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THE QUALITY OF RIVERS AND CANALS IN ENGLAND AND WALES (1990 TO 1992)

Report of the National Rivers Authority

May 1994

NRA

National Rivers Authority

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National Rivers Authority
Rivers House
Waterside Drive
Aztec West
Almondsbury
Bristol
BS12 4UD

Tel: 0454 624400
Fax: 0454 624409

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National Rivers Authority

THE QUALITY OF RIVERS AND CANALS IN ENGLAND AND WALES (1990 TO 1992)

As Assessed by a New General Quality Assessment Scheme

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LONDON: HMSO

PREFACE

An essential pre-requisite for the planning of any strategy for the future quality of the aquatic environment is an objective monitoring programme. Otherwise it is impossible to know what the starting line was, what progress is being made, and whether or not value for money is being obtained as expenditure on the programme increases. Whilst maps and reports of river and canal quality have been published for many years, the National Water Council (NWC) scheme on which they were based, and the way in which it was applied in practice, has proved not to be as objective or consistent as intended.

In 1991 the NRA published a report on the state of the rivers and canals in England and Wales as of 1990 according to the NWC scheme, in order to draw comparisons with the 1985 assessment. However the NRA also stated that an improved system was required; one which essentially looked at river quality through different 'windows', of which their basic chemistry was simply one. Any new system had also to be as objective as possible, within the bounds of a reasonable sampling programme. There is no room for subjective assessments when very large sums of money are being expended in order to obtain real and sustained environmental benefits. It is for these reasons that it was decided that a new more objective and comprehensive General Quality Assessment (GQA) scheme should be introduced.

The extent to which previous analyses of freshwater quality lacked sufficient objectivity can readily be seen by comparison of the ungraded stretches on the map in this report with the apparent comprehensive coverage of previous years in which subjective judgements had been used in place of actual chemical quality data. Steps are already in hand to provide such stretches with a suitable monitoring programme.

The most exciting prospects, however, lie in the real ability to bring an objective approach to other ways of assessing freshwater quality, particularly biology. There are now several ways of doing this and some of them are described in this report. They immediately demonstrate that an objective analysis of the basic chemistry and biology of rivers and canals produces different results. The search for the causes of such differences will be an invaluable exercise in itself, but the possibility now of following, objectively, trends in both sets of data will provide the most valuable management tool of the future.

Eventually it should be possible to create a means of assessing the state of our freshwater environment through a number of complementary windows. These could include other aspects of chemistry - for example nutrient status - as well as information on the state of fisheries, and conservation status. The aesthetic status of rivers, too, may be amenable to objective analysis, but in any case it is certainly desirable to be able to provide periodically a comprehensive statement on the 'state' of the aquatic environment, which for rivers would also need to include the whole river corridor. Without the ability to make such assessments it will not be possible to describe unequivocally what the current state is, whether or not it is getting better or worse, and thus whether or not value for money has been obtained in trying to change it. This report is the first step in this process.

Nevertheless it is also important to note that no classification scheme, regardless of the ultimate breadth of its component parts, can of itself adequately describe the actual state of a particular stretch of water at any specific time. Water quality can vary within a 24 hour period (oxygen concentration, for example), over periods of consecutive days, and between one season and another. The quality of discharges, within their consented limits, can also vary over similar periods of time. A balance therefore has to be struck between delivering a practical, nationally consistent, means of assessing the quality of rivers on a regular - albeit limited - basis and the data required fully to understand and manage river quality at catchment level. The GQA Scheme provides the practical regular 'snapshot' against which other managerial decisions can be made.

DR R J PENTREATH
Chief Scientist

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NB In some cases the values in tables and figures may not appear to sum to totals or sub-totals because of rounding.

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NB In some cases the values in tables and figures may not appear to sum to totals or sub- totals because of rounding.

REGIONAL ABBREVIATIONS USED IN TABLES

Abbreviation	New NRA Regions	Old NRA Regions
Anglian	NRA Anglian Region	NRA Anglian Region
N West	NRA North West Region	NRA North West Region
Ntm/Yks	NRA Northumbria and Yorkshire Region	NRA Northumbria Region NRA Yorkshire Region
S Trent	NRA Severn Trent Region	NRA Severn Trent Region
S Western	NRA South Western Region	NRA South West Region NRA Wessex Region
Southern	NRA Southern Region	NRA Southern Region
Thames	NRA Thames Region	NRA Thames Region
Welsh	NRA Welsh Region	NRA Welsh Region

1 EXECUTIVE SUMMARY

Introduction

In December 1991 the NRA published the results of the 1990 Survey of water quality in England and Wales[1], in which the quality of rivers and canals was reported according to the National Water Council (NWC) classification scheme. That survey was the last to use the NWC system and a new approach to classification, called the General Quality Assessment (GQA) Scheme, has been developed and introduced by the NRA to replace it.

The principal purpose of this report is to introduce the basic chemistry component of the new GQA Scheme for rivers and canals and to apply it for the first time in making an assessment of river water quality across England and Wales for the years 1988 - 1990 and 1991 - 1992. This will provide a baseline against which the results of future surveys can be compared. The report also includes, in its appendices, an analysis of the means by which the basic biological status of rivers could be assessed in the future.

The General Quality Assessment Scheme

In 1991 the NRA published proposals on the broad outline of a new GQA Scheme, as part of its advice to Government on a new system of water quality classification related to statutory Water Quality Objectives (WQOs)[4]. The purpose of the GQA Scheme is to provide a means of accurately assessing and reporting upon the general state of controlled waters in a manner which is nationally consistent and independent of the uses to which waters may be put.

The GQA Scheme will consist of a number of separate water quality assessments, each providing a separate 'window' through which water quality is viewed. The first of these to be developed is the chemical component, and the results of applying the new chemical GQA Scheme to data collected during 1988-90 are given here; they are referred to as the '1990' assessment. In the future it is intended that further 'windows' will be added, covering biology, nutrients and aesthetic quality, dependent upon successful development of suitable methods and classification systems.

The chemical grading defines six grades (denoted A to F) on the basis of the concentrations of biochemical oxygen demand (BOD), total ammonia and dissolved oxygen. Under the new scheme the total length of inspected rivers and canals in England and Wales for the 1990 assessment has been assigned to grades A to F as follows: A (18%), B (29%), C (24%), D (14%), E (13%), and F (3%). Grades A and B represent water of 'good' chemical quality, whilst grades C and D together equate to 'fair' quality and grades E and F represent 'poor' and 'bad' quality respectively.

It should be noted that the terms 'good', 'fair', 'poor' and 'bad' are broad descriptions and their use here does not equate directly with the use of the terms under the former NWC scheme. Indeed, direct comparison of descriptions of water quality according to the new chemical GQA grades with those according to the NWC grades would be mis-leading because although there are many similarities between the GQA and NWC schemes, there are also some fundamental differences. The GQA Scheme has associated with it a set of strict rules for its application. These rules are set out and explained in this report. The consequence of this is that there will be no room for subjective interpretation in applying the Scheme as there has been in the past with the NWC system. The GQA Scheme also has a different grading structure and different criteria, particularly for ammonia. The difference in approach between the NWC and GQA schemes is the reason why the results of the 1990 River Quality Survey have been published according to both schemes. The 1990 NWC Survey provides a means of looking backwards at trends in quality up to the end of 1990, whilst the reworking of the data according to the GQA Scheme which is presented here provides the basis for future assessment of trends.

The predictive techniques to support the biological component of the GQA are being further developed through the NRA's research and development programme. Various options for a biological grading system have been tested and two of these are presented in this report. It is intended that this development programme will finalise the biological component of the Scheme for the forthcoming river quality survey in 1995.

Changes in the chemical quality of rivers and canals since 1990

The chemical component of the new GQA Scheme has also been applied to data collected during the two years, 1991 and 1992, in order to provide an assessment of changes in water quality in England and Wales since 1990. For 1991 - 1992 the distribution of river and canal length across the chemical grades A to F was as follows: A (21%), B (32%), C (23%), D (12%), E (11%), and F (2%). Since 1990 there has therefore been an increase in river length in the best quality grades (A and B) and a reduction in length in the poorest (E and F). Indeed there has been an overall net upgrading of 10.7% of the total length of rivers and canals across England and Wales.

The reasons for this marked improvement over a relatively short period are twofold. Firstly, the position reported for 1990 was affected by lower than average rainfall which had an adverse effect on river quality. Weather conditions since then have been more typical. Secondly, the improvement reflects the sustained efforts that have been put into controlling polluting discharges, underpinned by the substantial capital investment programmes of the water utilities and other industries. Pollution prevention measures to control pollution from agriculture and other land uses are also beginning to make a real and positive difference to the water environment.

Future surveys

The new GQA Scheme will provide a sounder basis for assessing changes in the aquatic environment in future surveys. The basic chemical component, which is now completely developed, represents a substantial improvement in the NRA's approach to the assessment of river and canal quality. The analysis of data collected for the 1990 Survey established a baseline against which future changes in river quality can be judged. However, it has also revealed deficiencies in the sampling regimes in place until 1990 and work to improve sampling programmes for the next quinquennial survey in 1995 is currently in progress.

Further work is already under way to finalise a biological quality grading system in time for 1995. The NRA's approach to the management of data collected during 1988-90 has ensured that the data can be reworked and compared with 1995 data once the biology grading is finalised.

