



## Policy-driven monitoring and evaluation: Does it support adaptive management of socio-ecological systems?



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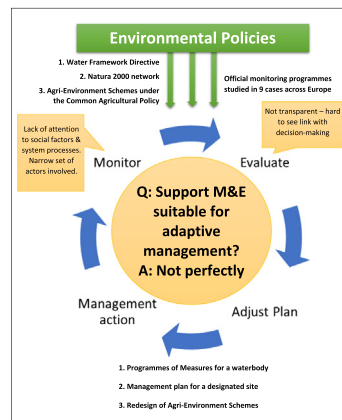
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### HIGHLIGHTS

- Policy strongly influences Monitoring & Evaluation (M&E) of socio-ecological systems.
- We examine M&E of 3 major European policies in 9 regional and national cases.
- Policy-driven M&E is imperfect versus ideals of M&E to support adaptive management.
- Attention needed to systems, social issues, sharing data, and sharing intended uses.
- Examples from across Europe and different policies offer ideas for improvement.

### GRAPHICAL ABSTRACT

Graphical abstract showing the key focus and findings of this study on policy-based monitoring



### ARTICLE INFO

#### Article history:

Received 12 September 2018

Received in revised form 29 December 2018

Accepted 30 December 2018

Available online 4 January 2019

### ABSTRACT

Inadequate Monitoring and Evaluation (M&E) is often thought to hinder adaptive management of socio-ecological systems. A key influence on environmental management practices are environmental policies: however, their consequences for M&E practices have not been well-examined.

We examine three policy areas - the Water Framework Directive, the Natura 2000 Directives, and the Agri-Environment Schemes of the Common Agricultural Policy - whose statutory requirements influence how the

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Editor: Damia Barcelo

**Keywords:**

Adaptive management  
Environmental governance  
Policy  
Monitoring & evaluation  
Socio-ecological systems  
Sustainability

environment is managed and monitored across Europe. We use a comparative approach to examine what is monitored, how monitoring is carried out, and how results are used to update management, based on publicly available documentation across nine regional and national cases.

The requirements and guidelines of these policies have provided significant impetus for monitoring: however, we find this policy-driven M&E usually does not match the ideals of what is needed to inform adaptive management. There is a tendency to focus on understanding state and trends rather than tracking the effect of interventions; a focus on specific biotic and abiotic indicators at the expense of understanding system functions and processes, especially social components; and limited attention to how context affects systems, though this is sometimes considered via secondary data. The resulting data are sometimes publicly-accessible, but it is rarely clear if and how these influence decisions at any level, whether this be in the original policy itself or at the level of measures such as site management plans.

Adjustments to policy-driven M&E could better enable learning for adaptive management, by reconsidering what supports a balanced understanding of socio-ecological systems and decision-making. Useful strategies include making more use of secondary data, and more transparency in data-sharing and decision-making. Several countries and policy areas already offer useful examples. Such changes are essential given the influence of policy, and the urgency of enabling adaptive management to safeguard socio-ecological systems.

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## 1. Introduction

Monitoring and evaluation (M&E) are essential to adaptive management (Stem et al., 2005). However, monitoring practices are often reported to be inadequate, limiting evaluation and learning within the adaptive management cycle (e.g. Engel-Cox and Hoff, 2005; Margoluis et al., 2009). Contemporary environmental management is no longer solely focused on single sites and single issues but must take account of ongoing global changes and challenges (Pahl-Wostl, 2007), which complicate the existing challenges of achieving sustainable and equitable outcomes from socio-ecological systems. The need for flexible approaches that involve multiple actors working across multiple levels is an essential prerequisite for achieving societal objectives in the face of global change (Duit et al., 2010). This is particularly pressing given the need for progress to the international agreed objectives set by the Sustainable Development Goals, which reinforce the need to consider socio-ecological systems and interconnections (Hajer et al., 2015; Nilsson et al., 2016). Thus, M&E should ideally enable environmental managers to respond to new understandings, changing contexts and goals.

Policies designed to safeguard or improve the environment remain a key influence on environmental management practices (Jordan et al., 2005). Conversely, successful environmental management is often judged in terms of whether the management practices have achieved these environmental policy objectives (Mickwitz, 2003). However, despite the importance of policies, their influences specifically on M&E of management practices have not been sufficiently examined. Some accounts suggest statutory policy requirements may not match with what is actually needed to inform management (e.g. Chapman, 2012), and that regulatory inflexibility can impede adaptive management (e.g. McLain and Lee, 1996), so a closer examination of this topic is vital.

We address this gap in the literature by exploring the monitoring programmes entailed by three European environmental policies. The European Union (EU) is often considered a world-leader in adopting policy designed to protect and enhance ecosystems and environmental quality (Kelemen, 2010; Zito, 2005), and so we have chosen three policy areas associated with European environmental management: the Water Framework Directive (WFD); The Natura 2000 network of protected areas; and Agri-Environment Schemes (AES) within the Rural Development Programmes of the Common Agricultural Policy. Exploring their implications is timely given the 20th anniversary of Aarhus (UNECE, 1998), which demands stakeholder access to information, consultation and active involvement in environmental management, and hence should reinforce the demand for M&E that is transparent and democratic.

The objectives of this study are:

1. To describe site-level monitoring and evaluation (M&E) driven by three European-level policies;
2. To compare existing practice to criteria for M&E advocated to support adaptive management; in terms of (i) what should be monitored (ii) how monitoring should be carried out and (iii) how monitoring information should be used in decision-making; and
3. To explore implications and recommendations for improving M&E to better support adaptive management.

In the following sections we review the literature to explore ideals for M&E that would best support adaptive management, before describing the policies we focus on in this study, and our methods for doing so. We address the first objective by describing our cases and current practices for M&E across the three policies. The findings section focuses on findings relevant to the second objective. These are structured according to the topics of monitoring, methods of monitoring, and then the uses of this information in evaluation and decision-making. We address the last objective by discussing the implications for future research and practice.

## 2. What should monitoring & evaluation consist of, to support adaptive management?

Adaptive management, at its simplest, is conducting natural resource management “in a manner that purposely and explicitly aims at increasing knowledge and reducing uncertainty” (Holling, 1978). A large body of theory and practice has developed on this topic (Macleod et al., 2016; Rist et al., 2013). The adaptive management cycle (Fig. 1) entails designing and revising plans so as to allow knowledge collection that informs decision-making about management. Additionally, the need to involve stakeholders at every part of this cycle has been emphasised by a literature on ‘adaptive co-management’ (Olsson et al., 2004). Although different authors emphasise different aspects of adaptive management—some focus on the need for systems approaches (e.g. Williams, 2011) whilst other focus on strengthening stakeholder involvement (e.g. Armitage et al., 2009) – all highlight the need to enable learning by those trying to achieve management objectives. Monitoring the effects of past actions provides information needed for this learning; therefore M&E is pivotal to adaptive management, in order to inform and update future decisions about environmental management.

The adaptive management literature tends to focus on how learning and change could occur at the level of management practices, though there is scope to link this with other governance levels. In this paper

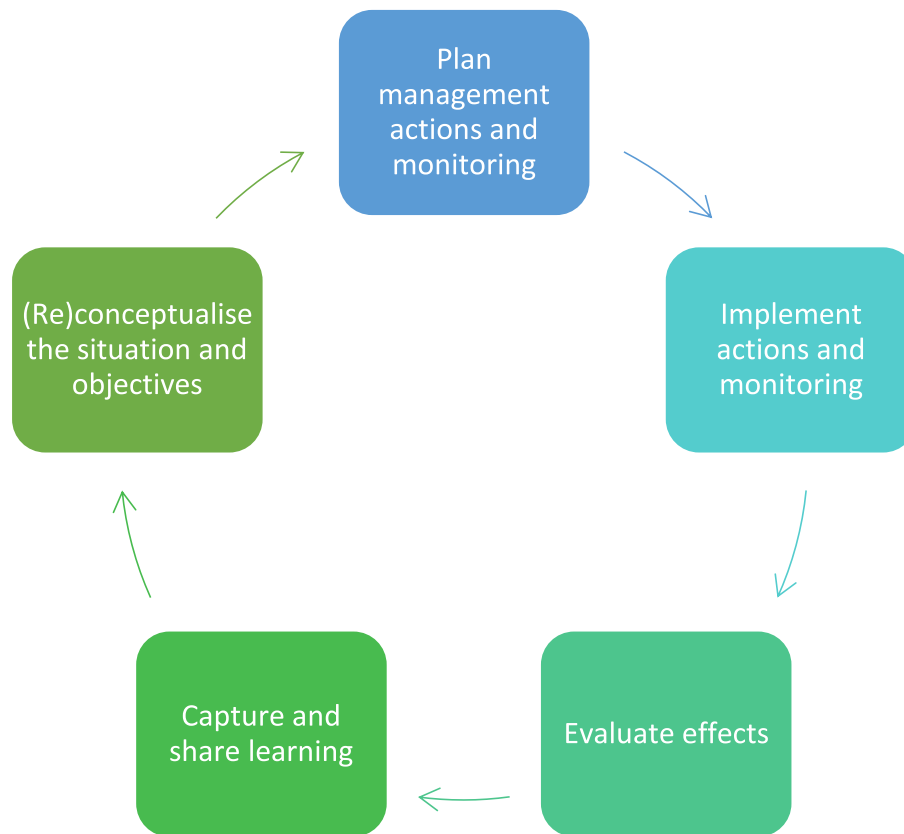


Fig. 1. The adaptive management cycle, adapted from various sources and in particular Macleod et al. (2016).

