	9	29	31	0.965
6107	Little Ouse	BRANDON	5783	2868	33034	-11	0	5	5	5	1982	1.874	2.123	88	12	30	40	0.959
6109	Little Ouse	BRANDON CREEK	5607	2917	33034	-32.7	11	6	5	5	1982	1.874	2.123	88	12	30	40	1.017
6111	Ouse/Cam	HILGAY BRIDGE	5604	2970	33034	-38.7	16	6	6	5	1982	1.874	2.123	88	12	30	40	0.951
6201	Unnamed	U/S BRACKLEY	4562	2380	33005	26.7	23	5	1	5	1984	0.412	0.868	47	3	22	14	0.900
6213	Great Ouse	SHARNBROOK	5010	2590	33009	-7.7	6	6	6	6	1984	2.786	4.129	67	5	22	23	0.925
6215	Great Ouse	ROXTON LOCK	5160	2535	33039	0.1	0	6	6	6	1984	3.407	4.851	70	8	26	31	0.888
6242	Nine Wells Spring	NINE WELLS	5460	2542	33024	16.2[1]	17	5	1	4	1991	0.314	0.597	53	5	30	17	0.913
6258	Mill	WENDY	5321	2475	33027	2	2	4	3	4	1991	0.088	0.216	41	5	30	17	0.987
6259	Babraham/Granta	HILDERSHAM	5545	2485	33055	4.9	0	3	3	3	1991	0.021	0.123	17	3	22	14	0.867
6264	Rhee	HARSTON	5417	2511	33021	1.7	1	2	4	4	1991	0.302	0.618	49	7	29	24	0.959
6265	Ouse/Cam	HAUXTON MILL	5432	2527	33024	-5.8	7	4	4	4	1991	0.314	0.597	53	5	30	17	0.862

RIVPACS site Code	River name	Site name	NGR East	NGR North	Flow Station	Distance apart (km)	Intervening Tributaries No.	Intervening Tributaries Max SO	Stream order (SO) at: Site	Stream order (SO) at: Station	Mean summer flow : sampling year	in sampling year	over all years	%flow	Flow rank of sampling year	out of n years	%rank	LIFE O/E
6285	Wissey	LINGHILLS FARM	5834	3009														0.962
6289	Wissey	DIDLINGTON LODGE	5771	2967	33006	-0.3	1	2	3	3	1990	0.493	1.043	47	4	30	13	0.995
6293	Wissey	FIVE MILE HOUSE	5664	2977	33006	-13.7	7	4	5	3	1990	0.493	1.043	47	4	30	13	0.947
6381	Unnamed	BONEMILLS HOLLOW	5042	3023	32020	6	3	2	1	3	1984	0.131	0.166	79	4	15	27	1.075
6405	Brue	SOUTH BREWHAM	3716	1363	52010	18.5	13	4	2	5	1988	0.945	0.650	145	22	29	76	0.973
6409	Brue	WYKE	3656	1340	52010	10.1	4	4	4	5	1988	0.945	0.650	145	22	29	76	1.032
6413	Brue	TOOTLE BRIDGE	3551	1327	52010	-5	0	5	5	5	1988	0.945	0.650	145	22	29	76	0.915
6417	Mounton Brook	BULLY HOLE BOTTOM	3460	1962	52010	-29.1	23	5	5	5	1988	0.945	0.650	145	22	29	76	1.045
6615	Severn	STOURPORT	3805	2710	54001	-6.8	5	3	7	7	1984	12.474	22.192	56	6	31	19	0.997
6691	Dowles Brook	D/S LEM BROOK	3723	2766	54034	6.2	7	2	3	3	1988	0.145	0.124	117	19	28	68	1.035
6693	Cannop Brook	SPECULATION	3610	2128	54034	-0.3	1	2	3	3	1988	0.145	0.124	117	19	28	68	1.025
6801	Stour	LONGHAM	4065	0973	43009	32.2	20	5	1	5	1984	0.816	1.742	47	3	30	10	0.782
6840	Unnamed	GASPER	3763	1335	43019	11.7[1]	11	3	2	3	1991	0.257	0.313	82	7	26	27	1.015
6841	Unnamed	WOODLANDS MANOR	3816	1309	43019	4.1	3	3	2	3	1991	0.257	0.313	82	7	26	27	0.851
6844	Unnamed	LYON'S GATE	3656	1055	43009	34.5	20	5	1	5	1991	1.872	1.742	107	18	30	60	0.982
6845	Unnamed	ALTON COMMON	3717	1047	43009	30.7	19	5	1	5	1991	1.872	1.742	107	18	30	60	0.948
6847	Unnamed	FARRINGTON	3846	1152	43009	4.2[1]	2	5	2	5	1991	1.872	1.742	107	18	30	60	0.906
6848	Unnamed	WOOLLAND	3782	1069	43009	19.3	16	5	2	5	1991	1.872	1.742	107	18	30	60	1.093
6849	Unnamed	OKEFORD FITZPAINE	3801	1105	43009	7.8	7	5	2	5	1991	1.872	1.742	107	18	30	60	0.891
6856	Allen	WALFORD MILL	4010	1006	43018	0.3	0	3	3	3	1992	0.513	0.688	75	8	25	32	1.090
6857	Cale	SYLES FARM	3759	1199	43019	19.7	8	4	4	3	1992	0.235	0.313	75	5	26	19	0.934
6858	Stour	TRILL BRIDGE	3790	1205	43019	-12.1	5	3	4	3	1991	0.257	0.313	82	7	26	27	1.013
6862	Lydden	BAGBER BRIDGE	3765	1157	43009	13.4	7	5	4	5	1991	1.872	1.742	107	18	30	60	0.913
6863	Stour	SPETISBURY	3919	1020	43009	-24.6	8	5	5	5	1991	1.872	1.742	107	18	30	60	0.997
6911	Thames/Isis	MALTHOUSE	4225	1984	39097	0.7	0	5	5	5	1984	1.764	3.498	50	3	18	17	0.997
6915	Thames/Isis	SHILLINGFORD	4590	1932	39002	-2.6	4	5	6	6	1984	4.75	9.714	49	5	30	17	0.964
6919	Thames/Isis	SPADE OAK	4884	1875	39023	1.9[1]	2	3	6	2	1984	0.839	0.953	88	11	30	37	0.926
6981	Loddon	OLIVER'S BATTERY	4667	1537	39022	18.7	16	4	3	4	1990	1.123	1.348	83	5	29	17	0.899
6985	Loddon	SHERFIELD ON LODDON	4683	1583	39022	11.1	9	4	3	4	1990	1.123	1.348	83	5	29	17	0.945
6993	Enborne	BRIMPTON	4568	1648	39025	0	0	5	5	5	1990	0.187	0.446	42	2	30	7	0.902
7205	Cree	WHEEB BRIDGE	2302	5806	81002	27	43	6	5	6	1986	7.805	8.072	97	17	30	57	0.990

RIVPACS site Code	River name	Site name	NGR East	NGR North	Flow Station	Distance apart (km)	Intervening Tributaries No.	Intervening Tributaries Max SO	Stream order (SO) at: Site	Stream order (SO) at: Station	Mean summer flow : in sampling year		Mean summer flow : over all years	%flow	Flow rank of sampling year	out of n years	%rank	LIFE O/E
7217	Cree	NEWTON STEWART	2415	5648	81002	0.6	0	6	6	6	1986	7.805	8.072	97	17	30	57	0.992
7605	Kyle of Sutherland/Oykel	CAPLICH	2351	9028	3003	6.7	17	5	5	6	1986	6.799	8.094	84	9	22	41	0.937
7611	Kyle of Sutherland/Oykel	STRATH OYKEL	2438	9014	3003	-4.6	11	6	6	6	1986	6.799	8.094	84	9	22	41	0.953
7705	Lunan Burn	FORNETH	3097	7452	15021	12.6	7	2	4	4	1986	0.763	0.549	139	12	15	80	1.043
8205	Teme	FELINDRE	3162	2821	54008	72.5	68	5	2	6	1987	3.948	4.312	92	13	30	43	1.015
8209	Teme	PENNANT POUND	3215	2773	54008	62.8	59	5	4	6	1987	3.948	4.312	92	13	30	43	1.048
8213	Teme	BRAMPTON BRYAN	3372	2729	54008	41.6	39	5	4	6	1987	3.948	4.312	92	13	30	43	1.018
8217	Teme	TENBURY	3595	2685	54008	0.3	0	6	6	6	1987	3.948	4.312	92	13	30	43	0.986
8221	Teme	POWICK BRIDGE	3837	2524	54029	-17.1	11	6	6	6	1987	5.535	5.530	100	14	30	47	1.044
8305	Bure	CORPUSTY	6105	3305	34003	12.6	5	3	3	4	1987	1.344	0.783	172	30	30	100	1.205
8309	Bure	WHITEHOUSE FARM FORD	6164	3305	34003	4.1	2	3	3	4	1987	1.344	0.783	172	30	30	100	1.117
8313	Bure	BUXTON MILL	6243	3231	34019	5.9	2	3	4	4	1987	2.419	1.583	153	24	24	100	1.011
8317	Bure	COLTISHALL BRIDGE	6267	3198	34019	0.4	0	4	4	4	1987	2.419	1.583	153	24	24	100	0.940
8421	Test	LOWER BROOK	4338	1276	42004	11	2	2	4	4	1987	8.53	7.808	109	19	29	66	1.040
8425	Test	ROMSEY	4352	1204	42004	1.7	0	4	4	4	1987	8.53	7.808	109	19	29	66	1.038
8505	Piddle	PIDDLETRENTHIDE	3703	1010	44002	31	6	2	1	3	1987	1.377	1.253	110	21	30	70	1.009
8509	Piddle	DRUCE	3744	0951	44002	22.5	6	2	2	3	1987	1.377	1.253	110	21	30	70	1.025
8513	Piddle	BROCKHILL BRIDGE	3839	0928	44002	11.2	5	2	3	3	1987	1.377	1.253	110	21	30	70	0.991
8517	Piddle	WAREHAM	3919	0876	44002	-0.7	0	3	3	3	1987	1.377	1.253	110	21	30	70	0.986
8521	Bere Stream	MIDDLE BERE	3858	0923	44002	9.1	2	3	2	3	1987	1.377	1.253	110	21	30	70	1.056
8613	Teign	WHETCOMBE BARTON	2843	0817	46002	9.5	9	4	5	5	1988	3.582	2.603	138	27	30	90	1.054
8705	Fowey	CODDA FORD	2183	0786	48001	10.8	9	3	2	4	1988	0.661	0.558	118	22	30	73	1.037
8709	Fowey	DRAYNES BRIDGE	2228	0689	48001	-1.2	1	1	4	4	1988	0.661	0.558	118	22	30	73	1.005
8713	Fowey	LEBALL BRIDGE	2134	0653	48011	6	12	3	4	4	1988	2.107	1.787	118	23	30	77	0.989
9105	Hull/West Beck	LITTLE DRIFFIELD	5010	4576	26006	0.2	0	2	2	2	1989	0.111	0.286	39	4	20	20	0.984
9113	Hull/West Beck	CORPSLANDING	5066	4529	26002	4.8	5	3	3	4	1989	0.838	2.036	41	5	26	19	0.798
9121	Kelk Beck/Frodingham Beck	HARPHAM	5084	4614	26003	7.6	4	3	2	4	1989	0.199	0.456	44	5	30	17	0.987
9205	Millburn Beck/Knock Ore Gill	GREEN CASTLE	3711	5306	76005	14.7[1]	5	6	2	6	1989	2.258	5.298	43	3	30	10	1.044
9481	Walkham	MERRIVALE	2550	0751	47014	7.9	7	2	2	3	1990	0.663	0.835	79	9	24	38	0.975
9485	Walkham	GRENOFEN	2489	0710	47014	-3	3	1	3	3	1990	0.663	0.835	79	9	24	38	0.994
9611	Coquet	SHARPERTON	3954	6038	22009	19.8	15	5	5	5	1990	1.04	2.251	46	3	28	11	0.962

RIVPACS site			NGR		Flow	Distance apart	Intervening Tributaries		Stream order (SO) at:		Mean summer flow :				Flow rank of	out of		LIFE
Code	River name	Site name	East	North	Station	(km)	No.	Max SO	Site	Station	sampling year	in sampling year	over all years	%flow	sampling year	n years	%rank	O/E
9615	Coquet	PAUPERHAUGH	4101	5995	22009	-4.7	5	3	5	5	1990	1.04	2.251	46	3	28	11	0.936
9703	Bladnoch	GLASSOCH BRIDGE	2333	5695	81004	22.8	27	6	4	6	1990	4.846	4.125	117	16	22	73	0.986
9711	Bladnoch	SPITTAL	2360	5579	81004	7.1	10	3	6	6	1990	4.846	4.125	117	16	22	73	1.022
AN02	Cringle Brook	THUNDERBRIDGE	4920	3287	30015	1.5	0	2	2	2	1990	0.084	0.181	46	2	24	8	0.945
AN06	Rase	BULLY HILLS	5168	3918	29004	25.5	9	3	1	3	1990	0.908	0.617	147	23	30	77	1.006
AN07	Waithe Beck	KIRMOND LE MIRE	5189	3926	29001	17.8	4	2	2	3	1990	0.062	0.154	40	4	29	14	1.035
AN08	Bain	BISCATHORPE	5231	3849	30011	7.4	2	1	3	3	1990	0.078	0.163	48	5	28	18	1.033
AN09	Goulceby Beck	GOULCEBY	5254	3791	30011	1.3[1]	1	3	2	3	1990	0.078	0.163	48	5	28	18	0.958
CL04	Ayr	MAINHOLM FORD	2363	6215	83006	0.3	0	6	6	6	1992	6.197	6.549	95	12	23	52	1.013
CL05	Leven/Loch Lomond/Falloch	KEILATOR	2370	7238	85003	7.1	40	5	4	5	1992	4.624	3.021	153	26	29	90	1.164
HI01	Finnan	GLEN FINNAN	1907	7808	92002	21[1]	74	5	4	3	1992	0.417	0.425	98	7	12	58	0.989
HI02	Foyers	DALCRAG	2495	8187	6007	31.2	54	6	5	6	1992	56.558	39.553	143	26	27	96	1.066
HI03	Fechlin/Killin	KILLIN LODGE	2530	8093	6007	45	67	6	5	6	1992	56.558	39.553	143	26	27	96	1.000
HI04	Spean	CORRIE COILLE	2252	7808	91002	15.1	39	5	6	7	1992	26.418	21.192	125	14	19	74	1.044
HI08	Arkaig/Dessarry	STRATHAN	1979	7913	91002	35.5	141	7	4	7	1992	26.418	21.192	125	14	19	74	1.059
HI09	Meig	BRIDGEND	2323	8549	4005	-5.6	10	4	5	4	1993	2.898	2.922	99	9	14	64	1.064
HI10	Conon/Bran	MOY BRIDGE	2477	8547	4001	0.7	1	5	6	6	1992	31.178	25.651	122	20	25	80	1.068
NE01	Lossie	CLODDACH	3203	8584	7006	-18.7	17	4	4	4	1992	0.14	0.271	52	4	13	31	1.043
NE02	Lossie	U/S BLACKBURN	3185	8620	7003	1.4	1	3	5	5	1992	0.717	1.713	42	2	30	7	1.016
NE03	Bervie Water	INVERBERVIE G.S.	3824	7735	13001	0.4	0	4	4	4	1992	0.606	0.866	70	8	20	40	1.036
NH03	Glen	EWART	3955	6302	21032	-4.3	3	3	5	5	1990	0.342	1.040	33	1	18	6	0.981
NH05	Gate Burn	FRAMLINGTON GATE	4118	6037	22001	24.1	17	5	1	5	1990	1.602	3.256	49	4	30	13	1.051
NH09	Wooler Water/Harthope Burn	CORONATION WOOD	3973	6248	21032	24.2[1]	19	5	3	5	1990	0.342	1.040	33	1	18	6	1.003
NW02	Lune	RIGMADEN	3616	4848	72005	-7.4	11	6	6	5	1990	3.141	4.314	73	11	29	38	1.031
NW03	Lune	FORGE WEAR	3512	4646	72004	-2.8	3	2	7	7	1990	9.616	16.897	57	8	29	28	0.922
NW04	Eden	TEMPLE SOWERBY	3604	5282	76005	0.2	0	6	6	6	1990	3.379	5.298	64	11	30	37	0.971
NW05	Eden	APPLEBY	3683	5206	76005	16.8	7	4	6	6	1990	3.379	5.298	64	11	30	37	0.977
NW06	Eden	WARWICK BRIDGE	3470	5567	76002	0.1	0	7	7	7	1990	8.568	15.593	55	4	28	14	0.977
SO01	Urr Water	CORSOCK	2766	5757	80001	19.7	34	4	5	5	1990	1.535	1.950	79	17	30	57	0.985
SO02	Urr Water	HAUGH OF URR	2806	5660	80001	6.4	7	4	5	5	1990	1.535	1.950	79	17	30	57	1.009
ST02	Severn	ISLE OF BICTON	3468	3164	54005	-13.8	10	4	6	6	1990	9.444	14.779	64	7	28	25	1.010

RIVPACS site Code	River name	Site name	NGR East	NGR North	Flow Station	Distance apart (km)	Intervening Tributaries No.	Intervening Tributaries Max SO	Stream order (SO) at: Site	Stream order (SO) at: Station	Mean summer flow : in sampling year		Mean summer flow : over all years	%flow	Flow rank of sampling year	out of n years	%rank	LIFE O/E
ST03	Sher Brook	SHUGBOROUGH	3988	3213	28012	20.8	16	6	1	6	1990	5.471	9.043	61	3	28	11	1.023
ST04	Sence	NEWTON LINFORD	4523	3098	28093	13.6	8	5	2	5	1990	2.914	4.845	60	1	11	9	1.002
ST05	Derwent	BASLOW	4252	3722	28043	4.3	3	3	6	6	1990	1.578	2.755	57	2	29	7	0.992
ST06	Derwent	CROMFORD MEADOWS	4301	3572	28011	-2.7	1	2	6	6	1993	6.623	5.823	114	22	29	76	1.037
SW05	Stithians Stream	SEARAUGH MOOR	1734	0374	48007	3.8	3	4	3	4	1990	0.072	0.187	38	1	30	3	1.007
TA01	Earn	FORTEVIOT	3048	7184	16004	0.5	0	6	6	6	1992	9.832	9.702	101	16	27	59	1.107
TA02	Isla	WESTER CARDEAN	3294	7466	15010	0.1	0	5	5	5	1992	3.023	3.224	94	16	28	57	1.056
TA04	Braan	U/S TAY CONFLUENCE	3023	7423	15023	-1.2	0	4	4	4	1992	1.629	2.436	67	6	17	35	0.995
TA05	Prosen Water	PROSEN BRIDGE	3394	7586	13004	0.2	0	4	4	4	1992	1.427	1.467	97	9	15	60	1.081
TA06	Vinny Water	PITMUIES	3568	7496	13005	10.8	8	3	3	4	1992	0.303	0.524	58	6	19	32	1.082
TH01	Kennet	U/S ALDERSHOT WATER	4544	1659	39103	-8.6	6	3	4	4	1990	2.567	3.051	84	3	10	30	1.041
TH02	Lambourn	BAGNOR	4453	1691	39019	2.3	2	3	2	3	1990	1.132	1.468	77	5	30	17	1.019
TH03	Lyde River	DEANLANDS FARM	4696	1542	39022	16.6	13	4	2	4	1992	1.043	1.348	77	3	29	10	1.031
TH06	Clayhill Brook	U/S BURGHFIELD STW	4655	1684	39016	5.6[1]	2	5	1	5	1990	4.654	6.514	71	4	30	13	0.926
TH08	Chess	U/S R. COLNE	5066	1947	39088	0.1	0	3	3	3	1990	0.485	0.579	84	7	24	29	1.028
TW02	Tarth Water	TARTH WATER FOOT	3165	6429	21018	6.9	9	5	4	5	1992	1.455	1.386	105	21	30	70	1.025
TW03	Eden Water	A6089 BRIDGE	3627	6451	21021	34.3[1]	27	7	2	7	1992	23.352	28.336	82	15	30	50	1.116
WE05	Morlas Brook	D/S GLYN MORLAS	3312	3381	67015	6.7	9	6	2	6	1990	11.142	13.692	81	8	30	27	1.040

APPENDIX 3

List of the National Water Archive (NWA) flow gauging stations with complete summer (June-August) flow data for at least five years since 1970, together with the mean summer flow in 1995. %flow = mean summer flow in 1995 relative to average over all available years; %rank = percentage rank of mean summer flow in 1995 amongst all available years; BFI = Base Flow Index (supplied by CEH Wallingford)

