

Association of Rivers Trusts

**SUBMISSION OF A BRIEF PAPER
REGARDING WATER QUALITY AND
INVERTEBRATE SAMPLING PROGRAMMES
AND THE MONITORING OF DIFFUSE
WATER POLLUTION**

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1.0 INTRODUCTION

1.0.1 Overview of Diffuse Pollution

Point sources of pollution have historically been the major cause of water quality problems in England and Wales and were responsible for the gross pollution of many rivers that occurred after the dawn of the Industrial Revolution. Dramatic increases in the water quality of UK rivers as a consequence of actions against end of pipe discharges have been a major environmental achievement over the last two decades or so (Environment Agency 2005). With very few major rivers now classified as seriously polluted, effort is increasingly concentrated at further improving rivers at upper end of the quality scale being driven by the Water Framework Directive (WFD) (Dines & Murray – Bligh 2000). Diffuse pollution represents one of the greatest hurdles to attaining the required 'good ecological status' in all UK River Basin Districts by 2015 (DEFRA 2003).

Sources and pathways of diffuse pollution are generally dispersed and inherently complex in nature. From a national perspective, agriculture contributes greatest to the problem (DEFRA 2003), with other land use activities such as forestry, industrial land use, construction, transport, urbanisation and recreation all contributing to a greater or lesser extent on local scales.

Diffuse pollution inputs vary in space and time and are characteristically episodic in nature (e.g. Ormerod & Jenkins 1994, Greig 2004). Reported estimates suggest that up to 80% of the total pollutant loadings occur in 3% of the time (Littlewood 1993 *cited in Greig 2004*). The timing of these inputs is usually associated with precipitation driven runoff events, although other climatic variations, seasonal changes in land use practices and hydro-geomorphological characteristics all have a part to play. Controlling these inputs, therefore, represents a major challenge if they are difficult to predict and act across political boundaries, for example, in the case of atmospheric deposition. Diffuse pollution is widespread, affecting all catchments from upland headwaters to lowland reaches and, furthermore, diffuse pollution cannot easily be traced back to point sources and individual polluters. Identification and assessment of the effects of diffuse and episodic pollution is fiendishly difficult requiring an effective monitoring programme providing extensive spatial coverage and temporal resolution across a range of hydrological conditions, landscape characteristics and potential management treatments.

1.0.2 Objectives

From correspondence sent to APEM at the start of June 2004 it is clear that the Association of Rivers Trusts (ART) believe insufficient progress is being made to monitor diffuse pollution in England and Wales. This is of particular concern considering diffuse pollution is specifically mentioned as part of the Water Framework Directive (WFD) (WFD: 2000/60/EC) and there is a requirement to address it by applying 'basic' and, where necessary, 'supplementary' measures (EA, Briefing Notes of Diffuse Pollution, Version 1 – Feb 2004).

The purpose of this paper is to provide an overview of the current status of water quality and biological monitoring carried out by the Environment Agency (EA) in England and Wales and to provide a discussion of the objectives of these programmes. In the light of current problems associated with diffuse pollution and WFD requirements, the effectiveness of these programmes will be critically assessed. The current status of developments towards a more effective monitoring programme by the EA and others to address the above issues under the WFD will be reviewed. This paper will inform the ART of potential monitoring approaches towards the potential role the ART could play in assisting with and constructively commenting on future monitoring to be adopted under the WFD for UK rivers.

2.0 CURRENT STATUS OF EA WATER QUALITY SAMPLING OF RIVERS IN ENGLAND AND WALES

2.0.1 Overview of the Current EA Water Quality Monitoring Programmes

The Agency's method for monitoring and classifying the quality of rivers and canals in England and Wales is known as the General Quality Assessment (GQA) scheme. The current GQA scheme was implemented in 1990 following the creation of the National Rivers Authority (NRA); previous chemical monitoring undertaken by the Water Authorities was adapted in this design. Four water quality parameters are monitored separately as part of the GQA: chemistry, macroinvertebrates, nutrients and aesthetics. For the purposes of this paper, the term water quality will, henceforth, refer to chemistry and nutrients only. Macroinvertebrates will be considered separately and aesthetics will not be considered further.

For chemistry, water samples are collected and three key determinands relating to the most common types of pollution (organic, from sewage and farms) traditionally encountered in rivers are analysed: biochemical oxygen demand (BOD), dissolved oxygen (DO) and ammonia. BOD and DO measure the degree of oxygen stress encountered by aquatic life and ammonia is directly toxic to aquatic life as a consequence of organic pollution. For nutrients, water samples are collected and concentrations of nitrate and phosphate are determined.

