Introduction

Restoration of fluvial geomorphological processes is increasingly used to address degradation of riverine ecosystems (Smith et al., 2014). Unfortunately, many schemes are poorly appraised (Roni and Beechie, 2013) meaning that the demonstration of ecological benefit remains limited (e.g. Palmer et al., 2010; Feld et al., 2011), despite some successes (e.g. Kail et al., 2015). Notwithstanding this uncertainty, an increasing number of restoration projects are undertaken and the call for effective evaluation continues (Angelopoulos et al., 2017). In 2016, the River Restoration Centre (RRC) UK National River Restoration Inventory contained over 2800 completed projects with only 21% stating some degree of monitoring. Of the 179 projects added in 2017, only 5% of the projects specifically reported any monitoring outcomes (RRC, 2018). These data demonstrate a greater recognition of the need to monitor. Nonetheless, demonstrable integrated successful outputs remain patchy.

Historically, monitoring has frequently evaluated one particular aspect such as morphology (e.g. Downs and Brookes, 1994), macro-invertebrates (e.g. Friborg et al., 1998), macrophytes (e.g. Pedersen et al., 2006) or fish (e.g. Gortz, 1998). Increasingly, the need for multi-assessments to determine success has been recognised (e.g. Muhar et al., 2016). A key challenge is to establish an appropriate monitoring strategy that includes physical parameters that link to ecological responses and focus on processes rather than habitats or species (Beechie et al., 2010; Gurnell et al., 2016a).

Wohl et al. (2005) recognised a lack of identified generic criteria to support strategic monitoring, although Palmer et al. (2005) simultaneously suggested five elements:

1. an image of the dynamic state to be restored
2. recognition of measurable improvements to the ecosystem
3. an increase in resilience
4. assurance that there is no lasting harm
5. inclusion of ecological assessment.

Other authors advocated a pragmatic approach (e.g. Woolsey et al., 2007), yet what remained missing, was a detailed and systematic explanation of how the appraisal process should be shaped to ensure specific questions can be answered. The process, it was argued, needed to be easily accessible to practitioners and stakeholders. In response, the RRC enlisted its supporting organisations and UK national experts to help develop monitoring guidance.

Development of a monitoring protocol

To ensure a strategic approach, a conceptual model was developed that targets limited resources to maximise the information gained. The approach ensures that the
monitoring effort focuses on projects with the most risk and/or potential to learn. The concept behind the model is that small-scale projects, using established techniques, are generally more predictable and therefore present a lower risk, so may need less or simpler monitoring (England et al., 2008). In contrast, large-scale projects, and techniques applied in new situations or using novel approaches present greater risk, provide more opportunity to learn and therefore warrant detailed scrutiny. This concept was presented at an invited audience meeting of academics and practitioners, who agreed that developing an integrated monitoring approach was desirable and that both pre- and post-project monitoring are essential to achieve robust scientific conclusions about the success or failure of river restoration projects (RRC, 2006). This integrated approach and the setting of clear project objectives was considered essential to give confidence that appraisals can demonstrate project effects. The outputs of this workshop, and a subsequent development workshop (RRC, 2007), led to the formulation of a decision-making process linking measurable objectives to appropriate monitoring based on the scale, complexity and cost of a project within ‘Practical river restoration appraisal guidance for monitoring options (PRAGMO)’ (RRC, 2011).

**Practical River Restoration Appraisal Guidance for Monitoring Options (PRAGMO) – an overview**

PRAGMO (RRC, 2011) provides pragmatic guidelines to help practitioners, from government agencies to community groups, determine the necessary level of monitoring. The guidance is broken down into a series of questions, summarised in this section.

1. **Do you understand your river?**
   Before making any decision about what river restoration is appropriate and what to monitor, the practitioner must have a good understanding of their river in its catchment context. Understanding hydrology, sediment load and water quality is critical in terms of setting realistic objectives and determining a monitoring strategy (Addy et al., 2016; Angelopoulos et al., 2017).