Station Id	River name	Station name	East	North	BFI	Year range	Flow 1995	Mean flow	rank 1995	No. years	% flow	% rank
2001	Helmsdale	Kilphedir	2997	9181	0.48	75-99	4.03	6.06	8	25	67	32
2002	Brora	Bruachrobie	2892	9039		95-99	1.08	3.98	1	5	27	20
3002	Carron	Sgodachail	2490	8921	0.32	74-99	1.42	3.99	2	26	36	8
3003	Oykel	Easter Turnaig	2403	9001	0.23	78-99	2.38	8.09	1	22	29	5
3004	Cassley	Rosehall	2472	9022	0.23	80-99	1.63	3.53	2	20	46	10
3005	Shin	Inveran	2574	8974	0.61	81-99	3.52	3.85	7	18	91	39
4001	Conon	Moy Bridge	2482	8547	0.55	70-99	20.94	25.65	7	25	82	28
4003	Alness	Alness	2654	8695	0.45	74-99	1.08	2.56	3	26	42	12
4004	Blackwater	Contin	2455	8563	0.39	81-99	1.93	2.87	2	19	67	11
4005	Meig	Glenmeannie	2286	8528	0.26	86-99	1.32	2.92	1	14	45	7
4006	Bran	Dosmucheran	2205	8602	0.24	90-99	1.26	2.94	1	10	43	10
4007	Blackwater	Garve	2396	8617		90-99	1.59	2.26	1	10	70	10
5002	Farrar	Struy	2390	8405	0.58	86-99	8.42	9.53	5	13	88	38
5003	Glass	Kerrow Wood	2354	8321	0.46	89-99	16.49	17.86	5	11	92	45
5004	Glass	Fasnakyle	2315	8288	0.40	91-99	1.61	2.19	2	9	73	22
6007	Ness	Ness-side	2645	8427	0.60	73-99	29.83	39.55	8	27	75	30
6008	Enrick	Mill of Tore	2450	8300	0.32	80-99	0.17	0.91	2	20	19	10
6011	Tarff	Ardachy Bridge	2379	8074		93-99	0.77	1.32	1	7	59	14
7001	Findhorn	Shenachie	2826	8337	0.36	70-99	3.98	6.63	5	30	60	17
7002	Findhorn	Forres	3018	8583	0.41	70-99	6.15	10.48	6	30	59	20
7003	Lossie	Sheriffmills	3194	8626	0.52	70-99	1.03	1.71	9	30	60	30
7004	Nairn	Firhall	2882	8551	0.45	79-99	1.46	3.08	6	21	47	29
7005	Divie	Dunphail	3005	8480	0.42	78-99	1.05	1.86	6	18	57	33
7006	Lossie	Torwinny	3135	8489	0.46	87-99	0.17	0.27	5	13	61	38
7008	Nairn	Balnafoich	2686	8352		93-99	0.59	1.24	2	7	47	29
8001	Spey	Aberlour	3278	8439	0.58	70-74		34.93		5		
8002	Spey	Kinrara	2881	8082	0.57	70-99	8.66	11.04	7	30	78	23
8004	Avon	Delnashaugh	3186	8352	0.56	70-99	8.20	9.78	15	30	84	50
8005	Spey	Boat of Garten	2946	8191	0.61	70-99	12.56	15.64	8	30	80	27
8006	Spey	Boat o Brig	3318	8518	0.61	70-99	31.01	39.12	12	30	79	40
8007	Spey	Invertruim	2687	7962	0.52	70-95	1.89	2.67	4	26	71	15
8008	Tromie	Tromie Bridge	2789	7995	0.64	70-99	1.49	1.48	17	29	101	59
8009	Dulnain	Balnaan Bridge	2977	8247	0.46	70-99	1.69	2.88	7	30	59	23
8010	Spey	Grantown	3033	8268	0.60	70-99	15.47	20.93	6	30	74	20
8011	Livet	Minmore	3201	8291	0.65	81-99	1.61	1.49	13	19	108	68
8013	Feshie	Feshie Bridge	2849	8047		93-99	3.39	3.79	4	7	90	57
8015	Fiddich	Auchindoun	3355	8399		91-98	0.64	0.62	4	5	104	80
9001	Deveron	Avochie	3532	8464	0.59	70-99	4.57	4.94	17	30	92	57
9002	Deveron	Muiresk	3705	8498	0.58	70-99	7.51	8.44	15	29	89	52
9003	Isla	Grange	3494	8506	0.54	70-99	1.16	1.51	15	29	77	52
9004	Bogie	Redcraig	3519	8373	0.71	81-99	1.67	1.75	11	19	96	58
9005	Allt Deveron	Cabrach	3378	8291	0.50	70-99	0.86	0.93	17	30	92	57

Station Id	River name	Station name	East	North	BFI	Year range	Flow 1995	Mean flow	rank 1995	No. years	% flow	% rank
9006	Deskford Burn	Cullen	3504	8667		90-96	0.12	0.16	2	7	77	29
10001	Ythan	Ardlethen	3924	8308	0.72	70-82		2.84		13		
10002	Ugie	Inverugie	4101	8485	0.64	71-99	1.64	2.22	11	29	74	38
10003	Ythan	Ellon	3947	8303	0.74	83-99	2.74	3.98	5	17	69	29
11001	Don	Parkhill	3887	8141	0.68	70-99	8.98	11.30	14	30	79	47
11002	Don	Haughton	3756	8201	0.68	70-99	6.85	8.16	15	30	84	50
11003	Don	Bridge of Alford	3566	8170	0.68	73-99	5.32	5.82	14	27	91	52
11004	Urie	Pitcaple	3721	8260	0.82	89-99	1.50	1.56	6	11	96	55
11005	Don	Mill of Newe	3371	8121	0.68	89-93		2.41		5		
12001	Dee	Woodend	3635	7956	0.54	70-99	13.59	19.23	7	30	71	23
12002	Dee	Park	3798	7983	0.54	73-99	16.42	22.17	10	27	74	37
12003	Dee	Polhollick	3344	7965	0.51	75-99	8.23	11.80	6	24	70	25
12004	Girnock Burn	Littlemill	3324	7956	0.40	70-99	0.14	0.20	13	27	69	48
12005	Muick	Invermuick	3364	7947	0.53	77-99	1.07	1.78	4	23	60	17
12006	Gairn	Invergairn	3353	7971	0.55	79-99	1.66	2.11	9	21	78	43
12007	Dee	Mar Lodge	3098	7895	0.47	83-99	4.61	6.53	5	17	71	29
12008	Feugh	Heugh Head	3687	7928	0.48	85-99	1.82	3.04	5	15	60	33
12009	Water of Dye	Charr	3624	7834	0.36	83-99	0.39	0.73	4	16	53	25
13001	Bervie	Inverbervie	3826	7733	0.56	80-99	0.70	0.87	9	20	81	45
13002	Luther Water	Luther Bridge	3658	7674	0.59	82-99	0.75	1.00	8	18	76	44
13004	Prosen Water	Prosen Bridge	3396	7586	0.61	85-99	0.84	1.47	3	15	57	20
13005	Lunan Water	Kirkton Mill	3655	7494	0.52	81-99	0.42	0.52	11	19	81	58
13007	North Esk	Logie Mill	3699	7640	0.53	76-99	6.25	8.32	9	24	75	38
13008	South Esk	Brechin	3600	7596	0.58	83-99	3.56	5.47	5	17	65	29
13009	West Water	Dalhouse Bridge	3592	7680	0.56	85-99	1.41	2.00	5	15	70	33
13010	Brothock Water	Arbroath	3639	7418	0.55	89-99	0.19	0.16	9	11	115	82
13012	South Esk	Gella Bridge	3372	7653	0.53	91-99	1.67	2.33	1	9	71	11
13017	Colliston Burn	Colliston	3609	7466		94-99	0.02	0.02	4	6	82	67
14001	Eden	Kemback	3415	7158	0.62	70-99	1.62	1.76	14	30	92	47
14002	Dighty Water	Balmossie Mill	3477	7324	0.59	70-99	0.44	0.57	12	30	77	40
14005	Motray Water	St Michaels	3441	7224	0.55	84-99	0.11	0.20	5	16	57	31
14006	Monikie Burn	Panbride	3574	7361	0.44	87-91		0.11		5		
14007	Craigmill Burn	Craigmill	3575	7360	0.45	87-99	0.09	0.10	8	13	96	62
14009	Eden	Strathmiglo	3226	7102	0.59	91-99	0.14	0.18	3	9	78	33
14010	Motray Water	Kilmany	3387	7217	0.56	91-99	0.05	0.07	3	9	64	33
15003	Tay	Caputh	3082	7395	0.64	70-99	49.45	61.74	9	30	80	30
15006	Tay	Ballathie	3147	7367	0.65	70-100	55.19	73.22	7	31	75	23
15007	Tay	Pitnacree	2924	7534	0.64	70-99	17.77	25.20	6	30	71	20
15008	Dean Water	Cookston	3340	7479	0.58	70-99	0.86	1.09	10	29	79	34
15010	Isla	Wester Cardean	3295	7466	0.54	72-99	1.80	3.22	2	28	56	7
15011	Lyon	Comrie Bridge	2786	7486	0.46	70-99	4.00	5.72	4	30	70	13
15012	Tummel	Pitlochry	2947	7574	0.63	73-99	27.30	30.19	12	27	90	44
15013	Almond	Almondbank	3068	7258	0.45	70-99	0.91	1.94	3	30	47	10
15014	Ardle	Kindrogan	3056	7631	0.43	85-99	0.66	1.50	1	15	44	7
15015	Almond	Newton Bridge	2888	7316	0.43	86-99	0.52	1.16	1	14	44	7
15016	Tay	Kenmore	2782	7467	0.65	74-99	13.07	17.96	7	26	73	27
15017	Braan	Ballinloan	2979	7406	0.39	76-80		1.42		5		
15021	Lunan Burn	Mill Bank	3182	7400	0.68	84-98	0.23	0.55	3	15	42	20
15023	Braan	Hermitage	3014	7422	0.46	83-99	0.76	2.44	2	17	31	12
15024	Dochart	Killin	2564	7320	0.26	82-99	3.23	7.21	3	18	45	17
15025	Ericht	Craighall	3174	7472	0.51	85-99	2.68	5.70	2	15	47	13

Station Id	River name	Station name	East	North	BFI	Year range	Flow 1995	Mean flow	rank 1995	No. years	% flow	% rank
15027	Garry Burn	Loakmill	3075	7339	0.49	87-99	0.04	0.12	2	13	36	15
15028	Ordie Burn	Luncarty	3090	7312	0.48	86-99	0.10	0.32	1	14	30	7
15030	Dean Water	Dean Bridge	3293	7458	0.62	90-99	0.97	1.14	4	10	85	40
15032	Ordie Burn	Jackstone	3070	7337	0.50	90-96	0.03	0.08	1	7	33	14
15034	Garry	Killiecrankie	2901	7637	0.43	91-99	4.33	6.48	2	9	67	22
15035	Tummel	Kinloch Rannoch	2663	7588	0.60	91-99	21.85	21.32	6	9	102	67
15038	Gaur	Bridge of Gaur	2497	7570		92-98	3.69	5.73	2	7	64	29
15039	Tilt	Marble Lodge	2892	7717	0.54	92-99	2.21	2.75	3	8	80	38
15041	Lyon	Camusvrachan	2620	7477		92-98	2.85	3.43	1	7	83	14
16001	Earn	Kinkell Bridge	2933	7167	0.50	70-99	4.95	8.39	4	30	59	13
16002	Earn	Aberuchill	2754	7216	0.46	70-77		3.79		8		
16003	Ruchill Water	Cultybraggan	2764	7204	0.30	71-99	0.91	2.04	3	29	45	10
16004	Earn	Forteviot Bridge	3044	7183	0.53	73-99	5.72	9.70	5	27	59	19
16007	Ruthven Water	Aberuthven	2975	7154	0.56	90-99	0.27	0.46	1	10	59	10
17001	Carron	Headswood	2832	6820	0.36	70-99	0.61	1.31	1	30	47	3
17002	Leven	Leven	3369	7006	0.67	70-99	1.79	2.86	7	30	63	23
17003	Bonny Water	Bonnybridge	2824	6804	0.45	71-99	0.27	0.61	1	29	44	3
17004	Ore	Balfour Mains	3330	6997	0.56	73-99	0.64	0.92	9	27	70	33
17005	Avon	Polmonthill	2952	6797	0.41	72-99	0.84	1.54	5	28	54	18
17008	South Queich	Kinross	3122	7015	0.47	88-99	0.16	0.31	1	11	52	9
17012	Red Burn	Castlecary	2788	6780	0.36	86-99	0.15	0.34	1	13	45	8
17015	North Queich	Lathro	3114	7042	0.46	87-99	0.10	0.25	2	13	41	15
17016	Lochty Burn	Whinnyhall	3220	6985	0.60	86-99	0.10	0.14	3	13	73	23
18001	Allan Water	Kinbuck	2792	7053	0.45	70-99	1.19	2.16	4	30	55	13
18002	Devon	Glenochil	2858	6960	0.55	70-99	1.17	2.01	4	30	58	13
18003	Teith	Bridge of Teith	2725	7011	0.43	70-99	6.18	10.33	5	30	60	17
18005	Allan Water	Bridge of Allan	2786	6980	0.47	71-99	1.43	2.66	5	28	54	18
18007	Devon	Fossoway Bridge	3011	7018	0.50	86-90		0.85		5		
18008	Leny	Anie	2585	7096	0.36	74-99	2.58	5.21	5	26	49	19
18010	Forth	Gargunnock	2714	6953	0.35	86-99	2.56	5.69	1	14	45	7
18011	Forth	Craigforth	2775	6955	0.41	81-99	10.27	19.12	4	19	54	21
18013	Black Devon	Fauld Mill	2914	6924	0.39	86-99	0.29	0.40	4	14	72	29
18014	Bannock Burn	Bannockburn	2812	6908	0.54	86-99	0.22	0.33	1	14	67	7
18015	Eas Gobhain	Loch Venachar	2602	7070	0.57	86-99	2.72	3.12	1	13	87	8
18016	Kelty Water	Clashmore	2468	6968	0.15	86-99	0.04	0.06	3	14	57	21
18017	Monachyle Burn	Balquhidder	2475	7230	0.18	82-96	0.08	0.22	4	15	38	27
18018	Kirkton Burn	Balquhidder	2532	7219	0.40	83-96	0.10	0.21	3	14	46	21
18020	Loch Ard Burn	Duchray	2468	6987	0.22	90-99	0.01	0.02	2	10	67	20
18021	Loch Ard Burn	Elrig	2469	6987	0.23	90-99	0.02	0.03	2	10	60	20
18022	Avon Dhu	Milton	2503	7014	0.44	90-99	0.58	0.91	2	10	64	20
18023	Monachyle Burn	Upper Monachyle	2480	7250		87-96	0.02	0.07	1	10	28	10
19001	Almond	Craigiehall	3165	6752	0.39	70-99	1.38	2.55	4	30	54	13
19002	Almond	Almond Weir	3004	6652	0.34	70-99	0.16	0.39	1	30	40	3
19003	Breich Water	Breich Weir	3014	6639	0.31	70-80		0.29		11		
19004	North Esk	Dalmore Weir	3252	6616	0.54	70-99	0.39	0.77	2	30	51	7
19005	Almond	Almondell	3086	6686	0.35	70-99	0.75	1.59	4	29	47	14
19006	Water of Leith	Murrayfield	3228	6732	0.48	70-99	0.40	0.75	2	30	53	7
19007	Esk	Musselburgh	3339	6723	0.53	70-99	1.04	1.98	2	29	53	7
19008	South Esk	Prestonholm	3325	6623	0.55	70-89		0.70		20		
19009	Bog Burn	Cobbinshaw	3026	6591	0.64	70-99	0.10	0.14	7	26	74	27
19010	Braid Burn	Liberton	3273	6707	0.56	70-99	0.08	0.11	18	29	75	62

Station Id	River name	Station name	East	North	BFI	Year range	Flow 1995	Mean flow	rank 1995	No. years	% flow	% rank
19011	North Esk	Dalkeith Palace	3333	6678	0.52	70-99	0.72	1.14	8	30	63	27
19012	Water of Leith	Colinton	3212	6688	0.54	86-99	0.38	0.64	1	13	59	8
19017	Gogar Burn	Turnhouse	3161	6733	0.42	86-99	0.07	0.21	1	13	32	8
19020	Almond	Whitburn	2948	6655	0.30	86-99	0.09	0.30	2	14	31	14
20001	Tyne	East Linton	3591	6768	0.52	70-99	0.65	1.26	3	29	52	10
20002	West Peffer Burn	Luffness	3489	6811	0.47	70-99	0.02	0.05	5	30	33	17
20003	Tyne	Spilmersford	3456	6689	0.49	70-99	0.32	0.62	5	29	52	17
20004	East Peffer Burn	Lochhouses	3610	6824	0.36	70-92		0.08		22		
20005	Birns Water	Saltoun Hall	3457	6688	0.49	70-99	0.21	0.42	4	30	49	13
20006	Biel Water	Belton House	3645	6768	0.62	73-98	0.18	0.33	3	26	53	12
20007	Gifford Water	Lennoxlove	3511	6717	0.57	73-99	0.19	0.36	6	27	54	22
21003	Tweed	Peebles	3257	6400	0.55	70-99	3.78	6.74	4	30	56	13
21005	Tweed	Lyne Ford	3206	6397	0.56	70-99	2.31	4.13	4	30	56	13
21006	Tweed	Boleside	3498	6334	0.51	70-99	8.03	16.48	2	30	49	7
21007	Ettrick Water	Lindean	3486	6315	0.40	70-99	2.40	6.39	1	30	38	3
21008	Teviot	Ormiston Mill	3702	6280	0.45	70-99	3.02	8.33	2	30	36	7
21009	Tweed	Norham	3898	6477	0.52	70-99	14.36	34.26	1	30	42	3
21010	Tweed	Dryburgh	3588	6320	0.51	70-80		16.95		11		
21011	Yarrow Water	Philiphaugh	3439	6277	0.47	70-99	1.61	3.01	2	30	53	7
21012	Teviot	Hawick	3522	6159	0.44	70-99	1.11	3.57	2	30	31	7
21013	Gala Water	Galashiels	3479	6374	0.52	70-99	0.59	1.52	1	30	39	3
21014	Tweed	Kingledores	3109	6285	0.45	70-99	1.20	1.96	4	30	61	13
21015	Leader Water	Earlston	3565	6388	0.49	70-99	0.50	1.33	1	30	37	3
21016	Eye Water	Eyemouth Mill	3942	6635	0.45	70-99	0.18	0.50	8	30	36	27
21017	Ettrick Water	Brockhoperig	3234	6132	0.34	70-99	0.31	0.96	2	30	32	7
21018	Lyne Water	Lyne Station	3209	6401	0.59	70-99	0.72	1.39	1	30	52	3
21019	Manor Water	Cademuir	3217	6369	0.60	70-99	0.32	0.70	2	30	46	7
21020	Yarrow Water	Gordon Arms	3309	6247	0.46	70-99	1.41	2.42	5	30	59	17
21021	Tweed	Sprouston	3752	6354	0.51	70-99	11.86	28.34	1	30	42	3
21022	Whiteadder Water	Hutton Castle	3881	6550	0.53	70-99	1.63	2.96	8	30	55	27
21023	Leet Water	Coldstream	3839	6396	0.35	71-99	0.04	0.23	3	29	19	10
21024	Jed Water	Jedburgh	3655	6214	0.42	71-99	0.47	1.10	1	28	43	4
21025	Ale Water	Ancrum	3634	6244	0.43	73-99	0.21	0.94	1	27	22	4
21026	Tima Water	Deephope	3278	6138	0.26	73-99	0.15	0.61	2	27	24	7
21027	Blackadder Water	Mouth Bridge	3826	6530	0.50	74-99	0.32	0.73	5	26	44	19
21030	Megget Water	Henderland	3231	6232	0.43	70-99	0.98	1.12	13	30	88	43
21031	Till	Etal	3927	6396	0.57	70-79		3.10		10		
21032	Glen	Kirknewton	3919	6310	0.47	70-92		1.04		18		
21034	Yarrow Water	Craig Douglas	3288	6244	0.48	70-99	1.37	1.94	8	30	70	27
22001	Coquet	Morwick	4234	6044	0.45	70-99	1.35	3.26	1	30	41	3
22002	Coquet	Bygate	3870	6083	0.47	70-80		0.47		10		
22003	Usway Burn	Shillmoor	3886	6077	0.40	70-80		0.24		10		
22004	Aln	Hawkhill	4211	6129	0.45	70-79		0.96		10		
22006	Blyth	Hartford Bridge	4243	5800	0.34	70-99	0.17	0.57	1	30	29	3
22007	Wansbeck	Mitford	4175	5858	0.37	70-99	0.25	0.99	2	30	25	7
22008	Alwin	Clennell	3925	6063	0.49	70-82		0.22		13		
22009	Coquet	Rothbury	4067	6016	0.48	72-99	1.00	2.25	2	28	44	7
23001	Tyne	Bywell	4038	5617	0.36	70-99	8.65	19.61	2	30	44	7
23002	Derwent	Eddys Bridge	4041	5508	0.51	70-99	0.38	0.44	7	30	87	23
23003	North Tyne	Reaverhill	3906	5732	0.33	70-99	4.94	9.56	4	30	52	13
23004	South Tyne	Haydon Bridge	3856	5647	0.34	70-100	2.88	8.07	2	30	36	7