The GQA scheme involves routine monthly sampling at 8,000 monitoring points on over 40,000 km of rivers and canals. These sites were chosen to provide reasonable spatial coverage of the major watercourses in England and Wales and usually correspond to those sites used to take decisions that may affect water quality, such as discharges, abstractions and changes in land use.

For analysis, data are collated over three years, thus producing 36 samples per site, giving the required precision to make judgements about the quality of rivers within the constraints of monitoring. The percentiles are calculated assuming a normal distribution for DO and lognormal distributions for BOD and ammonia. The GQA grade based on chemistry for each site is defined in Table 2.0. The general characteristics of each grade are described in Table 2.1.

Table 2.0 Definitions of Chemical GQA Grades

GQA Grade	DO (% saturation) 10-percentile	BOD (mg/l) 90-percentile	Ammonia (mgN/l) 90-percentile
A	80	2.5	0.25
B	70	4	0.6
C	60	6	1.3
D	50	8	2.5
E	20	15	9.0
F	<20	-	-

Source: EA 2005.

Table 2.1 Descriptions of chemical GQA Grades

Chemical grade		Likely uses and characteristics
A	Very good	All abstractions Very good salmonid fisheries Cyprinid fisheries Natural ecosystems
B	Good	All abstractions Salmonid fisheries Cyprinid fisheries Ecosystems at or close to natural
C	Fairly good	Potable supply after advanced treatment Other abstractions Good cyprinid fisheries Natural ecosystems, or those corresponding to good cyprinid fisheries
D	Fair	Potable supply after advanced treatment Other abstractions Fair cyprinid fisheries Impacted ecosystem
E	Poor	Low grade abstraction for industry Fish absent or sporadically present, vulnerable to pollution** Impoverished ecosystems**
F	Bad	Very polluted rivers which may cause nuisance Severely restricted ecosystems

* Provided other standards are met

** Where the grade is caused by discharges of organic pollution

Source: EA 2005.

For nutrients, classification grades range from 1 to 6 for both nitrate and phosphate separately. Unlike for water chemistry, they cannot be combined into a single grade. There are no set 'good' or 'bad' grades for nutrients in rivers as nutrient concentrations naturally differ across rivers determined by catchment geology and the influence of nutrients in a given waterbody depends on other factors such as amount of algae present, flow, depth and dissolved oxygen concentrations. Tables 2.2 and 2.3 give the limits of dissolved phosphate and nitrate concentrations for each grade.

Table 2.2 Limits for each phosphate grade

Classification for phosphate	Grade limit (mgP/l) average	Description
1	<0.02	Very low
2	>0.02 to 0.06	Low
3	>0.06 to 0.1	Moderate
4	>0.1 to 0.2	High
5	>0.2 to 1.0	Very high
6	>1.0	Excessively high

Source EA 2005.

Phosphate concentrations are described as ‘High’ when the average concentration is more than 0.1 mg/l. This corresponds to the concentration that is considered by the Agency to be indicative of possible existing or future problems of eutrophication¹. Of course, as described above, interpretation of these grades has to be context specific.

Table 2.3 Limits for each nitrate grade

Classification for nitrate	Grade limit (mg NO ₃ /l) average	Description
1	<5	Very low
2	>5 to 10	Low
3	>10 to 20	Moderately low
4	>20 to 30	Moderate
5	>30 to 40	High
6	>40	Very high

Nitrate concentrations are described as ‘High’ when the average concentration is above 30 mg/l. This limit is approaching the 95 percentile limit of 50 mg/l which is used by the EC Drinking Water Directive and the EC Nitrate Directive. These limits are strictly laid down by the Directives so there can be no direct comparison with the EA’s GQA data which are averages over three years.

In response to incidents or accidents the Agency will conduct special investigative sampling. To avoid bias, the extra data collected in these surveys is ignored in the context of water quality GQAs.

2.0.2 Objectives of Current EA Water Quality Monitoring

The Agency’s GQA system was designed to provide the most accurate and consistent assessments of the general state of water quality of watercourses in England and Wales, under the given constraints. Routine water quality monitoring using water chemistry has been undertaken for many decades since the Water Authority days and well before any other assessments of water quality were conducted (such as biology).

¹ Eutrophication is the term given to the enrichment of water by nutrients, especially compounds of phosphorous and/or nitrogen, causing accelerated growth of algae and higher plant forms to produce an undesirable disturbance to the balance of organisms present in the water and the quality of the water concerned (EA 2005).