The NRA has also proposed to Government that additional assessments of river quality, based on levels of nutrients and aesthetic considerations, should be developed and incorporated into future quinquennial river quality surveys. Research into such schemes is under way and subject to its outcome it should be possible to assess and report upon river quality through a number of separate but complementary 'windows', each of which provides important information for understanding the changes in water quality and their causes.

2 INTRODUCTION

The purpose of this report is to introduce the basic chemistry component of the General Quality Assessment (GQA) Scheme for rivers and canals. This scheme has been developed by NRA to replace the National Water Council (NWC) classification which has been in use since 1978.

The report first details the reasons why a change of approach to the classification of river and canal quality was required. It then describes the chemistry component of the new scheme and gives the results of applying it to the assessment of river and canal quality for the periods 1988-90 and 1991-92. Details of the quality of individual stretches (also known as reaches) of river and canal in 1988-90, assessed according to the new scheme are given on the enclosed map. The differences between the new and old schemes are discussed and supporting technical information is provided in the appendices.

The NRA has recently undergone re-organisation from 10 Regions to 8 (see: Regional Abbreviations table on page vii). This means that data is reported for the 8 new NRA Regions as opposed to the 10 Regions that are referred to in previous reports.

The appendices contain supporting technical information including a discussion of possible approaches to the definition of a biological component to the GQA Scheme.

3 HISTORICAL BACKGROUND

Since 1978 the quality of individual lengths of rivers and canals has been reported according to a classification scheme devised by the former National Water Council (NWC). The scheme has been described in detail in several previous publications[1,2,3]. Briefly, reaches of river and canal were classified from Good quality (Classes 1A and 1B), to Bad quality (Class 4) principally on the basis of measurements of the concentrations of three chemical determinands: dissolved oxygen, biochemical oxygen demand (BOD) and ammonia. The NWC scheme also allowed the use of additional assessments of water quality, such as data on concentrations of other chemical determinands or information about biological status, to help in assigning the class. This led to inconsistencies in the way the scheme has been applied in different parts of England and Wales and from one survey to the next. Furthermore, the statistical methods which have been used to calculate the class from data also varied substantially between different Water Authorities and with time. These factors made it difficult to derive a valid comparison of regional data.

A further problem with the scheme was that, although it attempted to provide an absolute measure of quality, so that all rivers and canals could be compared on a common scale, it also reflected, to some extent, the uses which the river could support by the incorporation of European Inland Fisheries Advisory Commission (EIFAC) standards for the protection of freshwater fish and some of the standards set out in the EC Directive on Surface Water Abstraction. One problem is that new uses, new standards and new Directives have been, and are being, introduced steadily over the years as more information becomes available. If new use-related standards were to be incorporated within the NWC scheme to reflect these changes, the apparent class would cease to be an absolute measure of quality because not all the uses, and hence the standards, apply to all rivers. Also if the definition of class changes over time, the ability of the scheme to detect temporal trends will be impaired.

The use of biological information has also varied in recent years. An assessment of biological status was included in previous quinquennial surveys of water quality, but the results were of limited use for a national report because of natural geographical differences in the characteristics of biological communities found in rivers and the lack of completely standardised methods for measuring biological quality.

The catalyst for change was provided by the 1989 Water Act, later consolidated into the Water Resources Act 1991, which brought the NRA into existence and provided powers to allow the Secretaries of State for the Environment and for Wales to introduce new classification systems and to use them as the basis for setting new statutory Water Quality Objectives (WQOs). In December 1991, in accordance with its role in advising the Secretaries of State, the NRA published a consultation document detailing its initial proposals on a new classification scheme for introducing WQOs[4]. Following extensive consultation these proposals were refined and the NRA's final recommendations to the Secretaries of State were published in October 1992. The Government drew upon these recommendations in setting out its own draft proposals in its consultation document "River Quality" [5] published in December 1992. Following this consultation the Government has issued Regulations[6] giving effect to the River Ecosystem Classification in rivers and canals.

It was clear that the NWC scheme was unsuitable as the basis for establishing WQOs because it was open to subjective interpretation and tended to confuse a general classification function with use-related aspects. The NRA therefore proposed that a clear separation should be made between the use-related standards which would be used to set WQOs according to local needs, and the standards of a General Quality Assessment (GQA) Scheme which would be used to provide a general measure of water quality irrespective of uses. The new GQA Scheme would therefore be used for the periodic assessment and reporting of water quality status at a national level, as in previous national quinquennial surveys.

It is generally accepted that there is now an outstanding need for more comprehensive assessments of river quality. Describing water quality simply in terms of a small range of chemical measurements, as has been the convention in the past, provides only a limited view of the state of the water environment. It is for this reason that the NRA has proposed that separate but complementary measures of biological quality, aesthetic quality, and nutrient status are needed to provide further important 'windows' through which the state of the environment can be viewed.

4 THE CHEMISTRY COMPONENT OF THE GENERAL QUALITY ASSESSMENT SCHEME

4.1 DEFINITION

The basic chemical grade of the GQA Scheme is defined by standards for the concentrations of BOD, ammonia and dissolved oxygen. These have been selected because they are indicators of the extent to which waters are affected by wastewater discharges and rural land use run-off containing organic, degradable material. The quality of many of our rivers and canals is affected by such discharges which include effluents from sewage treatment works and industries, and drainage from farms. These three simple determinands are therefore the best overall basic chemical measure of river water quality for the purposes of the GQA which will apply to all rivers and canals within the classified network.

The use of these three determinands provides some continuity with the NWC system. The standards for each of the three determinands are also a subset of those included in the Classification Regulations for the WQO scheme for rivers[6], upon which the Government consulted last October.

Table 1: GQA chemical grading for rivers and canals

Water Quality	Grade	Dissolved Oxygen (% saturation) 10-percentile	Biochemical Oxygen Demand (ATU[1]) (mg/l) 90-percentile	Ammonia (mgN/l) 90-percentile
Good	A	80	2.5	0.25
	B	70	4	0.6
Fair	C	60	6	1.3
	D	50	8	2.5
Poor	E	20	15	9.0
Bad	F[2]	-	-	-

1 as suppressed by adding allyl thio-urea
2 ie quality which does not meet the requirements of grade E in respect of one or more determinands.

A summary of the grade-limiting criteria is given in Table 1. The overall grade assigned to a river or canal reach is determined by the worst of the three grades for the individual determinands.

The new grades are defined in terms of the 90 percentile for BOD and ammonia and the 10 percentile for dissolved oxygen; in other words, the river reach should contain less than the specified levels of BOD and ammonia for at least 90 percent of the time, whilst the level of dissolved oxygen must not fall below the prescribed level for more than 10 percent of the time.

The use of measures of water quality based on estimates of percentiles is well established; the NWC system was based on 95 percentile values for BOD and ammonia and the 5 percentile for dissolved oxygen. Percentiles have the advantage that they combine a measure of the general level of a determinand with a measure of variability and hence are able to respond to the large fluctuations in quality common in rivers, as well as indicating the overall quality. The move from 95 percentiles to 90 percentiles allows the river grade to be determined more reliably from the inevitably limited numbers of samples which result from realistic sampling programmes, yet does not lose sight of the greater environmental significance of higher concentrations of pollutants.

4.2 THE NEED FOR A NEW CHEMICAL GRADING SYSTEM FOR RIVERS AND CANALS

With the NWC scheme, the procedures used to support decisions on assigning grades to river stretches varied across the ten former Water Authorities. The work of the 1990 Survey showed that differences existed between the former Water Authorities in:

(a) the statistical methods used to calculate the summaries of water quality (mainly 95-percentiles);

(b) the inclusion or exclusion of any analytical results suspected as being in error because they differed markedly from others at the same site (or because they were caused by extreme events like floods, drought, freezing or excessive plant growth);

(c) the sampling frequencies;

(d) the number of years' data used for the assessment;

(e) the inclusion of non-routine samples (like those for pollution incidents and special surveys);

(f) the pooling of data for different sites;

(g) the procedure used to interpolate between sampling points;

(h) the informal use of judgements based on the effects of algae, biological data and visual pollution to qualify or over-rule the classification suggested by other data;

(i) the weight given to the EIFAC standards;

(j) the status given to the standards in EC Directives; and

(k) the interpretation of the effects of the 'laws of chance' when deciding whether a river had changed class.

Unless there is to be a large increase in sampling programmes, the summary statistics which are used to assign class (such as percentiles) will always be estimated with a precision which is low in comparison with the ranges of concentration which define the better grades. This low precision tends to result in random changes in class. Faced with this, some former Water Authorities had sought confirmation that apparent changes were real ones by looking at extra data. Typical cases included:

- sites which 'failed' a standard because of a single bad analytical result at a place where river quality was good according to all the other indicators, such as biological data;
- cases where a site 'complied' with all the standards but had no fishery, or poor biology - in this case the site might be downgraded; or,
- sites which failed (or passed) marginally after several years of compliance (or failure) and where there was no obvious cause for the change.

Other Water Authorities preferred to ignore the uncertainty associated with assigning class to rivers but took account of poor precision and other factors as part of the process of deciding whether there was a real need for action to restore river quality. Either way, the former Water Authorities sensibly tried to avoid the expenditure of effort and money on downgradings caused by the effect of chance on the classification system.