we similarly focus on this level, i.e. primarily considering M&E at the level of specific management interventions and specific management objectives, rather than M&E of the overarching EU policies themselves (e.g. WFD, Natura 2000 or CAP). The term “public policy” refers to a stated objective and intention by the State: though often associated with legislation passed at the national-level, the term can encompass a range of levels from the regional through to EU and a range of activities. In the language of policy studies, we focus on the *implementation* of ‘level one’ steering policies. In other words, the subsidiary levels where the goals and objectives from ‘level one’ steering policies (WFD, Natura 2000, CAP) are operationalised with concrete manifestations in particular settings and places (Mickwitz et al., 2009). This is a focus that can help build knowledge of environmental policy implementation (Rauschmayer et al., 2009).

Our understanding of M&E appropriate to support adaptive management draws strongly on the review of monitoring ideals contained within Waylen and Blackstock (2017). This paper builds on a suite of existing literature that emphasises the need to consider both the subject and process of monitoring, i.e. both ‘what’ and ‘how’. Studying the effects of actions is necessary but it is important to also build understanding about systems’ processes (e.g. Cundill and Fabricius, 2009), socio-economic dimensions (e.g. Chapman, 2014), and context that influences the system (Morandi et al., 2014); so that the cumulative effects on the system can be assessed. All these approaches are needed to build confident understanding of the effect of interventions or management actions. For example, it is useful to monitor lake water quality before and after a management intervention e.g. to reduce effects of eutrophication, but to understand the treatment’s effects, information is also needed about other ecosystem processes and changes in the lake (e.g. changes in aquatic production and respiration rates), connectivity, other activities in the lake (e.g. pollution from recreational uses), and large-scale changes that directly or indirectly influence the system (such as seasonal changes in precipitation patterns). These factors

should ideally be tracked before and after treatments are applied, e.g. - before-after-control-impact (BACI) and related designs (Conner et al., 2016). Careful monitoring design may seem overwhelming given the plethora of objectives to be considered (Strobl and Robillard, 2008), but is needed or it can become impossible to distinguish between the effects of design, implementation or other factors (Hermans et al., 2013). Relevant information can be gathered and pooled from a variety of sources providing data in a variety of formats, including both qualitative and quantitative sources (Patton, 2010). Related to this, information should ideally be collected and analysed with the input broad support of a range of stakeholders in the system. This can not only enhance the knowledge base, but also support transparency and legitimacy of the management process itself (e.g. Krasny et al., 2014).

Of course, monitoring by itself is insufficient: evaluation is also required, and the results used to inform decisions about environmental management in order to fulfil the adaptive management cycle (Mickwitz, 2003; Schoenefeld and Jordan, 2017). There are many forms and objectives for evaluation (e.g. ex-ante, formative, substantive or ex-post) that all aim to systematically analyse evidence to make judgements about whether objectives have been achieved (Mark et al., 2006). Both the monitoring data – as well as a description of how these data are expected to be used – should be openly available and accessible, as transparency is widely accepted as principles of good governance (Lockwood et al., 2010) that can support adaptive management (Chaffin et al., 2014). Therefore, it is important to understand if and how the data are used to evaluate progress towards management goals (i.e. not simply using data to describe system states) and how this new knowledge is connected with reviewing past management actions and making new management decisions. Thus feedback and learning can potentially encompass decisions at any level up to national or supra-national institutions – the idea of ‘adaptive governance’ (Chaffin et al., 2014) – so for example at the level of European and national environmental policy design. Such policy change is in

principle possible, given the ‘Fitness checks’ to which many European policies have been subject (European Commission, 2012), though adaptive management is not explicitly cited in those checks.

Often, studies refer to a policy cycle spanning the process by which a policy is developed, formalised, implemented, evaluated and adjusted as needed, although this should be thought of as a heuristic rather than describing the reality of the policy process (Cairney, 2011; Jokinen et al., 2018). Therefore, there are similarities with the adaptive management cycle (Fig. 1) and in an ideal world we therefore expect policies that shape environmental management to also encourage M&E appropriate for adaptive management. Given that EU policies are the drivers, we are therefore focused on the ‘inside’ or ‘formal’ evaluation led by governments, rather than any ‘outside’ or ‘informal’ evaluation led by civil society (Hildén et al., 2014; Weiss, 1993). We would expect these formal monitoring programmes to guide the collection of information about several aspects of a socio-ecological system that is the target for management, using a range of information sources and involving a range of stakeholders. The resultant information should be reported and used to inform decision-making at one or more levels. This learning process should be documented and available to public scrutiny to fulfil the Aarhus objectives (Mason, 2010).

It is unclear whether we can reasonably expect policy-driven monitoring to perfectly satisfy these requirements at every level, from site management through to national or European policy reviews, since each level may have different priorities for learning and adaptation. Furthermore, the implementation of any environmental policy always occurs in the context of other policies and non-subsidiary objectives, whose goals may be added to monitoring and evaluation programmes. Therefore, we may find practices do not reflect the ideals of what is monitored and how monitoring should be carried out, as set out above and summarised in Table 1. However, whatever occurs, the expected and actual uses of monitoring information should be explicitly stated. Transparently documenting all processes of learning and updating management will best enable future learning and stakeholder involvement (Cundill and Fabricius, 2009); and lead to more effective outcomes for the socio-ecological system.

Unfortunately, many monitoring and evaluation processes have been reported as imperfect or inadequate. There is often an undue focus on biological or biophysical indicators (Brierley et al., 2010) without understanding how an intervention contributed to these (e.g. Margoluis et al., 2009), and insufficient attention to socio-economic aspects (e.g. Waylen and Blackstock, 2017) whilst overlooking non-scientific sources and non-quantitative types of knowledge (e.g. McLain and Lee, 1996). Since these studies sometimes cite requirements or restrictions by higher-levels as constraining project and programme M&E (McLain and Lee, 1996; Waylen and Blackstock, 2017), this suggests that policy-driven M&E may often not match the ideals of adaptive management. Policies are sometimes criticised as inflexible, but as they exert a strong and persistent influence on environmental management, this paper not only explores where they prompt divergence from an adaptive management ideal, but also considers how policy-driven M&E could be usefully re-orientated.

### 3. The three policy areas explored by this study

Our study explores the effects of three influential European policy areas: The Water Framework Directive (WFD); the Natura 2000 network designated under the Habitats Directive and Birds Directive; and Agri-Environment Schemes (AES) enabled by the European Agricultural Fund for Rural Development. Many other European and national-level policies also influence socio-ecological systems: however, we chose these three as they are commonly associated with environmental management, are all well-established, and provide a common basis for terrestrial and freshwater management across Europe. Despite their prominence, each policy is experiencing challenges which threaten to compromise legitimacy (OECD, 2015) and which may be further

**Table 1**

The criteria and questions used to structure analysis of monitoring programmes for each policy in every case.

