



Evidence

Report of the macrophyte surveying and
variability workshop 4–5 June 2009

Report: SC070051/R5

Integrated catchment science programme
Evidence Directorate

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E: enquiries@environment-agency.gov.uk.

Author(s):

Eliot Taylor (Atkins)
Tim Johns (Environment Agency)

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Chilbrook Office, Oasis Business Park
Eynsham, OX29 4AH
Oxfordshire

Environment Agency's Project Manager:

Tim Johns, Evidence Directorate

Collaborator(s):

Natural England
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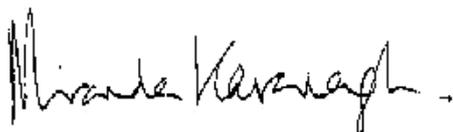
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Miranda Kavanagh
Director of Evidence

Executive summary

Introduction

This report summarises the presentations and discussions recorded at a two-day workshop, held in Wales in June 2009, to consider macrophyte surveying and variability. Macrophyte experts from the UK regulatory and conservation agencies, as well as experts from academic and consultancy organisations, were invited to attend the workshop. The workshop was the culmination of an Environment Agency led project and presented the opportunity for the invitees to examine and question the findings of the project studies on the components of macrophyte variability, carried out by the Water Research Centre. It also provided a forum for discussion on surveying methods, river macrophyte classification and the different surveying needs of the various organisations represented.

The main aims of the workshop were to develop a common understanding on the significance of the different types, sources and influences of variability in river macrophyte survey data; to improve comparability of macrophyte monitoring across the UK; and to work towards common survey method(s), identifying future research needs.

Key outputs

- Any survey method must be 'fit for purpose' and there is no 'one size fits all' method that will cover all needs. While the level of detail required will depend on the overall purpose of the survey the results need to be put into as much context as possible and so contemporaneous information is vital.
- Use of the 100 m LEAFPACS survey method is appropriate for classification of water bodies under the Water Framework Directive (WFD). The adaptation of this method for conservation classification of watercourses is possible, as is the use of a 500 m LEAFPACS survey for WFD classifications – no decision was made as to which might be best.
- There is a need to ensure consistency in the way in which surveys are undertaken and thus a need for a surveyor accreditation process. Some initial designs were proposed which could be integrated into future monitoring programmes.
- It was agreed that more survey work was needed to provide greater detail on the effects of uncertainty caused by temporal and spatial variability. A specific recommendation was developed for the Environment Agency's forthcoming round of WFD macrophyte surveying aimed at addressing this issue.
- Based on the current information on temporal and spatial variability, it was agreed that a single survey per water body was not enough to classify accurately a site for WFD purposes. A number between three and eight sites was proposed.
- A handbook on survey methodology is required for use by all practitioners.

Acknowledgements

We would like to thank all those who participated in the workshop event and those who provided important contributions to the wider project as a whole. Specifically we would like to thank: Andrew Davey and David Garrow (WRc), Nigel Willby (Sterling University), Tristan Hatton-Ellis and Rhian Thomas (CCW), Jo-Anne Pitt, Geoff Phillips, Richard Chadd and Bill Brierley (Environment Agency) and Sarah Clarke (ECUS). Special thanks also go to Catherine Duigan of CCW for chairing a very well-received workshop and to Eliot Taylor of Atkins for facilitation.

Contents

1	Introduction	1
2	Constraining factors and resources	3
2.1	Regulatory agencies	3
2.2	Conservation agencies	3
2.3	Discussion	5
3	The LEAFPACS field survey methodology	6
3.1	Presentation by Nigel Willby	6
3.2	Discussion	6
4	Sampling methods in practice	7
4.1	JNCC method	7
4.2	LEAFPACS method	8
4.3	Discussion	9
5	LEAFPACS – use in the classification of water bodies	11
5.1	Presentation by Nigel Willby	11
5.2	Discussion	11
6	Understanding and quantifying natural variability in macrophyte communities	14
6.1	Presentation by David Garrow	14
6.2	Discussion	14
6.3	Consideration of key questions raised in the WRc report (SC070051/SR4)	15
7	The consequences of variability for macrophyte surveying	20
7.1	Presentation by Andrew Davey	20
7.2	Discussion	20
7.3	Further consideration of key questions raised in the WRc report	22
8	The way forward – results from discussion on ‘key questions’	24
8.1	Presentation by Andrew Davey	24
8.2	Discussion	24
9	Conclusions and recommendations	26
	References	27
	List of abbreviations	28

Appendix 1

29

Appendix 2

33

1 Introduction

This is a report of the workshop entitled 'Report of the macrophyte surveying and variability workshop' that was held at the Lake Country House Hotel in Llangammarch Wells, Powys, Wales on 4–5 June 2009. The workshop was attended by 21 delegates drawn from a range of organisations and backgrounds, the full details of which can be found in Appendix 1. Delegates were drawn from the national conservation agencies, the Countryside Council for Wales (CCW), Natural England (NE) and Scottish Natural Heritage (SNH), although nobody from the latter two organisations could attend. The national regulatory bodies were represented by the Environment Agency of England and Wales and the Scottish Environment Protection Agency (SEPA). A range of nationally recognised freshwater macrophyte experts from academic and consultancy backgrounds were also present. The authors of the technical reports preceding this workshop from the Water Research Centre (WRC) were among the participating delegates.

The main aims and objectives of the workshop were to:

- develop a common understanding on the significance of different types, sources and influences of variability in river macrophyte survey data;
- improve comparability of macrophyte monitoring across the UK;
- work towards common survey method(s);
- identify future research needs.

The workshop was the culmination of Environment Agency Science Project No. SC070051 entitled 'Further Development of River Macrophyte WFD Classification Tool – River Variability Module'. The project started in November 2007 and is due to finish in December 2009 with the report of the workshop the conclusion of the project. It has been a phased study, consisting of the following parts:

1. Collation and assessment of current views on macrophyte variability and sampling methods.
2. An assessment of historical survey data from the Environment Agency, SEPA, CCW and NE. It also included an additional 'case study' of the River Allen.
3. Bespoke field surveys during summer 2008 to collect additional data, plus further assessment.
4. Development and submission of a summary report.
5. Workshop and write-up.

This write-up follows the same format as the workshop, the agenda of which is outlined below. It is accompanied by a CD containing copies of the slides from the various presentations made during the workshop.

1. Introduction.
2. Constraining factors and resources:
 - a. Regulatory agencies
 - b. Conservation agencies and the Joint Nature Conservation Committee (JNCC) methodology.
3. The LEAFPACS field survey methodology.
4. Sampling methods in practice; experience from the field:
 - a. JNCC.

- b. LEAFPACS
- 5. LEAFPACS – use in classification of water bodies for the Water Framework Directive (WFD).
- 6. Understanding and quantifying natural variability in macrophyte communities and discussion on key questions raised in the summary report (SC070051/SR4):
 - a. Are there any additional questions to those in the WRc summary report?
 - b. Are the results in agreement with practical experience?
 - c. What are the main sources of variation in macrophyte monitoring data?
 - d. How significant is measurement error (operator variability) and how can it be minimised?
- 7. The consequences of variability for macrophyte surveying.
- 8. Discussion on further key questions:
 - a. Can measurement error produce a biased result?
 - b. What is the optimum spatial and temporal sampling strategy?
 - c. How many surveys are adequate to characterise the status of macrophyte communities in a water body?
 - d. How long should each survey length be?
- 9. The way forward – results from discussion on ‘key questions’.

2 Constraining factors and resources

2.1 Regulatory agencies

Dr Jo-Anne Pitt from the Environment Agency made a presentation, summarised below.

A central problem is that there are thousands of water bodies that need monitoring, but we have only tens of ecologists to do this work. Furthermore, the agencies do not have much money and are likely to have even less in the near future.

There is a need for the agencies to be clear about what they want to achieve and for them to get best value for money, or preferably best value per ecologist.

Monitoring of macrophytes has to be balanced against monitoring of other elements, such as macroinvertebrates, fish and so on. The agencies need to be clear about what they want to use macrophyte data for. This has changed over the years from assessing impacts, such as surveys done for the Urban Waste Water Treatment Directive, to playing a part in the overall ecological assessment of an entire water body. They also now need to define the confidence they have in their results.