2. **Will your aspirations improve the river given the current conditions?**
   The knowledge gained under question 1 enables a better understanding of how a watercourse may respond to restoration and any limits to ecological recovery. The importance of catchment processes in understanding trajectories of change is well documented and their importance to river management noted (Kail et al., 2015; Gurnell et al., 2016b). These processes shape river reaches and determine if restoration measures are likely to be sustainable. For example, installation of boulders and gravel into a lowland river system where there is excess fine sediment input is not sustainable unless the source of the fine sediment is also managed (Mueller et al., 2014).

3. **Can you define ‘SMART’ project objectives?**
   Each project needs clear objectives against which success can be judged. Adopting the ‘SMART’ (Specific, Measureable, Achievable, Realistic and Time-Bound) approach ensures that sound objectives are set (Roni and Beechie, 2013; Angelopoulos et al., 2017).

4. **Can the monitoring needs be defined based on project risk and scale?**
   Determining the risk of a project considers the degree to which a specific technique has been used successfully elsewhere and whether it is suitable for the type of river being restored. The user is taken through a series of steps to help identify the project risk and scale to determine the necessary monitoring level. Published reviews of river restoration effectiveness (e.g. Smith et al., 2014; Kail et al., 2015; https://reformriver.eu/home) can help identify gaps in evidence which need to be addressed.

5. **Can ‘SMART’ monitoring objectives be confidently set?**
   Monitoring objectives need to assess measures of success both spatially and temporally. These differ from project objectives that establish overall aspirations, but they must relate back to them to demonstrate project success. Monitoring objectives should consider how morphology will be affected by the restoration measures and how biota will respond, thus helping predict expected timescales of change. Clearly, this is not a simple task, since recovery following restoration is one of the main areas of uncertainty and response time will vary depending on geomorphic processes (Beechie et al., 2010; Gurnell et al., 2016b), biological colonisation processes (Li et al., 2016; Stoll et al., 2016) and hydrological conditions (Groll, 2017).

6. **Prioritise monitoring**
   Identifying what is possible or desirable to monitor is often restricted by available resources and pre-project data, therefore limiting comprehensive long-term monitoring. In reality, different stakeholders and funders will have different priorities, so it is important that their views are considered during this process (Angelopoulos et al., 2017).

7. **Select monitoring techniques to demonstrate project performance related to objectives**
   Where a project has been identified as a priority for in-depth monitoring, the strategy should produce robust data that can be analysed with appropriate statistics to improve confidence in the outcomes. Techniques are likely to be quantitative and include replication, necessitate pre-project data and follow a BACI (Before–After–Control–Impact) approach (Kail et al., 2015). However, there is still a wealth of information that can be gathered from simpler or smaller projects, providing that a robust monitoring strategy is applied (Shuker et al., 2017).
Steps 6 and 7 comprise an iterative process because costs and resources will affect what is achievable within the constraints of a project. To help with this process, the RRC developed a monitoring planner (RRC, 2014) which can be used to review and prioritise monitoring in a systematic way, using a series of structured questions. The agreed strategy can be implemented as an integral part of the project delivery.

8. Sharing the results

The final step is to ensure that the results of the monitoring programme are communicated both to the stakeholders and the wider scientific community to ensure that we learn from successful schemes (Angelopoulos et al., 2017) and that we learn from the experiences where projects have not progressed as planned (Salant et al., 2012).

Is PRAGMO fit for purpose?

PRAGMO is currently a well-accessed document, with around 200 downloads per month (RRC, 2019; NRRI). How to manage and use data is a significant current topic. In January 2019, the Organisation for Economic Co-operation and Development (OECD, 2019) recognised the impact of biodiversity loss and called for better measuring and monitoring of the environment. Whilst in the United Kingdom, the government’s 25-year plan (Defra, 2018) identifies, amongst others within its targets, thriving plants and wildlife, resources from nature, engagement with the natural environment, reduction of pollutants and clean and plentiful water. To demonstrate, these goals will inevitably require a range of data sources and approaches that will collectively be able to explain benefits. Ensuring that this guidance remains relevant and useful is therefore essential. Incorporating current best practice such as the Modular River Survey, a citizen science technique (Shuker et al., 2017), remote sensing as a tool to track geomorphic change (e.g. Bentley et al., 2016) and the application of ecosystem service approaches (e.g. Large and Gilvear, 2015) will help to support these wider aspirations, within the context of river restoration, and support much needed ‘grass root’ appropriate and robust monitoring. Equally, it is critical to ensure that this guidance continues to reflect the increase in river restoration evidence, so that users have all the information they need to create sound monitoring assessments. To target future development, the RRC undertook an online survey to provide an overview of what practitioners find most and least useful within the current version and what they would like to see in any update.