At that time point sources (mainly sewage and industrial effluents) were the main causes of water quality problems and consequently the monitoring effort was geared to this situation. The present GQA system was developed and implemented following privatisation of the water industry and the creation of the NRA in 1989/90. At that time some of the problems with point-source pollution remained and so did the main objectives of a monitoring programme. The GQA system, therefore, remained largely focused at monitoring organic pollution from sewage and agricultural inputs and the core monitoring sites were based on previously monitored sites and largely coincided with those influenced by discharges, abstractions, and changes in land use.

3.0 WATER QUALITY MONITORING, DIFFUSE POLLUTION AND THE WATER FRAMEWORK DIRECTIVE (WFD)

3.0.1 Adequacy of the Water Quality General Quality Assessment (GQA) for the Monitoring of Diffuse Pollution

The GQA system is based on a set of objectives relating primarily to point source pressures for which it has been successful in tackling in the past, but is somewhat archaic in view of the modern challenges for water quality. The Agency currently conducts no water quality monitoring specifically aimed at diffuse pollution. As discussed above, the current water quality monitoring is targeted at average or base flow conditions with little or no consideration for hydrologic variability; data outliers (extreme values) are too routinely deleted from the data sets (Hendry *et al.* 2004).

Monitoring programmes based on regularly timed (monthly) sampling targeted at average conditions of flow do not adequately detect episodic inputs of pollutants from diffuse sources (Greig 2004). Several studies have concluded that pollutant load estimates based on low frequency regularly timed sampling (bi-weekly, monthly) are inaccurate and imprecise, particularly for pollutants that display an upward flow related trend. The detection of acidic episodes in upland Welsh streams, for example, was severely limited at low sampling frequencies (monthly) compared to weekly sampling; annual means, however, were not influenced by sampling frequency (Brewin *et al.* 1996). This and other studies (e.g. Webb *et al.* 1997, Soerens & Nelson 2001, *cited in Greig 2004*) conclude generally that a sampling programme such as the GQA system inaccurately measures total pollutant loadings because of (i) the limited range of flows that sampling is typically undertaken across, and (ii) the large assumptions that are made regarding pollutant loadings between samplings.

A further example of the inadequacy of regular spot sampling to detect loadings of diffuse pollution is given by Hendry *et al.* (2004). The Upper Tamar catchment in south west England is largely classified as 'good' under the GQA scheme. The catchment has undergone substantial agricultural intensification with dairy stock over a 30-year period. No significant increases in pollution loadings of the River Tamar have been detected by the GQAs, however, over this period. As part of a detailed study, automated water samplers (continuous spate river monitoring: CSRM) were deployed which were programmed to collect water samples every 2 – 3 hours during spate flow events. Additionally, continuous river monitoring (CRM) data loggers were deployed to measure turbidity, DO, conductivity and ammonium concentrations every 15 minutes. The data from these continuous samplings indicated many short-

lived spikes of increased ammonium concentration by up to 0.6 mg/l_N, lasting maybe just a few hours, positively associated with runoff which were missed by regular spot sampling (Fig.1). The authors concluded that the true extent of agricultural intensification on river water quality in the Upper Tamar catchment has been grossly underestimated arguably resulting in a misrepresentation of the severity of diffuse pollution.