One of the key issues for the agencies with regard to monitoring in general, not just for macrophytes, is that water bodies as they have been defined in the UK under the Water Framework Directive have not been defined ecologically, that is, on an ecological basis. They also vary enormously in length and are subject to multiple pressures.

The agencies need to be clear about what they need to do by way of survey for them to get a representative result. They need to know what the minimum requirement is in terms of how long surveys need to be, how many need to be undertaken and how often (as well as where and how quality will be controlled) in order for the results and interpretation of the data collected to 'stand up in court'. Issues of comparability between surveys and of quality control and assessment are also important. Once agencies have this information they will be able to know the resource needed to deliver what is required, to match this to the resources in hand, focus and prioritise their efforts to ensure that they are not gathering data they don't need and won't use.

One of the key questions in relation to the stated objectives of the project and workshop (in particular 'work towards common survey method(s)') is 'what do the regulatory agencies want that is different from what the conservation agencies want?'

2.2 Conservation agencies

Tristan Hatton-Ellis from CCW made a presentation, summarised below. This covered both the conservation agencies' perspective and an introduction to the JNCC survey methodology.

Conservation agencies survey water bodies for macrophytes for a number of reasons, for example, in order to select appropriate, as well as monitor the status of, Sites of Special Scientific Interest (SSSI) and sites designated under the Habitats Directive.

They also need to develop a general understanding of the river environment at such sites in order to assess issues such as:

- Is it (still) driven by natural processes?*
- Have human impacts/pressures increased or decreased?*
- Is it (still) representative of its type?*
- Are important or rare species (still) present?*

The key principles for conservation agencies are that it is important that any monitoring undertaken is linked to site management and has a consistency of approach, for example, using the Common Standards Monitoring (CSM) guidance (JNCC 2005), but with specific targets adjusted to match needs/designation of site. It is also important that site managers can use monitoring results and they also need good quality evidence, of things such as deterioration, to convince others to take (often expensive) action.

The challenges that conservation, and other, agencies face with monitoring are that problems in freshwater systems are not always immediately apparent and are sometimes hard to detect, such as pollution, and also that stresses are often episodic, such as floods and droughts or algal blooms. In addition to these external factors, there is also natural variation which is not well understood and for which better long-term datasets are needed to aid interpretation.

Opportunities exist, however, using existing monitoring programmes, mainly run by the Environment Agency. If there could be a redistribution of resources to meet Water Framework Directive needs and possibly an integration of monitoring methods and use of similar tools then both the conservation and regulatory agencies could mutually benefit.

Constraints to the above are that resources are often limited and the agencies often have insufficient monitoring staff in-house to carry out the required work, usually combined with restricted and/or variable funding. Freshwater work is also often complex and quite specialised, requiring training and particular equipment. Freshwater monitoring also requires careful planning, as well as a commitment to the long-term, and it is essential that results are properly written up and appropriately archived.

The requirements of the different agencies vary. For example, CCW has a 6-yearly planning cycle, during which time it needs to ensure that all features and sites are covered at least once. As with most agencies, CCW would also like to see efficient coordination of monitoring work at a national level as well as an agreement of the roles and responsibilities of the different agencies. CCW has a ring-fenced monitoring budget over a 6-year cycle and thus can continue its own monitoring work but, nevertheless, would like to see sharing of information and data as well as of actually monitoring to determine condition assessment.

The JNCC survey method for macrophytes which adheres to the CSM guidance was outlined and discussed, together with the pros and cons of the JNCC method. The benefits of using the JNCC method are that it is used to derive river typologies (Holmes 1983; Holmes et al. 1999) and as such has a direct link to SSSI features. There is also a large dataset available for this method and this allows extensive spatial and some temporal comparison. Many surveyors are familiar with use of the methodology and the long (500 m) survey length should reduce effects of natural spatial variations in macrophyte communities. The method also records both aquatic and bank species, although the bank species information is probably not adequately used. Finally, the method uses a clear and reasonably concise checklist and is taxonomically robust. The disadvantages of the method are that it was not originally designed for monitoring (rather for river classification) and that the method is not clearly described or enforced and no specific training in its use is provided/available. Indeed, there are some indications that different practitioners have developed different habits in implementing

the survey method. This, combined with the fact that the long survey length may also increase inter-operator variation (especially for estimating cover scores), may lead to greater variability in the results of JNCC surveys. It was also suggested that the small number of cover values available in the methodology may not be adequate for some purposes and that the method could perhaps be improved through the addition of performance indicators.

The JNCC survey is used to determine whether the macrophyte community at a site has achieved certain targets, of which there are seven. These targets are generally perceived to be too stringent (on the basis that many sites often fail to achieve them), the reasons for which are fourfold:

- 1. River types are poorly defined, adversely impacted and/or naturally unstable.*
- 2. There is high inter-annual variability in the presence and/or cover values of specific species (actual or perceived).*
- 3. Inappropriate values are often set for some of the seven targets.*
- 4. There is inconsistent taxon and cover recording between surveyors.*

Currently, the Freshwater Lead Coordination Network is reviewing the JNCC method and may amend the field method, especially if there are obvious benefits in doing so, for example development of a shared field method with the Environment Agency and SEPA. Amendments to the targets and/or performance indicators are also proposed in order to improve their reliability.

Similarly to the regulatory agencies' views, the key questions for the conservation agencies are:

- 1. What is the best method for collecting information about river plant communities?*
- 2. Once agreed, how should this method be deployed along a river system (i.e. how many sites and of what length should be surveyed and how often)?*
- 3. Having collected it, what is the best way to analyse the data to make the case that is needed (i.e. in the case of the conservation agencies, inferences about the conservation condition of rivers)?*

2.3 Discussion

The fact that the JNCC method was devised for the purpose of conservation assessment, and that now this method and the data collected from it are being used for another purpose (i.e. ecological status assessment), was identified as an issue. It was emphasised, however, that if a single method were to be adopted for overall use, protected sites (e.g. SSSIs, Special Areas of Conservation) can still be treated differently under the WFD.

There was a discussion on the 'boundaries' of the methods, that is, the extent to which they take in the flora of the margins (banks). It was agreed that the methods were focused on, and designed to primarily work with, the in-stream flora but that they should also take into account those plants present on the margins up to a certain level (depth) and frequency of flow (e.g. bank-full flow and Q50).

It was also recognised that the WFD's remit is wider than just the river channel, despite the current focus only on the channel, and that certain organisations such as CCW are taking advantage of this and starting to look at and work on floodplains. This work is being undertaken in conjunction with other organisations in order to share resources.

3 The LEAFPACS field survey methodology

3.1 Presentation by Nigel Willby

Nigel Willby from Sterling University gave a presentation on the development and application of the LEAFPACS methodology. This detailed presentation is presented through the slides provided with this report (on the attached CD).

3.2 Discussion

One view was that as 'high status' rivers were determined by their aesthetic values, and not by any direct measure of ecological or conservation value, they would never be able to achieve a scientifically measured good, or high, ecological status. Another view was that, with regards to the reference set used to determine predicted values in LEAFPACS, there are problems with the existing data; for example, there are big geographical holes, especially in the upland areas, and this would also affect the ability of sites to achieve good status. On the latter point it was proposed that modelling, using the existing data, should be able to address such issues.

A final point was made in relation to the occasional paucity of monitoring locations (and associated data) in some areas. Agencies need to be careful about the number and location of monitoring points and how they then interpret the data they collect; an example of this would be the danger of using a single downstream sampling site to determine what might be the status of all upstream sites.

4 Sampling methods in practice

4.1 JNCC method

Sarah Clarke from ECUS gave a presentation on the application of the JNCC method and a practical view on the project survey field work, from a consultant's point of view, as summarised below.