<p>What is monitored?</p> <ul style="list-style-type: none"> <li>To understand (eco)system processes, both biotic and abiotic elements should be monitored, with a focus on the interactions that form the system or ecological community.</li> <li>To understand social and economic aspects of systems, these issues should be monitored, likely entailing coverage of demographics, economics and social attitudes and preferences.</li> <li>To understand system change, influential aspects of the Social, Technical, Environmental, Economic and Policy context should be monitored.</li> </ul>	<ul style="list-style-type: none"> <li>Is there monitoring of both abiotic and biotic indicators?</li> <li>Is there monitoring of interactions?</li> <li>Is information relevant to understanding ecological aspects of the system available from other sources, but not used as secondary data?</li> <li>Is any social or economic information monitored?</li> <li>Is information relevant to understanding the social or economic aspects of the system available from other sources, but not used as secondary data?</li> <li>What aspects of context are incorporated into the monitoring programme (Social, Technical, Environmental, Economic, Policy)?</li> <li>Is information relevant to understanding the context available from other sources, but not used as secondary data?</li> </ul>
<p>How is monitoring carried out?</p> <ul style="list-style-type: none"> <li>Monitoring should use targeted collection of primary data and also relevant secondary data where available.</li> <li>Data provision can involve a range of individuals and organisations to improve data coverage as well as engagement.</li> <li>Monitoring data should be accessible to its users and the public.</li> </ul>	<ul style="list-style-type: none"> <li>What secondary data are used in the monitoring programme? How?</li> <li>Do state or also non-state agencies provide monitoring data?</li> <li>Is there any use of citizen science?</li> <li>Are the monitoring data publicly available and accessible?</li> <li>Are processes of data synthesis and interpretation described anywhere?</li> <li>Do any more general data-sharing policies affect how monitoring is shared?</li> </ul>
<p>How is monitoring information used in decision-making?</p> <ul style="list-style-type: none"> <li>The process by which monitoring data are expected to be used in decision making should be transparent and publicly accessible.</li> <li>Monitoring data should be used to inform and update management.</li> <li>Monitoring data should be used to inform and update policy.</li> </ul>	<ul style="list-style-type: none"> <li>Are any evaluation reports available? If so, how are these used?</li> <li>Is there any information on the process by which management is redesigned, and how monitoring should feed into that?</li> <li>Are the management actions ever updated/changed?</li> <li>If so, is it known how monitoring data feeds into these changes?</li> <li>Is lack of data ever explicitly noted as a problem?</li> <li>Is there any public information available on the process by which national policy has or will be redesigned?</li> </ul>

impeded by changes such as climate change (e.g. Heller and Zavaleta, 2009; Johnson et al., 2010). It is therefore timely to assess monitoring driven by these policies, and do so in terms of adaptive management, since all the policy areas must adapt to change in order to deliver on their original goals and be relevant to current global challenges.

The WFD (2000/60/EC) provides Europe with an ambitious approach to improving the ecological status of all its freshwaters, reinforcing where relevant the Natura 2000 provisions (Schmedtje and Kremer, 2011). Actions required to achieve Good Ecological Status are captured within ‘Programmes of Measures’ specified for every River Basin in Europe, which are reviewed and revised every 6-year cycles of planning and implementation (European Commission, 2010). The WFD has catalysed significant effort to re-organise water management around aquatic ecology and catchments, yet still faces challenges in tackling the full range of pressures, dealing with dynamic systems, and



understanding anthropogenic factors (Bouleau and Pont, 2015; Hering et al., 2010; Kampa et al., 2012; Voulvoulis et al., 2017).

Biodiversity protection is most associated with Natura 2000 network of sites to safeguard endangered habitats and species (Evans, 2012) designated under the Birds Directive (2009/147/EC) and Habitats Directive (92/43/EEC). Member states must take conservation measures for each site, which will often entail a management plan (European Commission, 2013). These measures may be revised to reflect new knowledge or changes in site status, but there is no fixed timetable or requirement to do so. Natura 2000 is now well recognised, with many sites designated, yet the network is often thought to lack either political or local support, which limits the resources available for designing or implementing site management (Kati et al., 2015).

In the wider landscape beyond these designated sites, the European Agricultural Fund for Rural Development (Regulation 1305/2013; otherwise known as the second pillar of the Common Agricultural Policy) is important as it requires member states to create Rural Development Programmes containing one or more AES (The European Parliament and Council of the European Union, 2013). These schemes provide financial support for farmers to deliver environmental improvements to their land – for example, by providing wildlife-friendly habitats. They are a major source of conservation funding in Europe (Batáry et al., 2015), affecting approximately 25% of its agricultural land (Science for Environment Policy, 2017). These programmes are periodically revised as part of the wider Common Agricultural Policy cycle, every seven years. AES can produce positive effects for wildlife on farmland, but their effectiveness depends strongly on design and targeting (Batáry et al., 2015).

### 3.1. Monitoring programmes designated by each policy

Importantly, each policy stipulates some form of monitoring and evaluation within their policy framework, though none of these monitoring programmes have been designed to explicitly support site specific adaptive management. Monitoring for the WFD is an important part of the directive and relatively tightly prescribed by Articles 5 and 8. Every member state in Europe must use standardized or comparable methodology (European Commission, 2009a) to monitor multiple aspects of the ecological status for every waterbody (European Commission, 2009b). Specific guidance on monitoring has been developed, as part of the Common Implementation Strategy for the Directive (European Commission, 2003). The directive allows for three types of monitoring: long-term “surveillance monitoring”, to provide a broad understanding of trends in the state of freshwaters; “operational monitoring” to understand problems where waterbodies are in a in less than good condition; and potentially “investigative monitoring” when Supplementary information is required to understand events (European Commission, 2009b). Although primary data collection is not needed to report on every aspect in every waterbody, even carrying out the surveillance monitoring still entails a significant investment in data collection, analysis and modelling (Dworak et al., 2005; Hering et al., 2010).

Natura 2000 directives specify that protected habitats and species must be monitored (according to Article 11 of the Habitats Directive) whilst Article 17 of the Habitats Directive requires Member States to report to the European Commission every six years on progress made with implementation, incorporating reporting under the Birds Directive. There has been less guidance for monitoring than for the WFD. The Commission’s website (European Commission, 2017a) states that “As the main focus of the directive is on maintaining and/or restoring a favourable conservation status for habitat types & species of community interest, monitoring & reporting under the directive is focusing on that”. Assessments of conservation status are based on four parameters (for habitats, they are range, area, structure and functions, and future prospects; for species they are range, population, habitat of species and future prospects) however, by contrast with the WFD there are no prescribed methods for assessing these parameters.

Lastly, monitoring of AES is required by Title VII of the Rural Development regulation (1305/2013), within a monitoring and evaluation framework covering the whole of CAP set up under Article 110 of Regulation (EU) No 1306/2013 of the European Parliament and of the Council of 17 December 2013 on the Financing, Management and Monitoring of the Common Agricultural Policy and Repealing Council Regulations (EEC) No 352/78, (EC) No 165/94, (EC) No 2799/98, (EC) No 814/2000, (EC) No 1290/2005 and (EC) No 485/2008 (OJ L 347 of 20.12.2013), 2013. Under Title VII, Article 68 states “The monitoring and evaluation system shall aim to: (a) demonstrate the progress and achievements of rural development policy and assess the impact, effectiveness, efficiency and relevance of rural development policy interventions; (b) contribute to better targeted support for rural development; (c) support a common learning process related to monitoring and evaluation.” Article 75 requires this information to be reported yearly. M&E receives more attention than in earlier years of CAP implementation (European Commission, 2017b) although the specification of what must be monitored and reported is less tightly prescribed than for the WFD or Natura 2000. Since 2014 member states have been obliged to evaluate their agri-environment programmes – i.e. collections of AES – in relation to socio-economic, agricultural and environmental aspects (The European Evaluation Helpdesk for Rural Development, 2015): however, most evaluation studies simply examine uptake and spending on different schemes within programmes. This means the consequences of those schemes are often poorly understood (Allen et al., 2014).

Every member state or region that implements these policies must comply with their legislative requirements on monitoring and reporting: they are of course free to go beyond these, but in practice compliance with policy often uses much of the resources available for environmental management. The resources dedicated to monitoring are rarely explicit in absolute terms, or in relation to the overall spending on policy implementation. However, we can infer that resources allocated will relate to the scope of monitoring that is prescribed. For the WFD, monitoring is an important part of the directive’s design, and tightly prescribed and relatively inflexible with respect to novel methodologies due to the requirements of intercalibration, so all implementing agencies must use considerable resources to comply with the required monitoring programme (Hering et al., 2018; Leese et al., 2018). Monitoring may receive less attention under the other two policy areas since their monitoring methods are less tightly prescribed, although all three policies share the requirement for some degree of pan-EU comparability (Waterton and Wynne, 2004). For example, combining and comparing various pieces of information allows us to estimate that Scotland’s budget for monitoring AES is less than 1% of its total budget for AES implementation.<sup>2</sup> However, it is not usually possible to directly estimate or compare effort or resources between cases or policies.