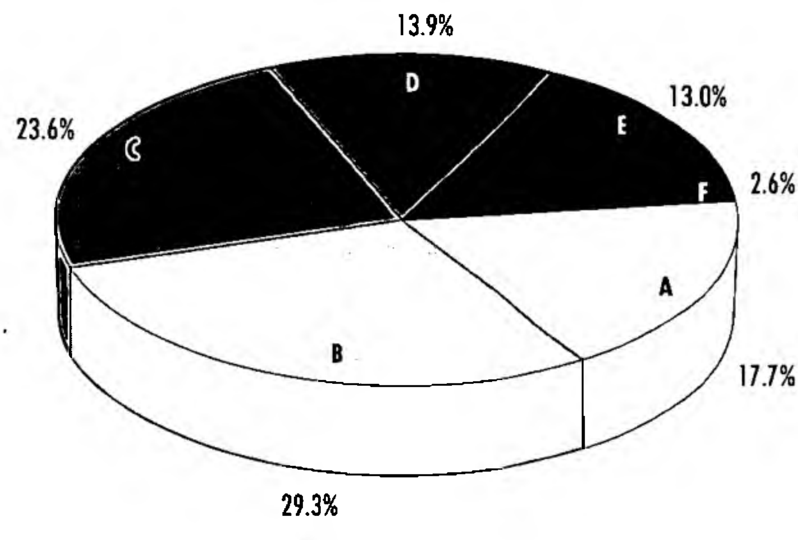
For the new GQA, the NRA has reduced the risk of mis-grading by:

- using three years' chemical data to calculate percentiles[7,8];
- re-defining the water quality standards as 90-percentiles instead of 95-percentiles; and
- using data for 1990 to establish a baseline against which future changes which are statistically significant can be distinguished, on a nationally consistent basis, from those which are not.

The 90-percentile is estimated with 35% more precision than the 95-percentile. This makes it easier to detect smaller changes in quality. The use of the 90-percentile also retains the advantages of being able to take the variable nature of water quality into account, yet does not lose sight of the greater environmental significance of higher concentrations of pollutants.

4.3 APPLICATION OF THE GQA SCHEME TO THE RESULTS OF THE 1990 SURVEY

Figure 1: Chemical quality of rivers and canals for 1990 according to the GQA Scheme



Total Length (34740 km)

The three years data collected during 1988, 1989 and 1990 for the 1990 quinquennial survey have been re-analysed according to the new chemistry GQA Scheme and the results are summarised in Figure 1 and Table 2. A total of 34740 km of rivers and canals in England and Wales was assigned a grade under the new scheme, with the proportions falling in each grade being: A (18%), B (29%), C (24%), D (14%), E (13%), and F (3%). The highest proportions of top grade waters were in the Welsh and South Western Regions. North West and Northumbria & Yorkshire Regions had the highest proportion of river length in the poorest grade.

Table 2: GQA chemical grading of rivers and canals for 1990

Region	% Length in Each Grade					
	GOOD		FAIR		POOR	BAD
	A	B	C	D	E	F
Anglian	0.7	15.8	35.3	26.5	18.2	3.5
N West	22.5	19.4	17.0	13.9	20.7	6.5
Ntm/Yks	19.9	37.8	13.4	10.3	14.4	4.2
S Trent	9.3	23.5	32.4	14.9	17.9	2.0
SWestern	24.3	39.6	19.3	10.3	5.4	1.2
Southern	10.8	32.8	30.8	12.9	10.9	1.7
Thames	9.0	27.7	29.8	16.3	15.8	1.3
Welsh	44.4	34.7	10.8	5.6	3.4	1.1
Total	17.7	29.3	23.6	13.9	13.0	2.6

4.4 COMPARISON OF THE GQA AND NWC SCHEMES

Although there are similarities between the GQA and NWC schemes, there are also some fundamental differences. The GQA Scheme has associated with it a set of strict rules for its application. These rules are set out and explained in Appendices A and E. The consequence of this is that there is no room for subjective interpretation in applying the Scheme as there has been in the past with the NWC system. The GQA Scheme also has a different grading structure and different criteria, particularly for ammonia.

For the most part, the 1990 Survey was undertaken on rivers and streams with a dry weather flow greater than 0.05 m^3s^{-1} (1 million gallons per day); this equates to a mean flow of 0.31 m^3s^{-1}. This cut off point may have been applied in a pragmatic manner in order to ensure that significant streams were included and less significant streams excluded. This resulted in a total of 42434 km of rivers and canals being included in the 1990 Survey[1]. Of this total a smaller length of 34740 km has been assigned a chemistry grade under the new GQA Scheme. The difference has arisen because the choice of which river stretches were sampled was, of necessity, based closely on the previous quinquennial survey in 1985 so that the results of the two surveys would be comparable. For some stretches of river this resulted in there being insufficient sample data for determination of the GQA grade.

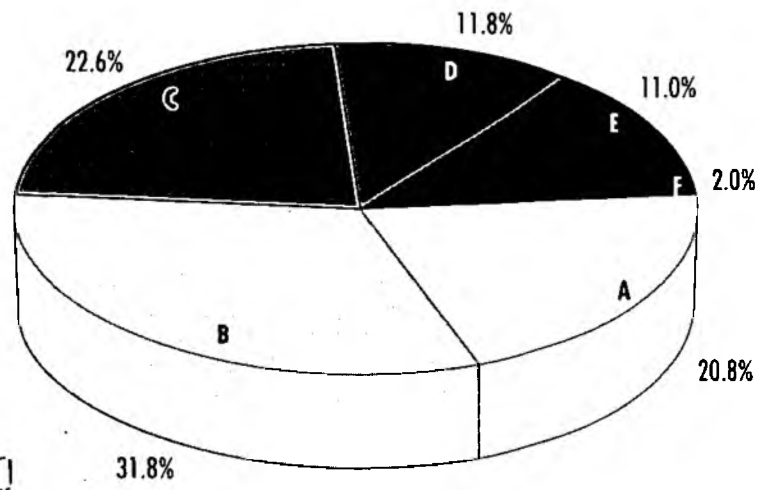
It is for these reasons that the GQA Scheme produces a different overall result for river quality in England and Wales and the old and new schemes are not directly comparable. The difference in approach between the NWC and GQA schemes is the reason why the results of the 1990 River Quality Survey have been published according to both schemes. The 1990 NWC results provide a means of looking backwards at trends in quality up to the end of 1990 whilst the reworking of the data according to the GQA Scheme which is presented here provides the basis for future assessments of trends. It should be noted that whilst the report[1] on the NWC Survey refers to the original 10 Regions of the NRA, this report refers to the current 8 Regions. Results for 8 Regions according to the NWC scheme can be obtained from the former report by simple addition. Details of how the current Regions are formed from the original ones are given at the front of this report.

River monitoring activities are currently being improved to ensure that sufficient data to grade all significant stretches will be available for the 1995 Survey.

4.5 SUMMARY OF CHANGES IN THE CHEMICAL QUALITY OF RIVERS AND CANALS SINCE 1990

To make an assessment of changes in river and canal water quality since 1990 the GQA chemical grading has been calculated using two years' data collected during 1991 and 1992 (referred to here as the 1992 grade). A total of 37523 km of rivers and canals in England and Wales was assigned a grade under the new scheme, with the proportions falling in each grade being: A (21%), B (32%), C (23%), D (12%), E (11%), and F (2%). The highest proportions of top grade waters were in the Welsh and South Western Regions. North West and Severn Trent had the highest proportion of river length in the poorest grade. The results are shown in Figure 2 and Table 3.

Figure 2: Chemical quality of rivers and canals for 1992 according to the GQA Scheme



Total Length (37523 km)

These figures are derived from data collected during the NRA's routine river monitoring activities for the years 1991 and 1992. Following the progressive rationalisation of the NRA's monitoring and reporting programmes, it has been possible to assign GQA chemical grades to more river stretches, in 1992 than was possible in 1990. There is some tendency for the stretches which were not graded in 1990, but have been graded in 1992, to be the better quality stretches. However, this is not the case for all the additional stretches graded in 1992 and the effect on the overall national picture is small.

The assessment of grade for 1992 is based on only two years data; in general, the use of a full three years data to make any chemical quality assessment is desirable. This will be possible for the next quinquennial report in 1995. Nevertheless, Table 3 is still a good indication of the national picture.

Table 3: GQA chemical grading of rivers and canals for 1992

Region	% Length in Each Grade					
	GOOD		FAIR		POOR	BAD
	A	B	C	D	E	F
Anglian	2.9	18.9	32.1	24.2	19.4	2.5
N West	27.2	25.8	15.8	12.0	15.4	3.8
Ntm/Yks	13.2	40.5	19.3	8.4	15.8	2.9
S Trent	6.7	31.7	28.0	16.9	13.5	3.2
S Western	31.8	37.6	21.3	4.8	3.8	0.7
Southern	8.3	43.0	30.2	9.8	7.6	1.1
Thames	6.7	32.3	34.3	16.8	9.1	0.7
Welsh	56.2	29.6	7.7	3.2	2.8	0.6
Total	20.8	31.8	22.6	11.8	11.0	2.0

Figure 3 and Table 4 compare the proportions of river and canal lengths assigned to each grade for 1990 and 1992. It is evident that there has been an increase in the length of the rivers in the best quality grades (A and B) since 1990 and a concomitant reduction in the length of the poorest grades (E and F). The overall result is a net upgrading of 10.7% of the total length of rivers and canals in England and Wales between 1990 and 1992. The net upgrading is the difference between the percentage of total river and canal length that has shown any change to a better grade and the percentage that has shown any change to a worse grade. Although there have been many positive and negative changes in quality grade assigned to individual stretches of water across the country during this period, some of which are caused by the effects of chance on the data collection process, this net change of 10.7% is a reliable assessment of the national picture because it has been derived from many thousands of samples taken from thousands of individual stretches. The calculation of the net change of 10.7% has not been affected by the inclusion of slightly more stretches of better quality in 1992 than 1990 because it is based only on stretches which were graded in both 1990 and 1992.