Variability in macrophyte survey results between sites, seasons and surveyors was investigated on behalf of CCW by survey of six sites on the River Dee, Wales, in 2008. Macrophyte survey of six 500 m sites on the River Dee was undertaken in July 2008 and then again in September 2008 by the same surveyor. At two of the six sites a further three surveys were undertaken during the same period in July by separate surveyors. All surveys were undertaken independently but within a nine-day period of each other.

Survey at each site consisted of one 500 m JNCC macrophyte survey and five contiguous 100 m LEAFPACS surveys. The sites were selected along the length of the River Dee between Bala and Wrexham and comprised a mixture of bedrock-dominated sites with rapids and riffles, sites with riffle–run/glide sequences over cobble/pebble substrate and sites with long, deep glides towards the downstream end of the study reach.

In order to achieve a realistic estimate of extent of inter-surveyor variation, all four surveyors were JNCC accredited river macrophyte surveyors for both upland and lowland rivers with previous experience of the methodologies used but working for four separate consultancies, as surveyors from the same company or organisation are more likely to have similar training histories and working methods. Surveyors were asked to spend the same amount of survey effort as they would for any other surveys using these methodologies and, therefore, equipment, time taken and bank level were not standardised across surveyors. River lengths surveyed were standardised with help from an assistant familiar with the sites.

In the field, four main sources of variation between surveys were noted:

- *survey effort;*
- *definition of bank and channel area;*
- *water levels;*
- *species lists.*

Variation in survey effort included differences in the time taken for survey, equipment used, and the skill and experience of the surveyor. During these surveys the equipment used by different surveyors was a large factor in determining the extent of channel surveyed, with one surveyor using a dry suit, snorkel and mask to cover the entire channel while the other three surveyors use chest waders and bathyscopes or polarised glasses and were limited to the area of channel safe to wade.

While making every effort to complete the surveys according to the brief of the project, the surveyors found the six separate surveys within one 500 m stretch caused mental fatigue and it was therefore difficult to keep surveys independent and expand the same amount of survey effort throughout.

Definition of channel and bank areas, as described by the respective survey methodologies, requires a judgement of the flow regime of the river to be made by the surveyor. This judgement can be affected by flow conditions on the day of survey and is likely to become more accurate the more familiar the surveyor is with the site. As

such, species 'missed' by one surveyor but recorded by another may just be a reflection of the judgement of channel and bank extent and variation in species richness between surveyors could therefore be due to differences in recording effort within the same area or differences in judgement of the area to be surveyed. In this project the extent of survey up side bars in particular may have been a factor in inter-surveyor variation.

Flow, in terms of both velocity and water level, can affect the area of channel accessible to survey. However, the extent of this effect can depend on the equipment used and the character of the site. Water levels may also influence surveyor judgement of channel and bank areas. During this project water levels were relatively high during both survey periods (July and September) due to a very wet summer. It was also noted during the September surveys that the water levels did not seem to be as expected to result from the weather conditions immediately previous to and during the surveys, which could be due to the highly regulated nature of the river. Therefore variation between seasons detected during this project may not be representative of variation that might be seen on a river with a more natural flow regime or during a more 'typical' year in terms of weather patterns.

A further source of variation between surveyors was the use (or non-use) of species lists. Both JNCC macrophyte and LEAFPACS surveys have standard lists of taxa to be recorded. However, in practice surveyors do not tend to take out pro formas that include every taxa from the standard lists, as flipping through numerous pages of forms is both time-consuming and fiddly. Therefore, if surveyors are regularly using different survey methods it can become difficult to remember what needs to be recorded to which taxonomic level for different surveys. Due to the recording of cover scores rather than percentage abundance it was found to be difficult when entering the data gathered for this project to amalgamate individual species/subspecies records where these had been collected rather than the more general taxa groups required for entry into standard spreadsheets to generate scores or river types.

Sticking to standard lists can mean collecting less data, especially on distribution of rare species, thereby potentially reducing the value for money of the survey. In practice therefore surveyors collect data above and beyond the lists and these 'additional taxa' are to some extent determined by individual interests and competencies. It is important that the standard data capture spreadsheets allow for collection of data to different taxonomic levels in order that any extra detail collected can be included in national datasets to ensure that such information is available for future analysis and method development.

Specific comments were made in relation to the 2008 survey on the River Dee. It was strongly emphasised that the unusualness of what was asked for in the context of the River Dee surveys in 2008 (i.e. 1 x 500 m JNCC survey followed by 5 x 100 m LEAFPACS surveys over the exact same site) led to unique problems with surveyor fatigue. Other issues raised with this specific work was that it was impossible for surveyors to forget what they had found earlier and thus not to be biased in the way they surveyed. There was a strong recommendation not to repeat this exercise, contrary to such a suggestion made in the WRc reports, as it was far too hard and simply not comparable with, or realistic in relation to, the usual surveying situation.

4.2 LEAFPACS method

Richard Chadd from the Environment Agency gave a presentation on the application of the LEAFPACS method and a practical view on the project survey work from a regulator's perspective, as summarised below.

- *A primary source of error, as is well known, is the visibility of the bed and associated macrophytes to the surveyors. Factors such as depth, width, turbidity, turbulence, shade and presence of overlying dominant taxa cannot be factored out by the use of multiple surveyors, but only (in part) by the use of tools to improve the visibility (bathyscopes, underwater cameras, polarising glasses or physically diving to depth). By nature, such sites will always produce data with a lower level of confidence. It is recognised that the LEAFPACS protocols acknowledge this problem, but, in practical terms, the error cannot be completely factored out and could be substantial.*
- *Embedded within this is the necessity for an operator to find taxa present in very low cover classes. Many contributing bryophytes, for example, may be present as extremely small, single plants, which require the efforts of a specialist to detect. It is arguable that protocols designed to detect coarse ecological state do not require resolution of the macrophyte community to fine levels of accuracy, so perhaps all plants present in cover class 1 (<0.1% cover) need exclusion from LEAFPACS analysis, thus reducing operator differences.*
- *The general fastidiousness of the surveyors is also a factor. Time pressures, weather, time of day, and so on, will all influence the care exercised during survey. The underlying interest will also play a part, when one considers that staff employed by the regulatory sector are, by necessity, generalists. Any two staff may have different levels of interest in the work, and so exercise differing levels of care. This, in turn, influences, and is influenced by, the factors discussed above. A fastidious operator may invest a lot of time in attempting to find single, tiny plants; a less fastidious one will be less inclined to get a good view of the reach.*

4.3 Discussion

The pros and cons of the different survey methods were considered, as well as the purpose for which the survey was being undertaken and the overall consensus was that there is no 'one size fits all needs' method that can be used.

The survey method used in any particular circumstance has to be driven by the purpose of the survey and must be clear at the outset; for example, is it being done for conservation value assessment, general ecological health assessment or the determination of the presence/absence of rare species? Conservation agencies should do bespoke surveys for rare species if necessary; this is part of their remit.

The need to record, and indeed the possible effect of recording, rare species (whether as in national conservation status or relative cover value at a site) was discussed. It was agreed that it is, for example, important to record such things if the purpose of the survey is to assess plant community conservation and/or conservation status of rivers but less important if it is to determine the ecological status of the site. In LEAFPACS, for example, the presence of rare or small amounts of one plant on the metrics the method produces should be reduced through the use of cover scores.

A standardised reference list of taxa likely to occur was suggested. This would be of benefit in improving sampling standards. But concerns were expressed over the risk of less experienced surveyors possibly being tempted to record species as being present, simply because they appear on such a list. Similarly, the possibility of misidentification of taxa, because they do not appear on the list, was also raised. An example of this is illustrated by the liverwort *Radula*, which could be accidentally recorded as another genus (such as *Nardia* or *Scapania*) because it does not appear on a list, and less experienced surveyors may be unaware of it as a possible taxa to record. On balance it was generally felt the benefits of a standard list outweigh the disadvantages of not

having a list. However, it was acknowledged that there also needs to be some flexibility for surveyors to be able to record and add additional taxa, or 'add-ons', they find. In this way survey methods and taxa lists may evolve over time.

The issue of accreditation of surveyors was also raised and is one that will be returned to later in this report (see Section 5.1.3).