Although each policy shapes M&E, none has been designed with explicit reference to adaptive management of socio-ecological systems. In particular, the Natura 2000 network, the oldest policy area we analyse, predates the widespread use of terms such as ‘socio-ecological systems’, and has goals that focus on achieving the protection of individual species and static habitats, rather than whole systems. Thus we may well expect that the M&E processes entailed by these policies do not reflect adaptive management or systems approaches. Despite this, it is still appropriate to ask to what extent these policies can enable M&E that supports adaptive management, since this perspective is now widely agreed as essential for sustainable and equitable outcomes from environmental management (Scott et al., 2015).

<sup>2</sup> The 2014–2020 budget for AES implementation in Scotland is £355 million (<http://www.gov.scot/Resource/0051/00514108.pdf>). This is about 25–30% of the total SRDP budget of £1.326bn. The budget for monitoring AES in Scotland (as evident from invitation to tender for monitoring the 2014–20 SRDP AES) is £350 k–£400 k, which includes monitoring of ‘greening’ measures which are not part of AES ([https://www.publiccontractsscotland.gov.uk/search/show/search\\_view.aspx?ID=MAR238898](https://www.publiccontractsscotland.gov.uk/search/show/search_view.aspx?ID=MAR238898)).

### 3.2. Policy implementation at the national and regional levels

European policies are always transposed into national law, or directly into regional law within countries which directly devolve environmental policy to the regional level (such as Spain, Belgium and the UK). Therefore here we focus on policy implementation in nine geographical cases, of which six are EU member states; Estonia; Finland, Hungary, Romania, Slovakia and Sweden; and of which three are regions within member states; Catalonia, Scotland, Flanders. These cases encompass a wide range of institutional and bio-climatic conditions, and the length of time they have been implementing the policies, and their approaches to transposing and implementing the policies. Therefore, there will be limits to the comparability of our cases; however, we expect that any commonalities or trends across this diverse group are likely to be generated by the common policy.

Every case defined the level of management as follows: for the WFD, Programmes of Measures designed to improve the ecological status of waterbodies; for Natura 2000, management plans to safeguard species and habitats on designated sites; for the Rural Development Programme, AES that operate at the farm-scale. These were chosen as they correspond to the level at which officially designated monitoring procedures also operate: for the WFD, the official WFD monitoring programme in each country, plus any plans for monitoring of measures that were listed within River Basin Management Plans; for Natura 2000, monitoring guidance for sites, plus any plans for monitoring of measures listed in the site plans; and for AES in the Rural Development Programmes, monitoring guidance for AES, plus any country-specific statements about how they apply the EU Common Evaluation and Monitoring Framework for the whole Common Agricultural Policy.

## 4. Data collection and analysis

The research methodology is based on qualitative analysis, which relies on looking for patterns based on texts and interpretation of those texts (Silverman, 2004). The basis of ‘validity’ and ‘reliability’ is different to statistically-based analyses: ‘validity’ comes from using a theoretically-derived approach and member checks (i.e. explicitly questioning interpretations of data), whilst ‘reliability’ comes from transparency about approach and recognition of and reflection on subjectivity. It recognises the importance of interpretation in analysis of data; and requires explicit deliberation about what we understand rather than believing that results are self-evident. Our thematic analysis was based in the theoretically-derived criteria for M&E highlighted in Table 1, with these criteria explicitly questioned, discussed and revised before and during their application.

Furthermore, the approach adopted a collective approach to analysis and interpretation of data using deliberation by experts from a range of perspectives. This approach is increasingly used in environmental and conservation science, bringing together plural perspectives to ensure a deeper and richer approach to analysis of data (e.g. Bartke et al., 2018; Sutherland et al., 2011). All co-authors also reflected on their own and others’ personal expectations, and backgrounds, to support a continuous process of member checks. The mix of co-authors reflects a wide range of disciplinary backgrounds (e.g. from sociology to hydrologists), and the resulting mix provided a good means to complement different expertise, highlight ambiguities or inconsistencies, and to reflect on differing epistemologies and subjectivities.

The first step in the methodology was to recruit teams to investigate and represent the effects of policy-driven monitoring in their country or region. The lead authors advertised for and selected teams to capture a spread of cases across Europe, representing both biogeographical diversity (i.e. from Mediterranean to boreal settings) and institutional variability (e.g. in length of time in which European policies have been implemented). This sample provided sufficient diversity to compare and contrast approaches; whilst allowing data-management to remain feasible. Each team of co-authors searched for and reviewed any

publicly available documentation about monitoring under each policy area in their case. They then documented policy-driven monitoring in their country or region, for all three policy areas, using a common template. The templates were filled in based on information available from publicly available documents, with references to these documents made for all statements within the completed templates. To ensure that each team had identified the relevant publicly available documents, members consulted experts from their networks. To ensure comparability, we have explicitly used only publicly-available documentation, even when participants, their institutions or other experts may have inside tacit knowledge of the practical implementation of monitoring of some schemes.

The information was then compared and discussed at a structured three-day workshop, in which the data from each partner was gathered into matrices of policies and countries to facilitate the identification of patterns. The workshop followed a structured process of looking for patterns by making comparisons across the directives and across countries; ambiguities and inconsistencies were also discussed; and preliminary themes and implications were iterated. A revised template (see Supplementary material) was then used to consolidate and supplement this first set of information, to clarify ambiguities and answer new questions. The set of public documents used by for analysis of the nine cases is reported in a companion Data In Brief article, together with the resulting tables of responses to each of the questions below, for all three policies in all nine cases. The completed templates were used to answer questions that allowed appraisal of M&E against the main criteria describing ‘what information is collected’, ‘how is monitoring carried out?’ and ‘how is monitoring information used in decision-making’ (see Table 1). These criteria for evaluation were derived from the review of M&E to support adaptive management in Waylen and Blackstock (2017), and structure the findings reported in the following section. Therefore, the paper presents the collective analysis (completed at the workshop and through follow-up co-author virtual meetings) of a large set of documents using a common set of criteria and based on deliberation regarding how to interpret and consolidate these rich data.

## 5. Findings

We review what we found about monitoring and its uses, discussing each of the main analytic criteria and then discussing any differences between policies. Table 2 presents an overview of our results, which are discussed below. These broad analyses necessarily synthesise messages and thereby remove the nuances within the detailed data; but help illustrate the main points arising from the comparative approach. In summary, whilst there is some variation in practices between each policy area, none can be said to perfectly match what is required to support adaptive management.

### 5.1. What is monitored?

Monitoring under the WFD included both biotic and abiotic components, and was relatively comprehensive and consistent, allowing some but not all aspects of ecosystem functioning to be understood. However, there was potentially redundancy in some information collected, as several taxonomic groups must be monitored even though they are likely to respond similarly to common pressures, such as eutrophication. There was less evidence of efforts designed to track the effects of management actions. The Natura 2000 directives often require habitat quality to be understood but provide less insight into ecosystem processes, though drivers of some processes are tracked (e.g. hunting pressures) often at the discretion of implementing agencies in different cases. Monitoring of AES was usually the most limited and narrowly focused on reporting management activities with little monitoring of resultant ecological outcomes, i.e. checking the status of certain bird or plant species. There was considerable variation between cases: some such as Scotland carry out limited or no evaluation of the consequences of schemes

**Table 2**

Summary of monitoring and evaluation practices driven by each policy, in the 9 cases, as appraised against our criteria (see Table 1) for M&E to support adaptive management. Traffic light symbols of green, amber and red respectively indicate good, moderate and poor compliance with the criteria. The ziz-zag symbol indicates very variable practices across cases, and question symbols indicate lack of publicly-available data.

Evaluation Criteria	Policy area <sup>a</sup>		
	Natura 2000	WFD	AES
What is monitored?			
• Ability to understand ecosystem processes	Some but mainly focused on biotic processes and target species	Yes, some understanding of processes is possible.	Limited due to field scale focus
• Ability to understand social and economic aspects of systems	Some cases measure human pressures on protected sites and species	Some information collected to understand causes of pressures	Farm attributes and activities often measured
• Ability to understand context <sup>b</sup>	Some cases track external pressures on system e.g. from climate change	Limited beyond that needed to understand pressures	Context not usually measured
How is monitoring is carried out?			
• Use of secondary information <sup>c</sup>	Yes	Very little	Varies greatly between cases
• Involvement of non-state actors	Common - Non-state organisations and citizen science often used	Occasional involvement of non-state organisations	Uncommon, except for some subcontractors
• Public availability and accessibility of monitoring data	Databases of species often available	Information on ecological status often available but not raw data	Usually limited or non-existent
How is monitoring information used in decision-making?			
• Transparency of intended process for evaluating and using monitoring data in management	Not well documented	Not well documented	Not well documented
• Publicly documented uses of monitoring data to update or adapt management <sup>d</sup>	Monitoring data sometimes is used, but in many cases it is too early to answer this question	In some cases but not others there is a clear link to revised programmes of measures	Cannot answer as not well documented
• Publicly documented uses of monitoring data to revise policy	Cannot answer as not well documented	Cannot answer as not well documented	Cannot answer as not well documented

<sup>a</sup> Summary based on reviewing publicly available information about implementation of the official monitoring programmes for each policy in our 9 countries. This table solely focuses on common themes across countries: however, where implementation varies greatly between countries this is noted.