There are several reasons for this improvement since 1990. Firstly, 1990 and the year preceding it, were years of unusually low rainfall. This affected river quality giving a rather more pessimistic assessment than would have been the case under normal weather conditions. Secondly, there are indications that pollution control measures are starting to make a real and positive difference to the water environment. Capital investment programmes of the water utilities and other industries are beginning to bear fruit. Compliance with consent conditions for discharges has improved over the last two years. Pollution prevention measures to control pollution from agriculture and other land use activities have also produced positive results.

Although these results are a welcome indication of a reversal in the trend of deteriorating river quality which took place throughout the 1980s, it should be remembered that they are based upon only two years of measurements since 1990. At the next quinquennial survey in 1995 a more robust assessment of trends in river quality since 1990 will be made.

Figure 3: Comparison of GQA chemical quality for 1990 with 1992

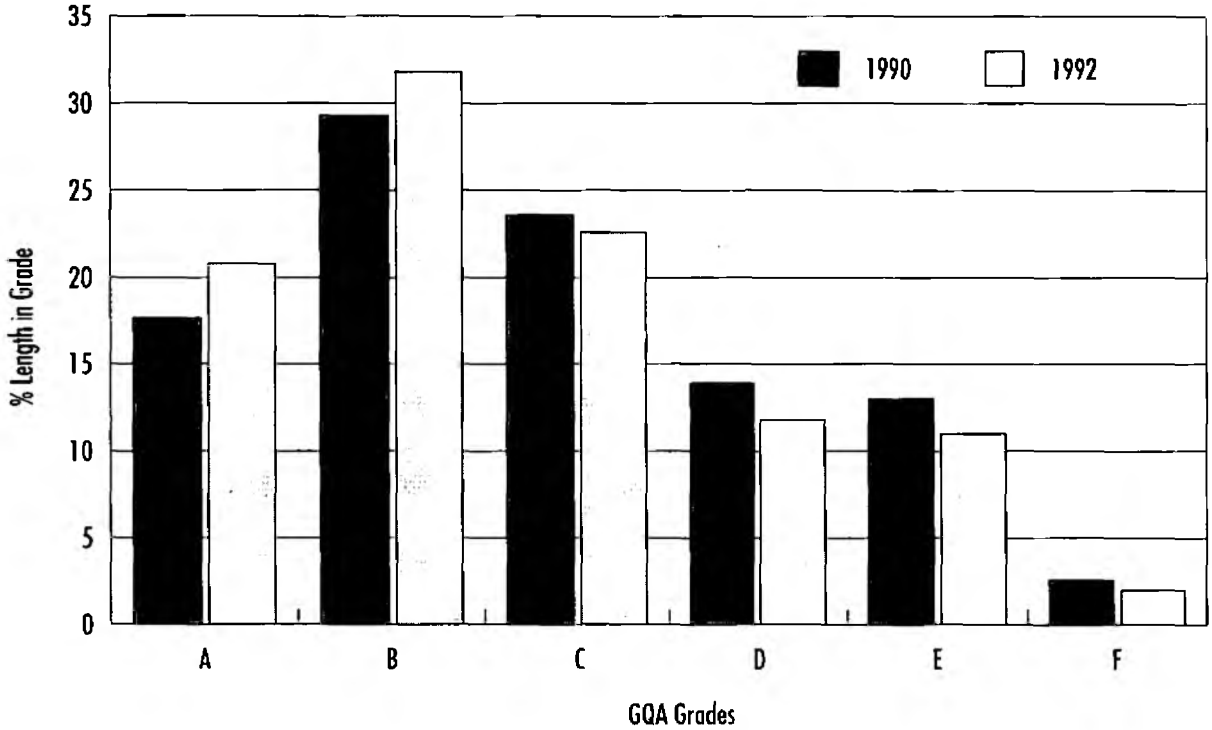


Table 4: Comparison of GQA chemical quality for 1990 with 1992

Year	% Length in Each Grade					
	GOOD		FAIR		POOR	BAD
	A	B	C	D	E	F
1990	17.7	29.3	23.6	13.9	13.0	2.6
1992	20.8	31.8	22.6	11.8	11.0	2.0

APPENDIX A: PUTTING A RIVER IN A CHEMICAL GRADE

Procedure

In assigning a chemical grade to any stretch (reach) of river or canal the NRA adopted the following procedures.

- For each sampling site, the NRA defined the reach of river which the site could characterise.
- If the site fell into a grade, then the entire reach was given that grade.
- Only results from the routine, predetermined sampling programmes were used.
- Within these programmes, all the valid chemical results collected over the three years 1988 to 1990 were included.
- It was therefore inevitable that a small number of the results were affected by the capabilities of the laboratory to detect low concentrations. These results were recorded as "less-than" values on the NRA's archives. Such results were taken as half the "less-than" value when used to assign grade. On rare occasions, the results for BOD were recorded as "greater-than"; these were taken as the value specified.
- A standard parametric method (Method of Moments, described below) was used to estimate percentiles for the chemical determinands.
- The estimates of the percentiles were compared with the standards in the GQA chemical grading. The grade was assigned according to the worst determinand.

The database

The NRA assembled a database which included:

- the name of the reach;
- the category of river flow (as defined for past surveys)[2,3];
- the length of the reach (km);
- the upstream National Grid Reference;
- the downstream National Grid Reference;
- the name of any chemical sampling point;
- the National Grid Reference for the chemical sampling point;
- the 1990 GQA grade for the reach;
- the mean, standard deviation and estimated 90-percentile BOD;
- the mean, standard deviation and estimated 90-percentile ammonia;

- the mean, standard deviation and estimated 10-percentile dissolved oxygen; and,
- the number of chemical samples used in the assessment of each of the above.

Estimation of percentiles

Even at a single site water quality can vary considerably in rivers and this makes it sensible to choose as standards summary statistics which take account of this variability. The average or mean is not well suited for this because it is an indicator of a central point in the range of quality and does not respond to changes in the variability of water quality. The standard deviation is the most common measure of variability, but it states the spread about the average quality without defining this average. A percentile may be thought of as a 'weighted average' combining the mean and the standard deviation into a single measure which attaches greater importance to instances of poor water quality.

For dissolved oxygen, percentiles are most reliably calculated assuming a normal distribution, as opposed to a log-normal distribution. (The effect of this assumption is small compared with the errors from the effect of chance in sampling.) Given the mean, m, and the standard deviation, s, the estimate of the 10-percentile (q) is:

$$q = m - 1.2816\ s$$

(Negative values of q are set to zero.)

The Biochemical Oxygen Demand and ammonia percentiles are most reliably calculated assuming a log-normal distribution. The values of m and s are thus converted to the values for the logarithms of the data (M and S respectively) using the Method of Moments:

$$S = \sqrt{[\ln (1 + s^2/m^2)]}$$

$$M = \ln [m / \sqrt{(1 + s^2/m^2)}]$$

M and S are estimates of the mean and standard deviation of the logarithms of the data. The characters, ln, denote the natural logarithm. The estimate of the 90-percentile (Q) is calculated using:

$$Q = e^{(M + 1.2816\ S)}$$

Where e is the constant, such that ln e = 1.

APPENDIX B: THE BIOLOGICAL COMPONENT OF THE GENERAL QUALITY ASSESSMENT SCHEME

B.1 THE NEED FOR A BIOLOGICAL GRADING

The health of rivers is reflected in the variety and abundance of animal and plant life that they support. Operating alone, the chemistry component of the GQA might allow a river to achieve a good grading but still have poor biology because of factors such as:

- pollution caused by the impact of mining, contaminated land and certain types of industrial discharge;
- intermittent pollution not detected by routine sampling for chemical analysis; or,
- the effect of acid deposition.

It might be thought that some of these effects could be overcome by including a large number of extra chemicals in the definition of the chemical grading. However, the cost alone prohibits undertaking the analysis of all these chemicals everywhere, and the need continually to add new standards would undermine the chemical grading as a measure of absolute quality and change.

To provide a more comprehensive picture of the health of rivers and canals in the future, a benthic biological grading will be reported in parallel with the chemical grading. The biological grading will be based on the monitoring of small animals which live in or on the bed of the river - the benthic macro-invertebrates. Each species thrives best under a narrow range of environmental conditions. The status of benthic macro-invertebrate communities therefore reflects the extent to which rivers are affected by environmental stresses, the major one of which is pollution. Because these communities take months or even years to recover, following pollution episodes, they reflect the pollution history at a particular site, providing evidence of pollution which may not have been detected through the routine sampling programme for the chemical quality assessment. Thus they provide a valuable additional 'window' through which the state of the water environment can be viewed.

B.2 SUMMARY MEASURES OF BIOLOGICAL QUALITY

One way to simplify the information on the variety of macro-invertebrate taxa found at any site is to reduce it to a small number of summary measures. In the United Kingdom there are over two thousand different species of aquatic invertebrates which are grouped into classes and families. These groupings are called taxa. A key piece of information provided by monitoring is the number of different taxa found at a site. A high Number of Taxa is itself a general indication that water quality is good.