5 LEAFPACS – use in the classification of water bodies

5.1 Presentation by Nigel Willby

Nigel Willby from Sterling University gave a further presentation on LEAFPACS, focusing more on its use in classification under the Water Framework Directive. This presentation can be viewed through the slides provided with this report (on the attached CD).

5.2 Discussion

Discussion centred on three main areas, namely:

1. LEAFPACS metrics.
2. Other factors that need to be recorded in surveys.
3. Accreditation.

5.1.1 LEAFPACS metrics

It was agreed that a number of factors strongly affect macrophyte communities, the strongest of which are alkalinity and slope, and that nutrients also play an important role. The River Macrophyte Nutrient Index (RMNI) metric tries to measure this latter impact. It was agreed that it is important for those interpreting LEAFPACS results to not only understand, but also to be able to distinguish as much as possible between, the different factors affecting macrophyte communities. In certain parts of the UK, pH and acidification are also key pressures and it was agreed that this would be picked up by LEAFPACS through a reduction in the total number of taxa recorded (NTAXA). The need to constantly improve methods was also raised; for example, refinement of mean trophic rank (MTR) scores.

Discussion shifted to questions as to how effective efforts to ameliorate nutrient enrichment or acidification were, and whether monitoring using LEAFPACS could be used to demonstrate this. It was agreed that, other than in lakes, it was difficult to say how effective mitigation has been and that, generally speaking, sustained improvement had not been shown. However, it was also agreed that there was no reason why LEAFPACS would not demonstrate an improvement over time if mitigation were successful. It was also emphasised that macrophytes, especially bryophytes, can be used as bio-indicators.

5.1.2 Other factors that need to be recorded in surveys

Shading was suggested as an important factor affecting macrophytes that is currently not recorded on data entry sheets. It was agreed that shading is important and that there are many different types. It is, however, very difficult to measure and it impacts different plants, in different rivers, in different ways. A number of suggestions were made as to how it could be measured, such as measuring the openness of macrophytes to the sun directly above them. No specific conclusions were reached on

how it should be measured or indeed whether it needed to be recorded at all. But it was agreed, that as much contemporaneous information should be recorded as possible (or that was sensible to record in a cost-effective way) so that results could be put into context once presented and that all factors affecting macrophyte communities could be adequately considered.

5.1.3 Accreditation

In the WRc reports and the presentations at the workshop, people are referred to as 'accredited surveyors' but the question was raised as to what they are accredited in? Currently, there is only a 'pseudo-accreditation' system, delivered by Nigel Holmes, in plant identification skills, but there is no training or accreditation for surveying. It was agreed that the current approach is flawed and that better assessment and accreditation methods are needed for the purposes of delivering work for the WFD as well as for the broader monitoring requirements.

It was agreed that it was important to make sure that any accreditation system developed is used to test surveyors' abilities to survey. In other words, it should test their knowledge of survey methods and how they would go about surveying under different circumstances in different rivers, rather than testing their results from any particular survey. It was also agreed that good surveyors would be created over time by implementation of an iterative approach to testing. Surveyors and examiners working together, comparing results and repeating this over time until surveyors are adequately trained, was felt to be the best initial approach.

The issues of who would be responsible for providing accreditation and who could/would accredit accreditors were also raised, although no firm solutions were proposed. It was agreed that surveyors needed to achieve a minimum acceptable standard of competency for survey, and that this could be achieved through peer review.

A specific method of providing accreditation, based on the 'ring-testing' method currently used for accrediting diatom workers, was suggested. Pre-agreed and set sites would be surveyed by an expert group, and then trainees and those seeking accreditation would also survey the same site and their results would be compared with those of the experts;¹ if they were within an agreed margin of error, they would achieve accreditation. In order to reduce the cost of this, it was proposed that possibly only one expert would need to attend each site (rather than a panel) but this was not agreed universally, with others adamant that more than one expert must attend. It was envisaged that this service would be free for members of the regulatory and conservation agencies but that consultants should pay for the service. The testing sites would be standard and located regionally and the expert 'panel' would move around to meet those seeking accreditation. It was agreed that this approach would be useful in general but that the details would need to be worked out. For example, issues were raised such as the expert panel survey possibly releasing silt into the water, obscuring species for those seeking accreditation, as well as some species disappearing and others appearing between the expert and trainee surveys. These issues were discussed but not universally agreed as necessarily relevant. Overall it was agreed that if a British Standards Institution (BSI) approach could be confirmed then this would overcome such issues and give the accreditation process the required gravitas.

Ultimately, however, all agencies would have to accept that there will always be some error in the data collected. It was emphasised that macrophyte surveys are in fact

¹ For the ring test to act as a quality control the experts would also need to be tested; this could be done by them collecting comparable survey data to establish the norm or acceptable range of variation in RMNI scores obtained on the same river sections, repeated at an agreed frequency.

samples of rivers, in the same way that macroinvertebrate samples are. Therefore a single survey/sample will never completely and accurately reflect the true conditions at a site, or indeed within a water body as a whole.

6 Understanding and quantifying natural variability in macrophyte communities

6.1 Presentation by David Garrow

David Garrow of WRc gave a presentation on the variability work that they have been engaged in as part of this project, as summarised below.

The presentation began with a brief overview of the four components of variation in macrophyte surveying (Spatial, Temporal, Operator, Spatial-temporal), the three datasets analysed and the indicators studied (EQR, RMNI, NTAXA, %Cover, Squared Chord Distance).

The presentation then focused on the results derived from the analysis of the datasets in the three work programmes. Spatial variation in macrophyte communities appears to be much higher than temporal variation, and is dominated by variation among reaches, with relatively little variation among sites within a reach. Analysis on the River Allen suggested that spatial variation increases with distance between sites before levelling off at a plateau. However, the applicability of the River Allen results to other water bodies is uncertain.

Operator variability also appears to be a considerable source of variation. Analysis of LEAFPACS surveys performed in 2008 revealed that operator variability can contribute significantly to variability in estimates of taxonomic richness and plant cover, and to a lesser extent to variability in community metrics such as EQR and RMNI.

6.2 Discussion

This discussion essentially consisted of a question and answer session on various details of the WRc reports. This is summarised below, with further details provided in the final WRc summary report (SC070051/SR4).

Q. Do the variograms show accurately whether or not there was a lot of variation as they are? Would they be better presented from 0–1?

A. This information is in the other reports but not in the summary report.

Q. Was the statement that measurement error could be reduced, an assumption or had it actually been measured?

A. It was an assumption.

Q. (Statements) The results that suggested that paired surveying may be better than lone surveying may well have been affected by the different nature of the Dee and Tern rivers where the surveys were undertaken and the nature of the surveying teams (Environment Agency pairs versus lone consultants).

A. Agree – more research is needed here but some were encouraged by the results as except for NTAXA variation between surveyors was pretty low although metrics do even out variation.

Q. Did the analysis look at how macrophytes vary along the length of the river as a source of variation?

A. Yes, use of the square chord data did this.

Q. Did you look at the variation caused by use of different equipment by different people and by more and less well-experienced surveyors?

A. Yes. No single person had significantly different scores from anyone else. The River Dee data was based on work done by a combination of very experienced and less experienced surveyors and there was little variability between them.

6.3 Consideration of key questions raised in the WRc report (SC070051/SR4)

This session started to consider the key questions raised in the WRc report (SC070051/SR4). The questions considered in this session were:

1. Are the results in agreement with practical experience?
2. What are the main sources of variation in macrophyte monitoring data and what are their relative importance?
3. How significant is measurement error (inter-operator variability) and how can it be minimised?
4. Are there any additional questions to those in the WRc report?

The outputs from these discussions are outlined below.

6.3.1 Are the results in agreement with practical experience?

The answers to this question were both positive and negative.

On the positive side, delegates felt that the results were in agreement with their experience and that the levels and kinds of variation recorded in the report matched those they expected. Specifically:

- NTAXA and cover values varied the most;
- spatial variation was higher than temporal variation;
- river size and type had an influence;
- survey equipment affected the results;
- teams were better than individuals;
- provision of training and accreditation would lead to more consistent results;
- operators had big impact, especially on NTAXA;
- inter-operator variability needs to be minimised.