<sup>b</sup> Potential aspects of context include Social, Technical, Environmental, Economic, Policy, following the 'STEEP' typology (Bradfield et al., 2005).

<sup>c</sup> We distinguish between primary data (information collected as part of official monitoring programme for the policy) and secondary data (information collected for other policies and purposes). Secondary data is only included in this analysis if we know it is incorporated into monitoring or evaluation.

<sup>d</sup> Management under each policy is defined as: WFD; Programmes of Measures, Natura 2000; Site Management Plans and EAFRD; Agri-Environment Schemes.

whereas countries such as Romania and Estonia collect information on a range of abiotic and biotic indicators relevant to assessing the impact of schemes.

Across all three directives there was some social and economic information collected in the monitoring schemes, especially under Natura 2000, as requirements to monitor 'pressures' on habitats had led some countries to monitor forestry, agriculture, urbanisation, tourism and hunting. For the other directives social and economic aspects were generally a negligible part of the formal monitoring or secondary data use. Many sources of information collected for other programmes and policies are overlooked as potential sources of secondary data: for example, many places track domestic water use but do not use this in WFD monitoring. As a result, the socio-economic data that is used permits very limited insight into the interaction between humans and the ecosystem. Related to this, the need to understand external factors that might influence a system – for example, planned infrastructure development affecting water abstraction – was rarely stated within formal monitoring and evaluation programmes, even though we could see such data was sometimes cited within plans for management.

5.2. How is monitoring carried out?

All three monitoring programmes placed a strong reliance on primary data, and although use of secondary data does occur, it is quite variable between places and policies. Monitoring programmes for the

WFD most strongly relied on primary data collection: though secondary data were sometimes used (i.e. soil erosion maps and 'biological evaluation' maps in Flanders) but this remains a minor and exceptional input into evaluation. Monitoring programmes for the Natura 2000 policies also relied mainly on primary data collection, but some cases also have a significant input of secondary data, such as Seabird 2000 and Wetland Bird Surveys led by statutory agencies in Scotland. Sweden and Catalonia appeared to most fully integrate secondary data into their Natura 2000 monitoring, sources of which include land use and climate data to establish threats on habitats and species (Sweden), and habitat mapping and bird and butterfly abundance status (Catalonia). Monitoring under AES was most likely to rely strongly on secondary data – e.g. satellite images are integral for compliance checks and modelling in Romania – but even so in many countries the use of secondary data appears to be absent (Catalonia, Flanders) or more limited than in others (Estonia, Scotland).

This focus on primary data collection appeared related to the dominance of state agencies as the main actors involved in M&E, since these agencies or their contractors working to their standards are usually tasked with the collection of primary data. Monitoring for the WFD was nearly always dominated by state agencies. Monitoring for the Natura 2000 directives was more often achieved via a mixture of state and non-state actors, often involving NGOs (sometimes directly contracted) and sometimes relying on citizen science, especially for butterflies and charismatic vertebrates such as birds and reptiles. In some



cases the information generated by non-state actors is integral to Natura 2000 monitoring programmes: for example, Sweden has species databases that are directly fed by citizen science, whereas other places use this information more as a supplement (e.g. Estonia) and may require it be validated (e.g. Catalonia). Monitoring of AES in our cases was nearly always carried out by state agencies, probably as the private contractual nature of the voluntary relationship between farmers and government may make it more sensitive to involve non-state actors.

Availability of the resulting data to stakeholders and the wider public varied widely. Monitoring data collected for WFD and Natura 2000 are reasonably accessible, often via interactive web-interfaces, whilst easy access to AES data is very rare. Countries that have developed norms and policies of data-sharing (Estonia, Finland and Sweden) tend to have the most open and accessible data-sharing. Imperfect data availability and accessibility is in turn likely to hinder transparency and engagement of stakeholder groups in other parts of the adaptive management cycle.

### 5.3. How is monitoring information used in decision-making?

It was usually very challenging to trace, using publicly available documentation, whether or how management actions were updated in response to monitoring data. We could often observe that management actions are updated – for example, Programme of Measures under the WFD are revised every 6 years – but the link between these changes and the data from the monitoring programmes is not clear. Our workshop discussions highlighted that this apparent lack of connection may occur for two reasons. Firstly, there genuinely is no link, because the data collected are not suitable for informing management updates (e.g. due to issues with spatial resolution or the difficulty in attributing changes in the environment to the specific intervention). Secondly, there may be links between the data and updated management, but we cannot detect them because these links are not apparent in publicly available information. The most difficult policy area to understand was AES, but the feedback processes by which monitoring data were used to review Natura 2000 site management plans and WFD programmes of measures were also opaque. Whether or not the monitoring data were widely accessible, processes of data synthesis, evaluation and decision-making were rarely publicly documented. It is possible that feedback could occur to higher-levels, such as to inform the redesign of policies themselves, but again this was not possible to detect using publicly available information.

## 6. Discussion

Our analysis shows that none of the studied European policies appear to drive monitoring that is sufficient to support learning for adaptive management of socio-ecological systems. Their monitoring requirements do provide important information regarding trends in the state of the environment and this is useful; but these data are not enough to understand the full socio-ecological system. Our study suggests that available data often do not enable understanding of dynamic ecological processes, the effects of socio-economic influences, nor external drivers, which in turn limits ability to understand the effect of management actions.

These findings confirm existing problems identified in the literature. The cases we studied seem to reflect and reinforce a trend for monitoring to focus on narrow aspects of biophysical systems (Butler et al., 2015; Hale and Adams, 2007). This may sometimes result in redundant information being collected on some aspects of systems (Kelly et al., 2016), whilst generating limited understanding of socio-economic aspects or the contextual drivers on the system to be managed (i.e. a designated site, waterbody or farm). Thus, at present, monitoring often seems to be seen as a technical issue, overly focussed on specified elements of a system (Chapman, 2012). This partial perspective is likely to limit learning by those responsible for land or water management.

For example, a study of AES indicators in Finland has concluded that they do not easily support either policy choices or management actions (Yli-Viikarä, 2011) and perhaps this is also the case elsewhere.

State agencies are usually the primary collector and user of these primary data, although we observed use of other sources and types of data to be more common for the Natura 2000 network. These arrangements tend to reinforce the exclusion of local or experiential knowledge observed in other research, although the promise of citizen science is increasingly being recognised (Conrad and Hilchey, 2011). Finally, a lack of transparency about decision-making hinders our ability to appraise if and how any of this monitoring is used in evaluation to influence learning and change at any level. This lack of attention to the ‘back loop’ of the policy implementation cycle is well reported in the evaluation literature and represents a governance challenge, with potential consequences for legitimacy (Schoenefeld and Jordan, 2017).

Since our data rely on publicly available information, it is important to note this may not always represent practice on the ground if this is undocumented, reflecting a common distinction between the formalised depiction of institutions in texts and the reality of implementation practices (Funke et al., 2007). Furthermore, sometimes we found it difficult to find or understand what was published; in other cases, we were overwhelmed by the amount of technical detail available. Therefore, this study summarises our expert interpretations of the published information and may not reflect the views of the responsible authorities for these monitoring regimes in each of our cases. Whilst valuable conclusions emerged from the analysis, including understanding the availability and accessibility of monitoring data itself, we cannot claim our findings represent the full picture of how M&E data are used. These caveats give rise to implications for policy, practice and further research.