Station Id	River name	Station name	East	North	BFI	Year range	Flow 1995	Mean flow	rank 1995	No. years	% flow	% rank
23005	North Tyne	Tarset	3776	5861	0.33	70-87		4.67		17		
23006	South Tyne	Featherstone	3672	5611	0.33	70-98	1.85	5.48	1	28	34	4
23007	Derwent	Rowlands Gill	4168	5581	0.58	70-99	0.94	1.29	2	29	72	7
23008	Rede	Rede Bridge	3868	5832	0.33	70-99	0.72	2.11	1	29	34	3
23009	South Tyne	Alston	3716	5465	0.30	70-99	0.57	1.85	1	18	31	6
23010	Tarset Burn	Greenhaugh	3789	5879	0.27	70-80		0.65		9		
23011	Kielder Burn	Kielder	3644	5946	0.33	70-99	0.40	1.03	2	26	39	8
23012	East Allen	Wide Eals	3802	5583	0.34	71-80		0.87		10		
23013	West Allen	Hindley Wrae	3791	5583	0.27	71-80		0.68		10		
23014	North Tyne	Kielder temporary	3631	5931	0.34	70-74		0.34		5		
23016	Ouse Burn	Crag Hall	4254	5674	0.26	89-99	0.06	0.13	2	9	48	22
23017	Team	Team Valley	4249	5585	0.76	91-99	0.73	0.85	2	8	86	25
23018	Ouse Burn	Woolsington	4196	5700		92-99	0.01	0.02	2	8	26	25
23022	North Tyne	Uglydub	3713	5875	0.54	82-99	3.58	5.16	5	17	69	29
23023	Tyne	Riding Mill	4032	5617	0.51	89-99	7.75	15.43	1	11	50	9
24001	Wear	Sunderland Bridge	4264	5376	0.42	70-99	2.40	4.12	2	28	58	7
24002	Gaunless	Bishop Auckland	4215	5306	0.51	70-83		0.34		14		
24003	Wear	Stanhope	3983	5391	0.35	70-99	0.43	1.34	1	29	33	3
24004	Bedburn Beck	Bedburn	4118	5322	0.47	70-99	0.14	0.47	1	30	29	3
24005	Browney	Burn Hall	4259	5387	0.52	70-99	0.36	0.77	1	30	47	3
24006	Rookhope Burn	Eastgate	3952	5390	0.35	70-80		0.27		10		
24007	Browney	Lanchester	4165	5462	0.45	70-83		0.20		14		
24008	Wear	Witton Park	4174	5309	0.44	73-99	1.35	2.88	1	27	47	4
24009	Wear	Chester le Street	4283	5512	0.47	78-99	3.44	6.34	1	22	54	5
24011	Wear	Burnhope Reservoir	3856	5395	0.38	92-99	0.09	0.15	1	8	61	13
25001	Tees	Broken Scar	4259	5137	0.30	70-99	4.52	7.36	7	30	61	23
25003	Trout Beck	Moor House	3759	5336	0.15	70-99	0.10	0.31	2	18	32	11
25004	Skerne	South Park	4284	5129	0.52	70-99	0.45	0.74	4	26	60	15
25005	Leven	Leven Bridge	4445	5122	0.44	70-99	0.35	0.78	2	29	45	7
25006	Greta	Rutherford Bridge	4034	5122	0.21	70-99	0.10	0.80	1	30	12	3
25007	Clow Beck	Croft	4282	5101	0.54	70-80		0.26		10		
25008	Tees	Barnard Castle	4047	5166	0.41	70-99	5.67	7.12	5	24	80	21
25009	Tees	Low Moor	4364	5105	0.37	70-99	4.27	8.26	3	30	52	10
25011	Langdon Beck	Langdon	3852	5309	0.20	70-83		0.16		14		
25012	Harwood Beck	Harwood	3849	5309	0.23	70-99	0.08	0.40	1	30	19	3
25018	Tees	Middleton in Teesdale	3950	5250	0.42	71-99	4.17	5.30	5	27	79	19
25019	Leven	Easby	4585	5087	0.59	71-96	0.05	0.11	3	26	50	12
25020	Skerne	Preston le Skerne	4292	5238	0.41	73-99	0.11	0.37	2	25	31	8
25021	Skerne	Bradbury	4318	5285	0.46	73-99		0.22		24		
25022	Balder	Balderhead Reservoir	3931	5182	0.23	75-80		0.66		5		
25023	Tees	Cow Green Reservoir	3813	5288	0.48	72-99	3.96	2.90	21	22	136	95
26002	Hull	Hempholme Lock	5080	4498	0.85	70-96	1.05	2.04	6	26	51	23
26003	Foston Beck	Foston Mill	5093	4548	0.96	70-99	0.43	0.46	12	30	93	40
26004	Gypsey Race	Bridlington	5165	4675	0.88	71-85		0.17		12		
26005	Gypsey Race	Boynton	5137	4677	0.95	81-99	0.04	0.12	8	19	37	42
26006	Elmswell Beck	Little Driffield	5009	4576	0.97	80-99	0.14	0.29	6	20	50	30
26007	Catchwater	Withernwick	5171	4403	0.35	70-79		0.01		10		
26008	Mires Beck	North Cave	4890	4316	0.86	86-99	0.11	0.12	7	14	92	50
26009	West Beck	Snakeholme Lock	5066	4555	0.93	89-99	0.99	1.06	6	10	93	60
27001	Nidd	Hunsingore Weir	4428	4530	0.50	70-99	1.30	3.28	1	28	40	4
27002	Wharfe	Flint Mill Weir	4422	4473	0.39	70-99	2.62	7.28	2	30	36	7

Station Id	River name	Station name	East	North	BFI	Year range	Flow 1995	Mean flow	rank 1995	No. years	% flow	% rank
27003	Aire	Beal Weir	4535	4255	0.52	70-99		17.67		28		
27005	Nidd	Gouthwaite Reservoir	4141	4683	0.48	70-99	0.50	0.89	2	29	56	7
27006	Don	Hadfields Weir	4390	3910	0.49	70-99	1.65	2.82	4	30	59	13
27007	Ure	Westwick Lock	4356	4671	0.39	70-99	3.50	8.48	2	28	41	7
27008	Swale	Leckby Grange	4415	4748	0.48	70-83		10.13		8		
27009	Ouse	Skelton	4568	4554	0.43	70-99	7.12	19.76	1	28	36	4
27010	Hodge Beck	Bransdale Weir	4627	4944	0.49	70-78		0.16		9		
27011	Washburn	Lindley Wood Reservoir	4219	4488	0.38	70-75		0.21		6		
27013	Ewden Beck	More Hall Reservoir	4289	3957	0.38	70-80		0.15		11		
27015	Derwent	Stamford Bridge	4714	4557	0.68	70-75		10.44		5		
27016	Little Don	Underbank Reservoir	4253	3992	0.40	70-80		0.29		10		
27017	Loxley	Damflask Reservoir	4286	3906	0.39	70-80		0.41		11		
27020	Scout Dike Stream	Scout Dike Resevoir	4236	4047	0.13	70-80		0.04		11		
27021	Don	Doncaster	4570	4040	0.56	70-99	5.43	9.49	3	28	57	11
27023	Dearne	Barnsley Weir	4350	4073	0.47	70-99	0.38	0.66	8	29	58	28
27024	Swale	Richmond	4146	5006	0.35	70-80		4.36		9		
27025	Rother	Woodhouse Mill	4432	3857	0.53	70-99	1.13	2.22	2	27	51	7
27026	Rother	Whittington	4394	3744	0.46	70-99	0.43	0.93	3	29	46	10
27027	Wharfe	Ilkley	4112	4481	0.37	70-75		6.96		6		
27028	Aire	Armley	4281	4340	0.48	70-99	2.93	7.15	1	29	41	3
27029	Calder	Elland	4124	4219	0.50	71-99	2.23	3.86	1	27	58	4
27030	Dearne	Adwick	4477	4020	0.61	70-99	1.01	1.90	3	26	53	12
27031	Colne	Colne Bridge	4174	4199	0.39	70-99	0.62	1.71	1	30	36	3
27032	Hebden Beck	Hebden	4025	4643	0.42	70-99	0.04	0.08	3	29	48	10
27033	Sea Cut	Scarborough	5028	4908	0.43	70-99	0.10	0.42	5	30	23	17
27034	Ure	Kilgram Bridge	4190	4860	0.32	70-99	1.23	6.03	1	30	20	3
27035	Aire	Kildwick Bridge	4013	4457	0.37	70-99	0.56	2.29	1	30	25	3
27038	Costa Beck	Gatehouses	4774	4836	0.97	71-99	0.44	0.52	9	26	84	35
27040	Doe Lea	Staveley	4443	3746	0.52	70-99	0.15	0.31	2	29	46	7
27041	Derwent	Buttercrambe	4731	4587	0.69	74-99	4.88	8.05	5	26	61	19
27042	Dove	Kirkby Mills	4705	4855	0.60	72-99	0.23	0.52	1	28	45	4
27043	Wharfe	Addingham	4092	4494	0.33	74-99	2.05	5.66	1	25	36	4
27044	Blackfoss Beck	Sandhills Bridge	4725	4475	0.46	74-99	0.05	0.10	2	24	43	8
27047	Snaizeholme Beck	Low Houses	3833	4883	0.19	72-99	0.06	0.24	1	26	24	4
27048	Derwent	West Ayton	4990	4853	0.74	72-99	0.18	0.21	17	28	86	61
27049	Rye	Ness	4694	4792	0.68	75-99	0.94	1.76	2	25	54	8
27050	Esk	Sleights	4865	5081	0.38	71-97	1.04	2.20	9	25	47	36
27051	Crimple	Burn Bridge	4284	4519	0.31	72-99	0.00	0.03	1	26	11	4
27052	Whitting	Sheepbridge	4376	3747	0.48	76-99	0.21	0.39	4	23	55	17
27053	Nidd	Birstwith	4230	4603	0.44	75-99	0.62	1.57	1	25	39	4
27054	Hodge Beck	Cherry Farm	4652	4902	0.53	74-99	0.15	0.30	1	26	49	4
27055	Rye	Broadway Foot	4560	4883	0.58	75-99	0.61	1.13	4	24	54	17
27056	Pickering Beck	Ings Bridge	4791	4819	0.69	75-99	0.26	0.45	5	24	58	21
27057	Seven	Normanby	4737	4821	0.38	74-99	0.22	0.69	2	24	32	8
27058	Riccal	Crook House Farm	4661	4810	0.66	75-99	0.19	0.25	2	24	75	8
27059	Laver	Ripon	4301	4710	0.42	78-99	0.13	0.37	2	21	34	10
27061	Colne	Longroyd Bridge	4136	4161	0.39	79-99	0.39	0.65	4	21	59	19
27062	Nidd	Skip Bridge	4482	4561	0.29	79-99	1.39	4.10	1	19	34	5
27063	Dibb	Grimwith Reservoir	4058	4639	0.31	81-99	1.45	0.81	15	16	178	94
27064	Went	Walden Stubbs	4551	4163	0.61	80-99	0.20	0.33	4	19	60	21
27065	Holme	Queens Mill	4142	4157	0.49	80-99	0.53	0.93	3	20	57	15

Station Id	River name	Station name	East	North	BFI	Year range	Flow 1995	Mean flow	rank 1995	No. years	% flow	% rank
27066	Blackburn Brook	Ashlowes	4393	3914	0.29	81-99	0.05	0.14	2	19	36	11
27067	Sheaf	Highfield Road	4357	3863	0.44	81-99	0.10	0.30	1	18	32	6
27068	Ryburn	Ripponden	4035	4189	0.56	81-99	0.26	0.28	9	19	93	47
27069	Wiske	Kirby Wiske	4375	4844	0.18	80-99	0.25	1.04	3	20	24	15
27070	Eller Beck	Skipton	3984	4502	0.19	81-99	0.08	0.39	1	17	22	6
27071	Swale	Crakehill	4425	4734	0.48	70-98	3.55	8.41	1	27	42	4
27072	Worth	Keighley	4063	4408	0.50	81-99	0.29	0.55	1	19	52	5
27073	Brompton Beck	Snainton Ings	4936	4794	0.91	81-99	0.09	0.14	4	18	63	22
27074	Spen Beck	Northorpe	4225	4210	0.57	82-99	0.40	0.49	3	16	81	19
27075	Bedale Beck	Leeming	4306	4902	0.45	83-99	0.43	0.78	5	17	55	29
27076	Bielby Beck	Thornton Lock	4760	4444	0.62	83-99	0.04	0.12	1	17	32	6
27077	Bradford Beck	Shipley	4151	4375	0.48	84-99	0.18	0.34	1	16	54	6
27079	Calder	Methley	4408	4257		88-99	6.61	9.69	1	11	68	9
27080	Aire	Lemonroyd	4381	4282	0.53	86-99	5.28	8.85	1	14	60	7
27081	Oulton Beck	Farrer Lane	4365	4281	0.57	87-99	0.04	0.07	2	13	49	15
27082	Cundall Beck	Bat Bridge	4419	4724	0.51	87-99	0.04	0.07	2	13	59	15
27083	Foss	Huntington	4612	4543	0.45	87-99	0.09	0.24	1	12	39	8
27084	Eastburn Beck	Crosshills	4021	4452	0.35	88-99	0.06	0.26	1	12	25	8
27085	Cod Beck	Dalton Bridge	4422	4766	0.63	89-99	0.24	0.50	1	10	47	10
27086	Skell	Alma Weir	4316	4709	0.47	84-99	0.21	0.54	2	14	38	14
27087	Derwent	Low Marishes	4833	4774		89-99	1.39	1.77	5	10	79	50
27089	Wharfe	Tadcaster	4477	4441		91-99	2.90	6.61	1	8	44	13
27090	Swale	Catterick Bridge	4226	4993		93-99	2.28	4.83	1	7	47	14
28001	Derwent	Yorkshire Bridge	4198	3851	0.47	70-99	0.68	0.83	10	30	82	33
28002	Blithe	Hamstall Ridware	4109	3192	0.50	70-83		0.48		13		
28003	Tame	Water Orton	4169	2915	0.62	70-99	2.96	4.46	2	20	66	10
28004	Tame	Lea Marston	4206	2935	0.69	70-82		10.62		13		
28005	Tame	Elford	4173	3105	0.65	70-84		14.75		15		
28007	Trent	Shardlow	4448	3299	0.66	91-99	18.09	27.85	2	8	65	25
28008	Dove	Rocester Weir	4112	3397	0.62	70-99	2.20	3.69	5	30	60	17
28009	Trent	Colwick	4620	3399	0.64	70-100	29.13	46.30	4	31	63	13
28010	Derwent	Longbridge Weir/St.Mary's Bridge	4356	3363	0.61	70-86		8.59		17		
28011	Derwent	Matlock Bath	4296	3586	0.64	70-99	3.64	5.82	2	29	63	7
28012	Trent	Yoxall	4131	3177	0.70	70-99	4.55	9.04	2	28	50	7
28014	Sow	Milford	3975	3215	0.65	70-99	1.76	4.88	1	15	36	7
28015	Idle	Mattersey	4690	3895	0.79	70-99	0.82	2.00	2	18	41	11
28016	Ryton	Serlby Park	4641	3897	0.69	70-78		1.10		8		
28017	Devon	Cotham	4787	3476	0.52	70-77		0.50		8		
28018	Dove	Marston on Dove	4235	3288	0.61	70-99	4.06	6.82	5	30	60	17
28019	Trent	Drakelow Park	4239	3204	0.66	70-99	16.33	25.26	2	30	65	7
28020	Churnet	Rocester	4103	3389	0.55	70-82		2.01		12		
28021	Derwent	Draycott	4443	3327	0.66	70-77		11.97		7		
28022	Trent	North Muskham	4801	3601	0.66	70-99	30.75	50.10	2	30	61	7
28023	Wye	Ashford	4182	3696	0.74	70-99	1.19	1.56	3	13	76	23
28024	Wreake	Syston Mill	4615	3124	0.42	70-99	0.32	0.97	2	28	33	7
28025	Sence	Ratcliffe Culey	4321	2996	0.42	70-83		0.62		14		
28026	Anker	Polesworth	4263	3034	0.49	70-99	0.91	1.54	5	28	59	18
28027	Erewash	Sandiacre	4482	3364	0.54	70-99	0.60	1.37	3	18	44	17
28029	Kingston Brook	Kingston Hall	4503	3277	0.38	70-83		0.16		13		
28030	Black Brook	Onebarrow	4466	3171	0.44	70-83		0.04		14		
28031	Manifold	Ilam	4140	3507	0.54	70-99	0.70	1.61	5	30	44	17

Station Id	River name	Station name	East	North	BFI	Year range	Flow 1995	Mean flow	rank 1995	No. years	% flow	% rank
28032	Meden	Church Warsop	4558	3680	0.77	70-99	0.31	0.44	3	22	70	14
28033	Dove	Hollinsclough	4063	3668	0.45	70-82		0.13		13		
28035	Leen	Triumph Road Nottingham	4549	3392	0.73	81-99	0.28	0.45	2	12	61	17
28036	Poulter	Twyford Bridge	4700	3752	0.85	70-98	0.27	0.42	3	10	63	30
28037	Derwent	Mytham Bridge	4205	3825	0.41	78-95	1.06	1.50	2	10	71	20
28038	Manifold	Hulme End	4106	3595	0.31	70-82		0.48		12		
28039	Rea	Calthorpe Park	4071	2847	0.48	70-99	0.36	0.59	3	30	62	10
28040	Trent	Stoke on Trent	3892	3467	0.47	70-99	0.14	0.34	1	30	40	3
28041	Hamps	Waterhouses	4082	3502	0.35	70-82		0.30		12		
28043	Derwent	Chatsworth	4261	3683	0.56	70-99	1.67	2.75	5	29	61	17
28044	Poulter	Cuckney	4570	3713	0.92	70-99	0.25	0.27	8	23	92	35
28045	Meden/Maun	Bothamsall/Haughton	4681	3732	0.77	70-83		1.34		13		
28046	Dove	Izaak Walton	4146	3509	0.79	70-99	0.80	1.06	8	30	76	27
28047	Oldcoates Dyke	Blyth	4615	3876	0.71	71-99	0.32	0.45	6	26	71	23
28048	Amber	Wingfield Park	4376	3520	0.50	72-99	0.49	0.70	7	28	70	25
28049	Ryton	Worksop	4575	3794	0.63	71-99	0.15	0.28	7	28	52	25
28050	Torne	Auckley	4646	4012	0.67	71-99	0.38	0.63	6	28	60	21
28052	Sow	Great Bridgford	3883	3270	0.67	71-99	0.39	0.70	3	29	55	10
28053	Penk	Penkridge	3923	3144	0.60	76-99	0.74	1.28	4	17	57	24
28054	Sence	Blaby	4566	2985	0.39	71-83		0.52		12		
28055	Ecclesbourne	Duffield	4320	3447	0.49	72-99	0.11	0.23	3	20	46	15
28056	Rothley Brook	Rothley	4580	3121	0.48	73-99	0.10	0.38	2	24	27	8
28058	Henmore Brook	Ashbourne	4176	3463	0.46	74-99	0.09	0.15	3	17	61	18
28059	Maun	Mansfield STW	4548	3623	0.71	70-83		0.39		13		
28060	Dover Beck	Lowdham	4653	3479	0.77	72-99	0.07	0.09	10	25	81	40
28061	Churnet	Basford Bridge	3983	3520	0.46	75-99	0.48	1.10	2	25	44	8
28066	Cole	Coleshill	4183	2874	0.44	74-99	0.28	0.61	1	26	45	4
28067	Derwent	Church Wilne	4438	3316	0.65	73-99	6.04	9.17	4	27	66	15
28070	Burbage Brook	Burbage	4259	3804	0.44	70-82		0.08		8		
28072	Greet	Southwell	4711	3541	0.68	75-95	0.12	0.19	6	21	61	29
28073	Ashop	Ashop diversion	4171	3896	0.40	77-83		0.68		7		
28074	Soar	Kegworth	4492	3263	0.54	79-99	3.71	6.62	1	14	56	7
28076	Tutbury Millfleam	Rolleston	4243	3283	0.60	80-99	0.13	0.29	1	18	47	6
28077	Spondon Outfall	Spondon Rec Works	4395	3345	0.85	80-91		1.03		6		
28079	Meece Brook	Shallowford	3874	3291	0.64	82-99	0.16	0.30	1	18	52	6
28080	Tame	Lea Marston Lakes	4207	2937	0.69	70-99	8.70	11.01	3	30	79	10
28081	Tame	Bescot	4012	2958	0.70	83-99	1.38	2.02	3	16	68	19
28082	Soar	Littlethorpe	4542	2973	0.51	71-99	0.26	0.64	2	28	40	7
28083	Trent	Darlaston	3885	3355	0.66	83-99	1.54	2.44	1	14	63	7
28085	Derwent	St. Marys Bridge	4355	3368	0.62	70-99	4.45	7.85	3	30	57	10
28086	Sence	South Wigston	4588	2977	0.39	71-99	0.14	0.42	2	28	33	7
28091	Ryton	Blyth	4631	3871	0.72	84-99	0.59	0.90	4	15	66	27
28093	Soar	Pillings Lock	4565	3182	0.53	86-99	3.34	4.85	3	11	69	27
28102	Blythe	Whitacre	4212	2911	0.45	87-95	0.32	0.47	2	8	68	25
29001	Waithe Beck	Brigsley	5253	4016	0.84	70-99	0.11	0.15	10	29	70	34
29002	Great Eau	Claythorpe Mill	5416	3793	0.88	70-99	0.44	0.50	11	29	88	38
29003	Lud	Louth	5337	3879	0.90	70-99	0.26	0.31	10	29	82	34
29004	Ancholme	Bishopbridge	5032	3911	0.45	70-99	1.43	0.62	28	30	232	93
29005	Rase	Bishopbridge	5032	3912	0.55	72-99	0.11	0.17	9	27	66	33
29009	Ancholme	Toft Newton	5033	3877	0.52	74-99	0.01	0.03	2	25	17	8
30001	Witham	Claypole Mill	4842	3480	0.67	70-99	0.45	0.96	3	30	47	10