On the negative side, delegates were surprised that the results did not seem to capture certain issues. For example, the delegates would have expected greater seasonal variation (although they acknowledged that the lack of this may well have been due to the nature of the year (2008) in which the surveys were done).

6.3.2 What are the main sources of variation in macrophyte monitoring data?

Delegates agreed that the summary report clearly identified and analysed the main sources of variation but that it had failed to identify the causes of these, especially those relating to inter-operator variability. It was agreed that if more information was available on the causes then they could be addressed.

The delegates identified and discussed the main causes of variation; this discussion is captured in the following sections.

Difficulty in defining survey boundaries

The problem of accurately defining the boundaries of each survey site was discussed. Each survey is supposed to include the channel and that part of the bank that might be wetted under varying flow conditions (Q50 or Q85). It was agreed that identifying that section of any particular channel that might be wetted under such different flow conditions was very difficult.

Use of checklists

Although it was generally agreed that surveyors need checklists in order to undertake surveys effectively, it was also felt that there is a temptation to include species in a survey because they are on a checklist even though they may not actually occur at a particular site, and that this was especially the case for less experienced surveyors. It was also suggested that the constant changes to species names were causing problems and that more complicated nomenclature exacerbated variability in NTAXA. It was proposed that the use of standardised lists and functional groups would help and might also reduce variability in NTAXA. The possible need to create bespoke lists for specific types of rivers and/or survey types was also raised. Discussion moved to consider whether or not it was possible to reduce checklists down to a required 'bare minimum' that would work for all surveys with all other species simply recorded as 'add-ons'. The possibility of working at higher taxonomic levels, such as genus, family, order and so on, to reduce misidentification and thus NTAXA variability, was also explored. Generally, however, it was agreed that the higher the taxonomic level used, the more meaningless the data recorded becomes, but it was also agreed that it was better to have more surveys done with a low level of resolution than to only have a few with a high level.

Differences between operators

This is a significant source of variation and one of the largest recorded sources of error. This variability may stem from areas such as differing levels of experience and the use of different equipment to conduct surveys.

Differences in scale

This was agreed to be a source of variability for the data analysed for this project and for the specific surveys undertaken in 2008 where comparisons were made between 100 m and 500 m survey lengths. It would, however, obviously not be a source of variation for a set of surveys using the same methodology as the scale (length) of the survey site would be the same for all sites.

The discussion over the impact of scale (survey length) on variability in results then also led to a discussion over exactly what is needed in terms of survey length and frequency, to characterise accurately a water body, for WFD status for example. The question was asked as to how many 100 m surveys were needed per water body in order to classify it accurately. It was queried as to whether three, as is indicated in the LEAFPACS methodology, was enough.

There was also discussion about at what spatial scale variability issues apply; for example, is there the same level of error in a 500 m survey as in a 100 m survey – opposite views on both were expressed. There was also discussion as to whether it would be better if 500 m surveys were spread over a larger scale and divided into separate 100 m surveys instead. As an example, outcomes of the analysis of the River Allen survey data were referred to where results suggest that a single 100 m survey every 800 m along the river would provide the most accurate picture. It was, however, also agreed that this would not be the case for all rivers.

The overall conclusion was that the ideal arrangement of survey sites and lengths probably depended to a large extent on the nature of the water body/river being surveyed and the purpose of the survey. In general, there was an agreement that three 100 m surveys per water body would probably suffice for WFD classification but that where there was certainty over the water body's status (WFD class) then less surveys would be needed for this particular purpose. Whether more surveys were needed in a water body whose status was unclear, that is those that fall very close to the boundary between the Good and Moderate classes, was open to some debate.

The presence of rare and/or low cover value species

The question was asked as to whether this was really a big source of variation in results. It was agreed that this specific factor was strongly influenced by operator experience and ability, as more-experienced surveyors would be likely to find and record more species, including rare and low cover ones. It was suggested that this issue could be addressed through the use of a weighted scoring system that gave relatively less importance to such species. Such a system would also reduce influence of bank side species on a site/water body's overall classification.

Inter-annual variability

It was suggested that the current reports had not adequately covered the issue of inter-annual variability on macrophyte data, such as the impact of flood and drought year on year. It was proposed that this source of temporal variability needed to be better assessed and reported on.

Inter-operator variability

It was agreed that there is a lot of variability in NTAXA due to inter-operator variability, and that if inter-operator variability could be reduced then so would variation in NTAXA. It was questioned as to whether NTAXA could possibly even be disposed of as a measure and variable in WFD classification altogether (i.e. develop an Environmental Quality Ratio (EQR) that does not use NTAXA). This was discussed, but as it was generally agreed that, except in high alkalinity rivers, NTAXA does not actually contribute much to the EQR it did not need to be removed from the classification method.

6.3.3. How significant is measurement error (inter-operator variability) and how can it be minimised?

All delegates agreed that this is a significant source of variation and that it needs to be minimised. The following suggestions were made as possible ways in which this might be achieved.

Training and accreditation

The urgent need for the development and implementation of a rigorous and approved training and accreditation system (developing and using a standard approved by the BSI) was discussed. This issue is covered in more detail elsewhere in this report (see Section 5.1.3).

Ensuring consistency in use of equipment

It was agreed that there should be consistency in the use of equipment between surveyors and survey sites, and especially in repeat surveys at the same sites, but it was also agreed that the kind of equipment needed at one site may not be needed at all sites. For example, a dry suit which is almost essential in a deep, fast-flowing river would not be needed in a stream 20 cm deep. Equipment should be standardised for the purpose at hand.

Use of paired surveyors

The use of pairs of surveyors, as opposed to lone workers, to undertake macrophyte surveys was discussed. This was based on the fact that there is some evidence in the WRc reports to show that paired surveyors produce more accurate results than lone workers. The relative merits of paired surveys versus lone surveys were explored. For example, it was agreed that although it is possible to do more surveys with lone workers, and thus produce more data, this approach raises Health and Safety issues and emphasises the need for operators to be adequately trained and accredited. It was agreed that fewer surveys done properly by accredited surveyors would be best if the aim of a survey was to characterise a single site/section of river. If, however, the aim was to classify a large area, such as a WFD water body, then more surveys would clearly be better. With regards to paired surveys, concerns were raised over the cost implications of such an approach. It was suggested that pairs could consist of one experienced, qualified and accredited surveyor and one less experienced field operative. The problem with the latter was that this may negate the initially purported benefits of surveying in pairs.

Changing the way LEAFPACS works

The idea here was that some of the variation produced from inter-operator variability might be negated by the use of slightly different metrics in LEAFPACS. Suggestions were made that the existing metrics might be calculated for and used at reach rather than water body scale. It was also suggested that the use of 'weighted scores' would reduce the influence of NTAXA in the calculations and thus also reduce the impact of rare species (both in terms of abundance and conservation status) on the final outcome. Another suggestion was to use average, rather than summed, data. Although these ideas were discussed, there was no firm suggestion or proposal to change the current way in which LEAFPACS works.

Defining WFD water bodies on an ecological basis

One of the main criticisms of the approach that has been taken to determining the boundaries of water bodies under the WFD in the UK is that they have not been defined on an ecological basis. It was felt that if water bodies were redefined using ecological criteria this would reduce other variability, such as that of operators, created during their surveying.

6.3.4 Are there any additional questions to those in the WRc report?

The general consensus here was that the WRc report had covered all relevant questions and that there were not any others.

7 The consequences of variability for macrophyte surveying

7.1 Presentation by Andrew Davey

Andrew Davey of WRc gave a presentation on the consequences of variability for macrophyte surveying, as summarised below.