### 6.1. Implications for policy and practice

Of the three policies we studied, monitoring under the WFD seemed most suited to building systems understanding, whilst monitoring under Natura2000 often demonstrated good involvement of stakeholders in data collection and access: however, no monitoring programmes showed a perfect fit with ideals from the literature. As policy-driven M&E often does not match recommendations derived from theory (Waylen and Blackstock, 2017) it is worthwhile to consider adjustments to the M&E systems that are required, guided or inspired by policy. High-level policies should not – and cannot – specify the fine detail of how to do M&E in different settings; however, policy objectives and requirements can help to enable M&E that will support adaptive management in different settings (Claruis et al., 2014).

We recognise that the policies we studied, as for many others, have not been explicitly designed around concepts of adaptive management or socio-ecological systems. Furthermore, environmental policies are not the only factor that can shape M&E practices – for example, in Europe any member state is free to go beyond the requirements of the European Directives. However, in practice, there may often be little appetite or ability to go further than compliance with their requirements (Vinke-de Kruijff et al., 2015). Given the influence that policy has on data collection and data use in decision making, and the need to respond to concerns such as climate change and the Sustainable Development Goals (Selomane et al., 2015; Vasseur et al., 2017), it is appropriate to consider how policy can help improve M&E. These insights are relevant both within and beyond Europe, since the challenges of improving M&E and practicing adaptive management are internationally shared (Allen and Gunderson, 2011). For example, in Australia, the principle of adaptive management explicitly informs the management and evaluation of the whole Murray-Darling Basin (Murray-Darling Basin Authority, 2017).

A key priority is to focus more on enabling learning about the effects of management actions. This may entail a greater attention to M&E as an essential part of the adaptive management cycle, accompanied by sufficient budgets: the literature suggests 10% of the total resources for



management is appropriate for monitoring (O'Sullivan, 2004). This need not entail solely more primary data collection, but also investment in the processes of interpretation, social learning and public engagement (Chapman, 2014). It also entails a rebalancing of what is studied, to start with a more systemic approach. This may highlight trade-offs associated with investing in different data types or different aspects of the M&E process. Such reflection would benefit all of M&E programmes that we studied, even programmes under the WFD, which was originally intended to promote a more systemic perspective (Voulvoulis et al., 2017). However, the need to prioritise and rebalance monitoring is particularly acute in the case of AES: these are sometimes only 'monitored' in terms of describing the distribution and spending on programmes; whereas adaptive management would require M&E of both the activities and their consequences (see research on payment by results, Hart et al., 2018).

Enabling policy-driven M&E to support adaptive management may not always require significant additional resources, if there are opportunities to rebalance attention towards learning about the effects of management actions, with less attention given to tracking trends that cannot be related to management. Such a rebalancing may not always be appropriate or feasible, but should be considered especially in the case of the WFD, where there are opportunities to reconsider the set of indicators that must be reported (Bouleau and Pont, 2015), i.e. away from "surveillance" and towards "operational" monitoring. Opportunities to improve the quality of monitoring and evaluation may also occur by capitalising on other initiatives that can provide secondary data (UNEP, 2009). Whilst not cost-free, it may be a cost-effective solution. For example, information about nitrogen depositions has not often been integrated into reporting under the Habitats Directive, even though nitrogen depositions are a major threat to the Natura 2000 objectives (Whitfield and McIntosh, 2014). Relevant information may often come from initiatives not directly concerning environmental policy, especial for social and economic information. For example, many countries monitor outdoor recreation and access (Sievänen et al., 2008).

In Europe, there are already proposals to link the reporting requirements for some policies<sup>3</sup> and this should perhaps go even further in the scope of policies considered. Appraising other possible sources of information was not a central consideration for our study, but several times our research team could easily identify sources of information that appeared to be relevant. Sometimes these datasets are collected by state agencies, such as landscape maps or forestry monitoring. Other groups of stakeholders may also hold relevant information and participatory information systems may offer a way to 'tap into' this local knowledge, as well as strengthen stakeholder involvement (Behmel et al., 2016). Such secondary information may be particularly useful for addressing gaps in understanding the social processes and features – including attitudes, preferences and activities – that are integral to understanding socio-economic systems and the causes of specific environmental problems (Jones et al., 2016). Overall, the priority should be to understand systems in their context, targeted around what can be used in decision-making for improved outcomes across the wider socio-ecological system, rather than collecting lots of data to give greater certainty about specific aspects of the state of the environment (Ortega-Argueta et al., 2016).

The processes of evaluation, interpretation, learning and decision-making themselves need more attention (Cundill and Fabricius, 2009). This paper has been able to report little about these, since little is publicly documented. If policy-driven M&E is not well suited to adaptive management, we may expect it has limited influence on decision-making about management – and may also limit what can be learnt by those working with higher-level policies – but we cannot know for sure. However, the principle of improving transparency applies not only to the monitoring data but also to the processes by which it is to

be reported and used (Chelimsky, 2006). Doing so can foster engagement and participation in adaptive management (e.g. Butler et al., 2015), allow observers and new actors to identify new possibilities and uses of the data, as well as enabling reflexive learning and updating on the management cycle itself (Cundill and Fabricius, 2009). Beyond these instrumental benefits to the environmental management process, the anniversary of the Aarhus convention is a reminder that fostering participation in environmental decision-making is a valuable goal in itself (Mason, 2010).

There is a great deal of heterogeneity in monitoring practices, as the three policy areas vary considerably in their remit and attention to monitoring, whilst every country and region we have studied has chosen different ways to interpret and implement the policies. This study has focused on the common themes across policies and cases, but the diversity requires further attention. Administrative styles and cultures of natural resource management vary between places (e.g. Pahl-Wostl et al., 2008), which will affect both ongoing practices and the best ways to apply principles. For example, additional challenges – yet also additional flexibility – may come where high-level policies are implemented within federal or devolved political structures, such as Germany or the UK (Verburg et al., 2016). Thus, even though we suggest that adjustments to high-level policies are needed to facilitate M&E that supports adaptive management, re-appraisal is also needed at other levels. Connecting principles for M&E with an in-depth understanding of contextual factors is a logical priority for future work. As we build experience in doing so, this will then generate opportunities to share learning across places and policies. For example, can frameworks or concepts such as DPSIR (Binder et al., 2013) help to operationalise principles about M&E? Are there risks to promoting transparency? What is an appropriate balance of efforts when trying to respond to multiple ideas from the literature? We can already see that monitoring under the WFD offers examples of how to understand ecosystem processes; whilst monitoring of the Natura 2000 network offers experiences on citizen involvement in monitoring and evaluation. Sharing experiences as they accumulate will identify more examples and build more understanding about strategies to improve M&E.

## 6.2. Implications for research

Trying to apply criteria for 'ideal' monitoring in real-world practices highlights several questions and tensions that are not easily resolved, and thus require attention from research. Otherwise, theoretically-derived ideas risk being seen as unworldly and inoperable by practitioners confronted by many competing demands and limited resources. We highlight three key issues which need more attention or guidance. Firstly, the calls for transparency are not always easily achieved. Individual and systematic barriers hinder ecological information sharing (Michener, 2015) whilst misgivings about confidentiality and transferability might further impede sharing of socio-economic information (King, 2011). Some of these barriers can be tackled, often by allocating institutional resources to enable and require data-sharing, whilst others may prove harder to overcome. In particular, transparency can be in tension with recommendations to widen the set of information sources that are used, since some actors may wish to protect their intellectual property or commercial data.

Secondly, more information is needed about the processes and needs of decision-making at all levels, before monitoring and evaluation can be better targeted to support them. Existing literatures e.g. on knowledge use (Weiss, 1980) or policy implementation 'deficits' (Jordan 1999) can be used to infer some challenges that decision-makers face in acting on information to achieve change, but further direct study of decision-making in environmental management is also needed. Unfortunately, the learning and deciding part of the adaptive management cycle receives far too little attention versus the attention given, say, to revising indicators and reducing uncertainty (Allen and Gunderson, 2011). There may also be political reasons why this happens

<sup>3</sup> [https://ec.europa.eu/info/law/better-regulation/initiatives/ares-2018-884453\\_en](https://ec.europa.eu/info/law/better-regulation/initiatives/ares-2018-884453_en).

– transparency about decision-making processes can risk exposing decision-makers to critiques, and identifying that changes are needed can be seen as admission of failure rather than celebrated for showing responsiveness and flexibility. Learning and decision-making needs more attention (Williams and Brown, 2014) understanding adaptive management as a socio-political process (Voß and Bornemann, 2011).