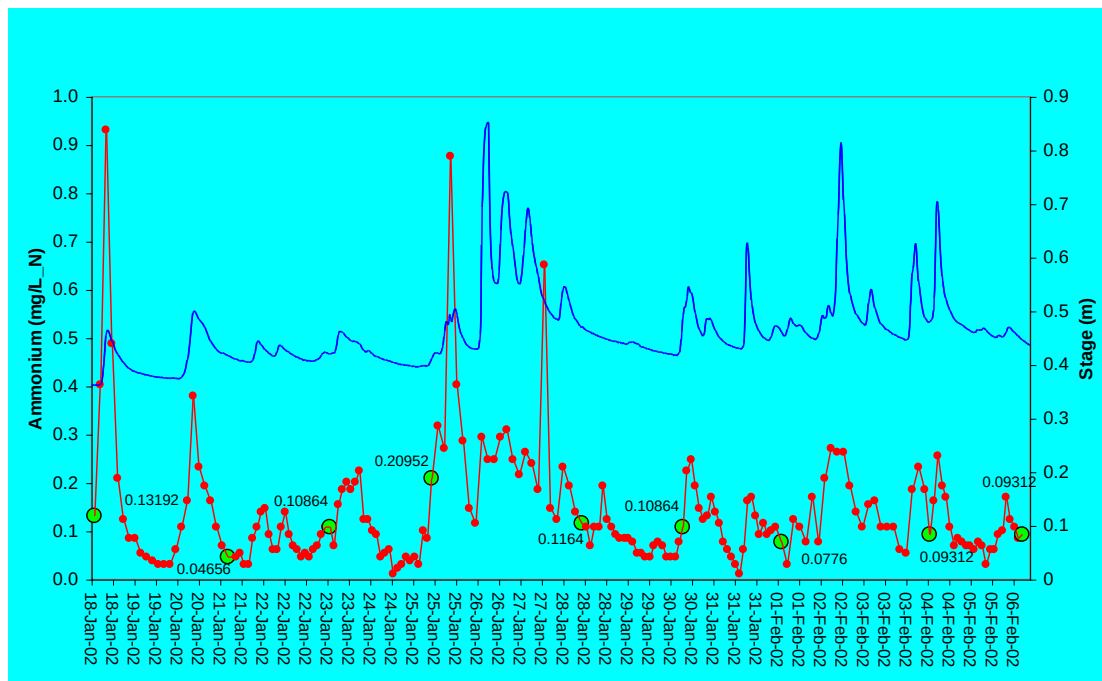


Figure 1. Ammonium concentrations derived from CSRM samples (red) and spot sampling (green) in the River Tamar over 3 weeks in 1992. River level (stage [m]) is indicated by blue line (Hendry et al. [2004]).

3.0.2 Water Quality Monitoring Requirements of the WFD

“The way we look at the water environment including rivers will change over the next few years because of a new European Law – the Water Framework Directive”. EA 2005.

Whereas the Agency’s (formerly NRA’s) GQA has been successful in solving past problems associated with point source pollution and helped clean up many UK rivers, further improvements will require tackling diffuse sources of pollution. The Agency’s first assessment of surface waters that may be at risk of failing to meet WFD requirements in September 2004 suggested that diffuse pollution as a whole was perhaps the greatest hurdle (EA 2005). In view of diffuse pollution, Article 8 of the WFD states that:

Member States shall collect and maintain information on the type and magnitude of the significant anthropogenic pressures to which the surface water bodies in each river basin district are liable to be subject, (including) the following: Estimation and

identification of significant diffuse source pollution, in particular by substances listed in Annex 8, from urban, industrial, agricultural and other installations and activities;

Article 8

The WFD requires Member States to establish a water quality monitoring programme for each River Basin Management Plan (RBMP) period that meets a series of specified monitoring objectives. Clearly the current GQAs for chemistry and nutrients are not adequate to fulfil this role, which the Agency recognise and the United Kingdom Technical Advisory Group (UKTAG) supporting the implementation of the WFD are presently devising a suitable monitoring strategy for the Agency to adopt. The UKTAG is a partnership of UK environment and conservation agencies (including Northern Ireland).

3.0.3 Potential Water Quality Monitoring Approaches

The development of WFD monitoring programmes by the UKTAG is still at an early stage. The following is, therefore, a discussion of the various approaches that could be taken with respect to diffuse pollution in England and Wales and possible roles the ART might play in assisting these.

The Scottish Environmental Protection Agency (SEPA) has achieved more progress towards these objectives than other UK environmental agencies at this time. The following discussion of potential WFD water quality monitoring is based on previous work by SEPA. SEPA currently undertake a similar routine river water quality monitoring programme to the Agency's GQA.

The WFD defines three distinct monitoring objectives which have to be fulfilled by all monitoring programmes (not just water quality) (*after CIS 2003*):

1. Surveillance Monitoring: Validating risk assessment. Detecting underlying long-term changes (natural and anthropogenic). Water body classification.
2. Operational Monitoring: Assessing the status of water bodies at risk from failing quality objectives. Assess programme of measures.
3. Investigative Monitoring: Assess causes of unknown exceedance of environmental objectives. Ascertain the magnitude and impact of accidental pollution.

Discussion of potential approaches will, therefore, be in the context of these objectives.

Based on the information presented in the preceding sections and previous reviews by SEPA (Greig 2004), potential monitoring approaches range from intensive storm event based sampling to simple modifications of the existing GQA spot sampling protocols.

The current GQA system is essentially a surveillance monitoring programme which should provide the integrator based datasets required to fulfil WFD objectives as it is. Modifications to the GQA might involve additional monitoring sites to enable adequate coverage of the River Basin Districts as current sites were chosen to fulfil other objectives. An example would be extending coverage in catchments such as

upland headwaters which are poorly represented in the GQA but potentially subject to diffuse pollution inputs from atmospheric deposition, for instance. To identify diffuse pollution related trends specifically, analysis and interpretation of GQA datasets should be modified from the existing methodologies (Greig 2004).