Station Id	River name	Station name	East	North	BFI	Year range	Flow 1995	Mean flow	rank 1995	No. years	% flow	% rank
30002	Barlings Eau	Langworth Bridge	5066	3766	0.46	70-99	0.08	0.30	3	20	25	15
30003	Bain	Fulsby Lock	5241	3611	0.58	70-99	0.12	0.36	4	30	33	13
30004	Lymn	Partney Mill	5402	3676	0.66	70-99	0.15	0.26	5	29	58	17
30005	Witham	Saltersford total	4927	3335	0.77	70-99		0.43		19		
30006	Slea	Leasingham Mill	5088	3485	0.87	74-99	0.08	0.40	7	24	21	29
30011	Bain	Goulceby Bridge	5246	3795	0.73	71-99	0.10	0.16	7	28	61	25
30012	Stainfield Beck	Creampoke Farm	5127	3739	0.45	71-99	0.02	0.06	5	27	28	19
30013	Heighington Beck	Heighington	5042	3696	0.75	76-99	0.02	0.06	3	24	38	13
30014	Pointon Lode	Pointon	5128	3313	0.48	72-99	0.01	0.03	3	23	17	13
30015	Cringle Brook	Stoke Rochford	4925	3297	0.89	76-99	0.11	0.18	6	24	59	25
30017	Witham	Colsterworth	4929	3246	0.50	79-99	0.03	0.10	5	21	32	24
30018	Honington Beck	Honington	4936	3433	0.67	84-99	0.03	0.06	5	12	44	42
30033	Brant	Brant Broughton	4929	3545		91-99		0.05		6		
31001	Eye Brook	Eye Brook Reservoir	4853	2941	0.41	70-99		0.10		24		
31002	Glen	Kates Br and King St Br	5106	3149	0.59	70-99	0.18	0.41	8	29	43	28
31004	Welland	Tallington	5095	3078	0.54	70-99	0.47	2.03	1	29	23	3
31006	Gwash	Belmesthorpe	5038	3097	0.79	70-99	0.42	0.56	8	29	75	28
31007	Welland	Barrowden	4948	2999	0.45	70-99		0.78		26		
31008	East Glen	Manthorpe	5068	3160	0.27	70-99	0.00	0.06	3	20	0	15
31009	West Glen	Shillingthorpe	5074	3113	0.71	71-99	0.17	0.15	13	19	111	68
31010	Chater	Fosters Bridge	4961	3030	0.52	70-99	0.10	0.21	6	30	49	20
31011	West Glen	Burton Coggles	4987	3261	0.32	70-99	0.00	0.02	3	15	5	20
31012	Tham	Little Bytham	5016	3179	0.79	70-96		0.06		11		
31013	East Glen	Irnham	5038	3273	0.34	70-99	0.00	0.03	4	26	13	15
31014	Grimsthorpe Brook	Grimsthorpe Park	5046	3203	0.16	70-96		0.00		14		
31015	Chater	Ridlington	4848	3037	0.44	70-84		0.02		9		
31016	North Brook	Empingham	4957	3089	0.94	70-99	0.12	0.18	3	28	67	11
31017	Stonton Brook	Welham Road Bridge	4759	2918	0.55	70-84		0.05		11		
31018	Langton Brook	Welham Road Bridge	4755	2908	0.64	71-84		0.06		5		
31019	Medbourne Brook	Medbourne	4798	2939	0.53	70-99	0.01	0.03	4	18	48	22
31020	Morcott Brook	South Luffenham	4939	3018	0.57	70-84		0.04		10		
31021	Welland	Ashley	4819	2915	0.41	71-99	0.14	0.41	3	24	34	13
31022	Jordan	Market Harborough	4740	2867	0.39	70-99	0.00	0.02	1	18	7	6
31023	West Glen	Easton Wood	4965	3258	0.14	72-99	0.00	0.01	4	28	0	14
31024	Holywell Brook	Holywell	5026	3148	0.94	72-99	0.08	0.10	9	24	73	38
31025	Gwash South Arm	Manton	4875	3051	0.28	79-99	0.01	0.05	4	20	23	20
31026	Egleton Brook	Egleton	4878	3073	0.34	79-99		0.01		19		
31027	Bourne Eau	Mays Sluice Bourne	5107	3199	0.71	82-88		0.10		5		
31028	Gwash	Church Bridge	4951	3082	0.72	83-99	0.20	0.20	8	15	102	53
32001	Nene	Orton	5166	2972	0.52	70-96		5.47		21		
32002	Willow Brook	Fotheringhay	5067	2933	0.73	70-98	0.44	0.64	4	29	69	14
32003	Harpers Brook	Old Mill Bridge	4983	2799	0.49	70-99	0.11	0.17	7	29	62	24
32004	Ise Brook	Harrowden Old Mill	4898	2715	0.55	70-99	0.19	0.63	1	30	30	3
32006	Nene/Kislingbury	Upton	4721	2592	0.57	70-99		0.73		29		
32007	Nene Brampton	St Andrews	4747	2617	0.56	70-99	0.38	0.63	4	28	61	14
32008	Nene/Kislingbury	Dodford	4627	2607	0.57	70-99	0.16	0.31	3	30	52	10
32012	Wootton Brook	Lady Bridge	4736	2571	0.74	70-99		0.09		7		
32015	Willow Bk Central	Tunwell Loop	4898	2892	0.47	70-98		0.07		6		
32016	Willow Brook Sth	Corby South	4901	2886	0.37	71-99	0.01	0.02	4	16	42	25
32018	Ise	Barford Bridge	4861	2831	0.67	70-99	0.06	0.12	2	8	51	25
32020	Wittering Brook	Wansford	5089	2995	0.86	70-84		0.17		15		

Station Id	River name	Station name	East	North	BFI	Year range	Flow 1995	Mean flow	rank 1995	No. years	% flow	% rank
32024	Southwick Brook	Southwick	5025	2921	0.46	71-84		0.02		9		
32025	Nene/Whilton	Surney Bridges	4620	2658	0.69	71-84		0.12		7		
32026	Nene/Brampton	Brixworth	4736	2707	0.63	71-99	0.05	0.07	3	14	64	21
32027	Billing Brook	Chesterton	5117	2949	0.39	72-96		0.01		8		
32029	Flore	Experimental Catchment	4655	2604	0.43	74-78		0.01		5		
32031	Wootton Brook	Wootton Park	4726	2577	0.47	83-98	0.06	0.13	2	14	45	14
33002	Bedford Ouse	Bedford	5055	2495	0.51	70-99	2.46	4.42	6	30	56	20
33003	Cam	Bottisham	5508	2657	0.65	70-87		2.19		17		
33004	Lark	Isleham	5648	2760	0.64	70-85		1.02		15		
33005	Bedford Ouse	Thornborough Mill	4736	2353	0.50	70-91		0.87		22		
33006	Wissey	Northwold	5771	2965	0.81	70-99	0.67	1.04	7	30	64	23
33007	Nar	Marham	5723	3119	0.91	70-99	0.65	0.83	9	30	79	30
33009	Bedford Ouse	Harrold Mill	4951	2565	0.52	70-92		4.13		22		
33011	Little Ouse	County Bridge Euston	5892	2801	0.73	70-99	0.16	0.25	9	30	64	30
33012	Kym	Meagre Farm	5155	2631	0.26	70-99	0.04	0.13	4	30	28	13
33013	Sapiston	Rectory Bridge	5896	2791	0.64	70-99		0.35		29		
33014	Lark	Temple	5758	2730	0.78	70-99		0.88		27		
33015	Ouzel	Willen	4882	2408	0.54	70-99	0.63	0.91	5	25	69	20
33016	Cam	Jesus Lock	5450	2593	0.64	70-83		1.58		14		
33018	Tove	Cappenham Bridge	4714	2488	0.53	70-99		0.48		29		
33019	Thet	Melford Bridge	5880	2830	0.78	70-99		0.98		29		
33020	Alconbury Brook	Brampton	5208	2717	0.29	70-99		0.14		28		
33021	Rhee	Burnt Mill	5415	2523	0.74	70-99	0.48	0.62	9	29	78	31
33022	Ivel	Blunham	5153	2509	0.73	70-99	1.21	1.74	6	30	69	20
33023	Lea Brook	Beck Bridge	5662	2733	0.71	70-99	0.08	0.14	12	29	57	41
33024	Cam	Dernford	5466	2506	0.77	70-99	0.46	0.60	12	30	77	40
33025	Babingly	West Newton Mill	5696	3256	0.92	70-76		0.29		5		
33026	Bedford Ouse	Offord	5216	2669	0.48	70-99	4.44	5.15	13	30	86	43
33027	Rhee	Wimpole	5333	2485	0.65	70-99	0.17	0.22	11	30	78	37
33028	Flit	Shefford	5143	2393	0.72	70-99		0.56		29		
33029	Stringside	Whitebridge	5716	3006	0.85	70-99	0.11	0.24	7	30	48	23
33030	Clipstone Brook	Clipstone	4933	2255	0.41	70-80		0.05		10		
33032	Heacham	Heacham	5685	3375	0.96	70-99	0.17	0.16	14	30	105	47
33033	Hiz	Arlesey	5190	2379	0.85	73-99	0.49	0.52	12	27	95	44
33034	Little Ouse	Abbey Heath	5851	2844	0.80	70-100	1.66	2.12	10	30	78	33
33035	Ely Ouse	Denver Complex	5588	3010	0.48	70-99	2.24	5.35	3	14	42	21
33037	Bedford Ouse	Newport Pagnell	4877	2443	0.48	70-99	0.52	1.60	5	30	32	17
33039	Bedford Ouse	Roxton	5160	2535	0.54	73-99	2.85	4.85	2	26	59	8
33040	Rhee	Ashwell	5267	2401	0.97	70-99	0.06	0.06	15	30	100	50
33044	Thet	Bridgham	5957	2855	0.74	70-99	0.53	0.75	9	30	70	30
33045	Wittle	Quidenham	6027	2878	0.64	70-99		0.06		29		
33046	Thet	Red Bridge	5996	2923	0.63	70-99	0.23	0.33	9	30	69	30
33048	Larling Brook	Stonebridge	5928	2907	0.82	70-99		0.04		25		
33049	Stanford Water	Buckenham Tofts	5834	2953	0.88	73-80		0.19		8		
33050	Snail	Fordham	5631	2703	0.89	70-99	0.18	0.25	7	26	71	27
33051	Cam	Chesterford	5505	2426	0.68	70-99	0.27	0.35	9	28	78	32
33052	Swaffham Lode	Swaffham Bulbeck	5553	2628	0.95	70-99	0.12	0.13	11	24	96	46
33053	Granta	Stapleford	5471	2515	0.57	70-99	0.09	0.13	11	23	72	48
33054	Babingley	Castle Rising	5680	3252	0.94	76-99	0.28	0.39	6	23	71	26
33055	Granta	Babraham	5510	2504	0.57	76-99		0.12		22		
33056	Quy Water	Lode	5531	2627	0.77	70-99	0.10	0.11	13	25	88	52

Station Id	River name	Station name	East	North	BFI	Year range	Flow 1995	Mean flow	rank 1995	No. years	% flow	% rank
33057	Ouzel	Leighton Buzzard	4917	2241	0.68	76-99		7.92		20		
33058	Ouzel	Bletchley	4883	2322	0.60	78-99		0.89		18		
33059	Cut-off Channel	Tolgate	5729	2757	0.47	70-99		0.08		24		
33060	Kings Dike	Stanground	5208	2973	0.75	70-98	1.03	0.56	21	22	184	95
33061	Shep	Fowlmere One	5402	2460		95-99	0.06	0.04	5	5	149	100
33062	Guilden Brook	Fowlmere Two	5403	2457	0.97	78-99	0.03	0.05	8	17	69	47
33063	Little Ouse	Knettishall	5955	2807	0.70	80-99	0.21	0.26	9	20	79	45
33064	Whaddon Brook	Whaddon	5359	2466	0.90	81-99	0.06	0.07	7	16	91	44
33065	Hiz	Hitchin	5185	2290	0.85	81-99		0.03		14		
33066	Granta	Linton	5570	2464	0.47	82-99	0.05	0.08	9	17	63	53
33067	New River	Burwell	5608	2696	0.96	82-99	0.15	0.27	4	14	56	29
33068	Cheney Water	Gatley End	5296	2411	0.96	82-99	0.01	0.01	7	13	93	54
34001	Yare	Colney	6182	3082	0.65	70-99	0.46	0.60	9	30	77	30
34002	Tas	Shotesham	6226	2994	0.58	71-99	0.27	0.33	10	27	82	37
34003	Bure	Ingworth	6192	3296	0.83	70-99	0.87	0.78	24	30	112	80
34004	Wensum	Costessey Mill	6177	3128	0.73	70-99		2.23		27		
34005	Tud	Costessey Park	6170	3113	0.65	70-99	0.14	0.16	12	29	86	41
34006	Waveney	Needham Mill	6229	2811	0.47	70-99	0.41	0.66	7	29	63	24
34007	Dove	Oakley Park	6174	2772	0.44	70-99	0.19	0.28	8	27	67	30
34008	Ant	Honing Lock	6331	3270	0.87	70-99	0.20	0.23	5	22	87	23
34010	Waveney	Billingford Bridge	6168	2782	0.43	70-98	0.15	0.21	10	25	70	40
34011	Wensum	Fakenham	5919	3294	0.83	70-99		0.53		27		
34012	Burn	Burnham Overy	5842	3428	0.95	70-99	0.28	0.26	14	30	106	47
34013	Waveney	Ellingham Mill	6364	2917	0.83	72-96		0.50		15		
34014	Wensum	Swanton Morley Total	6020	3184	0.74	70-99	1.38	1.57	8	23	88	35
34018	Stiffkey	Warham All Saints	5944	3414	0.80	72-99	0.30	0.31	13	21	98	62
34019	Bure	Horstead Mill	6267	3194	0.79	74-99	1.86	1.58	17	24	117	71
35001	Gipping	Constantine Weir	6154	2441	0.43	76-96		0.66		11		
35002	Deben	Naunton Hall	6322	2534	0.36	70-99	0.14	0.21	9	27	64	33
35003	Alde	Farnham	6360	2601	0.37	70-99	0.06	0.08	13	29	79	45
35004	Ore	Beversham Bridge	6359	2583	0.46	70-99	0.11	0.12	19	27	92	70
35008	Gipping	Stowmarket	6058	2578	0.38	70-99	0.13	0.19	11	30	70	37
35010	Gipping	Bramford	6127	2465	0.49	70-99	0.43	0.42	19	30	102	63
35011	Belstead Brook	Belstead	6143	2420	0.67	82-97		0.10		5		
35013	Blyth	Holton	6406	2769	0.35	70-99	0.09	0.12	11	30	77	37
36001	Stour	Stratford St Mary	6042	2340	0.50	70-92		1.47		23		
36002	Glem	Glemsford	5846	2472	0.44	70-99	0.10	0.16	8	30	63	27
36003	Box	Polstead	5985	2378	0.63	70-99	0.08	0.10	9	29	78	31
36004	Chad Brook	Long Melford	5868	2459	0.47	70-99	0.04	0.09	7	30	49	23
36005	Brett	Hadleigh	6025	2429	0.46	70-99	0.15	0.24	8	30	60	27
36006	Stour	Langham	6020	2344	0.52	70-99	0.94	1.36	7	30	69	23
36007	Belchamp Brook	Bardfield Bridge	5848	2421	0.41	70-99	0.05	0.06	19	30	88	63
36008	Stour	Westmill	5827	2463	0.41	70-99	0.64	0.67	15	30	95	50
36009	Brett	Cockfield	5914	2525	0.31	70-99	0.01	0.02	6	30	26	20
36010	Bumpstead Brook	Broad Green	5689	2418	0.22	70-99	0.01	0.03	5	30	20	17
36011	Stour Brook	Sturmer	5696	2441	0.37	70-99	0.08	0.10	11	30	77	37
36012	Stour	Kedington	5708	2450	0.51	70-99	0.87	0.61	25	30	142	83
36013	Brett	Higham	6032	2354	0.67	72-91		0.16		7		
36015	Stour	Lamarsh	5897	2358	0.50	72-99	0.85	1.17	7	27	73	26
36017	Ely Ouse Outfall	Kirtling Green	5681	2559	0.67	72-99	0.85	0.53	20	25	161	80
37001	Roding	Redbridge	5415	1884	0.39	70-99	0.27	0.67	1	30	40	3