The presentation began with a brief recap of the key findings from the WRc work programme before focusing on four key questions included in the WRc summary report (SC070051/SR4). These questions were:

- *Can measurement error yield a biased result? This is unlikely for LEAFPACS surveys and more likely for JNCC surveys at the sub-target level.*
- *What is the optimum spatial and temporal sampling strategy? This depends upon the scope and aim of the monitoring programme. Simulations have been run using the River Allen data and CAVE tools. To classify a water body, the optimal strategy is to get as much spatial and temporal coverage as possible (i.e. surveys in replicate reaches, years and months) but this may not be the most cost-effective strategy.*
- *How many surveys are adequate to characterise the status of macrophyte communities in a water body? Again, these have been analysed using the River Allen simulations and CAVE tool. The number of surveys depends upon the required precision of results and confidence in the classification. Increasing the number of surveys will improve the precision with which status is assessed, but at a diminishing rate of return.*
- *How long should each survey length be? A length of 100 m is fine for LEAFPACS surveys but the risk of false failures will increase for JNCC surveys as the length decreases.*

7.2 Discussion

Following on from the presentation, a question was raised as to whether it might be better to use the model, derived from the River Allen data and outlined in the WRc report (SC070051/SR4), as a way of choosing the number of surveys required to classify each water body. It was suggested that this approach might be better than the 'upturned wok' model developed previously by WRc.

The stability and uniformity of the River Allen dataset – as compared with many other rivers, especially upland ones – together with the fact that not all species present were recorded in the River Allen surveys were raised as factors that might count against using the model in a wider context. It was emphasised that the River Allen data was only used to show the difference between using this approach and using other, different approaches. It would in fact be possible to combine the River Allen analysis done here with the 'upturned wok model' if it was felt that there was mileage in such an approach.

The effect of survey length on RMNI was then considered. A suggestion was made that a comparison should be made between data derived from a range of different types of rivers to show the impact on RMNI of differences in survey length.

Comparisons were drawn between the use of average score per taxon (ASPT) in macroinvertebrate surveys and RMNI in macrophyte surveys. With macroinvertebrates surveys, it was pointed out that in general the more samples taken the higher the ASPT, demonstrating a directional bias. However, the same bias does not exist for RMNI scoring taxa.

Ultimately, it was agreed that as the LEAFPACS reference metrics were based on 100 m surveys, that practitioners must stick with this now, although it was also highlighted that LEAFPACS could be altered to deal with 500 m survey lengths if needed, but that this would need to be accounted for in the reference metrics. Conversely, it was highlighted that the JNCC methodology could be readapted to work on 100 m survey lengths although, if this was to happen, the conservation agencies would need to completely rewrite their macrophyte targets to accommodate for this change.

It was agreed that the current report showed little difference between the possible variability caused by temporal and spatial differences as factors, but that it might be easier to see this more clearly if more separate surveys were done at a range of fixed sites that are sampled year on year. It was agreed that if the purpose of surveying is to detect long-term change, then surveys should be repeated at the same site at the same time over many years and thus that the WFD water body classification process and determination of long-term change need separate sampling and analysis strategies. In undertaking such analysis, one would, however, have to ensure that surveyor error was not masking any other changes.

Reference was also made to Figure 3.3 in the WRc summary report (SC070051/SR4) and it was suggested that the analysis presented in this figure could be redone for different rivers and different years. In doing this, it was also suggested that other datasets could also be explored in the analysis, such as those held by Nigel Holmes or Nigel Willby.

Another area of concern was raised regarding the relative uncertainty of the various predictor variables such as alkalinity. These are based on a set of data, but clearly there is the potential for much variation around these figures. A future need to quantify the scale and importance of such variation was raised.

It was highlighted that the derivation of EQRs needs reference metrics and that these also each have their own associated variability and uncertainty. Delegates felt that it was important to know where these uncertainties lay and how significant they were; for example, how do they compare with the uncertainties created by inter-operator variability. Nigel Willby agreed that the error associated with these reference metrics could be calculated and stated in the LEAFPACS manual.

It was further agreed that it was important that those undertaking classifications are not tempted to change the predicted variables, such as alkalinity, based on their 'one-off' survey results. It is vital that those undertaking classifications use the original value determined for the site, as this reflects real conditions at a site or in a water body.

7.3 Further consideration of key questions raised in the WRc report

This session continued to consider the key questions raised in the WRc report (SC070051/SR4). The questions considered in this session were:

1. Can measurement error produce a biased result?
2. What is the optimum spatial and temporal sampling strategy?
3. How many surveys are adequate to characterise the status of macrophyte communities in a water body?
4. How long should each survey length be?

The outputs from these discussions are outlined below.

7.3.1 Can measurement error produce a biased result?

It was agreed that it is possible for measurement error (incorrect species identification), to produce a bias in the survey results. There was also some concern that the relative difficulty or ease of accessing certain river habitats, for example derived from the differential use of surveying equipment such as a dry suit and snorkel versus waders and viewing scope, might also bias the result. Experienced surveyors using dry suits and other equipment, who are able to access microhabitats and discover, identify and record small quantities of less common or rare species, such as bryophytes that tend to have lower scores, could well bias results.

The importance of site selection in biasing results was also discussed, in that the nature of the site chosen for surveying, and thus classifying, a water body will affect the overall ecological status that it is given. It was agreed that it was important to incorporate a range of factors in site selection within a water body, such as including both impacted and unimpacted sites. There was also a consensus that more training on such issues, and the impacts that they might have on the overall outcome of classification, is required for those people responsible for choosing sites for survey.

The degree of measurement error also depends on a number of other factors, such as river type and complexity and the ability and enthusiasm of the surveyor, and on-the-day factors like flow, weather, terrain and so on will all have an impact. The need for consistency in approach, regular training, practice, assessment and accreditation were re-emphasised as a consequence of this discussion.

Despite the above, it was also agreed that due to the way that the LEAFPACS metrics are calculated the index itself generally minimises many of these biases, but also that the possible influence of measurement error on LEAFPACS needs more testing.

7.3.2 What is the optimum spatial and temporal sampling strategy?

The consensus here was that the answer to this question depends entirely on the question being asked; for example, is the survey work to classify the site for WFD purposes, or for water quality purposes, or to determine the conservation status of the site? It also depends to a large extent on the physical nature of the water body being sampled. A relatively uniform lowland river such as the River Allen will require a different sampling strategy to a highly variable upland river. The work done by WRc has provided evidence that three evenly spaced, 100 m LEAFPACS surveys per water body are sufficient for WFD classification purposes. But overall, the feeling was that the specific question being asked, combined with the nature of the watercourse, should dictate the survey strategy.

It was also recognised that the ultimate spatial and temporal sampling strategy employed needed to balance the ideal with the pragmatic and that resources and costs would largely dictate the latter.

Issues of whether, and to what extent, the temporal and spatial strategy employed should take account of different (external or anthropogenic) pressures was also raised. For example, should the sites chosen for survey be located in unnatural (engineered) as well as more natural sections, or in both, or something in between? Should surveys be done immediately before or after weed-cutting operations and should sites be located above or below sewage outfalls? It was agreed that part of the purpose of using a macrophyte survey technique, such as LEAFPACS, is to detect the impacts of pressures. On this basis it was agreed that sites affected by pressures should not be actively avoided and that a range of sites, some with and some without pressures and their related impacts, are required for accurate classification. It was, however, agreed that survey sites should not be located immediately within or downstream of significant pressures, such as the presence of point source pollution. The crucial issue of knowing what the survey is for in choosing an appropriate spatial and temporal programme was reiterated.

7.3.3 How many surveys are adequate to characterise the status of macrophyte communities in a water body?

There was a general consensus that one survey site per water body was not enough but that the exact number required would vary from case to case. The number of sites needed and chosen would, as with the issues discussed under the ideal temporal and spatial programme, have to be driven by the exact purpose of the survey being undertaken, the nature of the water body being surveyed, and the time and resources available for such work. Despite this, it was also agreed that there must be guidance, a written framework for example, on what to do, when and where and that, crucially, this should also include advice on what not to do. It was suggested that any such handbook developed should stipulate standardised ways in which to reduce error wherever possible. Such guidance would also need to recognise the purpose of the survey being undertaken, such as whether it is for classification for WFD and development of programmes of measures or for conservation assessment and so on; different purposes would have slightly different associated guidance notes.

7.3.4 How long should each survey length be?

It was agreed that 100 m was long enough for the LEAFPACS survey.