The current GQA will not adequately fulfil WFD requirements for operational monitoring. To provide improved assessments of pollutant status, to identify a subset of waterbodies at risk of failing quality standards for diffuse pollution, and to assess changes over time at these sites as a result of measures, one of two sampling amendments is necessary: (i) higher sampling frequency (weekly – fortnightly) or (ii) flow related sampling (Greig 2004).

Table 2 provides a summary of all water quality monitoring options and potential application within WFD defined monitoring categories.

To assess the effectiveness of storm event sampling at improving the precision of pollutant load quantification for a future monitoring; SEPA established a series of storm event monitoring sites in Scotland. Automated pump samplers were programmed to begin sampling when the flow at the four monitoring sites reached a critical threshold. Water samples were obtained across the ascending and descending limbs of high flow events. SEPA concluded that storm event/flow related water quality sampling provided the most precise and accurate assessments of diffuse pollutant loadings that would produce datasets compatible with operational monitoring objectives (Greig 2004). If automated flow-triggered samplers can be deployed cost-effectively, the advantages suggest it is likely that they will form the basis of an operational water quality monitoring scheme targeted at diffuse pollution under the WFD.

Investigative monitoring will be undertaken on a case by case basis and the sampling methodology used will differ to suit the specific circumstances and environmental conditions (see Table 2 for range of options) (Greig 2004). It is in this respect that the ART might be able to provide most useful comment and assistance on a catchment-specific basis.

Table 3.0. Potential water quality monitoring options and application within WFD defined monitoring categories

Monitoring Option	Advantages	Disadvantages	Potential WFD application
Storm event	- Robust quantification of loads - Robust assessments of changes in water quality - High temporal accuracy	- High running and equipment costs - More development required (triggering, data analysis)	Operational - Validation of long-term load estimates and model predictions - Assessing effectiveness of measure
Routine sampling	- Low running costs - Already established as GQA	- Poor load estimation - Poor characterisation of diffuse pressures and trends (non event). Difficult to assess change in pollutant status (diffuse) and effectiveness of remediation measures	Surveillance - Long-term trend analysis - Assessing currently unmonitored sites
Enhanced routine sampling (higher frequency)	Improved load estimation (long-term) (over routine)	- Difficult to quantitatively assess short-term change in pollutant status - Chemistry resource implications	All applications - Assessing currently unmonitored sites - Providing long/medium-term trend analysis
Flow related sampling (spot sampling)	- Reliable and accurate load quantification - No equipment requirements	- Resource constraints (timing of sampling dictated by flow) - Requirement to develop analytical techniques	Operational/ investigative - Assessing pollutant loads - Assessing effectiveness of measures
Flow related sampling (automated)	- Reliable and accurate load quantification - Reasonable assessment of changes in water quality	- Equipment costs (pump sampler) - Problems with sample decay (nutrients) - Requirement to develop analytical techniques	Operational - Assessing pollutant loads - Assessing effectiveness of measures
Continuous probes	- Accurate load estimates for some pollutants - Robust assessment of changes in loads and changes in pollutant status	- Can only measure limited number of variables - For other variables proxy measures must be used - Require calibration of proxy values (from storm/flow related sampling) - High equipment costs	Operational/investigative - Assessing short, medium and long-term trends - Assessing effectiveness of measures (must be complemented by flow related monitoring)
Sediment pots and stilling tubes	Potentially inexpensive and effective for load quantification and identifying pollutants	- Requires testing - Likely to be less accurate than flow related/storm event monitoring	All applications - Identification of pressures - Assessment of sediment bound pollutants
Modelling	- Cost and resource effective (once developed) - Ability to test management scenarios	- Limited availability of good process-based models - Development costs	Surveillance/operational - Predicting potential yields to water courses - Setting remediation targets

(Adapted from Greig 2004)

4.0 CURRENT STATUS OF EA BIOLOGICAL MONITORING OF RIVERS IN ENGLAND AND WALES

4.0.1 Overview of the Current EA biological Monitoring Programmes

The first generation of the Agency's biology GQA system became operational in 1990 following the formation of the NRA as the single regulator in England and Wales. The methodology was further refined and the current GQA has been used from 1995. This system uses benthic macroinvertebrates exclusively as they are the most practical and reliable biological indicators to use for classifying and monitoring the quality of rivers (Helmsley – Flint 2000).