Station Id	River name	Station name	East	North	BFI	Year range	Flow 1995	Mean flow	rank 1995	No. years	% flow	% rank
37002	Chelmer	Rushes Lock	5794	2090	0.45	70-99	0.44	0.81	3	30	54	10
37003	Ter	Crabbs Bridge	5786	2107	0.49	70-99	0.08	0.13	5	29	63	17
37005	Colne	Lexden	5962	2261	0.52	70-100	0.26	0.40	6	30	66	20
37006	Can	Beach's Mill	5690	2072	0.42	70-99	0.22	0.46	2	30	49	7
37007	Wid	Writtle	5686	2060	0.40	70-99	0.18	0.33	4	29	54	14
37008	Chelmer	Springfield	5713	2071	0.55	70-99	0.42	0.45	16	30	93	53
37009	Brain	Guithavon Valley	5818	2147	0.67	70-99	0.21	0.23	11	29	91	38
37010	Blackwater	Appleford Bridge	5845	2158	0.56	70-99	0.78	0.68	23	29	115	79
37011	Chelmer	Churchend	5629	2233	0.43	70-99	0.07	0.10	7	30	66	23
37012	Colne	Poolstreet	5771	2364	0.27	70-99	0.04	0.06	17	28	62	61
37013	Sandon Brook	Sandon Bridge	5755	2055	0.34	70-99	0.06	0.08	10	29	71	34
37014	Roding	High Ongar	5561	2040	0.35	70-99	0.03	0.09	5	30	35	17
37015	Cripsey Brook	Chipping Ongar	5548	2035	0.32	70-99	0.05	0.12	3	23	42	13
37016	Pant	Copford Hall	5668	2313	0.37	70-99	0.45	0.22	26	30	204	87
37017	Blackwater	Stisted	5793	2243	0.50	70-99	0.51	0.40	22	30	128	73
37018	Ingrebourne	Gaynes Park	5553	1862	0.49	71-99	0.12	0.18	3	29	69	10
37019	Beam	Bretons Farm	5515	1853	0.37	70-99	0.11	0.19	3	29	58	10
37020	Chelmer	Felsted	5670	2193	0.52	70-99	0.20	0.26	8	29	79	28
37021	Roman	Bounstead Bridge	5985	2205	0.59	70-98	0.12	0.13	19	27	91	70
37022	Holland Brook	Thorpe le Soken	6179	2212	0.41	70-99	0.03	0.06	11	28	43	39
37023	Roding	Loughton	5442	1955	0.32	72-99	0.16	0.29	3	21	54	14
37024	Colne	Earls Colne	5855	2298	0.47	72-99	0.13	0.28	3	27	47	11
37026	Tenpenny Brook	Tenpenny Bridge	6079	2207	0.64	70-75		0.02		5		
37028	Bentley Brook	Saltwater Bridge	6109	2193	0.64	70-76		0.01		5		
37029	St Osyth Brook	Main Road Bridge	6134	2159	0.41	70-75		0.01		5		
37031	Crouch	Wickford	5748	1934	0.30	77-99	0.07	0.20	1	16	35	6
37033	Eastwood Brook	Eastwood	5859	1888	0.36	75-99		0.04		21		
37034	Mar Dyke	Stifford	5596	1804	0.26	75-98		0.22		21		
37039	Blackwater	Langford (low flows)	5835	2090	0.19	74-99	0.02	0.13	4	18	18	22
38001	Lee	Feildes Weir	5390	2092	0.57	70-99	1.96	2.42	11	28	81	39
38002	Ash	Mardock	5393	2148	0.54	80-99	0.12	0.12	13	19	98	68
38003	Mimram	Panshanger Park	5282	2133	0.94	70-100	0.55	0.46	22	30	118	73
38004	Rib	Wadesmill	5360	2174	0.59	80-99	0.23	0.23	11	20	101	55
38005	Ash	Easneye	5380	2138	0.54	70-81		0.13		12		
38006	Rib	Herts Training School	5335	2158	0.58	70-82		0.29		11		
38007	Canons Brook	Elizabeth Way	5431	2104	0.41	70-99	0.07	0.12	4	30	63	13
38011	Mimram	Fulling Mill	5225	2169	0.96	70-98		0.19		16		
38012	Stevenage Brook	Bragbury Park	5274	2211	0.28	74-99	0.03	0.07	2	26	49	8
38013	Upper Lee	Luton Hoo	5118	2185	0.62	70-99	0.06	0.17	6	30	36	20
38014	Salmon Brook	Edmonton	5343	1937	0.27	70-99	0.05	0.08	8	29	65	28
38015	Intercepting Drain	Enfield	5355	1932	0.51	70-80		0.10		11		
38016	Stansted Sp	Mountfitchet	5500	2246	0.98	70-99	0.06	0.05	15	30	111	50
38017	Mimram	Whitwell	5184	2212	0.97	70-99	0.11	0.09	21	30	120	70
38018	Upper Lee	Water Hall	5299	2099	0.81	72-99	0.86	1.00	10	28	86	36
38020	Cobbins Brook	Sewardstone Road	5387	1999	0.25	71-99	0.03	0.06	5	26	48	19
38021	Turkey Brook	Albany Park	5359	1985	0.21	72-99	0.02	0.06	2	28	27	7
38022	Pymmes Brook	Edmonton Silver Street	5340	1925	0.49	70-99	0.29	0.33	11	30	88	37
38023	Lee flood relief	Low Hall	5356	1880	0.23	80-99	0.41	0.77	6	20	54	30
38024	Small River Lee	Ordnance Road	5370	1988	0.46	73-99	0.10	0.19	2	27	53	7
38026	Pincey Brook	Sheering Hall	5495	2126	0.39	74-99	0.04	0.08	4	25	49	16
38027	Stort	Glen Faba	5393	2093	0.40	85-99	0.26	0.59	2	13	44	15

Station Id	River name	Station name	East	North	BFI	Year range	Flow 1995	Mean flow	rank 1995	No. years	% flow	% rank
38028	Stansted Brook	Gypsy Lane	5506	2241	0.44	73-99	0.02	0.03	8	27	66	30
38029	Quin	Griggs Bridge	5392	2248	0.45	78-99	0.06	0.06	13	22	100	59
38030	Beane	Hartham	5325	2131	0.77	79-99	0.46	0.43	13	20	108	65
38031	Lee	Rye Bridge	5385	2098		94-99	1.75	1.57	3	6	112	50
39001	Thames	Kingston	5177	1698	0.64	70-99	11.42	22.92	7	30	50	23
39002	Thames	Days Weir	4568	1935	0.64	70-99	4.54	9.71	3	30	47	10
39003	Wandle	Connollys Mill	5265	1705	0.85	70-99	1.83	1.71	15	26	107	58
39004	Wandle	Beddington Park	5296	1655	0.77	72-99	0.19	0.16	12	23	115	52
39005	Beverley Brook	Wimbledon Common	5216	1717	0.64	70-99	0.45	0.51	8	23	90	35
39006	Windrush	Newbridge	4402	2019	0.87	70-99	0.90	1.54	5	30	59	17
39007	Blackwater	Swallowfield	4731	1648	0.67	70-99	1.45	1.88	4	30	77	13
39008	Thames	Eynsham	4445	2087	0.67	70-99	1.51	4.74	3	30	32	10
39009	Thames	Bray Weir	4909	1797	0.70	70-81		31.66		12		
39010	Colne	Denham	5052	1864	0.86	70-99	3.72	3.47	14	30	107	47
39011	Wey	Tilford	4874	1433	0.72	70-99	1.66	1.87	11	30	89	37
39012	Hogsmill	Kingston upon Thames	5182	1688	0.74	70-99	0.80	0.87	9	28	93	32
39013	Colne	Berrygrove	5123	1982	0.67	70-99	0.51	0.47	17	28	108	61
39014	Ver	Hansteads	5151	2016	0.86	70-99	0.42	0.30	23	30	143	77
39015	Whitewater	Lodge Farm	4731	1523	0.95	70-99	0.29	0.31	11	30	95	37
39016	Kennet	Theale	4649	1708	0.87	70-99	5.40	6.52	10	30	83	33
39017	Ray	Grendon Underwood	4680	2211	0.16	70-99	0.00	0.01	6	25	15	24
39019	Lambourn	Shaw	4470	1682	0.97	70-99	1.49	1.47	15	30	101	50
39020	Coln	Bibury	4122	2062	0.94	70-99	0.59	0.79	8	30	74	27
39021	Cherwell	Enslow Mill	4482	2183	0.65	70-99	0.85	1.64	4	30	52	13
39022	Loddon	Sheepbridge	4720	1652	0.76	70-99	1.26	1.35	13	29	94	45
39023	Wye	Hedsor	4896	1867	0.93	70-99	1.08	0.95	19	30	114	63
39024	Gatwick Stream	Gatwick	5288	1402	0.56	70-77		0.27		8		
39025	Enborne	Brimpton	4568	1648	0.54	70-99	0.24	0.45	4	30	54	13
39026	Cherwell	Banbury	4458	2411	0.40	70-99	0.04	0.26	3	28	16	11
39027	Pang	Pangbourne	4634	1766	0.86	70-99	0.50	0.45	18	30	112	60
39028	Dun	Hungerford	4321	1685	0.95	70-99	0.40	0.50	10	30	81	33
39029	Tillingbourne	Shalford	5000	1478	0.89	70-99	0.42	0.43	14	30	97	47
39030	Gade	Croxley Green	5082	1952	0.86	71-99	1.00	0.87	17	29	114	59
39031	Lambourn	Welford	4411	1731	0.98	70-83		0.96		14		
39032	Lambourn	East Shefford	4390	1745	0.97	70-83		0.68		14		
39033	Winterbourne St	Bagnor	4453	1694	0.96	70-99	0.15	0.13	18	29	113	62
39034	Evenlode	Cassington Mill	4448	2099	0.71	71-99	0.83	1.62	3	29	51	10
39035	Churn	Cerney Wick	4076	1963	0.81	70-99	0.07	0.31	3	30	22	10
39036	Law Brook	Albury	5045	1468	0.93	70-99	0.09	0.10	7	26	89	27
39037	Kennet	Marlborough	4187	1686	0.95	72-99	0.43	0.51	12	28	84	43
39038	Thame	Shabbington	4670	2055	0.54	70-93		1.16		20		
39040	Thames	West Mill Cricklade	4094	1942	0.62	72-99	0.09	0.36	2	27	23	7
39042	Leach	Priory Mill Lechlade	4227	1994	0.78	73-99	0.12	0.30	3	27	39	11
39043	Kennet	Knighton	4295	1710	0.95	70-99	1.46	1.81	9	30	81	30
39044	Hart	Bramshill House	4755	1593	0.64	73-99	0.38	0.39	12	27	98	44
39046	Thames	Sutton Courtenay	4516	1946	0.62	74-99		9.29		11		
39049	Silk Stream	Colindeep Lane	5217	1895	0.28	74-99	0.08	0.15	2	21	53	10
39051	Sor Brook	Adderbury	4475	2346	0.74	70-87		0.47		18		
39052	The Cut	Binfield	4853	1713	0.44	70-99	0.13	0.20	5	30	66	17
39053	Mole	Horley	5271	1434	0.44	70-99	0.44	0.65	8	29	68	28
39054	Mole	Gatwick Airport	5260	1399	0.24	70-99	0.01	0.09	1	30	14	3

Station Id	River name	Station name	East	North	BFI	Year range	Flow 1995	Mean flow	rank 1995	No. years	% flow	% rank
39055	Yeading Bk West	Yeading West	5083	1846	0.40	79-94		0.10		14		
39056	Ravensbourne	Catford Hill	5372	1732	0.61	78-99	0.26	0.35	3	22	74	14
39057	Crane	Cranford Park	5103	1778	0.36	78-99	0.21	0.35	1	22	60	5
39058	Pool	Winsford Road	5371	1725	0.57	78-99	0.20	0.25	6	21	80	29
39061	Letcombe Brook	Letcombe Bassett	4375	1853	0.96	71-99	0.05	0.07	9	28	73	32
39065	Ewelme Brook	Ewelme	4642	1916	0.98	70-99	0.05	0.05	17	24	113	71
39068	Mole	Castle Mill	5179	1502	0.43	72-99	0.87	1.46	2	26	59	8
39069	Mole	Kinnersley Manor	5262	1462	0.39	73-99	0.50	0.89	4	26	56	15
39072	Thames	Royal Windsor Park	4982	1773	0.72	79-99	19.60	26.30	3	13	75	23
39073	Churn	Cirencester	4020	2028	0.88	79-99	0.09	0.29	2	20	29	10
39074	Ampney Brook	Sheepen Bridge	4105	1950	0.73	80-99	0.02	0.17	2	20	9	10
39076	Windrush	Worsham	4299	2107	0.84	77-99	0.80	1.40	2	22	57	9
39077	Og	Marlborough Poulton Fm	4194	1697	0.97	80-99	0.16	0.19	7	20	85	35
39078	Wey(north)	Farnham	4838	1462	0.71	78-99	0.45	0.39	15	21	115	71
39079	Wey	Weybridge	5068	1648	0.64	79-99	2.72	3.07	3	9	89	33
39081	Ock	Abingdon	4481	1966	0.62	70-99	0.45	0.68	6	30	66	20
39084	Brent	Brent Cross	5236	1880	0.37	89-99	0.13	0.20	1	11	62	9
39086	Gatwick Stream	Gatwick Link	5285	1417	0.61	76-99	0.30	0.40	3	24	75	13
39087	Ray	Water Eaton	4121	1935	0.58	74-99		0.72		25		
39088	Chess	Rickmansworth	5066	1947	0.94	74-99	0.63	0.58	14	24	109	58
39089	Gade	Bury Mill	5053	2077	0.92	75-99	0.19	0.15	17	24	129	71
39090	Cole	Inglesham	4208	1970	0.55	77-99	0.20	0.45	2	23	44	9
39091	Misbourne	Quarrendon Mill	4975	1963	0.81	79-84		0.12		6		
39092	Dollis Brook	Hendon Lane Bridge	5240	1895	0.29	79-99	0.06	0.12	1	20	48	5
39093	Brent	Monks Park	5202	1850	0.18	79-98	0.44	0.70	1	20	63	5
39094	Crane	Marsh Farm	5154	1734	0.33	78-99	0.31	0.41	8	22	76	36
39095	Quaggy	Manor House Gardens	5394	1748	0.49	78-99	0.07	0.11	2	20	61	10
39096	Wealdstone Brook	Wembley	5192	1862	0.26	79-99	0.04	0.10	1	18	42	6
39097	Thames	Buscot	4230	1981	0.72	80-98	1.35	3.50	1	18	39	6
39098	Pinn	Uxbridge	5062	1826	0.18	85-99	0.02	0.08	2	12	29	17
39099	Ampney Brook	Ampney St. Peter	4076	2013	0.77	83-99	0.03	0.17	2	17	18	12
39100	Swill Brook	Oaksey	3997	1927	0.34	85-96		0.05		6		
39101	Aldbourne	Ramsbury	4288	1717	0.97	82-99	0.11	0.12	8	17	90	47
39102	Misbourne	Denham Lodge	5046	1866	0.88	84-99	0.22	0.18	7	13	121	54
39103	Kennet	Newbury	4472	1672	0.92	89-99	3.07	3.05	6	10	101	60
39104	Mole	Esher	5130	1653	0.49	85-99		2.32		6		
39105	Thame	Wheatley	4612	2050	0.63	89-99	0.97	1.49	1	5	65	20
39106	Mole	Leatherhead	5161	1564	0.62	87-99	1.18	1.57	1	8	75	13
39107	Hogsmill	Ewell	5216	1633	0.87	89-99	0.06	0.04	9	10	171	90
39108	Churn	Perrott's Brook	4022	2057	0.95	91-99	0.09	0.22	1	9	38	11
39109	Coln	Fossebridge	4080	2112	0.90	91-99	0.07	0.15	2	9	44	22
39110	Coln	Fairford	4151	2012	0.95	91-99	0.88	1.16	2	8	76	25
39111	Thames	Staines	5034	1713	0.69	91-99	18.15	20.73	3	7	88	43
39112	Letcombe Brook	Arabellas Lake	4374	1852	0.37	92-99	0.01	0.01	4	8	90	50
39113	Manor Farm Brook	Letcombe Regis	4383	1861	0.82	92-98	0.00	0.01	3	7	67	43
39114	Pang	Frilsham	4537	1730	1.00	92-98	0.22	0.12	5	6	179	83
39115	Pang	Bucklebury	4556	1711	0.43	92-98	0.22	0.15	5	6	151	83
39116	Sulham Brook	Sulham	4642	1741	0.82	92-99	0.01	0.01	3	8	86	38
39117	Colne Brook	Hythe End	5019	1723	0.84	91-99	1.16	1.00	4	5	116	80
39118	Wey	Alton	4717	1394	0.78	91-99	0.04	0.03	4	7	132	57
39119	Wey	Kings Pond (Alton)	4724	1395	0.37	92-99	0.07	0.05	5	7	138	71

Station Id	River name	Station name	East	North	BFI	Year range	Flow 1995	Mean flow	rank 1995	No. years	% flow	% rank
39120	Caker Stream	Alton	4729	1388	0.21	92-99	0.00	0.00	3	8	25	38
39121	Thames	Walton	5099	1670	0.62	92-99		21.58		6		
39122	Cranleigh Waters	Bramley	4999	1462		90-99	0.24	0.27	1	8	88	13
39125	Ver	Redbourn	5109	2118		93-99	0.08	0.05	6	7	147	86
39126	Red	Redbourn	5107	2119		93-99	0.04	0.03	4	6	124	67
39127	Misbourne	Little Missenden	4934	1984		94-99		0.08		5		
39128	Bourne (South)	Addlestone	5061	1650		94-99		0.49		5		
39129	Thames	Farmoor	4438	2068		93-99	1.27	3.82	1	7	33	14
39130	Thames	Reading	4718	1741		93-99	7.20	11.23	2	7	64	29
39131	Brent	Costons Lane, Greenford	5149	1823		93-99	0.47	0.75	1	7	62	14
39134	Ravensbourne East	Bromley South	5406	1687		93-98	0.02	0.03	1	6	69	17
39135	Quaggy River	Chinbrook Meadows	5410	1720		93-99	0.07	0.06	5	7	121	71
39147	Wendover Springs	Wendover Wharf	4869	2083		89-98	0.07	0.06	7	9	128	78
40002	Darwell	Darwell Reservoir	5722	1213	0.41	70-75		0.01		6		
40003	Medway	Teston	5708	1530	0.41	70-99	2.35	3.30	6	28	71	21
40004	Rother	Udiam	5773	1245	0.39	70-99	0.25	0.60	4	27	41	15
40005	Beult	Stile Bridge	5758	1478	0.24	70-99	0.14	0.29	7	30	48	23
40006	Bourne	Hadlow	5632	1497	0.62	70-99	0.25	0.24	12	16	102	75
40007	Medway	Chafford Weir	5517	1405	0.47	70-99	0.65	1.17	2	30	55	7
40008	Great Stour	Wye	6049	1470	0.57	70-99	0.58	1.00	3	27	59	11
40009	Teise	Stone Bridge	5718	1399	0.46	70-99		0.74		28		
40010	Eden	Penshurst	5520	1437	0.36	70-99	0.32	0.59	3	27	54	11
40011	Great Stour	Horton	6116	1554	0.70	70-99	1.51	1.70	12	29	89	41
40012	Darent	Hawley	5551	1718	0.70	70-99	0.29	0.28	16	30	105	53
40013	Darent	Otford	5525	1584	0.59	70-99	0.30	0.30	15	30	97	50
40014	Wingham	Durlock	6276	1576	0.56	73-96	0.01	0.01	9	19	60	47
40015	White Drain	Fairbrook Farm	6055	1606	0.52	70-99	0.02	0.03	10	28	64	36
40016	Cray	Crayford	5511	1746	0.69	70-99	0.56	0.43	24	30	128	80
40017	Dudwell	Burwash	5679	1240	0.45	71-99	0.05	0.10	3	21	52	14
40018	Darent	Lullingstone	5530	1643	0.71	70-99	0.35	0.39	11	28	91	39
40020	Eridge Stream	Hendal Bridge	5522	1367	0.44	73-99	0.13	0.24	3	21	53	14
40021	Hexden Channel	Hopemill Br Sandhurst	5813	1290	0.45	75-99		0.09		15		
40023	East Stour	South Willesborough	6015	1407	0.43	76-99	0.12	0.24	4	16	48	25
40024	Bartley Mill St	Bartley Mill	5633	1357	0.44	74-81		0.10		5		
40027	Sarre Penn	Calcott	6174	1625	0.35	75-93		0.02		17		
40029	Len	Lenside	5765	1556	0.68	85-99	0.58	0.49	8	10	118	80
40033	Dour	Crabble Mill	6300	1430	0.94	76-99	0.45	0.32	11	13	143	85
41001	Nunningham Stream	Tilley Bridge	5662	1129	1.00	70-99	0.02	0.04	6	30	49	20
41002	Ash Bourne	Hammer Wood Bridge	5684	1141	0.51	70-99	0.06	0.09	8	28	73	29
41003	Cuckmere	Sherman Bridge	5533	1051	0.28	70-99	0.10	0.30	4	28	34	14
41004	Ouse	Barcombe Mills	5433	1148	0.40	70-97	0.43	1.03	4	20	41	20
41005	Ouse	Gold Bridge	5429	1214	0.49	70-99	0.76	0.86	15	28	89	54
41006	Uck	Isfield	5459	1190	0.41	70-99	0.27	0.39	8	29	67	28
41009	Rother	Hardham	5034	1178	0.62	70-98		2.35		8		
41010	Adur W Branch	Hatterell Bridge	5178	1197	0.25	70-99	0.23	0.23	16	27	97	59
41011	Rother	Iping Mill	4852	1229	0.63	70-99	0.76	0.92	7	29	82	24
41012	Adur E Branch	Sakeham	5219	1190	0.35	70-99	0.21	0.37	4	29	56	14
41013	Huggletts Stream	Henley Bridge	5671	1138	0.36	70-99	0.02	0.04	7	25	55	28
41014	Arun	Pallingham Quay	5047	1229	0.32	70-99	0.30	1.01	2	28	29	7
41015	Ems	Westbourne	4755	1074	0.92	70-99	0.14	0.20	10	28	68	36
41016	Cuckmere	Cowbeech	5611	1150	0.44	70-98	0.03	0.06	14	29	53	48