The questionnaire was made available on the RRC website, a link sent to all RRC members and advertised in the RRC newsletter. It featured questions on the usefulness and ease-of-use of PRAGMO and suggested improvements. A total of 47 people responded to the questionnaire over a 3-month period. The majority (55%) of respondents used PRAGMO regularly or occasionally with only 13% stating they had never used it (Fig. 1a). The largest group of respondents belonged to regulatory bodies, matched by nonprofit organizations (NGOs) reflecting the increase in restoration activity undertaken by these organisations (Fig. 1b). User focus of interest (there could be more than one per respondent) varied from geomorphology (51%) to hydrology (35%), biology (40%), fisheries (35%) and social well-being (19%) as well as engineering and planning (14%).

The main reasons for respondents using PRAGMO (multiple-choice question; Fig. 2a) was setting monitoring objectives, identifying monitoring intensity, developing monitoring protocols and setting and prioritising monitoring objectives. This focus on monitoring objectives, application and timescales is also reflected in the top five sections used (multiple-choice question; Fig. 2b). Also popular are the sections which link biological and morphological processes possibly emphasising the increased interest in process-based restoration (Addy et al., 2016).

---

**Fig. 1.** Responses to the Practical River Restoration Appraisal Guidance for Monitoring Options (PRAGMO) use questionnaire on the frequency of use and audience.
and the need for integrated assessments (Angelopoulos et al., 2017). Nearly 36% of respondents recognised the value in helping set SMART objectives. The least used sections highlighted in the survey (multiple-choice question; Fig. 2c) were the appendices about water quality and the Water Framework Directive, and information on data and costs. These sections are not the main focus of the PRAGMO guidance and their lack of popularity may reflect that this information and data are held elsewhere in a more accessible format.

When asked if PRAGMO should be updated, 81% of respondents said yes, only 2% said no and the remaining 17% were undecided. Comments were made on the size of the document (320 pages) and the need to make it shorter and more interactive, with links to more detailed guidance as needed.

Respondents also expressed wishes for new sections with an emphasis on decision support, data analysis, Natural Flood Management (NFM) and both simpler and more detailed guidance on methodologies. This need for technical guidance may potentially reflect the growing base of nonexpert users and the lack of structured or easily available guidance elsewhere. The most sought-after additions (multiple-choice question; Fig. 3) were for desk-based assessments, tools to aid decision support, data analysis, statistics and additional guidance on
monitoring techniques. There was also interest in adaptive management strategies and more informal sources of help such as access to a help line, a discussion forum or Question and Answer sections, which may reflect the uncertainty of understanding the success of restoration measures. There were requests in the free text questions to add guidance material on NFM monitoring.

The results of the survey provide credence for the need to update PRAGMO in the context of improved understanding and to incorporate new technology and innovation.

**PRAGMO for the future**

The frequent access to PRAGMO demonstrates its continued use to the UK practitioner community. However, the results of the questionnaire indicated some limitations in its use. Essentially, users felt that the manual would benefit from being streamlined and their wish for decision help in the shape of a software with simple step-by-step procedures and specific guidance on potential techniques was clear.

To address these user needs and concerns, the guidance could be re-designed as a decision support tool to enable the identification of options based on scheme characteristics, and as a repository of techniques with various levels of detail. To achieve this, PRAGMO could be split into three integrated online modules (a knowledge base, a decision support tool and a data repository) which can link to existing evidence and information (Fig. 4). The growing knowledge base will be able to feed into other outcome needs such as demonstration of benefits for 25-year plan indicators.

---

*Fig. 3.* Responses to the *Practical River Restoration Appraisal Guidance for Monitoring Options (PRAGMO)* use questionnaire on what people would like to see included in an updated version.