Some animals are more susceptible than others to pollution and the presence of the more sensitive creatures is also a sign that water quality is good. This fact was taken into account in 1979 by the Biological Monitoring Working Party (BMWP), when it developed a method of summarising biological information in the form of a simple index. This became known as the BMWP Score[3].

The BMWP system assigns points to particular taxa according to their sensitivity to pollution. The most sensitive taxa, such as stone-flies, score ten, the less sensitive taxa, like freshwater shrimps, score five, while the most pollution insensitive oligochaete worms score one. Approximately eighty different taxa make up the BMWP system, each scoring between one and ten. The BMWP Score for a site is the sum of all the scores of the taxa found in standard samples. The weightings in the BMWP Score specifically reflect the impact of organic pollution such as that from sewage effluents and farms. The BMWP Score sheet is reproduced in Table B1.

A third summary statistic, the Average Score per Taxon, or ASPT, is the BMWP Score divided by the Number of Taxa. This attempts to give a measure of the average sensitivity to pollution of the taxa found at a site.

Water quality is only one of the many factors that influence the status of benthic macro-invertebrate communities. The characteristics of communities differ in different rivers across the country according to a range of natural features such as geology, altitude and temperature. The communities also differ in relation to more local influences such as river width and depth, and the nature of the river bed. The consequence of this is that in the past it has been difficult to compare the status of macro-invertebrates across the country because of the difficulties in separating the influence of water pollution from other quite natural factors.

The development of a computerised predictive tool called RIVPACS (River Invertebrate Prediction and Classification System)[9], developed by the Institute of Freshwater Ecology, provides a promising way forward in developing a biological grading system for assessing macro-invertebrate community status on a common basis across the country. It allows predictions to be made on the type of community that would be expected according to a range of natural features assuming the river is not affected by pollution. It is then possible to compare this prediction with the actual community status to provide a measure of the extent to which the river is affected by pollution. The ratio of observed to predicted community status can be expressed as a quotient, termed the Ecological Quality Index (EQI). For example, using the BMWP Score as a measure of community status, the EQI is calculated as follows:

$$EQI_{BMWP} = \frac{\text{BMWP Score observed by monitoring}}{\text{BMWP Score predicted by RIVPACS}}$$

EQIs can be expressed in the same way for the ASPT and the Number of Taxa.

A value for the EQI of approximately unity indicates that the biological communities found in the river are those that would be expected under conditions of natural water quality. Lower values indicate that the biota may be stressed by pollution, drought or other causes.

An alternative approach to assessing the shortfall between the observed biological status and that which should be found under unpolluted conditions is to develop a measure of the agreement between the list of taxa actually found at a site and the list predicted by RIVPACS, without first reducing the information to one of the three summary measures described above. This approach is being investigated through the NRA's R&D programme.

TABLE B1: Allocation of biological scores in the BMWP system

Taxa	Score
Siphlonuridae Heptageniidae Leptophlebiidae Ephemerellidae Potamanthidae Ephemeridae Taeniopterygidae Leuctridae Capniidae Perlodidae Perlidae Chloroperlidae Aphelocheiridae Phryganeidae Molannidae Beraeidae Odontoceridae Leptoceridae Goeridae Lepidostomatidae Brachycentridae Sericostomatidae	10
Astacidae Lestidae Agriidae Gomphidae Cordulegasteridae Aeshnidae Corduliidae Libellulidae Psychomyiidae (Ecnomidae) Philopotamidae	8
Caenidae Nemouridae Rhyacophilidae (Glossosomatidae) Polycentropodidae Limnephilidae	7
Neritidae Viviparidae Ancylidae (Acroloxidae) Hydroptilidae Unionidae Corophiidae Gammaridae (Crangonyctidae) Platycnemididae Coenagriidae	6
Mesovelidae Hydrometridae Gerridae Nepidae Naucoridae Notonectidae Pleidae Corixidae Haliplidae Hygrobiidae Dytiscidae (Noteridae) Gyrinidae Hydrophilidae (Hydraenidae) Clambidae Scirtidae Dryopidae Elmidae Hydropsychidae Tipulidae Simuliidae Planariidae (Dugesiidae) Dendrocoelidae	5
Baetidae Sialidae Piscicolidae	4
Valvatidae Hydrobiidae (Bithyniidae) Lymnaeidae Physidae Planorbidae Sphaeriidae Glossiphoniidae Hirudinidae Erpobdellidae Asellidae	3
Chironomidae	2
Oligochaeta	1

A taxon name in brackets defines a new grouping of organisms, that was contained in the preceding taxa, when the score sheet was originally drawn up; eg Psychomyiidae (Ecnomidae). The new taxa are the result of subsequent developments in the taxonomic classification system.

B.3 OPTIONS FOR A BIOLOGICAL GRADING

There are many aspects which need to be considered in designing a grading system for assessing and reporting upon the biological quality of rivers on a national basis. The system must allow objective comparisons to be made of the biological quality of different river types in different parts of the country. It must also allow changes over time to be properly assessed. The RIVPACS approach has the potential to produce a nationally consistent measure of biological quality, and although considerable progress in developing this tool has already been made, further work is ongoing to improve its reliability. It is important to produce a system which is as robust as possible from the outset. Techniques and procedures will need to be as constant as possible if trends over time are to be properly assessed.

The final system adopted for the GQA Scheme should provide as comprehensive a statement on river benthic biological quality as feasible, but at the same time should not be over-complicated. Its structure should take account of the statistical uncertainties associated with placing a river stretch in a particular grade. It should also be constructed in such a way that comparisons with the chemical quality can be conveniently made.

Taking all these factors into account, the design of the biological grading system is clearly a complex task. The survey of biological quality in 1990 covered thousands of sites across England and Wales. The national database of biological quality which resulted has provided, for the first time, the opportunity to assess different options for a national grading scheme. Two of the options are presented here as examples for comparison. Further work is ongoing to investigate other possibilities with a view to publishing a final scheme to report the results of the forthcoming 1995 national survey. The results of the 1990 survey will also then be reported retrospectively, for comparative purposes, using the final scheme.

The BAPC system

One possible option is based on the simple arithmetic averages of the BMWP Scores (expressed, through RIVPACS, as the EQI). It is called the BAPC system (BMWP Averages which Parallel the Chemical grading).

For the BAPC system, the EQIs for BMWP Score in each of the three seasons are combined into a simple arithmetic average. In practice this means that the BAPC system will distinguish sites which have only one good sample in the three taken in the year from those which have two or three good samples in the year.

The use of the simple average (with the corresponding standard deviation) allows, in theory, the better handling of sampling error and thus the ability to take more sensible decisions on sampling rates. This would in turn help prepare the way towards using biological data to take the sort of decisions on water quality planning which have hitherto only been considered in relation to chemical information.

One feature of the approach is that the use of an average magnifies the effect of bias caused by a failure of the sampling procedure to capture all the different taxa present at a site. Hence it tends to give a more pessimistic result than other systems.

The BAPC system defines six grades according to the average EQI_{BMWP} set out, for illustrative purposes, in Table B2. Under this option the number of grades would match the number of grades used in the chemical GQA Scheme.

Table B2: The BAPC system of biological grading

Grade	EQI_{BMWP}
a	≥ 1.0
b	≥ 0.8
c	≥ 0.6
d	≥ 0.4
e	≥ 0.2
f	< 0.2

Table B3 shows the results of the 1990 biological survey according to the BAPC system in terms of the percentage length of sampled rivers in each grade.

Table B3: Rivers in BAPC biological grade for 1990

Region	% Length of River in Each Grade					
	a	b	c	d	e	f
Anglian	18.8	21.5	28.3	19.5	9.7	2.1
N West	7.5	23.8	21.1	10.2	18.0	19.4
Nlm/Yks	33.7	21.7	15.0	12.2	10.9	6.4
S Trent	8.0	16.2	23.3	26.1	19.2	7.3
S Western	42.4	25.5	16.2	10.9	4.3	0.6
Southern	37.2	26.1	18.4	11.3	6.7	0.3
Thames	49.5	15.2	10.7	11.9	11.0	1.7
Welsh	34.5	28.3	20.0	10.6	5.8	0.8
Total	27.2	21.9	19.7	14.9	11.1	5.2

The 5M system

Another method for the biological grading of rivers and canals is defined by the EQIs for each of the three summary measures: BMWP Score, Average Score per Taxon (ASPT) and Number of Taxa. Although these three measures are all related (ASPT is the quotient of the BMWP Score and Number of Taxa) they provide different ways of assessing the information contained within a biological sample and so it is often more informative to consider all three together. Under this system there are only four grades; the grade-limiting criteria are summarised in Table B4. At this stage however these criteria and the actual number of grades are largely illustrative.

Table B4: The 5M system of biological grading

Grade	EQI_{ASPT}	EQI_{Taxa}	EQI_{BMWP}
a	≥ 0.89	≥ 0.79	≥ 0.75
b	≥ 0.77	≥ 0.58	≥ 0.50
c	≥ 0.66	≥ 0.37	≥ 0.25
d	< 0.66	< 0.37	< 0.25

For a typical biological sampling site, three biological samples are taken in a year - in Spring, Summer, and Autumn. The results from these three samples are combined to produce, in effect, a single measure for the whole sampling period, in this case one year. A site is placed in a grade by calculating the values of the three EQIs and assigning a grade for each based on the criteria set out in Table B4. The three individual grades are then arranged in rank order, from a to d. The overall biological grade is then determined by:

- the EQI_{ASPT} where this is ranked lowest; or,
- where this is not the case, the middle ranking EQI.