Station Id	River name	Station name	East	North	BFI	Year range	Flow 1995	Mean flow	rank 1995	No. years	% flow	% rank
41017	Combe Haven	Crowhurst	5765	1102	0.42	70-99	0.03	0.08	6	29	41	21
41018	Kird	Tanyards	5044	1256	0.17	70-99	0.01	0.09	2	30	7	7
41019	Arun	Alfoldean	5117	1331	0.30	70-99	0.17	0.43	2	29	39	7
41020	Bevern Stream	Clappers Bridge	5423	1161	0.28	70-99	0.03	0.10	2	28	29	7
41021	Clayhill Stream	Old Ship	5448	1153	0.17	70-99	0.00	0.01	7	30	0	23
41022	Lod	Halfway Bridge	4931	1223	0.35	70-98	0.08	0.13	7	26	62	27
41023	Lavant	Graylingwell	4871	1064	0.84	71-98	0.01	0.05	8	25	16	32
41024	Shell Brook	Shell Brook	5335	1286	0.51	71-99	0.36	0.16	25	26	234	96
41025	Loxwood Stream	Drungewick	5060	1309	0.23	72-98	0.03	0.17	2	25	20	8
41026	Cockhaise Brook	Holywell	5376	1262	0.53	72-99	0.09	0.13	10	26	73	38
41027	Rother	Princes Marsh	4772	1270	0.62	73-99	0.16	0.22	3	27	71	11
41028	Chess Stream	Chess Bridge	5217	1173	0.39	70-99		0.05		26		
41029	Bull	Lealands	5575	1131	0.39	79-99	0.04	0.13	1	20	28	5
41031	Fulking Stream	Fulking	5247	1113	0.89	70-97	0.01	0.01	9	23	86	39
41033	Costers Brook	Cocking	4880	1174	0.90	73-98	0.02	0.03	6	21	76	29
41034	Ems	Walderton	4786	1104	0.82	70-83		0.01		14		
41035	North	Brookhurst	5130	1325	0.27	84-99	0.01	0.10	1	15	8	7
41037	Winterbourne Stream	Lewes	5403	1096	0.59	70-98	0.00	0.00	16	26	0	62
42001	Wallington	North Fareham	4587	1075	0.41	70-99	0.04	0.13	2	28	34	7
42003	Lymington	Brockenhurst	4318	1019	0.37	70-99	0.05	0.25	2	28	19	7
42004	Test	Broadlands	4354	1189	0.95	70-99	6.86	7.81	8	29	88	28
42005	Wallop Brook	Broughton	4311	1330	0.94	70-99		0.15		23		
42006	Meon	Mislingford	4589	1141	0.93	70-99	0.44	0.49	14	30	91	47
42007	Alre	Drove Lane Alresford	4574	1326	0.98	70-99	1.68	1.46	24	28	115	86
42008	Cheriton Stream	Sewards Bridge	4574	1323	0.97	70-99	0.44	0.45	11	29	97	38
42009	Candover Stream	Borough Bridge	4568	1323	0.96	71-99	0.42	0.42	13	29	99	45
42010	Itchen	Highbridge+Allbrook	4467	1213	0.96	70-99	3.78	4.00	10	30	94	33
42011	Hamble	Frogmill	4523	1149	0.67	73-99	0.16	0.22	6	26	74	23
42012	Anton	Fullerton	4379	1393	0.96	75-99	1.33	1.49	8	24	89	33
42013	Test	Longbridge	4355	1178	0.94	85-99		8.42		8		
42014	Blackwater	Ower	4328	1174	0.50	77-99	0.21	0.31	5	23	69	22
42015	Dever	Weston Colley	4496	1394	0.96	80-95	0.03	0.07	1	12	49	8
42016	Itchen	Easton	4512	1325	0.98	76-99	3.50	3.51	10	19	100	53
42017	Hermitage	Havant	4711	1067	0.48	88-99	0.05	0.15	1	11	35	9
42018	Monks Brook	Stoneham Lane	4443	1179	0.43	88-99	0.05	0.08	3	12	62	25
42019	Tanners Brook	Millbrook	4388	1133	0.69	78-99	0.07	0.13	4	19	56	21
42020	Tadburn Lake	Romsey	4362	1212	0.77	78-99	0.46	0.21	19	21	222	90
42023	Itchen	Riverside Park	4445	1154	0.92	82-99	2.61	3.66	1	11	71	9
42024	Test	Chilbolton (Total)	4386	1394	0.96	89-99	4.38	4.06	7	10	108	70
42025	Lavant Stream	Leigh Park	4721	1072	0.46	82-99	0.01	0.02	6	14	44	43
43003	Avon	East Mills	4158	1144	0.91	70-99	7.35	9.16	7	29	80	24
43004	Bourne	Laverstock	4157	1304	0.92	70-99	0.31	0.39	8	25	81	32
43005	Avon	Amesbury	4151	1413	0.91	70-99	1.66	2.02	9	30	82	30
43006	Nadder	Wilton	4098	1308	0.82	70-99	1.42	1.51	13	30	94	43
43007	Stour	Throop	4113	958	0.67	73-99	2.79	4.78	2	27	58	7
43008	Wylye	South Newton	4086	1343	0.91	70-99	1.80	2.29	6	30	79	20
43009	Stour	Hammoon	3820	1147	0.33	70-99	0.86	1.74	6	30	49	20
43010	Allen	Loverley Mill	4006	1085	0.90	70-99	0.23	0.38	2	20	60	10
43011	Ebble	Bodenham	4165	1265	0.84	70-75		0.47		5		
43012	Wylye	Norton Bavant	3909	1428	0.87	71-99	0.59	0.63	13	28	94	46
43013	Mude	Somerford	4184	936	0.56	72-83		0.04		10		

Station Id	River name	Station name	East	North	BFI	Year range	Flow 1995	Mean flow	rank 1995	No. years	% flow	% rank
43014	East Avon	Upavon	4133	1559	0.89	72-99	0.64	0.60	16	28	106	57
43017	West Avon	Upavon	4133	1559	0.71	72-99	0.16	0.26	6	28	63	21
43018	Allen	Walford Mill	4008	1007	0.91	75-99	0.35	0.69	2	25	50	8
43019	Shreen Water	Colesbrook	3807	1278	0.66	74-99	0.29	0.31	10	26	92	38
43021	Avon	Knapp Mill	4156	943	0.89	75-99	8.03	10.79	3	23	74	13
43022	Moors River	Hurn Court	4126	969		92-97	0.39	0.55	1	6	71	17
44001	Frome	East Stoke Total	3866	867	0.85	70-99	2.20	3.60	2	29	61	7
44002	Piddle	Baggs Mill	3913	876	0.89	70-99	1.00	1.25	7	30	79	23
44003	Asker	Bridport	3470	928	0.64	70-99		0.32		13		
44004	Frome	Dorchester Total	3708	903	0.84	72-99	1.11	1.61	4	27	69	15
44006	Sydling Water	Sydling St Nicholas	3632	997	0.87	70-99	0.09	0.11	8	30	84	27
44008	Sth Winterbourne	W'bourne Steepleton	3629	897	0.88	75-99	0.02	0.04	3	15	55	20
44009	Wey	Broadwey	3666	839	0.94	75-99	0.14	0.19	6	23	74	26
45001	Exe	Thorverton	2936	1016	0.50	70-99	2.03	5.27	3	30	39	10
45002	Exe	Stoodleigh	2943	1178	0.52	70-99	2.08	4.45	5	30	47	17
45003	Culm	Wood Mill	3021	1058	0.53	70-99	1.21	1.69	5	30	71	17
45004	Axe	Whitford	3262	953	0.50	70-99	1.55	2.18	7	30	71	23
45005	Otter	Dotton	3087	885	0.53	70-99	1.04	1.45	4	30	71	13
45008	Otter	Fenny Bridges	3115	986	0.49	75-99	0.61	0.88	2	25	69	8
45009	Exe	Pixton	2935	1260	0.51	70-99	1.09	1.53	10	30	71	33
45010	Haddeo	Hartford	2952	1294	0.55	73-79		0.34		7		
45011	Barle	Brushford	2927	1258	0.54	76-99		1.80		6		
45012	Creedy	Cowley	2901	967	0.45	70-99	0.39	0.84	4	30	46	13
45013	Tale	Fairmile	3088	972	0.53	79-99	0.12	0.20	2	20	61	10
46002	Teign	Preston	2856	746	0.55	70-99	1.25	2.60	3	30	48	10
46003	Dart	Austins Bridge	2751	659	0.53	70-99	1.96	4.10	5	30	48	17
46005	East Dart	Bellever	2657	775	0.43	70-99	0.24	0.57	4	30	43	13
46006	Erme	Ermington	2642	532	0.49	74-99	0.28	0.80	4	26	35	15
46007	West Dart	Dunnabridge	2643	742	0.42	73-99		1.17		17		
46008	Avon	Loddiswell	2719	476	0.51	71-99	0.40	1.27	2	20	32	10
47001	Tamar	Gunnislake	2426	725	0.47	70-99	3.61	6.56	7	30	55	23
47003	Tavy	Lopwell	2475	652	0.46	74-79		1.47		5		
47004	Lynher	Pillaton Mill	2369	626	0.58	70-99	0.65	1.55	3	30	42	10
47005	Ottery	Werrington Park	2337	866	0.39	70-99	0.15	0.84	2	17	17	12
47006	Lyd	Lifton Park	2389	842	0.49	70-99	2.00	1.75	12	18	115	67
47007	Yealm	Puslinch	2574	511	0.56	70-99	0.23	0.59	3	30	39	10
47008	Thrushel	Tinhay	2398	856	0.39	70-99	1.69	0.74	29	30	230	97
47009	Tiddy	Tideford	2344	596	0.61	70-99	0.16	0.31	4	30	50	13
47010	Tamar	Crowford Bridge	2290	991	0.26	72-99	0.10	0.60	4	27	16	15
47011	Plym	Carn Wood	2522	613	0.48	71-81		0.86		10		
47013	Withey Brook	Bastreet	2244	764	0.57	73-99	0.11	0.22	3	27	48	11
47014	Walkham	Horrabridge	2513	699	0.59	76-99	0.43	0.84	4	24	51	17
47015	Tavy	Denham / Ludbrook	2476	681	0.46	82-99	1.23	2.85	3	18	43	17
47016	Lumburn	Lumburn Bridge	2459	732	0.65	76-99	0.09	0.19	5	22	50	23
47017	Wolf	Combe Park Farm	2419	898	0.38	77-99		0.19		12		
47018	Thrushel	Hayne Bridge	2416	867		89-99	0.05	0.34	1	11	14	9
47019	Tamar	Polson Bridge	2353	849		89-99	0.60	2.78	1	11	22	9
48001	Fowey	Trekeivesteps	2227	698	0.63	70-99	0.29	0.56	3	30	52	10
48002	Fowey	Restormel one	2108	613	0.64	70-84		2.30		14		
48003	Fal	Tregony	1921	447	0.68	78-99	0.48	0.90	3	21	54	14
48004	Warleggan	Trengoffe	2159	674	0.73	70-99	0.21	0.39	3	30	53	10

Station Id	River name	Station name	East	North	BFI	Year range	Flow 1995	Mean flow	rank 1995	No. years	% flow	% rank
48005	Kenwyn	Truro	1820	450	0.66	70-99	0.06	0.12	5	30	56	17
48006	Cober	Helston	1654	273	0.73	70-88		0.36		19		
48007	Kennal	Ponsanooth	1762	377	0.67	70-99	0.10	0.19	7	30	54	23
48009	St Neot	Craigshill Wood	2184	662	0.63	71-99	0.99	0.51	21	22	192	95
48010	Seaton	Trebrownbridge	2299	595	0.73	70-99	0.21	0.41	3	30	52	10
48011	Fowey	Restormel	2098	624	0.63	70-99	0.96	1.79	4	30	54	13
49001	Camel	Denby	2017	682	0.62	70-99	1.02	2.38	3	30	43	10
49002	Hayle	St Erth	1549	341	0.83	70-99	0.27	0.42	2	30	63	7
49003	De Lank	De Lank	2133	765	0.57	70-99	0.12	0.33	5	29	36	17
49004	Gannel	Gwills	1829	593	0.69	70-99	0.12	0.24	3	30	51	10
50001	Taw	Umberleigh	2608	1237	0.42	70-99	1.31	5.08	3	30	26	10
50002	Torridge	Torrington	2500	1185	0.39	70-99	0.98	4.16	4	30	23	13
50005	West Okement	Vellake	2557	903	0.31	75-99	0.14	0.35	4	24	40	17
50006	Mole	Woodleigh	2660	1211	0.47	70-99	0.87	3.06	4	30	28	13
50007	Taw	Taw Bridge	2673	1068	0.46	74-99	0.45	0.49	12	24	91	50
50008	Lew	Gribbleford Bridge	2528	1014		88-99	0.03	0.39	1	12	8	8
50009	Lew	Norley Bridge	2501	999		89-99	0.02	0.13	2	11	16	18
50010	Torridge	Rockhay Bridge	2507	1070		89-99	0.36	2.19	2	11	16	18
50011	Okement	Jacobstowe	2592	1019	0.39	74-99	0.41	0.89	2	16	47	13
50012	Yeo	Veraby	2775	1267	0.41	70-99	0.27	0.56	4	27	48	15
51001	Doniford Stream	Swill Bridge	3088	1428	0.64	70-99	0.33	0.40	11	29	82	38
51002	Horner Water	West Luccombe	2898	1458	0.61	73-99	0.11	0.17	5	22	66	23
51003	Washford	Beggearn Huish	3040	1395	0.63	70-99	0.14	0.29	4	26	49	15
52003	Halsewater	Halsewater	3206	1253	0.74	70-99	0.36	0.51	8	29	72	28
52004	Isle	Ashford Mill	3361	1188	0.48	70-99	0.35	0.51	2	30	69	7
52005	Tone	Bishops Hull	3206	1250	0.58	70-99	0.70	1.12	3	30	62	10
52006	Yeo	Pen Mill	3573	1161	0.40	70-99	0.40	0.71	3	30	56	10
52007	Parrett	Chiselborough	3461	1144	0.45	70-99	0.21	0.37	4	30	58	13
52009	Sheppey	Fenny Castle	3498	1439	0.68	70-99	0.27	0.57	2	30	47	7
52010	Brue	Lovington	3590	1318	0.47	70-99	0.27	0.65	2	29	42	7
52011	Cary	Somerton	3498	1291	0.37	70-99	0.06	0.21	3	30	31	10
52014	Tone	Greenham	3078	1202	0.59	70-99	0.15	0.35	3	24	44	13
52015	Land Yeo	Wraxall Bridge	3483	1716	0.71	71-99	0.06	0.11	2	24	53	8
52016	Currypool Stream	Currypool Farm	3221	1382	0.71	71-99	0.08	0.11	4	29	67	14
52017	Congresbury Yeo	Iwood	3452	1631	0.59	73-99	0.22	0.34	1	14	66	7
52020	Gallica Stream	Gallica Bridge	3571	1100	0.26	70-78		0.05		7		
52025	Hillfarrance	Milverton	3113	1270		92-99	0.14	0.23	2	8	62	25
52026	Alham	Higher Alham	3679	1411		83-99	0.04	0.06	2	15	65	13
53001	Avon	Melksham	3903	1641	0.54	70-80		3.60		10		
53002	Semington Brook	Semington	3907	1605	0.57	70-99	0.64	0.74	13	30	87	43
53004	Chew	Compton Dando	3648	1647	0.63	70-99	0.46	0.52	12	30	88	40
53005	Midford Brook	Midford	3763	1611	0.62	70-99	0.53	0.87	6	30	61	20
53006	Frome(Bristol)	Frenchay	3637	1772	0.40	70-99	0.22	0.56	2	30	40	7
53007	Frome(Somerset)	Tellisford	3805	1564	0.52	70-99	0.72	1.36	3	29	53	10
53008	Avon	Great Somerford	3966	1832	0.58	70-99	0.36	0.95	3	30	38	10
53009	Wellow Brook	Wellow	3741	1581	0.62	70-99	0.26	0.48	2	30	53	7
53013	Marden	Stanley	3955	1729	0.64	70-99	0.32	0.56	3	30	57	10
53016	Spring Flow	Dunkerton	3803	1399	0.75	73-78		9.79		6		
53017	Boyd	Bitton	3681	1698	0.46	74-99	0.07	0.15	2	26	43	8
53018	Avon	Bathford	3785	1670	0.61	70-99	3.81	6.40	3	30	60	10
53019	Woodbridge Brook	Crabb Mill	3946	1866	0.34	70-99	0.06	0.16	5	30	41	17

Station Id	River name	Station name	East	North	BFI	Year range	Flow 1995	Mean flow	rank 1995	No. years	% flow	% rank
53020	Gauze Brook	Rodbourne	3937	1840	0.53	70-99	0.03	0.07	4	30	38	13
53022	Avon	Bath ultrasonic	3738	1651	0.58	77-84		8.62		8		
53023	Sherston Avon	Fosseway	3891	1870	0.67	77-99	0.16	0.28	4	23	55	17
53024	Tetbury Avon	Brokenborough	3914	1893	0.66	78-99	0.10	0.20	6	22	49	27
53025	Mells	Vallis	3757	1491	0.59	80-99	0.31	0.57	4	20	55	20
53026	Frome (Bristol)	Frampton Cotterell	3667	1822	0.42	78-99	0.21	0.31	5	22	68	23
53028	By Brook	Middlehill	3813	1688	0.75	82-99	0.25	0.52	2	18	48	11
53029	Biss	Trowbridge	3857	1576		84-99	0.17	0.27	3	16	62	19
54001	Severn	Bewdley	3782	2762	0.53	70-100	11.42	22.19	2	31	51	6
54002	Avon	Evesham	4040	2438	0.51	70-99	5.08	8.52	4	30	60	13
54003	Vyrnwy	Vyrnwy Reservoir	3019	3191	0.35	70-99	0.78	0.81	15	30	96	50
54004	Sowe	Stoneleigh	4332	2731	0.60	70-99	1.75	2.27	3	30	77	10
54005	Severn	Montford	3412	3144	0.46	70-99	8.75	14.78	6	28	59	21
54006	Stour	Callows Lane, Kidderminster	3830	2768	0.72	70-99	1.33	2.16	3	30	62	10
54007	Arrow	Broom	4086	2536	0.53	70-99	0.98	1.48	4	25	66	16
54008	Teme	Tenbury	3597	2686	0.57	70-99	1.86	4.31	3	30	43	10
54010	Stour	Alscot Park	4208	2507	0.50	70-82		0.88		12		
54011	Salwarpe	Harford Hill	3868	2618	0.65	70-99	0.45	0.72	2	22	63	9
54012	Tern	Walcot	3592	3123	0.69	70-99	2.63	3.77	6	30	70	20
54013	Clywedog	Cribynau	2944	2855	0.47	70-78		1.99		9		
54014	Severn	Abermule	3164	2958	0.42	70-99	4.51	5.28	18	30	85	60
54015	Bow Brook	Besford Bridge	3927	2463	0.40	70-99	0.15	0.35	4	25	42	16
54016	Roden	Rodington	3589	3141	0.61	70-99	0.43	0.78	4	30	55	13
54017	Leadon	Wedderburn Bridge	3777	2234	0.50	70-99	0.37	0.69	3	28	53	11
54018	Rea Brook	Hookagate	3466	3092	0.51	70-99	0.33	0.55	6	27	60	22
54019	Avon	Stareton	4333	2715	0.49	70-99	0.49	1.08	2	30	45	7
54020	Perry	Yeaton	3434	3192	0.65	70-99	0.55	0.69	9	30	79	30
54022	Severn	Plynlimon flume	2853	2872	0.32	70-99	0.14	0.28	5	29	50	17
54023	Badsey Brook	Offenham	4063	2449	0.42	70-99		0.23		24		
54024	Worfe	Burcote	3747	2953	0.71	70-99	0.41	0.65	6	30	63	20
54025	Dulas	Rhos-y-pentref	2950	2824	0.37	70-99	0.07	0.37	4	30	19	13
54026	Chelt	Slate Mill	3892	2264	0.70	72-83		0.46		10		
54027	Frome	Ebley Mill	3831	2047	0.86	70-99	1.08	1.59	4	30	68	13
54028	Vyrnwy	Llanymynech	3252	3195	0.45	70-99	3.58	7.28	5	30	49	17
54029	Teme	Knightsford Bridge	3735	2557	0.57	70-99	2.40	5.53	3	30	43	10
54032	Severn	Saxons Lode	3863	2390	0.56	71-99	17.23	32.18	2	29	54	7
54034	Dowles Brook	Oak Cottage, Dowles	3768	2764	0.42	72-99	0.04	0.12	3	28	35	11
54036	Isbourne	Hinton on the Green	4023	2408	0.53	72-99	0.12	0.24	5	27	51	19
54038	Tanat	Llanyblodwel	3252	3225	0.47	73-99	0.85	1.98	5	26	43	19
54040	Meese	Tibberton	3680	3205	0.80	74-99	0.47	0.72	3	26	65	12
54041	Tern	Eaton On Tern	3649	3230	0.71	72-99	0.71	1.02	3	27	70	11
54042	Clywedog	Clywedog Dm Lower Weir	2914	2867	0.67	71-77		1.56		6		
54044	Tern	Ternhill	3629	3316	0.76	73-99	0.47	0.57	5	27	82	19
54045	Perry	Perry Farm	3347	3303	0.71	74-78		0.30		5		
54046	Worfe	Cosford	3781	3046	0.62	75-99	0.05	0.09	5	21	60	24
54048	Dene	Wellesbourne	4273	2556	0.45	76-99	0.09	0.20	5	22	43	23
54049	Leam	Princes Drive Weir	4307	2654	0.37	80-99	0.57	0.85	6	19	67	32
54050	Leam	Eathorpe	4388	2688		87-99	0.31	0.61	3	13	51	23
54052	Bailey Brook	Ternhill	3629	3316	0.65	70-99	0.13	0.27	4	30	46	13
54057	Severn	Haw Bridge	3844	2279	0.57	71-99	20.62	40.33	2	28	51	7
54058	Stoke Park Brook	Stoke Park	3644	3260	0.59	72-78		0.05		7		