*Fig. 4.* Conceptual model of a potential revision to *Practical river restoration appraisal guidance for monitoring options (PRAGMO)* in response to a review by users; creating a knowledge base of a benefit to the river restoration community which can support wider goals such as Natural Flood Management (NFM) and climate change adaptation.
(Defra, 2018), natural flood management (Environment Agency, 2018a) and increasing resilience to climate change (Environment Agency, 2018b).

1. Knowledge base

The knowledge base would be an online Wiki, containing an updated version of the existing PRAGMO, techniques and methods. Prior to including new information, each section would need to be reviewed and updated based on current knowledge of existing and new techniques. The sections that were considered less useful could be replaced with links to information available elsewhere and additional sections added to address the requests highlighted in the questionnaire (Fig. 3). The evidence base would have links to other sources of information such as the RRC Manual of Techniques (MOT; RRC, 2013), the NFM evidence directory (Environment Agency, 2018b), river restoration and NFM case studies from the National River Restoration Inventory database (NRRI; www.therrc.co.uk/uk-projects-map), the RiverWiki (https://restorerivers.eu/wiki/index.php?title=Main_Page) and reviews of river restoration effectiveness (e.g. Smith et al., 2014; Kail et al., 2015; https://reformrivers.eu/home).

In addition to the suggestions from practitioners, sections would be included to enable monitoring strategies and design to be supported by statistical evaluations and power analyses. This would include sections on monitoring scales, data management and statistical analysis. Together with establishing standards for the monitoring, this will allow the coordination and collation of the data across multiple projects that will support programme evaluation. Consideration would need to be given to how to incorporate natural capital and ecosystem service assessments and how community monitoring can provide a wider contribution and enhance stakeholder engagement.

Developing the knowledge base as a wiki would ensure that it contains the most current information on techniques, their application and appraisal. It would be informed by inviting editors, specialists in their fields, to edit and contribute evidence. Thus, it would provide the facility to disseminate guidance and information quickly and effectively across practitioners. It would also allow the involvement of the wider community of practice and enable them to feedback and interact.

2. Decision support tool

The decision support tool would need to be developed as a web application or software that contains the decision flow charts and matrices in PRAGMO with additional contextual information on river and floodplain types to help users identify potential monitoring techniques and strategies. It would also include existing tools such as the monitoring planner (RRC, 2014). The tool would communicate with the knowledge base, enabling users to cross-reference to techniques and obtain the level of detail required without burdening them with extra information. Worked examples of the decision support tool would also be included within the knowledge database.

3. Data repository

Even when a monitoring strategy is implemented, the results are often not shared or reside within grey literature with limited accessibility. This restricts the more strategic assessments, using a weight of evidence approach to assess particular techniques and approaches or where replication of assessments would be useful. Providing a data repository would ensure that valuable data are not lost and can be made available for integrated assessments.

The data repository would provide a structure for uploading or inputting project records and standardised data and photographs associated with river restoration projects to facilitate archiving, retrieval, assessment and audit. The system would need to link to the NRRI database which contains some 4500 river restoration schemes and is the UK standard for recording river restoration information. The NRRI database in turn is linked to the RiverWiki database that contains information on schemes across Europe and further abroad.

The secure repository would have different levels of data accessibility depending on user requirements. Some of the data and documents uploaded may only be visible to the author, selected user groups or as open data. This would allow it to be used as a practical tool whilst project assessments are underway, with the ability to make the data available and their release embargoed until user-specified dates.

Other advantages of this approach are that it can aid with ensuring data quality and encourage the sharing of data. Standardised approaches to data archiving with the necessary meta-data would ensure that the data can be more readily analysed using statistical tools. It could provide students and academics with access to data, allow them to revisit schemes and facilitate the appraisal of river restoration success over the long term and build a stronger evidence base.

Future direction

It is essential that any restoration appraisal is well structured and based on sound principles, as poorly planned approaches waste resources and provide meaningless or misleading information (Anderson and Dugger, 1998). By using approaches such as PRAGMO and the proposed update, this could be prevented by leading the end-user to adopt an appropriate monitoring protocol that will help address evidence gaps.