Complete national surveys involving biology were carried out in 1990, 1995 and 2002. From 2002 the Agency has been sampling one-third of all sites each year, so each site is sampled once every three years. Two samples are collected from each site in the sampling year: one in spring (March to May) and one in autumn (September to November).

The biological sampling sites correspond as close as possible to the 8,000 water quality (chemistry and nutrients) sites described above; so they are subject to the same water quality and not separated by tributaries, discharges, weirs and other potential influences.

Considerable effort has been made to standardise all field and laboratory procedures UK wide to minimise all sources of error and provide the most comparable data. Sampling involves three-minutes of active kick-sampling with a standard Freshwater Biological Association (FBA) pond net in wadeable areas. In deeper areas samples are collected by three to five trawls with a dredge or using an air-lift sampler, followed by a one-minute marginal sweep with a pond net (full details are provided in the Agency's guidebook BT 001).

Samples are processed in laboratories of an approved standard by fully trained biologists, following standardised procedures (EA BT 001). The GQA biology programme is subject to the strictest quality control procedures of this kind in the world (Dines & Murray – Bligh (2000). External quality audits are conducted on the work all GQA biologists by the Centre of Ecology and Hydrology (CEH) to ensure the highest standards are maintained across the board.

Macroinvertebrates are identified to the taxonomic level of family and enumerated to logarithmic abundance classes. Data are recorded using the Biological Monitoring Working Party (BMWP) system and from these data three metrics are derived for each site: the number of families present, BMWP score and the Average Score Per Taxon (ASPT). The BMWP score is the accepted index for assessing pollution stress in rivers using macroinvertebrates in the UK. Families of invertebrates are assigned a score from 1 to 10 according to their perceived tolerance/sensitivity to organic pollution specifically. The BMWP score is the sum of the values of scoring families in a sample; the ASPT is simply the BMWP score divided by the number of scoring families to allow valid comparison across rivers. It should be noted that the BMWP scoring system only accounts for the presence of families in samples; no account is

made for their abundances. In addition, although this score was derived from organisms' tolerance/sensitivity to organic pollution specifically, it can be used to detect stress from other pollutants to varying degrees.

The ecological 'quality' of each site is assessed using a computer programme called RIVPACS (River InVertebrate Prediction And Classification System; Wright, Sutcliffe & Furse 2000). RIVPACS compares the actual BMWP statistics of a site and compares them to the values that would be predicted if the site was unstressed using physico-chemical measures obtained from the site at the time of sampling (national grid reference; altitude; distance from source; slope; alkalinity; discharge category; mean water width; mean water depth; substratum characteristics as percentage cover of boulders/cobbles, pebbles/gravel, sand, and silt/clay). The output from RIVPACS is a simple Ecological Quality Index (EQI) which is the ratio of observed to expected (O/E) for each BMWP statistic. Sites are classified based on EQIs as in Table 4.0.

Table 4.0. GQA biological grades

Grade*	EQI for ASPT	EQI for number of taxa	Environmental quality
a	1.00	0.85	Very good
b	0.90	0.70	Good
c	0.77	0.55	Fairly good
d	0.65	0.45	Fair
e	0.50	0.30	Poor
f	-	-	Bad

* The grade assigned to a site is whichever one is the poorest, based on either EQI ASPT or EQI number of taxa.

Source: EA 2005.

4.0.2 Objectives of the Current EA Biological Programmes

As for water quality, the Agency's biological GQA was designed to provide comprehensive assessments of the general biological state of rivers and canals in England and Wales, geared towards the major water quality issues of the day, which have traditionally involved point source inputs.

5.0 BIOLOGICAL MONITORING, DIFFUSE POLLUTION AND THE WFD

5.0.1 Adequacy of the Biology GQA system for the Monitoring of Diffuse Pollution

The biological GQA has been successful in improving the state of rivers in the past. For instance, 95% of rivers were classified as ‘good’ or ‘fair’ in 2002 compared to 90% in 1990 (EA 2005). As for chemical water quality, future improvements in the biological status of rivers in England and Wales will require tackling issues of diffuse pollution. This is required under the WFD. The Agency currently conducts no dedicated programme of biological monitoring aimed specifically at diffuse pollution.