Station Id	River name	Station name	East	North	BFI	Year range	Flow 1995	Mean flow	rank 1995	No. years	% flow	% rank
54059	Allford Brook	Allford	3654	3223	0.70	72-78		0.05		5		
54060	Potford Brook	Sandyford Bridge	3634	3220	0.76	72-99	0.08	0.08	11	23	94	48
54061	Hodnet Brook	Hodnet	3628	3288	0.76	72-76		0.01		5		
54062	Stoke Brook	Stoke	3637	3280	0.75	72-83		0.07		11		
54063	Stour	Prestwood Hospital	3865	2858	0.66	72-99		0.89		14		
54066	Platt Brook	Platt	3628	3229	0.60	73-83		0.05		11		
54067	Smestow Brook	Swindon	3861	2906	0.62	74-78		0.34		5		
54069	Springs Brook	Lower Hordley	3387	3297	0.65	74-78		0.02		5		
54070	War Brook	Walford	3432	3198	0.57	74-83		0.04		10		
54081	Clywedog	Bryntail	2913	2868	0.52	77-99	3.53	1.98	21	22	178	95
54083	Crow Brook	Horton	3678	3141	0.73	78-83		0.12		5		
54084	Cannop Brook	Parkend	3616	2075	0.58	78-83		0.14		5		
54085	Cannop Brook	Cannop Cross	3609	2115	0.61	79-83		0.06		5		
54086	Cownwy Diversion	Cownwy Weir	2999	3179	0.24	80-99	0.09	0.27	3	15	31	20
54087	Allford Brook	Childs Ercall	3667	3228	0.66	73-99	0.00	0.01	8	19	50	42
54088	Little Avon	Berkeley Kennels	3683	1988	0.61	79-99	0.26	0.45	2	21	59	10
54089	Avon	Bredon	3921	2374		88-99	3.37	7.16	1	11	47	9
54090	Tanllwyth	Tanllwyth Flume	2843	2876	0.29	74-99	0.02	0.03	5	26	52	19
54091	Severn	Hafren Flume	2843	2878	0.39	76-99	0.06	0.12	5	24	48	21
54092	Hore	Hore Flume	2846	2873	0.32	75-99	0.05	0.10	5	24	46	21
54094	Strine	Crudgington	3640	3175	0.63	85-99	0.20	0.38	1	11	53	9
54095	Severn	Buildwas	3644	3044		84-99	13.54	22.40	2	13	60	15
54096	Hadley Brook	Wards Bridge	3870	2631		90-99	0.11	0.14	2	9	75	22
54097	Hore	Upper Hore flume	2831	2869		86-99	0.03	0.06	1	12	47	8
55002	Wye	Belmont	3485	2388	0.46	70-99	7.29	18.06	3	30	40	10
55003	Lugg	Lugwardine	3548	2405	0.63	70-99	1.78	4.02	3	23	44	13
55004	Irfon	Abernant	2892	2460	0.37	70-82		1.51		12		
55006	Elan	Caban Coch Reservoir	2926	2645	0.34	70-84		1.64		15		
55007	Wye	Erwood	3076	2445	0.41	70-99	5.53	12.73	4	30	43	13
55008	Wye	Cefn Brwyn	2829	2838	0.32	70-99	0.16	0.41	3	29	39	10
55010	Wye	Pant Mawr	2843	2825	0.31	70-82		0.99		12		
55011	Ithon	Llandewi	3105	2683	0.38	70-82		0.62		11		
55012	Irfon	Cilmery	2995	2507	0.39	70-99	1.39	3.61	5	28	39	18
55013	Arrow	Titley Mill	3328	2585	0.56	70-99		0.74		29		
55014	Lugg	Byton	3364	2647	0.67	70-99	0.90	1.40	5	30	64	17
55015	Honddu	Tafolog	3277	2294	0.52	70-82		0.29		11		
55016	Ithon	Disserth	3024	2578	0.38	70-99		2.10		28		
55017	Chwefru	Carreg-y-wen	2998	2531	0.34	70-81		0.24		12		
55018	Frome	Yarkhill	3615	2428	0.50	70-99	0.24	0.40	5	30	60	17
55020	Pinsley Brook	Cholstrey Mill	3462	2598		93-99	0.22	0.34	2	7	64	29
55021	Lugg	Butts Bridge	3502	2589	0.65	70-99	1.40	2.21	5	27	64	19
55022	Trothy	Mitchel Troy	3503	2112	0.49	70-82		0.44		10		
55023	Wye	Redbrook	3528	2110	0.55	70-99	10.51	26.70	3	30	39	10
55025	Llynfi	Three Cocks	3166	2373	0.57	70-99	0.19	0.57	3	29	34	10
55026	Wye	Ddol Farm	2976	2676	0.36	70-99	1.00	2.69	5	30	37	17
55027	Rudhall Brook	Sandford Bridge	3641	2257	0.81	72-97	0.03	0.05	4	14	57	29
55028	Frome	Bishops Frome	3667	2489	0.50	72-99	0.05	0.22	1	28	24	4
55029	Monnow	Grosmont	3415	2249	0.59	70-99	0.90	1.85	5	30	49	17
55031	Yazor Brook	Three Elms	3492	2415	0.55	73-97	0.13	0.14	9	24	88	38
55032	Elan	Elan Village	2934	2653	0.29	70-99	2.32	2.05	26	29	113	90
55033	Wye	Gwy flume	2824	2853	0.52	74-99	0.07	0.16	4	25	43	16

Station Id	River name	Station name	East	North	BFI	Year range	Flow 1995	Mean flow	rank 1995	No. years	% flow	% rank
55034	Cyff	Cyff flume	2824	2842	0.30	74-99	0.05	0.12	4	26	39	15
55035	Iago	Iago flume	2826	2854	0.29	74-98	0.03	0.04	6	24	64	25
56001	Usk	Chain Bridge	3345	2056	0.51	70-99	4.86	9.42	4	30	52	13
56002	Ebbw	Rhiwderyn	3259	1889	0.58	70-99	1.32	3.18	1	26	42	4
56003	Honddu	The Forge Brecon	3051	2297	0.52	70-84		0.40		15		
56004	Usk	Llandetty	3127	2203	0.47	70-79		5.31		10		
56005	Lwyd	Ponthir	3330	1924	0.55	70-98	0.84	1.42	5	28	59	18
56006	Usk	Trallong	2947	2295	0.45	70-83		2.32		14		
56007	Senni	Pont Hen Hafod	2928	2255	0.37	70-99	0.13	0.42	4	30	31	13
56008	Monks Ditch	Llanwern	3372	1885	0.60	70-74		0.12		5		
56010	Usk	Trostrey Weir	3358	2042	0.57	70-99	5.22	8.77	4	23	59	17
56011	Sirhowy	Wattsville	3206	1912	0.50	70-82		0.83		12		
56012	Grwyne	Millbrook	3241	2176	0.59	71-99	0.37	0.83	3	24	44	13
56013	Yscir	Pontaryscir	3003	2304	0.46	72-99	0.26	0.65	5	28	40	18
56014	Usk	Usk Reservoir	2840	2290	0.45	79-99	0.95	0.30	13	14	315	93
56015	Olway Brook	Olway Inn	3384	2010	0.49	75-99	0.13	0.34	3	25	39	12
56016	Caerfanell Outfall	Talybont Reservoir	3104	2206	0.48	79-88		0.33		10		
56018	Sirhowy	Shon Sheffrey	3131	2114	0.23	81-88		13.47		5		
56019	Ebbw	Brynithel	3210	2015		84-99	0.52	1.10	1	16	48	6
57004	Cynon	Abercynon	3079	1956	0.41	70-99	0.59	1.60	4	30	37	13
57005	Taff	Pontypridd	3079	1897	0.47	71-99	4.39	8.26	5	28	53	18
57006	Rhondda	Trehafod	3054	1909	0.42	71-99	0.99	2.75	3	28	36	11
57007	Taff	Fiddlers Elbow	3089	1951	0.49	73-99	1.35	2.57	3	27	53	11
57008	Rhymney	Llanedeyrn	3225	1821	0.50	73-99	0.69	1.95	2	27	35	7
57009	Ely	St Fagans	3121	1770	0.49	75-99	0.64	1.77	2	25	36	8
57010	Ely	Lanelay	3034	1827	0.43	75-99	0.24	0.66	4	24	37	17
57015	Taff	Merthyr Tydfil	3043	2068	0.40	79-99	0.84	1.43	3	21	59	14
57016	Taf Fechan	Pontsticill	3060	2115	0.42	79-99	0.26	0.28	8	20	95	40
58001	Ogmore	Bridgend	2904	1794	0.48	70-99	1.21	3.39	3	30	36	10
58002	Neath	Resolven	2815	2017	0.35	75-99	1.41	4.20	4	24	34	17
58005	Ogmore	Brynmenyn	2904	1844	0.49	71-99	0.69	1.89	4	28	37	14
58006	Mellte	Pontneddfechan	2915	2082	0.36	72-99	0.58	1.41	4	28	41	14
58007	Llynfi	Coytrahen	2891	1855	0.49	71-99	0.42	1.26	2	29	33	7
58008	Dulais	Cilfrew	2778	2008	0.39	72-99	0.24	0.96	2	25	25	8
58009	Ewenny	Keepers Lodge	2920	1782	0.58	72-99	0.34	0.89	2	28	38	7
58010	Hepste	Esgair Carnau	2969	2134	0.24	76-99	0.08	0.20	2	15	39	13
58011	Thaw	Gigman Bridge	3017	1716	0.70	76-99	0.20	0.39	4	24	51	17
58012	Afan	Marcroft Weir	2771	1910		78-99	1.01	2.86	2	21	35	10
59001	Tawe	Ynystanglws	2685	1998	0.36	70-100	2.01	6.35	3	30	32	10
59002	Loughor	Tir-y-dail	2623	2127	0.43	70-99	0.38	0.96	4	30	39	13
60002	Cothi	Felin Mynachdy	2508	2225	0.43	70-99	1.30	4.35	4	30	30	13
60003	Taf	Clog-y-Fran	2238	2160	0.55	70-99	0.70	2.48	4	29	28	14
60004	Dewi Fawr	Glasfryn Ford	2290	2175	0.53	70-99	0.08	0.44	1	24	19	4
60005	Bran	Llandovery	2771	2343	0.36	70-99	0.19	0.85	4	30	22	13
60006	Gwili	Glangwili	2431	2220	0.46	70-99	0.41	1.90	2	30	22	7
60007	Tywi	Dolau Hirion	2762	2362	0.42	70-99	0.38	4.70	1	30	8	3
60008	Tywi	Ystradffin	2786	2472	0.53	83-99	3.17	2.96	12	15	107	80
60009	Sawdde	Felin-y-cwm	2712	2266	0.34	71-99	0.51	2.56	3	29	20	10
60010	Tywi	Nantgaredig	2485	2206	0.46	70-99	5.55	14.95	5	30	37	17
60012	Twrch	Ddol Las	2650	2440	0.34	71-99	0.06	0.28	2	20	21	10
61001	Western Cleddau	Prendergast Mill	1954	2177	0.65	70-99	0.76	1.96	3	30	39	10

Station Id	River name	Station name	East	North	BFI	Year range	Flow 1995	Mean flow	rank 1995	No. years	% flow	% rank
61002	Eastern Cleddau	Canaston Bridge	2072	2153	0.55	70-99	1.31	2.48	6	30	53	20
61003	Gwaun	Cilrhedyn Bridge	2005	2349	0.57	70-99	0.26	0.49	7	30	54	23
62001	Teifi	Glan Teifi	2244	2416	0.54	70-100	3.43	10.99	5	31	31	16
62002	Teifi	Llanfair	2433	2406	0.49	71-82		5.54		11		
63001	Ystwyth	Pont Llolwyn	2591	2774	0.41	70-99	0.78	2.72	4	30	29	13
63002	Rheidol	Llanbadarn Fawr	2601	2804	0.51	70-99		4.83		19		
63003	Wyre	Llanrhystyd	2542	2698	0.40	70-79		0.42		9		
63004	Ystwyth	Cwm Ystwyth	2791	2737		84-99	0.37	1.12	2	16	33	13
64001	Dyfi	Dyfi Bridge	2745	3019	0.38	70-99	5.72	9.97	6	25	57	24
64002	Dysynni	Pont-y-Garth	2632	3066	0.48	70-99	1.49	2.81	4	30	53	13
64006	Leri	Dolybont	2635	2882	0.47	70-99	0.33	0.85	6	30	39	20
64010	Afon Mawddach	Tyddyn Gwladys	2735	3264		95-99	0.87	1.91	1	5	46	20
65001	Glaslyn	Beddgelert	2592	3478	0.31	70-99	2.12	3.71	4	30	57	13
65004	Gwyrfai	Bontnewydd	2484	3599	0.43	72-99	0.54	1.23	3	28	44	11
65005	Erch	Pencaenewydd	2400	3404	0.54	73-99	0.14	0.25	7	27	55	26
65006	Seiont	Peblig Mill	2493	3623	0.40	76-99	1.34	2.60	2	21	52	10
65007	Dwyfawr	Garndolbenmaen	2500	3429	0.38	75-99	0.81	1.47	5	25	55	20
65008	Nant Peris	Tan-Yr-Alt	2608	3579		82-99	0.41	0.74	3	18	55	17
66001	Clwyd	Pont-y-Cambwll	3069	3709	0.59	70-99	1.51	2.18	11	30	69	37
66003	Aled	Bryn Aled	2957	3703	0.48	74-95		0.41		13		
66004	Wheeler	Bodfari	3105	3714	0.83	70-99	0.35	0.43	10	28	80	36
66005	Clwyd	Ruthin Weir	3122	3592	0.58	71-99	0.23	0.33	11	25	70	44
66006	Elwy	Pont-y-Gwyddel	2952	3718	0.46	74-99	0.53	1.06	8	26	50	31
66008	Aled	Aled Isaf Reservoir	2915	3598	0.87	77-95		0.16		13		
66011	Conwy	Cwm Llanerch	2802	3581	0.28	70-99	3.84	8.43	4	30	46	13
66025	Clwyd	Pont Dafydd	3044	3749		95-99	1.32	2.29	2	5	58	40
67001	Dee	Bala	2942	3357	0.50	70-99	8.28	7.62	24	30	109	80
67003	Brenig	Llyn Brenig outflow	2974	3539	0.40	70-95	1.17	0.60	24	26	194	92
67005	Ceiriog	Brynkinalt Weir	3295	3373	0.54	70-99	0.60	1.07	4	14	57	29
67006	Alwen	Druid	3042	3436	0.46	70-99	1.97	1.93	19	30	102	63
67008	Alyn	Pont-y-Capel	3336	3541	0.56	70-99	0.63	0.94	10	30	67	33
67009	Alyn	Rhydymwyn	3206	3667	0.40	70-99	0.00	0.10	12	30	0	40
67010	Gelyn	Cynefail	2843	3420	0.26	70-99	0.16	0.30	4	24	51	17
67011	Nant Aberderfel	Nant Aberderfel	2851	3392	0.14	70-80		0.05		7		
67013	Hirnant	Plas Rhiwedog	2946	3349	0.40	70-76		0.50		7		
67015	Dee	Manley Hall	3348	3415	0.52	70-99	12.09	13.69	12	30	88	40
67017	Tryweryn	Llyn Celyn outflow	2880	3399	0.41	70-99	6.07	3.90	28	30	156	93
67018	Dee	New Inn	2874	3308	0.27	70-99	0.78	1.47	6	30	53	20
67020	Dee	Chester Weir	3408	3659		84-97	7.22	10.68	5	14	68	36
67025	Clywedog	Bowling Bank	3396	3483	0.63	76-99	0.34	0.67	2	24	50	8
67026	Dee	Eccleston Ferry	3415	3612	0.59	74-86		15.32		13		
67027	Dee	Ironbridge	3418	3600		94-99	12.58	13.97	3	6	90	50
67028	Ceidiog	Llandrillo	3034	3371	0.45	78-99	0.25	0.44	3	12	56	25
67029	Trystion	Pen-y-felin Fawr	3066	3405	0.44	77-86		0.11		7		
67033	Dee	Chester Suspension Bridge	3409	3659		94-99	7.53	9.69	3	6	78	50
68001	Weaver	Ashbrook	3670	3633	0.53	70-99	1.36	2.80	2	30	49	7
68002	Gowy	Picton	3443	3714	0.51	70-75		1.48		6		
68003	Dane	Rudheath	3668	3718	0.51	70-99	1.13	2.56	3	30	44	10
68004	Wistaston Brook	Marshfield Bridge	3674	3552	0.62	70-98	0.23	0.50	3	28	45	11
68005	Weaver	Audlem	3653	3431	0.50	70-99	0.24	0.57	5	30	42	17
68006	Dane	Hulme Walfield	3845	3644	0.48	70-84		1.12		9		

Station Id	River name	Station name	East	North	BFI	Year range	Flow 1995	Mean flow	rank 1995	No. years	% flow	% rank
68007	Wincham Brook	Lostock Gralam	3697	3757	0.54	70-99	0.23	0.88	2	28	26	7
68011	Arley Brook	Gore Farm	3696	3799	0.33	75-81		0.09		5		
68015	Gowy	Huxley	3497	3624	0.49	79-98	0.09	0.19	1	18	46	6
68019	Weaver	Pickerings Cut	3574	3762		93-97	6.85	8.28	2	5	83	40
68020	Gowy	Bridge Trafford	3448	3711	0.46	80-99	0.23	0.52	3	19	45	16
69001	Mersey	Irlam Weir	3728	3936	0.56	70-78		10.86		9		
69002	Irwell	Adelphi Weir	3824	3987	0.49	70-99	5.99	10.04	2	28	60	7
69003	Irk	Scotland Weir	3841	3992	0.54	70-98		1.46		23		
69004	Etherow	Bottoms Reservoir	4023	3971	0.40	70-81		0.71		12		
69005	Glaze Brook	Little Woolden Hall	3685	3939	0.52	70-83		2.16		9		
69006	Bollin	Dunham Massey	3727	3875	0.57	70-98	1.83	2.68	4	26	69	15
69007	Mersey	Ashton Weir	3772	3936	0.51	76-99	4.46	6.36	5	24	70	21
69008	Dean	Stanneylands	3846	3830	0.49	76-98	0.17	0.35	3	22	48	14
69012	Bollin	Wilmslow	3850	3815	0.62	76-99	0.54	0.78	4	24	69	17
69013	Sinderland Brook	Partington	3726	3905	0.55	76-98	0.19	0.32	1	22	60	5
69015	Etherow	Compstall	3962	3908	0.48	72-98	0.98	1.59	5	26	61	19
69017	Goyt	Marple Bridge	3964	3898	0.51	70-99	0.81	1.64	2	25	50	8
69019	Worsley Brook	Eccles	3753	3980	0.48	70-99	0.09	0.20	3	18	48	17
69020	Medlock	London Road	3849	3975	0.54	75-98	0.24	0.60	1	24	40	4
69023	Roch	Blackford Bridge	3807	4077	0.50	76-98	1.43	2.59	1	23	55	4
69024	Croal	Farnworth Weir	3743	4068	0.39	76-99	0.86	1.66	2	23	52	9
69027	Tame	Portwood	3906	3918	0.58	70-99	1.57	2.62	3	25	60	12
69028	Mersey	Brinksway	3884	3900		74-99	4.74	6.38	7	25	74	28
69030	Sankey Brook	Causey Bridge	3588	3922	0.54	77-99	1.01	1.58	2	21	64	10
69031	Ditton Brook	Greens Bridge	3457	3865	0.55	74-98	1.84	1.03	17	18	179	94
69032	Alt	Kirkby	3392	3983	0.52	78-99	0.57	0.85	2	20	66	10
69035	Irwell	Bury Bridge	3797	4109	0.34	76-97	0.41	2.01	1	20	20	5
69037	Mersey	Westy	3617	3877	0.51	86-99		24.18		8		
69040	Irwell	Stubbins	3793	4188	0.44	76-99	1.08	1.76	6	23	61	26
69041	Tame	Broomstair Bridge	3938	3953	0.62	74-99	1.38	2.11	2	25	65	8
69042	Ding Brook	Naden Reservoir	3850	4175		82-99	0.01	0.04	1	17	22	6
69044	Dane	Hugbridge	3931	3636		92-99	0.58	1.08	1	6	53	17
70002	Douglas	Wanes Blades Bridge	3476	4126	0.54	74-99	1.96	2.40	6	24	82	25
70003	Douglas	Central Park Wigan	3587	4061	0.55	77-99	0.50	0.69	4	20	72	20
70004	Yarrow	Croston Mill	3498	4180	0.42	76-98	0.55	0.92	2	23	60	9
70005	Lostock	Littlewood Bridge	3497	4197	0.50	76-99	0.51	0.76	3	23	66	13
71001	Ribble	Samlesbury	3587	4314	0.32	70-98	5.59	15.24	2	29	37	7
71002	Hodder	Stocks Reservoir	3719	4546	0.30	70-98	0.00	0.07	19	25	0	76
71003	Croasdale	Croasdale flume	3706	4546	0.35	70-74		0.23		5		
71004	Calder	Whalley Weir	3729	4360	0.43	70-99	2.30	4.28	2	28	54	7
71005	Bottoms Beck	Bottoms Beck flume	3745	4565	0.21	70-74		0.22		5		
71006	Ribble	Henthorn	3722	4392	0.29	70-99	1.32	5.79	1	30	23	3
71008	Hodder	Hodder Place	3704	4399	0.31	76-99	1.26	4.07	2	24	31	8
71009	Ribble	New Jumbles Rock	3702	4376	0.32	79-98	4.87	15.21	1	20	32	5
71010	Pendle Water	Barden Lane	3837	4351	0.41	72-98	0.50	1.39	1	27	36	4
71011	Ribble	Arnford	3839	4556	0.25	70-99	0.72	3.32	1	29	22	3
71013	Darwen	Ewood	3677	4262	0.44	76-98	0.38	0.69	2	21	56	10
71014	Darwen	Blue Bridge	3565	4278	0.49	76-99	1.60	2.46	2	23	65	9
72001	Lune	Halton	3503	4647	0.32	70-76		16.66		7		
72002	Wyre	St Michaels	3463	4411	0.32	70-99	0.95	2.85	2	30	33	7
72004	Lune	Caton	3529	4653	0.32	70-100	6.06	16.90	4	29	36	14