Whilst the spatial extent and period of monitoring represent the bottom line for project managers, the consensus amongst academics is that these must be determined on a case-by-case basis, depending on what aspects are being monitored.
(Roni and Beechie, 2013). Geomorphological effects may be rapid under some circumstances but decades or longer in others (Gilvear et al., 2013). Equally, timescales of ecological response will vary (Stoll et al., 2016). It is critical that timescales and the trajectories of anticipated change are considered within the restoration process. The framework developed by Gurnell et al. (2016a, 2016b) provides an integrated approach to river systems that can be taken into account when establishing the targets against which restoration activity is assessed (Angelopoulos et al., 2017). The importance of understanding these temporal and spatial variations and using them to anticipate restoration success cannot be underestimated. We need to undertake monitoring before restoration work is carried out and afterwards for a sufficient length of time to detect both rapid and longer term changes (Addy et al., 2016). Best practice guidance such as PRAGMO offers the capability to ensure that this notion is considered realistically within any monitoring framework and, hence, work towards a coherent approach to increase the underlying evidence base. This evidence base is critical to understand how we ensure that we continue to implement restoration techniques that result in environmental, economic and societal benefits and reduction of catchment pressures. The approach presented can underpin these aspirations by making the basic principles of the approach transferable to ecological restoration at an international scale.

Although much of the discussion above has been around environmental and natural physical processes and habitat project goals, we need, as implied above, to understand the social and economic constraints and set goals that provide benefits to society. This will help gain wider support and funding for restoration activities (Addy et al., 2016) as river restoration benefits are better understood. The use of citizen science approaches not only provides useful information but also connects people with rivers and improves general understanding (Smith et al., 2014). As new techniques and approaches are developed, these need to be incorporated into guidance material. Nonetheless, the need for a robust monitoring programme remains the same. The key is ensuring that there is sufficient flexibility within the system to make sure that new ideas and techniques can be integrated as they evolve. The monitoring guidance outlined in this paper and its potential development provides a robust way of ensuring the most effective and appropriate (relative to project size, knowledge known and budget) monitoring approaches are captured and used within any monitoring process. It can instil confidence to the users that the suite of monitoring they select are more likely to demonstrate change, identifying both restoration benefits and where future adaptive management may be necessary. Furthermore, it can help everyone to be part of national and international processes to demonstrate that collectively we can achieve environmental, societal and economic goals and benefits. By publishing online, innovative and new effective monitoring practices and analytical techniques can be incorporated alongside the increasing evidence base that more effective monitoring and appraisal can produce.

**Conclusions**

1. Monitoring and appraisal should be an integral part of any river restoration scheme, but effort should be targeted to where we will learn the most.
2. Monitoring and appraisal is only effective if it is well designed and the lessons learnt are shared. This could be aided by decision support tools, a collated evidence base and data repository.
3. Monitoring guidance is valued by those that use it, but needs to be regularly updated to incorporate new technology and innovation.
4. We need to widen our consideration of restoration effectiveness by incorporating societal and economic benefits.
5. Continuing to develop and update this guidance, which is already being regularly used, can aid in delivering wider environmental national and international goals and enable a pool of information for ongoing decision support purposes.

**Acknowledgements**

We thank all the experts who have been integral to the development of the monitoring guidance. Especially: Andrew Gill (Cranfield University), Martin Janes (RRC) and former RRC staff: Nick Elbourne (Environment Agency), Diana Hammond (Affinity Water) and Dr James Holloway (Queen Mary University). We also pay tribute to the involvement of the late Dr Nigel Holmes. Without funding from the Environment Agency, Scottish Environment Protection Agency and the Thames River Restoration Trust guidance would not have been possible. The views expressed here are those of the authors and not necessarily those of their organisations. We thank the two anonymous reviewers and the editorial board for their helpful comments which have greatly improved this manuscript. Data available on request from the River Restoration Centre.

To submit a comment on this article please go to http://mc.manuscriptcentral.com/wej. For further information please see the Author Guidelines at wileyonlinelibrary.com

**References**

Addy, S., Cooksley, S., Dodd, N., Waylen, K., Stockan, J., Byg, A., et al. (2016) *River restoration and biodiversity,*
nature-based solutions for restoring the rivers of the UK and Republic of Ireland. Report of the International Union for Conservation of Nature National Committee, UK. Available at: http://www.crew.ac.uk/publication/river-restoration [accessed 1 December 2016].