The consequence of the adoption of this procedure is that the overall biological grade is never 'better' than the grade given by EQI_{ASPT} alone. This reduces the possibility that the biological quality of a stretch of water could be made to look better than it should by incorrect sampling technique, such as sampling for longer than specified in the standard procedures, because ASPT is much less affected by variations in the amount of effort put into sampling than the Score or Number of Taxa.

The system was chosen by NRA biologists from a number of options. The various options were denoted by numbers and letters, hence the name 5M.

The statistical uncertainties associated with assigning biological grades to rivers are discussed in Appendix D.

Table B5 shows the results of the 1990 biological survey of rivers expressed in terms of the 5M system in terms of the percentage length of sampled rivers in each grade.

Table B5: Rivers in 5M biological grade for 1990

Region	% Length in Each Grade			
	a	b	c	d
Anglian	52.2	33.3	11.0	3.5
N West	45.8	15.4	12.8	26.0
Ntm/Yks	64.8	15.2	10.8	9.3
S Trent	37.5	30.1	22.2	10.2
S Western	78.8	15.4	4.8	1.0
Southern	71.7	17.0	8.1	3.2
Thames	67.6	15.5	10.6	6.3
Welsh	77.4	16.5	4.9	1.1
Total	60.2	20.8	11.2	7.8

Future development

The BAPC system has been designed specifically to be consistent with the chemistry grading, whereas other considerations were the motivation for 5M. For both systems the numbers of grades and the exact standards used to delimit those grades presented here are largely illustrative. Research into these and other biological grading methods will continue, along with work to improve the performance of RIVPACS and to develop new procedures for dealing with errors. As has been noted in section B.2, it may also be possible to define a grading based on a direct comparison of observed and predicted lists of taxa without the need to reduce the biological information to summary measures first. Research into this approach is currently under way.

The NRA's database containing the results of the 1990 Survey has been arranged so that whatever grading system is adopted in the future for the biological component of the GQA Scheme the results for 1990 can be reworked in relation to it. This will ensure that it is possible to detect any trends which occur between 1990 and the next quinquennial survey in 1995.

B.4 DETAILS OF THE 1990 BIOLOGICAL SURVEY

Selection of sampling sites

The 1990 biological survey was undertaken on rivers and streams with a dry weather flow greater than 0.05 m^3s^{-1} (1 million gallons per day); this equates to a mean flow of 0.31 m^3s^{-1}. For the purposes of grading, rivers were divided into reaches defined by tributaries or discharge locations. It was intended to sample biologically each reach having a routine chemical sampling site. This intention was achieved in most Regions but some reaches were not sampled in 1990 in some parts of the country. A total of 37,689 km of river were sampled biologically.

Each site was chosen to be characteristic of the major habitat type found in that reach. For example, if the predominant environment was deep, slow-flowing and shaded by trees then the sample site typified this habitat. Wherever possible disturbed sites - influenced by livestock, recreation, fords, bridges or other constructions - were avoided.

RIVPACS could not be applied to those sites that had environmental characteristics markedly different from those used to derive the system; this included many canals. Some 984 km of reaches were not graded for this reason, representing 2.8% of the reaches that were surveyed. A total of 35557 km of river was therefore graded biologically.

Sampling methodology

Objectives

The RIVPACS sampling methodology was adopted for the biological survey to ensure that the resulting data could be directly compared with RIVPACS predictions to produce Ecological Quality Indices.

The aim of sampling was to obtain a comprehensive list of taxa by using standard techniques to collect fauna from each major habitat within the site. The duration of sampling was also standardised and this time was apportioned according to the relative abundance of each habitat type. Thus, if 20% of the site was occupied by aquatic plants, then 20% of the time would be allocated to them.

Equipment and sampling methods

The duration of active sampling was limited to three minutes with a further minute being allowed for a search of significant habitats not covered by the standard method.

Shallow water sites were sampled using a standard pond net having an aperture of approximately 230 x 255 mm fitted with a bag, 275 mm deep, of 0.9 mm mesh. This was placed vertically against the river bed and the substratum immediately upstream kicked vigorously so that organisms were dislodged and washed into the net (kick sampling). In slow flowing water and in weed beds or along margins the net itself was used to dislodge the organisms (sweep sampling). In both cases, the net was emptied as necessary to prevent it becoming blocked by debris. To improve standardisation of this method a video film illustrating it was shown to all biologists involved in the survey.

Deeper waters could often be sampled using the sweep technique from the bank, but when this was inadequate a medium Naturalist's Dredge, or an air lift sampler, was employed. This comprised a rectangular metal frame of approximately 450 x 200 mm to which a 600 mm deep mesh bag, of 0.9 mm mesh, was attached. A tow rope allowed it to be thrown out into the river and dragged back over the substratum. The number of throws (usually three to five) was varied to obtain the required amount of material.

RIVPACS environmental variables

During sampling the following environmental variables were measured.

Measured at the site on each sampling occasion

Channel width: The mean width of the wet channel to the nearest 0.5 metre (rounded up).

Water depth: The mean depth in cm, being the mean of the depths at 0.25, 0.5 and 0.75 of the channel width (estimated to 0.1 metres for depths greater than 1 metre).

Substrate composition: An estimate of the particle size distribution of the substrate in four size classes:

Boulders and cobbles	>63 mm
Pebbles	2 - 63 mm
Sand	0.06 - 2 mm
Clay/silt	<0.06 mm

Derived from maps or other sources

Alkalinity: Annual mean value expressed as milligrams of $CaCO_3 l^{-1}$ derived from routine water chemistry monitoring. Where no routine chemical data were available a single value was accepted. Alternatively hardness, calcium or conductivity values could be used. (The RIVPACS programme is able to calculate a surrogate alkalinity value from any of these, though a 'true' value gives the most satisfactory result).

Latitude and longitude: These were derived by the RIVPACS programme from the National Grid Reference of each site.

Altitude: Estimated to the nearest 5 metres from 1:50,000 scale maps.

Distance from source: Measured to 0.01 kilometres from the main source of the river using 1:50,000 scale maps.

Slope: The mean slope between the nearest upstream and downstream contour lines measured in m/km from 1:50,000 scale maps using the rules given in the RIVPACS manual.

Discharge category: Derived from standard information compiled by the Water Data Unit for the 1975 Survey and measured in cubic metres/second. Ten categories were used as follows:

Discharge Category	Flow Rate (m^3s^{-1})
1 =	>0.31
2 =	0.31 - 0.62
3 =	0.62 - 1.25
4 =	1.25 - 2.50
5 =	2.50 - 5.00
6 =	5.00 - 10.00
7 =	10.00 - 20.00
8 =	20.00 - 40.00
9 =	40.00 - 80.00
10 =	<80.00

Temperature: Annual mean air temperature and annual air temperature range were derived from standard data held within the RIVPACS program.

Analytical methodology

Sorting

Samples were either processed live soon after collection or preserved on site with 4% formaldehyde solution or 10% alcohol. With the exception of North-West Region all analysis was carried out in the laboratory. Each sample was washed through a 0.5 mm mesh sieve to remove silt. Large stones and debris were discarded after inspection for attached organisms.

The sample was then sorted in white trays, a small portion at a time. When large amounts of organic debris were present sub-sampling was permitted, though the unsorted material was quickly checked for additional taxa. Representatives of all taxa found were removed for identification and the abundance of each recorded on a logarithmic scale as follows:

A	1 - 9
B	10 - 99
C	100 - 999
D	1,000 - 9,999
E	10,000+

As a general rule sorting and identification were limited to two hours each, though this was dependent on sample size.

Identification

Organisms were identified to the levels required by the BMWP score system (principally family) using the best currently available keys. The list of taxa and their abundances was recorded on a standard data sheet.

Audit

Specimens of each taxon were placed in a vial and the entire sample was re-preserved and sent to the Institute of Freshwater Ecology (IFE) to be stored for future reference purposes. Seven hundred of these, selected at random by the IFE, but including samples processed by every analyst from each Region, were re-analysed by IFE staff. The resulting data were then compared with those obtained by the original NRA analyst to provide a continuous feedback on the quality of data being produced. The results of the audit showed that all Regions were able to analyse their biological samples accurately to within 3 to 5 BMWP families. Some Regions achieved a mean number of families omitted as low as 1 or 2.

Data handling

Standard site description and sample forms containing environmental and invertebrate data were forwarded to NRA Thames Region for incorporation onto a database. All data were carefully validated before calculation of RIVPACS predictions and biological grades.

APPENDIX C: COMPARISON OF THE BIOLOGICAL AND CHEMICAL QUALITY FOR 1990

Tables C1 and C2 show the chemical grades together with the biological grades according to the BAPC system and 5M system respectively. Only those river stretches for which pairing of biological and chemical information is possible have been used in this analysis. The proportions of river length falling into the different quality grades are therefore different from those shown in the separate analyses of chemical and biological information shown earlier in this report.