Station Id	River name	Station name	East	North	BFI	Year range	Flow 1995	Mean flow	rank 1995	No. years	% flow	% rank
72005	Lune	Killington New Bridge	3622	4907	0.35	70-99	2.06	4.31	6	29	48	21
72007	Brock	U/S A6	3512	4405	0.32	78-99	0.10	0.43	1	21	24	5
72008	Wyre	Garstang	3488	4447	0.31	70-98	0.57	1.71	2	29	33	7
72009	Wenning	Wennington	3615	4701	0.30	76-99	0.30	1.63	1	24	19	4
72011	Rawthey	Brigg Flatts	3639	4911	0.26	70-99	1.23	4.23	2	25	29	8
72014	Conder	Galgate	3481	4554	0.30	76-99	0.09	0.30	2	21	29	10
72015	Lune	Lunes Bridge	3612	5029	0.33	80-99	1.15	2.54	5	20	45	25
72016	Wyre	Scorton Weir	3501	4500	0.36	72-98	0.59	2.22	2	26	27	8
73001	Leven	Newby Bridge	3371	4863	0.48	70-76		7.27		6		
73002	Crake	Low Nibthwaite	3294	4882	0.57	70-99	1.18	2.07	6	30	57	20
73003	Kent	Burneside	3507	4956	0.32	81-98	0.58	1.70	2	16	34	13
73005	Kent	Sedgwick	3509	4874	0.46	70-99	1.81	4.19	3	30	43	10
73006	Cunsey Beck	Eel House Bridge	3369	4940	0.43	76-98	0.13	0.36	5	19	37	26
73008	Bela	Beetham	3496	4806	0.50	70-99	0.82	1.54	9	29	53	31
73009	Sprint	Sprint Mill	3514	4961	0.38	76-99	0.39	0.92	3	24	42	13
73010	Leven	Newby Bridge FMS	3367	4863	0.50	70-99	3.08	6.56	3	30	47	10
73011	Mint	Mint Bridge	3524	4944	0.38	70-98	0.44	1.10	3	24	40	13
73013	Rothay	Miller Bridge House	3371	5042	0.33	76-98	0.83	2.05	3	20	41	15
73014	Brathay	Jeffy Knotts	3360	5034	0.28	76-99	1.27	2.46	4	16	52	25
73015	Keer	High Keer Weir	3523	4719		76-98	0.11	0.20	3	11	51	27
74001	Duddon	Duddon Hall	3196	4896	0.28	70-98	1.66	2.90	5	29	57	17
74002	Irt	Galesyke	3136	5038	0.46	70-98	2.11	2.40	12	28	88	43
74003	Ehen	Bleach Green	3084	5154	0.31	73-99	1.00	1.32	11	26	76	42
74005	Ehen	Braystones	3009	5061	0.40	74-99	2.41	2.75	12	26	88	46
74006	Calder	Calder Hall	3035	5045	0.41	70-99	0.92	1.22	10	28	75	36
74007	Esk	Cropple How	3131	4978	0.30	76-98	2.00	2.86	7	23	70	30
74008	Duddon	Ulpha	3209	4947	0.25	76-98	1.00	1.83	5	23	54	22
75001	St Johns Beck	Thirlmere Reservoir	3313	5195	0.35	70-98	0.22	0.21	20	27	102	74
75002	Derwent	Camerton	3038	5305	0.48	70-99	5.43	11.43	2	30	47	7
75003	Derwent	Ouse Bridge	3199	5321	0.50	70-99	3.46	7.59	2	30	46	7
75004	Cocker	Southwaite Bridge	3131	5281	0.43	70-99	1.15	2.62	3	30	44	10
75005	Derwent	Portinscale	3251	5239	0.41	72-98	2.72	5.55	5	26	49	19
75006	Newlands Beck	Braithwaite	3240	5239	0.32	70-96	0.19	0.73	1	13	25	8
75007	Glenderamackin	Threlkeld	3323	5248	0.29	70-98	1.00	1.43	8	21	70	38
75009	Greta	Low Briery	3286	5242	0.35	71-98	0.79	2.05	1	28	38	4
75010	Marron	Ullock	3074	5238	0.48	72-77		0.34		6		
75016	Cocker	Scalehill	3149	5214	0.35	76-98	0.94	1.76	4	22	54	18
75017	Ellen	Bullgill	3096	5384	0.49	76-99	0.30	0.79	1	23	38	4
76001	Haweswater Beck	Burnbanks	3508	5159	0.47	70-98	0.26	0.26	12	23	102	52
76002	Eden	Warwick Bridge	3470	5567	0.49	70-97	9.50	15.59	5	28	61	18
76003	Eamont	Udford	3578	5306	0.53	70-99	2.47	5.99	3	28	41	11
76004	Lowther	Eamont Bridge	3527	5287	0.41	70-98	0.85	1.16	9	28	73	32
76005	Eden	Temple Sowerby	3605	5283	0.37	70-99	1.99	5.30	1	30	38	3
76007	Eden	Sheepmount	3390	5571	0.50	70-99	11.84	22.15	3	29	53	10
76008	Irthing	Greenholme	3486	5581	0.31	70-98	2.01	4.22	3	28	48	11
76009	Caldew	Holm Hill	3378	5469	0.49	70-97	0.94	1.86	4	28	50	14
76010	Petteril	Harraby Green	3412	5545	0.46	70-98	0.28	0.64	2	29	43	7
76011	Coal Burn	Coalburn	3693	5777	0.19	70-99	0.01	0.02	2	28	25	7
76014	Eden	Kirkby Stephen	3773	5097	0.24	72-99	0.24	0.95	1	24	25	4
76015	Eamont	Pooley Bridge	3472	5249	0.55	70-98	1.58	3.36	4	28	47	14
77001	Esk	Netherby	3390	5718	0.37	70-99	5.20	13.06	2	29	40	7

Station Id	River name	Station name	East	North	BFI	Year range	Flow 1995	Mean flow	rank 1995	No. years	% flow	% rank
77002	Esk	Canonbie	3397	5751	0.39	70-99	2.94	8.72	2	30	34	7
77003	Liddel Water	Rowanburnfoot	3415	5759	0.32	74-99	1.93	4.92	2	26	39	8
77004	Kirtle Water	Mossknowe	3285	5693	0.31	79-99	0.25	0.91	2	20	27	10
77005	Lyne	Cliff Bridge	3412	5662	0.26	76-98	1.22	2.82	5	20	43	25
78003	Annan	Brydekirk	3191	5704	0.44	70-99	5.34	13.66	3	30	39	10
78004	Kinnel Water	Redhall	3077	5868	0.28	70-99	0.31	1.20	2	30	26	7
78005	Kinnel Water	Bridgemuir	3091	5845	0.37	79-99	1.09	3.84	2	21	28	10
78006	Annan	Woodfoot	3099	6010	0.42	84-99	1.57	4.34	2	16	36	13
79001	Afton Water	Afton Reservoir	2631	6050	0.10	70-81		0.04		11		
79002	Nith	Friars Carse	2923	5851	0.39	70-99	3.77	10.61	2	30	36	7
79003	Nith	Hall Bridge	2684	6129	0.27	70-99	0.52	2.07	2	30	25	7
79004	Scar Water	Capenoch	2845	5940	0.32	70-99	0.50	2.13	2	30	24	7
79005	Cluden Water	Fiddlers Ford	2928	5795	0.38	70-99	0.67	2.86	2	30	24	7
79006	Nith	Drumlanrig	2858	5994	0.34	70-99	1.94	6.39	2	30	30	7
79007	Lochar Water	Kirkblain Bridge	3026	5695		92-99		1.01		7		
80001	Urr	Dalbeattie	2822	5610	0.36	70-99	0.31	1.95	2	30	16	7
80002	Dee	Glenlochar	2733	5641	0.40	78-99	9.71	17.14	8	22	57	36
80003	White Laggan Burn	Loch Dee	2468	5781	0.19	80-99	0.09	0.27	1	20	34	5
80004	Green Burn	Loch Dee	2481	5791	0.32	84-99	0.03	0.11	1	14	28	7
80005	Dargall Lane	Loch Dee	2451	5787	0.29	83-99	0.04	0.12	2	14	37	14
80006	Blackwater	Loch Dee	2478	5797	0.45	83-99	0.29	0.72	2	15	40	13
81002	Cree	Newton Stewart	2412	5653	0.27	70-99	2.84	8.07	2	30	35	7
81003	Luce	Airyhemming	2180	5599	0.23	70-99	1.15	2.62	6	30	44	20
81004	Bladnoch	Low Malzie	2382	5545	0.33	78-99	1.03	4.12	2	22	25	9
81005	Piltanton Burn	Barsolus	2107	5564	0.37	86-99	0.08	0.30	1	13	26	8
81006	Water of Minnoch	Minnoch Bridge	2363	5746	0.26	86-99	1.94	4.55	1	13	43	8
81007	Water of Fleet	Rusko	2592	5590	0.30	88-99	0.48	1.61	1	12	30	8
82001	Girvan	Robstone	2217	5997	0.32	70-99	0.45	2.39	2	29	19	7
82002	Doon	Auchendrane	2338	6160	0.57	74-99	3.29	4.39	4	24	75	17
82003	Stinchar	Balnowlart	2108	5832	0.30	73-99	1.49	4.42	4	27	34	15
83002	Garnock	Dalry	2293	6488	0.21	70-77		1.00		7		
83003	Ayr	Catrine	2525	6259	0.29	70-99	0.68	2.40	2	29	28	7
83004	Lugar Water	Langholm	2508	6217	0.25	72-99	0.66	2.18	5	28	30	18
83005	Irvine	Shewalton	2345	6369	0.26	72-99	0.99	3.97	3	28	25	11
83006	Ayr	Mainholm	2361	6216	0.29	76-99	1.88	6.55	2	23	29	9
83007	Lugton Water	Eglinton Castle	2315	6420	0.25	78-99	0.23	0.69	4	21	33	19
83008	Annick Water	Dreghorn	2352	6384	0.29	81-99	0.54	1.59	4	18	34	22
83009	Garnock	Kilwinning	2307	6424	0.22	78-99	1.08	2.87	3	22	38	14
83010	Irvine	Newmilns	2532	6372	0.38	80-99	0.32	1.20	2	20	27	10
83013	Irvine	Glenfield	2430	6369	0.27	82-99	0.45	2.90	1	17	16	6
83082	Unknown	Unknown	0	0		82-94		3.23		12		
84001	Kelvin	Killermont	2558	6705	0.44	70-99	2.34	5.18	1	30	45	3
84002	Calder	Muirshiel	2309	6638	0.15	70-99		0.34		6		
84003	Clyde	Hazelbank	2835	6452	0.51	70-99	5.61	12.28	2	30	46	7
84004	Clyde	Sills of Clyde	2927	6424	0.52	70-99	3.57	8.15	2	29	44	7
84005	Clyde	Blairston	2704	6579	0.45	70-99	8.51	18.27	2	29	47	7
84006	Kelvin	Bridgend	2672	6749	0.44	70-82		1.38		13		
84007	South Calder Wtr	Forgewood	2751	6585	0.61	70-99		1.22		28		
84008	Rotten Calder Wtr	Redlees	2679	6604	0.33	70-99	0.25	0.62	4	30	41	13
84009	Nethan	Kirkmuirhill	2809	6429	0.32	70-99	0.18	0.58	1	25	31	4
84011	Gryfe	Craigend	2415	6664	0.31	70-99	0.44	1.76	2	29	25	7

Station Id	River name	Station name	East	North	BFI	Year range	Flow 1995	Mean flow	rank 1995	No. years	% flow	% rank
84012	White Cart Water	Hawkhead	2499	6629	0.35	70-99	0.87	2.60	3	30	33	10
84013	Clyde	Daldowie	2672	6616	0.45	70-100	11.67	22.69	2	31	51	6
84014	Avon Water	Fairholm	2755	6518	0.26	70-99	0.70	2.85	2	30	25	7
84015	Kelvin	Dryfield	2638	6739	0.43	70-99	3.19	4.52	9	29	71	31
84016	Luggie Water	Condorrat	2739	6725	0.40	70-99	0.20	0.39	4	30	52	13
84017	Black Cart Water	Milliken Park	2411	6620	0.37	70-99	0.87	2.00	4	30	43	13
84018	Clyde	Tulliford Mill	2891	6404	0.52	70-99	4.91	10.83	3	30	45	10
84019	North Calder Wtr	Calderpark	2681	6625	0.49	70-99	0.16	1.15	1	30	14	3
84020	Glazert Water	Milton of Campsie	2656	6763	0.31	70-99	0.38	1.00	3	29	38	10
84022	Duneaton	Maidencots	2929	6259	0.44	70-99	0.50	1.35	1	26	37	4
84023	Bothlin Burn	Auchengeich	2680	6717	0.50	74-99	0.20	0.35	2	25	57	8
84024	North Calder Wtr	Hillend	2828	6678	0.66	73-99	0.12	0.19	1	27	63	4
84025	Luggie Water	Oxgang	2666	6734	0.43	75-99	0.38	1.03	2	25	37	8
84026	Allander Water	Milngavie	2558	6738	0.35	75-99		0.62		24		
84027	North Calder Wtr	Calderbank	2765	6624	0.36	70-99		0.37		17		
84028	Monkland Canal	Woodhall	2765	6626	0.77	75-99	1.16	0.60	20	21	194	95
84029	Cander Water	Candermill	2765	6471	0.29	76-99		0.16		23		
84030	White Cart Water	Overlee	2579	6575	0.33	81-99	0.49	1.42	2	17	35	12
84031	Watstone Burn	Watstone	2763	6470		86-92		0.01		7		
84033	White Cart Water	MacQuisten Bridge	2568	6614		91-99	0.46	1.25	1	9	36	11
84034	Auldhouse Burn	Spiers Bridge	2544	6589		91-99	0.09	0.12	3	9	80	33
84035	Kittoch Water	Waterside	2596	6562		91-99		0.27		8		
84036	Earn Water	Letham	2567	6549		91-99	0.10	0.28	2	8	35	25
84037	Douglas Water	Happendon	2855	6333		90-99		1.12		9		
85001	Leven	Linnbrane	2394	6803	0.77	70-99		20.45		29		
85002	Endrick Water	Gaidrew	2485	6866	0.31	70-99	1.21	2.70	4	30	45	13
85003	Falloch	Glen Falloch	2321	7197	0.17	71-99	1.37	3.02	4	29	45	14
85004	Luss Water	Luss	2356	6929	0.29	76-100	0.62	1.42	2	22	43	9
85005	Burn Crooks	Burncrooks No1	2478	6787		77-99	0.08	0.08	10	20	100	50
86001	Little Eachaig	Dalinlongart	2143	6821	0.22	70-99	0.41	0.96	3	28	43	11
86002	Eachaig	Eckford	2140	6843	0.35	70-97	8.43	6.48	19	27	130	70
89002	Linne nam Beathach	Victoria Bridge	2272	7422	0.16	82-99	1.44	2.51	3	17	58	18
89003	Orchy	Glen Orchy	2239	7310	0.23	77-99	6.55	10.26	5	22	64	23
89004	Strae	Glen Strae	2146	7294	0.24	77-99	1.07	1.78	5	20	60	25
89005	Lochy	Inverlochy	2197	7274	0.20	79-99	1.39	2.31	4	20	60	20
89006	River Avich	Barnaline Lodge	1971	7139	0.50	80-99	0.60	1.09	4	18	55	22
89007	Abhainn a' Bhealaich	Braevallich	1957	7076	0.23	82-99	0.55	1.15	3	18	47	17
89008	Eas Daimh	Eas Daimh	2239	7276	0.29	81-92		0.28		11		
89009	Eas a' Ghaill	Succoth	2209	7265	0.20	82-92		0.43		10		
90003	Nevis	Claggan	2116	7742	0.26	83-99	2.28	3.74	3	17	61	18
91002	Lochy	Camisky	2145	7805	0.39	80-99	14.73	21.19	4	19	69	21
92002	Allt Coire nan Con	Polloch	1793	7688		86-99		0.43		12		
93001	Carron	New Kelso	1942	8429	0.26	79-99	3.48	6.02	3	21	58	14
94001	Ewe	Poolewe	1859	8803	0.65	71-99	9.67	15.27	3	29	63	10
95001	Inver	Little Assynt	2147	9250	0.64	77-99	2.85	5.05	1	22	56	5
95002	Broom	Inverbroom	2184	8842	0.24	85-99	1.36	3.40	1	15	40	7
96001	Halladale	Halladale	2891	9561	0.25	76-99	0.79	2.15	7	24	37	29
96002	Naver	Apigill	2713	9568	0.42	77-99	2.28	5.75	4	22	40	18
96003	Strathy	Strathy Bridge	2836	9652	0.26	86-99	0.43	1.35	3	14	32	21
96004	Strathmore	Allnabad	2453	9429	0.19	88-99	1.96	4.29	1	12	46	8
97002	Thurso	Halkirk	3131	9595	0.46	72-99	1.86	3.18	10	28	58	36

Station Id	River name	Station name	East	North	BFI	Year range	Flow 1995	Mean flow	rank 1995	No. years	% flow	% rank
101001	Eastern Yar	Alverstone Mill	4577	857	0.59	70-97		0.20		8		
101002	Medina	Upper Shide	4503	874	0.64	70-97	0.15	0.13	15	20	117	75
101003	Lukely Brook	Newport	4491	886	0.78	80-99	0.03	0.04	7	13	80	54
101004	Eastern Yar	Burnt House	4583	853	0.50	83-99	0.11	0.12	9	16	88	56
101005	Eastern Yar	Budbridge	4531	835	0.63	83-99	0.09	0.11	4	17	83	24
101006	Wroxall Stream	Waightshale	4536	839	0.47	83-92		0.06		8		
101007	Scotchells Brook	Burnt House	4583	852	0.34	84-95	0.02	0.07	2	11	30	18
102001	Cefni	Bodffordd	2429	3769	0.51	89-99	0.03	0.08	2	11	33	18