Lastly, there is potentially a tension between employing policy to drive change, whilst also allowing flexibility. Public policies can be a powerful force to shape and improve environmental management practices (Jordan et al., 2005) including monitoring; but complying with their mandates often limits flexibility and adaptiveness (Young, 2002), which are inherent to the adaptive management cycle. Allowing flexibility must be accompanied by efforts to safeguard processes that ensure legitimacy (Cosens, 2013). This tension is apparent in European policies: although they allow member states flexibility in implementation (the principle of subsidiarity), M&E procedures are constrained by the need for annual reporting and comparability, possibly due to concern to ensure that environmental policy is implemented across Europe (Jordan and Jeppesen, 2000). The challenge of how top-down policies can best drive change whilst allowing flexibility, is an ongoing challenge for research on environmental governance (Chaffin et al., 2014).

## 7. Conclusion

In many ways, Europe is well endowed with ecological data, which has often resulted from the statutory requirements of environmental policies. However, some of the most important policies are driving monitoring that is not well-suited to the needs of adaptive management or a systems approach. These policies may not have been designed to support adaptive management of socio-ecological systems, but the need to do so is increasingly obvious given global and systemic challenges like climate change. Our analysis illustrates priorities for rebalancing M&E, which may often be facilitated by sharing examples across policies and across places. Of course, it is impossible for any policy to dictate a monitoring programme that perfectly satisfies all the varied and constantly-changing needs of all levels of decision-making. However, improvements are possible. The time is ripe for policy to drive an explicit reconsideration of how and why we monitor, to best enable learning and action for sustainable environmental management.

## Acknowledgements

We thank the ALTER-Net High Impact Action for its financial support for the study that has led to this paper. ALTER-Net (<http://www.alternet.info/>) is a network of partner institutes who research biodiversity and ecosystem services and inform policymakers and the public about these topics. The research time for KAW, KLB, KM and FH was funded by the Scottish Government Strategic Research Programme 2016–21. Research time for JP was funded by CREAM (Centre for Ecological Research and Forestry Applications) and the Autonomous University of Barcelona. Each author team would also like to thank colleagues who provided input or expert feedback: in Catalonia, Carles Castells (Barcelona Province Council) and Pau Sainz de la Maza (Autonomous Government of Catalonia); in Estonia, Irja Truuma (Estonian Ministry of Environment); in Flanders, Desiré Paelinckx, An Leyssen, Jo Packet (Research Institute for Nature and Forest - INBO); in Scotland, Alison Hester, Antonia Eastwood, Marc Stutter, Rob Brooker, Robin Pakeman; and Sophie Tindale (James Hutton Institute); in Slovakia, Miriam Vlachovičová (the Slovak Academy of Sciences); in Sweden, Pavel Bina (Swedish Species Information Centre, SLU) and Katarina Kyllmar (Department of Soil and Environment, SLU). We also appreciate the useful insights of Ketil Skogen and Helene Figari (Norwegian Institute for Nature Research) who shaped the framing of the research and the development of our ideas.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.scitotenv.2018.12.462>.

## References

- Allen, C.R., Gunderson, L.H., 2011. Pathology and failure in the design and implementation of adaptive management. *J. Environ. Manag.* 92 (5), 1379–1384. <https://doi.org/10.1016/j.jenvman.2010.10.063>.
- Allen, B., Hart, K., Radley, G., Tucker, G., Keenleyside, C., Oppermann, R., Underwood, E., Menadue, H., Poux, X., Beaufoy, G., Herzon, I., Povellato, A., Vanni, F., Pražan, J., Hudson, T., Yellachich, N., 2014. Biodiversity protection through results based remuneration of ecological achievement. Report prepared for the European Commission, DG Environment, contract no ENV.B.2/ETU/2013/0046, Institute for European Environmental Policy, London. <http://ec.europa.eu/environment/nature/rbaps/handbook/docs/rbaps-report.pdf> (Accessed 13th June 2018).
- Armitage, D.R., Plummer, R., Berkes, F., Arthur, R.I., Charles, A.T., Davidson-Hunt, I.J., Diduck, A.P., Doubleday, N.C., Johnson, D.S., Marschke, M., McConney, P., Pinkerton, E.W., Wollenberg, E.K., 2009. Adaptive co-management for social–ecological complexity. *Front. Ecol. Environ.* 7 (2), 95–102. <https://doi.org/10.1890/07089>.
- Bartke, S., Hagemann, N., Harries, N., Hauck, J., Bardos, P., 2018. Market potential of nanoremediation in Europe – market drivers and interventions identified in a deliberative scenario approach. *Sci. Total Environ.* 619–620, 1040–1048. <https://doi.org/10.1016/j.scitotenv.2017.11.215>.
- Batáry, P., Dicks, L.V., Kleijn, D., Sutherland, W.J., 2015. The role of agri-environment schemes in conservation and environmental management. *Conserv. Biol.* 29 (4), 1006–1016. <https://doi.org/10.1111/cobi.12536>.
- Behmel, S., Damour, M., Ludwig, R., Rodriguez, M.J., 2016. Water quality monitoring strategies – a review and future perspectives. *Sci. Total Environ.* 571, 1312–1329. <https://doi.org/10.1016/j.scitotenv.2016.06.235>.
- Binder, C.R., Hinkel, J., Bots, P.W.G., Pahl-Wostl, C., 2013. Comparison of frameworks for analyzing social-ecological systems. *Ecol. Soc.* 18 (4), 26. <https://doi.org/10.5751/ES-05551-180426>. doi:10.5751/ES-05551-180426.
- Bouleau, G., Pont, D., 2015. Did you say reference conditions? Ecological and socio-economic perspectives on the European Water Framework Directive. *Environ. Sci. Pol.* 47, 32–41. <https://doi.org/10.1016/j.envsci.2014.10.012>.
- Bradfield, R., Wright, G., Burt, G., Cairns, G., Van Der Heijden, K., 2005. The origins and evolution of scenario techniques in long range business planning. *Futures* 37 (8), 795–812. <https://doi.org/10.1016/j.futures.2005.01.003>.
- Brierley, G., Reid, H., Fryirs, K., Trahan, N., 2010. What are we monitoring and why? Using geomorphic principles to frame eco-hydrological assessments of river condition. *Sci. Total Environ.* 408 (9), 2025–2033. <https://doi.org/10.1016/j.scitotenv.2010.01.038>.
- Butler, J.R.A., Young, J.C., McMyn, I.A.G., Leyshon, B., Graham, I.M., Walker, I., Baxter, J.M., Dodd, J., Warburton, C., 2015. Evaluating adaptive co-management as conservation conflict resolution: learning from seals and salmon. *J. Environ. Manag.* 160, 212–225. <https://doi.org/10.1016/j.jenvman.2015.06.019>.
- Cairney, P., 2011. *Understanding Public Policy: Theories and Issues*. Palgrave Macmillan, Basingstoke, England.
- Chaffin, B.C., Gosnell, H., Cosens, B.A., 2014. A decade of adaptive governance scholarship: synthesis and future directions. *Ecol. Soc.* 19 (3). <https://doi.org/10.5751/ES-06824-190356>.
- Chapman, P.M., 2012. Adaptive monitoring based on ecosystem services. *Sci. Total Environ.* 415, 56–60. <https://doi.org/10.1016/j.scitotenv.2011.03.036>.
- Chapman, S., 2014. A framework for monitoring social process and outcomes in environmental programs. *Eval. Program Plann.* 47, 45–53. <https://doi.org/10.1016/j.evalprogplan.2014.07.004>.
- Chelmsky, E., 2006. The purposes of evaluation in a democratic society. In: Shaw, I., Greene, J.C., Mark, M.L. (Eds.), *The SAGE Handbook of Evaluation*. SAGE, London, pp. 33–55.
- Claruis, M.H., Faticchi, S., Allan, A., Fuhrer, J., Stoffel, M., Romerio, F., Gaudard, L., Burlando, P., Beniston, M., Xoplaki, E., Toreti, A., 2014. Governing and managing water resources under changing hydro-climatic contexts: the case of the upper Rhone basin. *Environ. Sci. Pol.* 43, 56–67. <https://doi.org/10.1016/j.envsci.2013.11.005>.
- Conner, M.M., Saunders, W.C., Bouwes, N., Jordan, C., 2016. Evaluating impacts using a BACI design, ratios, and a Bayesian approach with a focus on restoration. *Environ. Monit. Assess.* 188 (10), 555. <https://doi.org/10.1007/s10661-016-5526-6>.
- Conrad, C.C., Hilchey, K.G., 2011. A review of citizen science and community-based environmental monitoring: issues and opportunities. *Environ. Monit. Assess.* 176 (1), 273–291. <https://doi.org/10.1007/s10661-010-1582-5>.
- Cosens, B.A., 2013. Legitimacy, adaptation, and resilience in ecosystem management. *Ecol. Soc.* 18 (1). <https://doi.org/10.5751/ES-05093-180103>.
- Cundill, G., Fabricius, C., 2009. Monitoring in adaptive co-management: toward a learning based approach. *J. Environ. Manag.* 90 (11), 3205–3211. <https://doi.org/10.1016/j.jenvman.2009.05.012>.
- Duit, A., Galaz, V., Eckerberg, K., Ebbesson, J., 2010. Governance, complexity, and resilience. *Glob. Environ. Chang.* 20 (3), 363–368. <https://doi.org/10.1016/j.gloenvcha.2010.04.006>.
- Dworak, T., Gonzalez, C., Laaser, C., Interwies, E., 2005. The need for new monitoring tools to implement the WFD. *Environ. Sci. Pol.* 8 (3), 301–306. <https://doi.org/10.1016/j.envsci.2005.03.007>.
- Engel-Cox, J.A., Hoff, R.M., 2005. Science-policy data compact: use of environmental monitoring data for air quality policy. *Environ. Sci. Pol.* 8 (2), 115–131. <https://doi.org/10.1016/j.envsci.2004.12.012>.