It was also agreed that 100 m might suffice for the JNCC type survey done for conservation purposes although, if this was adopted as the survey length for the latter, the way in which the results are assessed and decisions made on the conservation status of a site would also need to be considered first.

8 The way forward – results from discussion on ‘key questions’

8.1 Presentation by Andrew Davey

Andrew Davey of WRc gave a presentation on future research needs, as summarised below.

Three key areas for future research were identified as:

- *understanding and quantifying natural variability;*
- *monitoring design and survey practice;*
- *translating information into tools.*

Our understanding of temporal variability is still poor and could be improved by further research. There is also potential to move from the generic variance components identified to date to typology-specific components as more data becomes available. Variance components could also be adapted to take account of water body size and status.

Operator variability has been identified as a key source of variation. Research into the most cost-effective methods of reducing this would enable this component to be addressed. There is also value in obtaining a better understanding of the impacts of operator variability and survey length on JNCC surveys, as this was not achievable with the available data in this project.

The variance components that have been quantified should be incorporated into tools such as VISCOUS and ROMANSE to improve assessments of confidence of class and predict how many surveys are required to achieve the desired confidence of class.

8.2 Discussion

8.2.1 Risk of misclassification

The risk of misclassification of sites was discussed and it was reiterated that LEAFPACS showed that the use of three survey sites provided a 95% confidence for water body classification, but only if the water body falls in the middle of an ecological status ‘class’. Reference was also made to use of the ‘upturned wok model’ and questions were asked as to what the most sensible strategy was to minimise misclassification and choose a suitable number of surveys per water body. For example, is it better to use modelling or to base decisions on what has actually been recorded – is it better to utilise the information gathered from the WRc work presented at the workshop and compare it with LEAFPACS modelling work to see if three surveys is still enough? Currently, LEAFPACS suggests that three surveys is fine but WRc’s work might suggest that more sites (6–8) are required for accurate classification.

It was agreed that once a site has been classified using the agreed minimum number of surveys required to get an accurate classification there is little benefit in spending resources doing a lot more survey work. This is especially important in relation to sites that sit on the ‘good–moderate’ boundary, as the risk of misclassification will always be high, irrespective of the amount of sampling effort. More generally, more surveys may

help to resolve a site/water body's 'true' class, but the gain in precision diminishes as the number of samples increases.

Those from the conservation agencies stated they also really needed confidence in classification, especially as they essentially only have two classes (favourable or unfavourable) to choose from. The question was posed as to whether the conservation agencies could use the same, or slightly different (modified), metrics as those used for LEAFPACS for conservation classification? The answer was that it was possible but that the details would need to be worked out, probably through a dedicated project.

8.2.2 Making the most of forthcoming monitoring work in light of this project

With regards to the LEAFPACS monitoring that the Environment Agency will be doing for the purposes of classifying sites under the WFD, it was agreed that one of the key outputs from the workshop should be a recommendation on how the Environment Agency and SEPA might maximise the usefulness of the information collected during the next round of monitoring. It was suggested that this recommendation should be along the lines that in order to make the most of surveys with regards to the possible impacts of both temporal and spatial variability, and possibly also as a test of operator variability, each area within each region should choose one site and monitor it each year on three occasions using three different operators. After further discussion on exactly what should be surveyed and where (e.g. whether it should include both good and bad sites), it was agreed that the details would be worked out after the workshop and that statistical advice for this would be provided by WRc. The actual recommendation that went forward to the Environment Agency's national monitoring team for consideration is shown in Appendix 2.

8.2.3 Need for a handbook

There was a general consensus that it would be useful to produce a handbook that covered and elaborated on a number of the issues raised in the WRc reports and during the workshop, although the representatives from CCW said they would need to test the level of support for such a 'unified handbook' within their organisation before committing to it. It was agreed that a team would be needed to develop such a book and that this group would be led by the Environment Agency. It would also need to consider the requirements of the conservation agencies, as well as those of the regulators. One of the key issues for the handbook to cover would be to highlight to practitioners the impacts of what they do on the variability of the data they collect, explaining what the sources of variability are and what effect different 'mistakes' practitioners might make, such as incorrect addition of species in NTAXA, might have on the end result. This would enable them to see how what they do impacts on the end results and thus what they can do to minimise and mitigate against such things in the future.

9 Conclusions and recommendations

- There is a need for the specific survey method used in any specific circumstance to be 'fit for purpose' and it was agreed that there is no 'one size fits all' method that will cover all needs.
- The level of detail required, for example the accuracy required in recording and identifying all the taxa occurring within a site, will depend on the overall purpose of the survey.
- Use of the 100 m LEAFPACS survey method was agreed as appropriate for classification of water bodies under the WFD.
- Conservation bodies could adapt their conservation classification of watercourses to use the 100 m LEAFPACS survey method or conversely LEAFPACS WFD classifications could be adapted to a 500 m survey – no decision was made as to which might be best.
- There is a pressing need to ensure consistency in the way in which surveys are undertaken and thus a need for a surveyor accreditation process.
- A number of suggestions were made for a suitable accreditation process but no final decision was reached.
- The results of surveys need to be put into as much context as possible and so the need for contemporaneous information at survey sites is absolute.
- There was consensus on the general findings of the WRc reports.
- Some specific suggestions for changes to the WRc reports, for example the need to explain better the variability in the reference metrics, were made and these will be addressed in the WRc final report and review process.
- It was agreed that more survey work was needed to provide greater detail on the effects of uncertainty caused by temporal and spatial variability. A specific recommendation was developed for the Environment Agency's forthcoming round of WFD macrophyte surveying aimed at addressing this. The recommendation can be seen in full in Appendix 2.
- Based on the current information on temporal and spatial variability, it was agreed that a single survey per water body was not enough to classify accurately a site for WFD purposes. No suggestions were made as to what the correct number was, but it was proposed that it may be between three and eight sites.
- It was suggested that this additional work may also provide a platform to undertake further observations with regard to inter-operator variability and/or that it might be used to launch an accreditation process. No specific recommendation on this was agreed
- A handbook on survey methodology is required for use by all practitioners.

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List of abbreviations

ASPT	Average score per taxon
CAVE	Combines Appropriate Variance Estimates
CCW	Countryside Council for Wales
CSM	Common Standards Monitoring
ECUS	Environmental Consultancy University of Sheffield
EQR	Environmental Quality Ratio
JNCC	Joint Nature Conservation Committee
LEAFPACS	Aquatic macrophyte prediction and classification system
MTR	Mean trophic rank
NE	Natural England
NTAXA	Number of taxa recorded at a site
pH	Measure of alkalinity or acidity with lower numbers acid and higher numbers alkali
Q50, Q85	Average flow for 50 or 85% of the time
RMNI	River Macrophyte Nutrient Index
ROMANSE	Risk Of Misclassification And Number of Samples Estimator
SEPA	Scottish Environment Protection Agency
SNH	Scottish Natural Heritage
SSSI	Site of Special Scientific Interest
UK	United Kingdom
VISCOUS	Variability In Spatial Component Objectively Unified Statistically
WFD	Water Framework Directive
WRc	Water Research Centre

Appendix 1

Agenda

Day 1. Thursday 4 June: Survey methods and dealing with sources of variability

Item	Time	Subject/Task	Who
	10.30 – 11.00	Coffee	
	11.00 – 11.15	Welcome and introductions Workshop outline, aims and objectives	Tim Johns / Catherine Duigan
	11.15 – 11.45	Constraining factors and resources: <ul style="list-style-type: none"> • Regulatory agencies • Conservation agencies 	Jo-Anne Pitt Tristan Hatton-Ellis
	11.45 – 12.05	The JNCC survey methodology	Tristan Hatton-Ellis
	12.05 – 12.25	The LEAFPACS field survey methodology	Nigel Willby
	12.25 – 13.00	Sampling methods in practice; experience from the field: <ul style="list-style-type: none"> • LEAFPACS • JNCC 	Richard Chadd Sarah Clarke
	13.00 – 14.00	Lunch	
	14.00 – 14.30	LEAFPACS – use in classification of water bodies for WFD	Nigel Willby
	14.30 – 15.00	Discussion	Catherine Duigan
	15.00 – 16.00	Walk by river, discussion of cover values (Nigel Holmes) and survey methods (all)	
		Tea	
	16.00 – 16.20	Understanding and quantifying natural variability in macrophyte communities	WRc
	16.20 – 18.00	Discussion on key questions: <ul style="list-style-type: none"> • <i>Are there any additional questions to those in the WRc report?</i> • <i>Are the results in agreement with practical experience?</i> • <i>What are the main sources of variation in macrophyte monitoring data?</i> • <i>How significant is measurement error (operator variability) and how can it be minimised?</i> 	WRc / Catherine Duigan