Unlike for the monitoring of water chemistry, the frequency of sampling is not so crucial for biological assessments using macroinvertebrates. Freshwater macroinvertebrates take several months and in most cases at least one year to complete their aquatic life stages, so the organisms that are present in a community reflect an integration of all environmental fluctuations across this period. This is one of the reasons why they are such useful and reliable indicators of pollution status. Studies have reported, for example, that examination of the macroinvertebrate assemblages in upland Welsh streams sampled just once a year can indicate the occurrence of brief episodes of acidity which are associated with perhaps just a few high flow events over this period (Bradley & Ormerod 2002). The current GQA sampling frequency would, therefore, seem adequate for the detection of diffuse pollution in surveillance and operational monitoring under the WFD given the constraints of sample processing. Investigative monitoring using macroinvertebrates would be conducted on a case by case basis depending on the specific problem and nature of the environment.

Inadequacies of the current biology GQA system for the monitoring of diffuse pollution potentially lie in the spatial coverage of sites (already discussed for water quality), and if the taxonomic and numerical resolution of the BMWP – RIVPACS system provides the required accuracy and precision. BMWP scores are considered effective for detecting organic inputs into watercourses; especially large point source loadings (e.g. sewage outfalls) which is what the system was developed for. How sensitive is this system alone for detecting and assessing the ecological effects of diffuse loadings of organics, pesticides, transport runoff and sediment inputs, for example?

Concerns have recently been raised by game anglers and other river users over perceived dramatic declines in the hatches of ‘riverflies’² on many rivers across the UK over the past few decades. These claims have been backed up to some extent by empirical long-term data indicating widespread declines in benthic densities of invertebrate larvae in several ‘grade a’ rivers (S. Brooks & D.T. Monteith

² The term ‘riverflies’ refers to those aquatic larvae that comprise a major component of the diet of trout and grayling and which anglers regularly imitate to catch them: mayflies (Ephemeroptera), stoneflies (Plecoptera) and caddisflies (Trichoptera). These insect orders are among the most sensitive aquatic organisms to pollution and other disturbances.

unpublished data). The explanations for these trends largely involve diffuse pollution and abstraction. The Agency's GQAs of these rivers have consistently failed to detect these impacts as the BMWP scoring system does not consider invertebrate abundances (C. Bennett *unpublished data*). An invertebrate family, for example, will give the same score if just one individual or a thousand occurred in the sample. Logarithmic abundance categories are recorded by the Agency for reference purposes, but these are too crude to detect declines of the magnitudes reported.

4.0.2 Biological Monitoring Requirements of the Water Framework Directive

One of the key changes to the way the water environment must be managed across the European Community under the WFD will be greater emphasis on ecological objectives. Macroinvertebrates will remain perhaps the most important group of indicators overall, but other organisms including diatoms, algae, macrophytes and fish will have to be incorporated into ecological monitoring programmes. The results of biological monitoring will follow the RIVPACS approach and be expressed as an Ecological Quality Ratio (EQR) for the purposes of classification of ecological status. The EQR is the ratio between the values of the biological parameters observed for a site and the predicted values for that site if it were unstressed based on reference conditions (Nixon 2003).

Implementation of the WFD will take the form of River Basin Management Planning (RBMP) where each basic unit or River Basin District (RBD) will be managed in a holistic way as outlined by the Directive. A considerable degree of flexibility is granted for the management of individual RBDs for each Member State, so monitoring programmes will differ between Member States and are likely to differ to some degree between RBDs. This flexibility and the wide range of monitoring tools available provides powerful opportunities to tackle issues like, for example, diffuse pollution. It is recognised, however, that this diversity could cause strategic problems when assessing the ecological status of surface waters in a pan-European perspective. There are currently efforts underway to develop Europe-wide standards, firstly for determining class boundaries of Ecological Status, and secondly for intercalibrating existing monitoring methods (for example, EC funded Standardisation of River Classifications: STAR Project EVK1-CT 2001-00089).

4.0.3 Potential Biological Monitoring Approaches

Given the broad ecological remit and the flexibility of approaches to the monitoring and management of individual RBDs available under the WFD, it is likely that several monitoring strategies (most likely under operational and investigative monitoring) will be adopted to best suit the issues (including diffuse pollution) of individual RBDs, under the guidance of STAR. It is in this way that the WFD provides a real opportunity to deal with the issues of diffuse water pollution.

Surveillance monitoring is likely to be incorporated with the Agency's GQAs. Likely modifications might be to include new sites to give the required spatial coverage in the defined RBDs. In addition to monitoring macroinvertebrates, the WFD requires other organism groups be included in these schemes. It is likely, therefore, that routine

monitoring of other ecological indicator groups: diatoms (frustulated unicellular algae), algae, macrophytes and fish will be adopted in a GQA-like programme.