Table C1: Comparison of BAPC biological and GQA chemical quality for 1990

% Length of River in Chemical and Biological Grades							
BAPC Biological Grade	Chemical Grade						Total
	A	B	C	D	E	F	
a	8.5	12.0	5.4	2.1	0.7	0.0	28.8
b	4.9	8.5	5.6	2.1	1.2	0.1	22.4
c	2.5	5.9	5.3	3.0	2.0	0.2	18.8
d	0.9	2.6	4.9	3.1	2.4	0.4	14.3
e	0.5	1.3	2.6	2.8	3.0	0.7	10.9
f	0.0	0.2	0.4	0.7	2.5	0.8	4.7
Total	17.4	30.4	24.2	13.8	11.9	2.2	100.0

Table C2: Comparison of 5M biological and GQA chemical quality for 1990

% Length of River in Chemical and Biological Grades							
5M Biological Grade	Chemical Grade						Total
	A	B	C	D	E	F	
a	15.3	24.7	13.4	5.7	2.6	0.2	61.8
b	1.7	4.1	6.6	4.0	3.2	0.4	20.0
c	0.5	1.3	3.2	2.6	2.5	0.6	10.8
d	0.0	0.3	1.0	1.5	3.6	1.1	7.5
Total	17.4	30.4	24.2	13.8	11.9	2.3	100.0

Both systems show a general pattern that where chemical quality is good the biological quality also tends to be good; conversely waters of poor chemical quality also usually have poor biological quality. There are, however, exceptions to this pattern and this is to be expected. Indeed, the principal purpose of examining separately the basic chemical and some of the biological characteristics of stretches of water is to identify such differences. These may then be relatively easily explained at a local level, or may be quite unexplainable. Such information is vital in order to plan future management strategies. Further data will be required, however, to construct a more complete picture of the state of the aquatic environment and the necessary additional 'windows' needed to do so are now being developed.

APPENDIX D: ASSESSING THE RISK OF MIS-GRADING

For the first time in national reports on river quality, this survey has calculated the risk that any river reach has been placed in the wrong grade. This appendix summarises the risks for both chemical and biological gradings [11,12].

The risk of mis-grading depends on the frequency of sampling - the more samples taken at a site, the more confident the assessment of the grade - and also on the true river quality and particularly its proximity to the boundary of a grade.

For the chemical grading, the average risk is 25% that a particular site is assigned the wrong grade. This is split evenly between the risk of placing the river in a grade which is better than the true grade and the risk of putting the river in a grade which is worse than the true grade.

For the 5M system of biological grading the average risk is 17%. This is smaller than the error for chemistry largely because there are more chemical grades. The average risk of mis-grading under the BAPC method of biological grading is 31%. This is bigger than the 17% for the 5M system mainly because of the increased number of grades. This figure also does not include any assessment of the systematic bias to which the BAPC grade is prone.

Results for several individual rivers are given in Table D1 as examples. The biological grade is assigned according to the 5M system only. For some rivers there is almost 100% confidence that the assigned grade is correct. For others the risk of error is close to 50%. For each reach, Table D1 gives the confidence that the true grade is any of chemical grades A to F or any of the biological grades.

These error rates apply to individual river stretches and so to the colours on the national map of river quality included with this report. The national figures, quoted in the tables and elsewhere, are not subject to the same error rates. They are accurate because they are based on aggregations of data from a great many rivers.

Table D1: Examples of results for individual reaches

Region	**Anglian**	
River	**Ouse**	
Reach	**Radclive to Buckingham**	**Length = 3.0 km**

Chemistry	Mean	Standard Deviation	Number of Samples	90-percentile
BOD	1.61	0.70	30	2.52
Ammonia	0.11	0.11	31	0.23
Diss. Ox	88.83	12.08	28	73.35

Biology	Value	EQI	Number of Samples
BMWP Sc.	165	1.100	3
ASPT	5.00	0.980	
No. Taxa	33	1.122	

Confidence of Chemical Grade		Confidence of Biological Grade	
A	1%	a	91%
B	80%	b	9%
C	19%	c	0%
D	0%	d	0%
E	0%		
F	0%		
Grade: B		Grade: a	

Region	North West					
River	Smoker Brook					
Reach	Gale Brook (Lodge Lane) to Wincham Brook					Length = 14.9 km

Chemistry	Mean	Standard Deviation	Number of Samples	90-percentile
BOD	2.77	1.46	21	4.62
Ammonia	0.41	0.52	20	0.89
Diss. Ox	89.56	29.11	18	52.25
Biology	**Value**	**EQI**	**Number of Samples**	
BMWP Sc.	42	0.226	3	
ASPT	4.20	0.737		
No. Taxa	10	0.306		

Confidence of Chemical Grade		Confidence of Biological Grade	
A	0%	a	0%
B	1%	b	0%
C	15%	c	8%
D	42%	d	92%
E	42%		
F	0%		
Grade: D		Grade: d	

Region	Severn Trent					
River	Trent					
Reach	River Soar to Nottingham STW					Length = 29.5 km

Chemistry	Mean	Standard Deviation	Number of Samples	90-percentile
BOD	3.80	1.58	62	5.85
Ammonia	0.30	0.25	64	0.58
Diss. Ox	95.80	9.63	61	83.46
Biology	**Value**	**EQI**	**Number of Samples**	
BMWP Sc.	97	0.516	3	
ASPT	4.20	0.764		
No. Taxa	23	0.676		

Confidence of Chemical Grade		Confidence of Biological Grade	
A	0%	a	1%
B	0%	b	44%
C	62%	c	52%
D	38%	d	3%
E	0%		
F	0%		
Grade: C		Grade: c	

Region	**South West**	
River	**Lyd**	
Reach	**Lifton Bridge**	**Length = 5.1 km**

Chemistry	Mean	Standard Deviation	Number of Samples	90-percentile
BOD	1.76	0.70	41	2.67
Ammonia	0.06	0.04	41	0.11
Diss. Ox	97.66	6.26	41	89.64

Biology	Value	EQI	Number of Samples
BMWP Sc.	216	1.113	3
ASPT	6.80	1.097	
No. Taxa	31	1.015	

Confidence of Chemical Grade		Confidence of Biological Grade	
A	18%	a	100%
B	82%	b	0%
C	0%	c	0%
D	0%	d	0%
E	0%		
F	0%		
Grade: B		Grade: a	

APPENDIX E: FUTURE SURVEYS

For future surveys the actual grade recorded will be reported. Where a change of grade from one survey to the next occurs the risk that the reported change of grade was not caused by a genuine change in water quality but by the effect of chance in sampling will be calculated. This information will be used in the form of ranked lists of sites showing where there is most confidence that the quality has truly improved or deteriorated. These lists will help decide where action is needed to improve water quality.

Table E1 gives examples of a report on reaches which have changed chemical grade. In the first case the reported grade has improved from E to C. There is high confidence (93.5%) that this change is not caused by the chance effects of sampling and almost total confidence that an improvement of at least one grade has occurred. In the second case there is a reported deterioration from Grade B to Grade C. There is a fair degree of confidence that this change is real, but there remains a risk of 17.5% that the report was caused by the effect of chance in monitoring. (There will be some cases where this effect of chance is close to 50%).

This method of analysis will be used in the future, for example, to target effort towards correcting any significant deteriorations in water quality and so avoid wasting effort on changes caused by the effects of chance on the reporting system.

Table E1: Examples of reports on reaches which have changed chemical grade from one survey to the next

Name of River:	Great Stour
Name of Reach:	Bybrook Bridge to Lenham
Chemical Grade Allocated for 1990:	E
Chemical Grade Allocated for 1992:	C
Confidence that Quality has Improved by at Least Two Grades:	93.5%
Confidence that Quality has Improved by at Least One Grade:	100.0%

Name of River:	Colne Water
Name of Reach:	Church Clough to Colne Sewage Treatment Works
Chemical Grade Allocated for 1990:	B
Chemical Grade Allocated for 1992:	C
Confidence that Quality Grade has Worsened by at Least One Grade:	82.5%
Confidence that the Grade has Not Improved:	99.6%

APPENDIX F: SUPPORTING TABLES

Table F1: Length of rivers and canals in GQA chemical grades for 1990

Region	Length in Each Grade (km)						
	GOOD		FAIR		POOR	BAD	
	A	B	C	D	E	F	Total
Anglian	36.0	764.0	1706.1	1284.8	879.7	169.0	4839.6
N West	718.6	618.2	542.2	442.8	661.9	208.7	3192.4
Ntm/Yks	865.3	1644.3	581.1	449.8	627.9	181.7	4350.1
S Trent	546.2	1381.0	1901.1	873.6	1050.9	119.1	5871.9
S Western	1644.5	2679.6	1306.4	695.4	365.1	80.7	6771.7
Southern	237.5	719.8	676.0	283.8	239.4	36.8	2193.3
Thames	318.8	981.2	1054.0	577.6	560.7	46.2	3538.5
Welsh	1769.7	1380.9	431.1	222.2	134.1	44.8	3982.8
Total	6136.6	10169.0	8198.0	4830.0	4519.7	887.0	34740.3