Day 2. Friday 5 June: Dealing with variability and coming to a consensus

Item	Time	Subject/Task	Who
	08.45 – 09.00	Review of previous day/ intro to this day	Catherine Duigan / Eliot Taylor
	09:00 – 09.30	The consequences of variability for macrophyte surveying	WRc
	09.30 – 11.00	Discussion on key questions: <ul style="list-style-type: none"> • <i>Can measurement error produce a biased result?</i> • <i>What is the optimum spatial and temporal sampling strategy?</i> • <i>How many surveys are adequate to characterise the status of macrophyte communities in a water body?</i> • <i>How long should each survey length be?</i> • <i>Other questions raised on Thurs</i> 	Catherine Duigan
	11.00 – 11.15	Coffee	
	11.15 – 11.30	The way forward – results from discussion on ‘key questions’	WRc
	11.30 – 12.45	Discussion: <ul style="list-style-type: none"> • <i>How can survey methods be improved?</i> • <i>Potential for convergence in methodologies?</i> • <i>What tools do users need to plan surveys and analyse the resulting data?</i> • <i>Future research needs</i> 	Eliot Taylor / Catherine Duigan
	12.45 – 13.00	Closing remarks	Bill Brierley
	13:00	Lunch	

Delegate list

Delegate	Organisation
Bill Brierley*	Environment Agency
Richard Chadd	Environment Agency
Sarah Clarke	Environmental Consultancy University of Sheffield
Andy Davey*	Water Research Centre
Benoit Demas	The Macaulay Land Use Research Institute
Catherine Duigan (Chair)	Countryside Council for Wales
Judy England	Environment Agency
David Garrow*	Water Research Centre
Tristan Hatton-Ellis*	Countryside Council for Wales
Damien Hicks*	Scottish Environment Protection Agency
Nigel Holmes	Alconbury Environmental Consultants
Tim Johns*	Environment Agency
Richard Landsdown	Ardeola Environmental Services
Claire Liversage	Environment Agency
Geoff Phillips*	Environment Agency
Jo-Anne Pitt*	Environment Agency
Sue Ralph*	Environment Agency
Pete Scarlett	Centre for Ecology & Hydrology
Jane Southey	Scott Wilson
Eliot Taylor	Atkins Global
Nigel Willby*	Sterling University

* part of project steering group &/or contractor

List of macrophyte variability project reports and associated documents

Environment Agency – project / document	Report / document title	Authors
SC070051/SR1	River macrophyte sampling methodologies & variability	Pentecost, Willby, Pitt
SC070051/SR2	Variability components of macrophytes in rivers – Final report	Davey & Garrow (WRc)
SC070051	Macrophyte variability Final dataset_24 April 2009	Davey & Garrow (WRc)
SC070051/SR2A	Variability components of macrophytes in rivers – Appendix C: River Allen analysis	Davey & Garrow (WRc)
SC070051/SR3	Variability components for macrophyte communities in rivers: 2008 survey	Davey & Garrow (WRc)
SC070051/SR3 (data)	Variability components for macrophyte communities in rivers 2008 survey_Final dataset_24 April 2009	Davey & Garrow (WRc)
SC070051/SR4	Variability components for macrophyte communities in rivers: Summary report	Davey & Garrow (WRc)
	Determining the main variability components for macrophyte communities in rivers: JNCC and LEAFACS macrophyte surveys on the River Dee	Clarke, Lansdown, Birkinshaw

Appendix 2

Output from river macrophyte surveying and variability workshop

Urgent recommendation on river macrophyte monitoring for 2010

Summary

Two key recommendations need to be brought to the attention of Monitoring Policy and the Environmental Monitoring Service:

- 1. A minimum of three surveys per water body, distributed evenly along its length, are needed to provide a confident classification, allowing spatial variability to be factored in to the classification.**
- 2. As surveyor variability has been shown to have a significant influence on classification, an auditing process needs to be incorporated into future sampling. In order to address this, repeat annual surveys at one or more sites per Environment Agency Area, surveying the same 100 m stretch on three occasions using three independent surveyors each time, are required.**

These recommendations will provide essential information on both annual changes in river macrophyte communities and surveyor error; improving our ability to interpret related and future data, by factoring in this variation, and improving the precision of water body classification, in a cost-effective way.

Further details and the rationale behind these recommendations are described below.

Environment Agency Science Project No. SC070051, entitled 'Further Development of River Macrophyte WFD Classification Tool – River Variability Module' and concentrating on variability and uncertainty in river macrophyte populations, is drawing to a close. As part of the project conclusion a workshop was held on 4–5 June 2009 to discuss and agree upon the project's main outcomes. The workshop participants were drawn from all of the main conservation and regulatory agencies in England, Wales and Scotland and also included a number of nationally recognised macrophyte experts and consultants working with the Environment Agency on the project. A consensus view for a set of common sampling methods was formed during the workshop with a willingness to share data and surveying resources.

The workshop participants agreed a series of important conclusions that should influence the design of future monitoring strategies for river macrophytes. Details of these recommendations will follow in the workshop report in due course; however, there are two important recommendations that need to be drawn to the attention of Monitoring Policy and the Environmental Monitoring Service leads, so that the recommended strategy can be incorporated into the 2010–2012 monitoring programme. These are outlined below:

1. More than a single survey site is needed to provide a confident classification; the outputs from the project and workshop indicated that three surveys per water body is the absolute minimum. Furthermore, sites should be distributed evenly along the length of a water body. This would allow software such as VISCOUS to be used to determine if spatial variability within a water body results in a confident failure of targets.

2. Surveyor variability is a key factor influencing classification and Analytical Quality Control (AQC) should be incorporated into future sampling strategies. It was recommended that the most cost effective approach would be to undertake macrophyte surveys annually at one or more sites per area in each region and that, on each occasion, the same 100 m stretch of river be surveyed independently by three separate surveyors

The rationale for this second recommendation is threefold:

Firstly, a network of intensively monitored sites will provide valuable information about year-to-year changes in river macrophyte communities. This information will allow the Environment Agency to interpret more fully the results of the 2010–2012 macrophyte monitoring and potentially allow the influence of inter-annual variations in flow and weather to be factored out of the monitoring results, leading to more accurate and reliable water body classifications.

Secondly, the information collected from these surveys will provide vital data on variability, particularly in relation to the size and nature of temporal variation and measurement error. Measurement error has been identified as an important source of variability, while the magnitude of temporal variation remains largely unquantified. Better quantification of these two sources of variation will guide the development of more cost-effective monitoring programmes in the future.

Thirdly, there is an urgent need to establish a formal programme of testing and accreditation for macrophyte surveyors in order to minimise measurement error. Ring-testing of surveyors at a small number of selected sites would help to maintain consistency and lead to more precise results.

More detailed recommendations on the following areas will follow shortly:

1. The exact number of sites that need to be surveyed within a water body.
2. The nature of the sites that need to be surveyed (whether they should be all of high ecological status, or a mixture of high, moderate and poor), and whether they should also comprise a range of river types, such as upland and lowland, chalk and clay catchments and so on.
3. The details of personnel that carry out the surveys, that is whether it should be Environment Agency or contract staff that undertakes the work.
4. The way in which the surveys should be delivered, that is whether the survey is conducted by pairs of accredited surveyors or by a pair comprising one accredited person and one assistant.
5. Suggested associated reduction in other macrophyte monitoring to compensate for this monitoring (i.e. reduce monitoring at sites where we are confident of the classification status).

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