Anderson, D.H. and Duggar, B.D. (1998) A conceptual base for evaluating restoration success. Transactions of the 63rd North American Wildlife and Natural Resources Conference, Washington, DC.

Angelopoulos, N.V., Cowx, I.G. and Buijse, A.D. (2017) Integrated planning framework for successful river restoration projects: upscaling lessons learnt from European case studies. Environmental Science and Policy, 76, 12–22.

Beechie, T.J., Sear, D.A., Olden, J.D., Pess, G.R., Buffington, J.M. and Moir, H. (2010) Process-based principles for restoring river ecosystems. BioScience, 60(3), 209–222.

Bentley, S.G., England, J., Heritage, G., Reid, H., Mould, D. and Bithell, C. (2016) Long-reach biotope mapping: deriving low flow hydraulic habitat from aerial imagery. River Research and Application, 32, 1597–1608.

Defra. (2018) A Green Future: Our 25 Year Plan to Improve the Environment. London: OLG Crown Copyright. Available at: www.gov.uk/government/publications/25-year-environment-plan [Accessed 6 February 2019].

Downs, P.W. and Brookes, A. (1994) Developing a standard geomorphological approach for the appraisal of river projects. In: Kirby, C. and White, W.R. (Eds.) Integrated River Basin Development. Chichester: John Wiley and Sons, pp. 299–310.

England, J., Skinner, K.S. and Carter, M.G. (2008) Monitoring, river restoration and the Water Framework Directive. Water and Environment Journal, 22, 227–234.

Environment Agency. (2018a) Working with Natural Processes – Evidence Directory Environment Agency. Bristol, UK. pp. 295. Available at: www.gov.uk/government/publications/working-with-natural-processes-to-reduce-flood-risk [Accessed 16 January 2019].

Environment Agency. (2018b) Climate Change Impacts and Adaptation Environment Agency. Bristol, UK. pp. 18. Available at: www.gov.uk/government/publications/climate-change-impacts-and-adaptation [Accessed 16 January 2019].

Feld, C.K., Birk, S., Bradley, D.C., Hering, D., Kail, J., Marzin, A., et al. (2011) From natural to degraded rivers and back again: a test of restoration ecology theory and practice. In: Woodward, G. (Ed.) Advances in Ecological Research. Amsterdam, The Netherlands: Academic Press, pp. 119–209. Available at: https://www.sciencedirect.com/science/article/pii/B978012374794500031.

Friberg, N.I., Kronvang, B., Hansen, H.O. and Svendsen, L.N. (1998) Long-term, habitat-specific response of a macroinvertebrate community to river restoration. Aquatic Conservation: Marine and Freshwater Ecosystems, 8, 87–99.

Gilvear, D.J., Spray, C.J. and Casas-Mulet, R. (2013) River rehabilitation for the delivery of multiple ecosystem services at the river network scale. Journal of Environmental Management, 126, 30–43.

Gortz, P. (1998) Effects of stream restoration on the macroinvertebrate community in the River Esrom, Denmark. Aquatic Conservation, Marine and Freshwater Ecosystems, 8, 115–130.

Groll, M. (2017) The passive river restoration approach as an efficient tool to improve the hydromorphological diversity of rivers – case study from two river restoration projects in the German lower mountain range. Geomorphology, 293, 69–83.

Gurnell, A.M., Rinaldi, M., Buijse, A.D., Brierley, G. and Piegay, H. (2016a) Hydromorphological frameworks, emerging trajectories. Aquatic Sciences, 78, 135–138.

Gurnell, A.M., Rinaldi, M., Belletti, B., Bizzi, S., Blamauer, B., Braca, G., et al. (2016b) A multi-scale hierarchical framework for developing understanding of river behaviour to support river management. Aquatic Sciences, 78, 1–16.

Kail, J., Brabec, K., Poppe, M. and Januschk, K. (2015) The effect of river restoration on fish, macroinvertebrates and aquatic macrophytes, a meta-analysis. Ecological Indicators, 58, 311–321.