Table F2: Lengths of rivers and canals in GQA chemical grades for 1992

Region	Length in Each Grade (km)						
	GOOD		FAIR		POOR	BAD	
	A	B	C	D	E	F	Total
Anglian	139.7	897.4	1527.1	1149.5	920.6	118.0	4752.3
N West	1481.2	1405.9	861.9	654.9	836.1	206.6	5446.6
Ntm/Yks	627.9	1925.8	916.8	397.2	749.6	138.0	4755.3
S Trent	365.7	1721.4	1523.2	917.2	733.3	173.7	5434.5
S Western	2025.6	2399.5	1359.4	307.1	241.7	42.6	6375.9
Southern	180.3	937.7	658.8	214.6	165.9	22.9	2180.2
Thames	246.8	1188.3	1264.4	619.9	335.5	27.4	3682.3
Welsh	2753.3	1447.1	376.4	154.9	135.9	28.0	4895.6
Total	7820.5	11923.1	8488.0	4415.3	4118.6	757.2	37522.7

Table F3: Length of rivers in BAPC biological grades for 1990

Region	Length in Each Grade (km)						
	a	b	c	d	e	f	Total
Anglian	1128.3	1287.3	1697.0	1169.9	582.0	127.0	5991.5
N West	312.0	992.6	880.9	425.1	752.3	810.1	4173.0
Ntm/Yks	2057.8	1326.2	917.1	744.6	663.2	391.0	6099.9
S Trent	427.8	862.1	1239.0	1387.3	1021.6	386.0	5323.8
S Western	2004.5	1203.5	767.2	516.9	205.4	27.3	4724.8
Southern	713.4	500.9	352.2	216.1	128.0	6.4	1917.0
Thames	1696.1	520.3	367.7	408.3	377.0	59.6	3429.0
Welsh	1331.2	1090.5	771.2	408.2	222.6	31.0	3854.7
Total	9671.1	7783.4	6992.3	5276.4	3952.1	1838.4	35513.7

Table F4: Comparison of BAPC biological quality and GQA chemical quality for 1990

BAPC Biological Grade	Length of River in Chemical and Biological Grades (km)						
	Chemical Grade						
	A	B	C	D	E	F	Total
a	2390.6	3370.1	1519.6	576.6	194.1	10.2	8061.2
b	1379.8	2370.8	1569.6	585.1	341.6	33.5	6280.4
c	703.1	1639.1	1480.4	837.1	551.4	52.5	5263.6
d	261.2	715.9	1382.4	873.5	671.9	103.4	4008.3
e	137.1	351.8	723.5	790.3	851.8	190.0	3044.5
f	0.0	65.1	107.0	205.1	709.7	235.0	1321.9
Total	4871.8	8512.8	6782.5	3867.7	3320.5	624.6	27979.9

Table F5: Length of rivers in 5M biological grades for 1990

Region	Length in Each Grade (km)				
	a	b	c	d	Total
Anglian	3127.7	1996.6	659.7	207.5	5991.5
N West	1913.1	641.3	535.7	1082.9	4173.0
Ntm/Yks	3949.7	929.4	656.4	564.4	6099.9
S Trent	1994.1	1601.6	1183.3	544.8	5323.8
S Western	3756.1	733.4	230.3	48.7	4768.5
Southern	1374.0	325.9	155.4	61.7	1917.0
Thames	2317.4	532.4	363.6	215.6	3429.0
Welsh	2982.8	637.7	190.8	43.4	3854.7
Total	21414.9	7398.3	3975.2	2769.0	35557.4

Table F6: Comparison of 5M biological quality and GQA chemical quality for 1990

5M Biological Grade	Length of River in Chemical and Biological Grades (km)						
	Chemical Grade						Total
	A	B	C	D	E	F	
a	4274.3	6915.1	3745.9	1601.6	725.9	62.9	17325.7
b	466.7	1145.4	1858.2	1132.2	887.2	104.8	5594.5
c	133.9	374.3	904.3	716.1	710.5	174.7	3013.8
d	5.7	92.9	275.8	417.8	998.9	298.5	2089.6
Total	4880.6	8527.7	6784.2	3867.7	3322.5	640.9	28023.6

GLOSSARY OF TERMS

Acid deposition	The transfer of acidic material from air to land and to water. Acid deposition is a result of emissions, of oxides of nitrogen and sulphur, into the atmosphere from the combustion of fossil fuels. This deposition can affect the acidity of rivers and can damage the plants and animals within them. This is especially the case in areas in the west of England and in Wales where the geological strata do not neutralise the acidity.
Alkalinity	A chemical characteristic of water often defining for natural waters the geology with which the water has been in contact. For river waters the alkalinity is primarily a measure of the amount of dissolved carbonate.
Allyl Thio-Urea (ATU)	See Biochemical oxygen demand.
Algae	Simple plants, usually aquatic.
Ammonia	A water soluble chemical compound, produced by the decomposition of organic material, which is widely used to characterise water quality. Ammonia affects the quality of fisheries and the suitability of abstractions for potable water supply.
Average score per taxon (ASPT)	A summary statistic to describe the results of monitoring rivers for the presence of benthic macro-invertebrates. The Score refers to the BMWP Score.
Benthic	Pertaining to the bed of a river or other body of water.
BMWP; BMWP Score	BMWP is an acronym for Biological Monitoring Working Party. Some invertebrates are more susceptible than others to pollution and so the presence of such sensitive species is a sign that water quality is good. This fact was taken into account by the BMWP when it set up a method of summarising biological information in the form of a simple index. This became known as the BMWP Score. It assigns points to each Taxon according to its sensitivity to pollution. For example, many mayfly nymphs and caddis larvae score ten points, water beetles score five, molluscs three, and worms, one. The BMWP Score for a site is the sum of all the scores of all the Taxa found.
BOD; BOD(ATU); biochemical oxygen demand	A measure of the amount of oxygen consumed in water (over 5 days, in the dark), usually by the decomposition of organic material. The value can be misleading because much more oxygen is taken up by ammonia in the test than in the natural water. This effect is suppressed by adding a chemical (allyl thio-urea) to the sample of water taken for testing. Hence BOD(ATU).
Biological grading	A way of placing waters in categories according to the biota observed in monitoring. Data on macro-invertebrates have long been used for this purpose.
Biota	All the plants and animals in a particular area.

Chemical grading	A way of placing waters in categories according to assessments of water quality based on measurements of the amount of particular chemicals in the water (especially BOD, dissolved oxygen and ammonia).
Compliance assessment	A procedure applied to the results of a monitoring programme to determine whether or not a water has met its quality standards.
Consent	A statutory document issued by the NRA which defines the legal limits and conditions on the discharge of an effluent into controlled waters.
Controlled Waters	Estuarine and coastal waters, extending three miles from the coastline, inland freshwaters including canals and reservoirs and groundwaters in England and Wales (described in section 104 of the Water Resources Act 1991)
Directive	A type of legislation issued by the European Community which is binding on Member States in terms of the results to be achieved.
Dissolved oxygen	The amount of oxygen dissolved in water. Oxygen is vital for life so this measurement is a test of the health of a river. Used to grade waters.
Determinand	Literally 'that which is to be determined'. A general term for any numerical property of a sample (eg the amount of ammonia or copper) whose value is required.
Ecological Quality Index (EQI)	A summary of the ecological health usually expressed as a simple numeric score.
EIFAC	An acronym for the European Inland Fisheries Advisory Commission.
Invertebrates	Animals which lack a vertebral column. A combination of many groups of animals used for biological grading. It includes insects, crustaceans, worms and molluscs.
Macro-invertebrates	Invertebrate animals of sufficient size to be retained in a net with a specified mesh (1 mm).
NWC Class	A summary of the quality of river water based largely on the measured chemical quality. Used to report on river quality from 1980 to 1990. Originally devised by the former National Water Council.
Number of Taxa	A summary statistic to describe the results of monitoring rivers for the presence of benthic macro-invertebrates. See Taxon.
Nutrient	A substance that provides nourishment for living organisms.
Organic pollution	A general term used to describe the type of pollution which through the action of bacteria consumes the dissolved oxygen in rivers. It applies to the effects of sewage, treated sewage effluents, farm wastes and the waste from many types of industry like dairies, breweries and abattoirs. The effects of organic pollution are described by the levels of BOD, ammonia and dissolved oxygen.
Parametric method	A statistical method which assumes knowledge of the family of statistical distributions from which samples have been drawn.

Percentile	A numerical value that is not exceeded for a stated percentage of the time over a specified assessment period. Therefore a 90-percentile is not exceeded for 90% of the time.
Quality objective	The statement or category of water quality that a body of water should achieve, usually to be suitable for uses identified by the agency setting the objective.
Quality standard	The concentration of a substance which must not be exceeded by some statistical measure (eg mean, percentile or maximum) if a specified quality objective of the aquatic environment is to be maintained.
RIVPACS	An acronym for the River Invertebrate Prediction and Classification System. A mathematical model used to predict the invertebrate life in a river under conditions of natural water quality. RIVPACS is used to calculate the Ecological Quality Indices.
Statistically significant	A description of a conclusion which has been reached after making proper allowance for the effects of random chance.
Statutory Water Quality Objectives (WQOs)	Statutory water quality planning targets for controlled waters, specifying formal minimum quality standards, served by Notice from the Secretaries of State under Section 83 of the Water Resources Act 1991.
Taxon; (plural: Taxa)	A term for a sub-unit of the taxonomic classification system applied to living organisms. Organisms may be grouped together in, for example, classes, families, genera and species. Any of these groupings may be called a taxon.
Use	A purpose to which a controlled water may be put, and for which quality standards will be put in place under the statutory Water Quality Objectives scheme.
Use-related Objective	A quality objective required to achieve a particular Use.
Use-related Standards	Quality standards needed to protect a Use.

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