Operational monitoring will require a targeted approach to suit the requirements of each RBD. For macroinvertebrates it is recommended that this sampling incorporates measures of absolute abundance as it is increasingly recognised that problems associated with diffuse pollution and abstraction are not being detected by the current GQA which only accounts for the presence of indicator organisms. Furthermore, surely species abundances should figure highly in ecological classifications and assessments as changes in abundance can have dramatic consequences for the structure and functioning of freshwater ecosystems just as their presence/absence? For example, declines in the abundance of 'riverflies' can have serious consequences for trout populations in a river, whereas the absence of certain indicator families might make no difference to the trout and overall ecosystem functioning. The WFD is dedicated to addressing these issues.

Quantitative sampling of defined areas of riverbed, using Surber samplers is recommended for surveys requiring estimates of invertebrate density/abundance in operational and investigative monitoring to provide the required levels of precision. Taxonomy to family level is likely to be acceptable in most cases given constraints of time and money, but species level will be required in some circumstances under operational monitoring and in special surveys under investigative monitoring. This is, however, how the Agency operates at present with regard to taxonomy.

Investigative monitoring will be devised to target specific problems, and as it operates currently, it will take whichever approach is necessary to give the required accuracy and precision within the constraints of time and costs. In this sense, therefore, it is likely that investigative monitoring strategies will not change significantly in the future. The ART might have useful input to the implementation of investigative monitoring programmes in the catchments they help manage.

6.0 CONCLUSIONS

It is hoped that this brief paper will inform and guide the ART towards commenting on and contributing to the development of future monitoring programmes that will commence under the WFD.

The Agency's GQAs of watercourses in England and Wales have successfully tackled past problems of water pollution resulting in the substantial clean up of many rivers, but are not adequate to address the modern challenges facing the riverine environment, especially diffuse pollution. The WFD requires that these problems be addressed.

The main issues are that diffuse pollution is more widespread and diverse than point source pollution and is typically episodic with a positive flow related trend. For all parameters, spatial coverage of sites is probably inadequate and will need extending within each RBD.

For water quality monitoring (chemistry and nutrients), sampling frequency and timing is crucial to the precision of estimates of diffuse and episodic loadings of pollutants. Future sampling under the WFD will certainly have to be conducted more frequently than monthly; ideally flow-weighted or storm event based. It is suggested that the most efficient and cost-effective approach would be to use automated water samplers at targeted sites under operational and investigative monitoring programmes. In reality, surveillance monitoring of water quality will probably be a slightly modified version of the current GQA system.

For biological monitoring using macroinvertebrates, sampling frequency is not so crucial as they integrate all conditions experienced throughout their aquatic life stages. What is crucial, however, is precision of the sampling method (quantitative vs qualitative) and the recording of data. The current GQA method is qualitative and does not account for invertebrate abundances in samples. This is considered inadequate for future operational and perhaps surveillance monitoring under the WFD. It has been recently highlighted and has come to public attention that are perhaps serious declines in the abundance of aquatic insect life in rivers across the UK that can be attributed significantly to diffuse pollution. The Agency has largely failed to detect these effects in their GQAs. It is likely that the WFD will consider organism abundances in the criteria for assessing ecological quality and future programmes should record abundances and ideally be quantitative. Quantitative sampling does not increase time and costs above qualitative sampling, what does, however, is taxonomic effort. It is considered that current levels of taxonomy (family level identifications) are adequate for future monitoring except for special surveys.

The monitoring of other organism groups: diatoms, algae, macrophytes and fish is required in addition to macroinvertebrates under the WFD. These might provide further indications of the extent and impacts of diffuse pollutant inputs to the riverine environment.

It is anticipated that the ART will have considerable input to the planning and development of all levels of future monitoring in the RBDs where they are interested.

The huge overall increase in sample collections and processing that is anticipated will mean that the Agency is likely to require assistance in various ways from other capable groups. This could be in the form of assistance with statutory sampling programmes or more likely with special additional monitoring that can further inform of the ecological status of rivers. For the undertaking of biological sample processing, the Agency requires a very high standard of expertise and quality which is controlled by internal and external audit. Analytical quality control (AQC) has been a key to the success of GQAs in monitoring and improving rivers in the past and will be an integral part of all statutory monitoring programmes in the future. Furthermore, sample processing must be conducted in dedicated laboratories that comply fully with the Agency's requirements of Health & Safety and Environmental Policy. The establishment of such a laboratory would be in the region of £100,000 – £200,000. All chemical analyses are conducted in the Agency's National Laboratories.

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