Large, A.R.G. and Gilvear, D.J. (2015) Using Google Earth, a virtual-globe imaging platform, for ecosystem services-based river assessment. River Research and Application, 31, 406–421.

Li, F., Sundermann, A., Stoll, S. and Haase, P. (2016) A newly developed dispersal metric indicates the succession of benthic invertebrates in restored rivers. Science of the Total Environment, 569–570, 1570–1578.

Mueller, M., Pander, J. and Geist, J. (2014) The ecological value of stream restoration measures: an evaluation on ecosystem and target species scales. Ecological Engineering, 62, 129–139.

Muhar, S., Januschke, K., Kail, J., Poppe, M., Schmutz, S., Hering, D., et al. (2016) Evaluating good-practice cases for river restoration across Europe, context, methodological framework, selected results and recommendations. Hydrobiologia, 769, 3.

OECD. (2019) OECD Environmental Performance Reviews: Australia 2019. Paris: OECD Publishing. Available at: http://www.oecd.org/publications/oecd-environmental-performance-reviews-australia-2019-9789264310452-en.htm [Accessed 6 February 2019].

Palmer, M.A., Bernhardt, E.S., Allan, J.D., Lake, P.S., Alexander, G., Brooks, S., et al. (2005) Standards for ecologically successful river restoration. Journal of Applied Ecology, 42, 208–217.

Palmer, M.A., Menninger, H.L. and Bernhardt, E.S. (2010) River restoration, habitat heterogeneity and biodiversity: a failure of theory or practice? Freshwater Biology, 55(1), 205–222.
Pedersen, T.C.M., Baattrup-Pedersen, A. and Marsen, T.V. (2006) Effects of stream restoration and management on plant communities in lowland streams. *Freshwater Biology*, 5, 161–179.

Roni, P. and Beechie, T.J. (2013) *Stream and Watershed Restoration: A Guide to Restoring Riverine Processes and Habitats*. Chichester, UK: John Wiley and Sons Ltd.

RRC. (2006) Outputs from a Monitoring Seminar, 12th–13th December 2006. Available at: www.therrc.co.uk/rrc_themed_workshops.php [Accessed 16 June 2017].

RRC. (2007) River Restoration Monitoring Working Group 12th December 2007. Available at: www.therrc.co.uk/rrc_themed_workshops.php [Accessed 16 June 2017].

RRC. (2011) Practical River Restoration Appraisal Guidance for Monitoring Options (PRAGMO). Available at: www.therrc.co.uk/rrc_pragmo.php [Accessed 16 June 2017].

RRC. (2013) Manual of River Restoration Techniques. Available at: www.therrc.co.uk/manual-river-restoration-techniques [Accessed 16 June 2016].

RRC. (2014) Monitoring Planner. Available at: www.therrc.co.uk/monitoring-planner [Accessed 16 June 2016].

Salant, N.L., Schmidt, J.C., Budy, P. and Wilcock, P.R. (2012) Unintended consequences of restoration: loss of riffles and gravel substrates following weir installation. *Journal of Environmental Management*, 109, 154–163.

Shuker, L.J., Gurnell, A.M., Wharton, G., Gurnell, D.J., England, J., Finn Leeming, B.F., *et al*. (2017) MoRPh: a citizen science tool for monitoring and appraising physical habitat changes in rivers. *Water and Environment Journal*, 31, 418-424.

Smith, B., Clifford, N.J. and Mant, J. (2014) The changing nature of river restoration. *Wiley Interdisciplinary Reviews: Water*, 1, 249–261.

Stoll, S., Breyer, P.D., Tonkin, J.D., Früh, D. and Haase, D. (2016) Scale-dependent effects of river habitat quality on benthic invertebrate communities – implications for stream restoration practice. *Science of the Total Environment*, 553, 495–503.

Wohl, E., Angermeier, P.L., Bledsoe, B., Kondolf, G.M., MacDonnell, L., Merritt, D.M., *et al*. (2005) River restoration. *Water Resources Research*, 41, 10.

Woolsey, S., Capelli, F., Gonser, T., Hoehn, E., Hostmann, M., Junker, B., *et al*. (2007) A strategy to assess river restoration success. *Freshwater Biology*, 52, 752–769.