- European Commission, 2003. Common Implementation strategy for the Water Framework Directive (2000/60/EC) - Guidance Document No 7: monitoring under the Water Framework Directive Produced by Working Group 2.7 - Monitoring, Luxembourg, Office for Official Publications of the European Communities. [https://circabc.europa.eu/sd/a/63f7715f-0f45-4955-b7cb-58ca305e42a8/Guidance%20No%207%20-%20Monitoring%20\(WG%202.7\).pdf](https://circabc.europa.eu/sd/a/63f7715f-0f45-4955-b7cb-58ca305e42a8/Guidance%20No%207%20-%20Monitoring%20(WG%202.7).pdf).
- European Commission, 2009a. Commission Directive 2009/90/EC of 31 July 2009 laying down, and pursuant to 2000/60/EC of the European Parliament and of the Council, technical specifications for chemical analysis and monitoring of water status. *Off. J. Eur. Communities L* 201, 36–38.
- European Commission, 2009b. Monitoring programmes: taking the pulse of Europe's waters, WISE Water Note No.6 - Notes on the Implementation of the Water Framework Directive, European Commission, Brussels. [http://ec.europa.eu/environment/water/participation/pdf/watnotes/water\\_note6\\_monitoring\\_programmes.pdf](http://ec.europa.eu/environment/water/participation/pdf/watnotes/water_note6_monitoring_programmes.pdf) (Accessed 13th June 2018).
- European Commission, 2010. Factsheet: the Water Framework Directive, European Commission, Brussels. <http://ec.europa.eu/environment/pubs/pdf/factsheets/water-framework-directive.pdf> (Accessed 13th June 2018).
- European Commission, 2012. Fitness checks, European Commission, Brussels. [http://ec.europa.eu/smart-regulation/evaluation/docs/fitness\\_checks\\_2012\\_en.pdf](http://ec.europa.eu/smart-regulation/evaluation/docs/fitness_checks_2012_en.pdf) (Accessed 13th June 2018).
- European Commission, 2013. Commission note on establishing conservation measures for Natura 2000 sites. Doc. Hab.13-04/05, European Commission, Brussels. [http://ec.europa.eu/environment/nature/natura2000/management/docs/commission\\_note/comNote%20conservation%20measures\\_en.pdf](http://ec.europa.eu/environment/nature/natura2000/management/docs/commission_note/comNote%20conservation%20measures_en.pdf) (Accessed 13th June 2018).
- European Commission, 2017a. Habitats directive reporting, DG environment, Brussels. [http://ec.europa.eu/environment/nature/knowledge/rep\\_habitats/index\\_en.htm](http://ec.europa.eu/environment/nature/knowledge/rep_habitats/index_en.htm).
- European Commission, 2017b. Technical handbook on the monitoring and evaluation framework of the common agricultural policy 2014–2020, directorate general for agriculture and rural development, Brussels. <http://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetailDoc&id=21095&no=3> (Accessed 27th September 2018).
- Evans, D., 2012. Building the European Union's Natura 2000 network. *Nat. Conserv.* 1, 11. <https://doi.org/10.3897/natureconservation.1.1808>.
- Funke, N., Oelofse, S.H.H., Hattingh, J., Ashton, P.J., Turton, A.R., 2007. IWRM in developing countries: lessons from the Mhlathuze Catchment in South Africa. *Phys. Chem. Earth* 32 (15–18), 1237–1245. <https://doi.org/10.1016/j.pce.2007.07.018>.
- Hajer, M., Nilsson, M., Raworth, K., Bakker, P., Berkhout, F., de Boer, Y., Rockström, J., Ludwig, K., Kok, M., 2015. Beyond cockpit-ism: four insights to enhance the transformative potential of the sustainable development goals. *Sustainability* 7 (2), 1651. <https://doi.org/10.3390/su7021651>.
- Hale, B.W., Adams, M.S., 2007. Ecosystem management and the conservation of river-floodplain systems. *Landsc. Urban Plan.* 80 (1–2), 23–33. <https://doi.org/10.1016/j.landurbplan.2006.05.002>.
- Hart, K., Baldock, D., Tucker, G., 2018. Ideas for defining environmental objectives and monitoring systems for a results-oriented CAP post 2020. A report for WWF Deutschland, Institute for European Environmental Policy - IEEP, Brussels & London. <https://ieep.eu/publications/agriculture-and-land-management/future-of-the-cap-measuring-the-cap-s-environmental-and-climate-performance> (Accessed 8th August 2008).
- Heller, N.E., Zavaleta, E.S., 2009. Biodiversity management in the face of climate change: a review of 22 years of recommendations. *Biol. Conserv.* 142 (1), 14–32. <https://doi.org/10.1016/j.biocon.2008.10.006>.
- Hering, D., Borja, A., Carstensen, J., Carvalho, L., Elliott, M., Feld, C.K., Heiskanen, A.-S., Johnson, R.K., Moe, J., Pont, D., Solheim, A.L., de Bund, W.V., 2010. The European Water Framework Directive at the age of 10: a critical review of the achievements with recommendations for the future. *Sci. Total Environ.* 408 (19), 4007–4019. <https://doi.org/10.1016/j.scitotenv.2010.05.031>.
- Hering, D., Borja, A., Jones, J.I., Pont, D., Boets, P., Bouchez, A., Bruce, K., Drakare, S., Hänfling, B., Kahlert, M., Leese, F., Meissner, K., Mergen, P., Reyjol, Y., Segurado, P., Vogler, A., Kelly, M., 2018. Implementation options for DNA-based identification into ecological status assessment under the European Water Framework Directive. *Water Res.* 138, 192–205. <https://doi.org/10.1016/j.watres.2018.03.003>.
- Hermans, L.M., Slinger, J.H., Cunningham, S.W., 2013. The use of monitoring information in policy-oriented learning: insights from two cases in coastal management. *Environ. Sci. Pol.* 29, 24–36. <https://doi.org/10.1016/j.envsci.2013.02.001>.
- Hildén, M., Jordan, A., Rayner, T., 2014. Climate policy innovation: developing an evaluation perspective. *Environ. Polit.* 23 (5), 884–905. <https://doi.org/10.1080/09644016.2014.924205>.
- Holling, C.S., 1978. *Adaptive Environmental Assessment and Management*. John Wiley & Sons, Chichester, UK.
- Johnson, R.K., Bennion, H., Hering, D., Soons, M., Verhoeven, J., 2010. Climate change: defining reference conditions and restoring freshwater ecosystems. In: Kernan, M., Moss, B., Battarbee, R.W. (Eds.), *Climate Change Impacts on Freshwater Ecosystems*. Blackwell & Wiley, Oxford, pp. 203–215.
- Jokinen, P., Blicharska, M., Primmer, E., Van Herzele, A., Kopperoinen, L., Ratamäki, O., 2018. How does biodiversity conservation argumentation generate effects in policy cycles? *Biodivers. Conserv.* 27 (7), 1725–1740. <https://doi.org/10.1007/s10531-016-1216-5>.
- Jones, N.A., Shaw, S., Ross, H., Witt, K., Pinner, B., 2016. The study of human values in understanding and managing social-ecological systems. *Ecol. Soc.* 21 (1). <https://doi.org/10.5751/ES-07977-210115>.
- Jordan, A., 1999. The implementation of EU environmental policy: a policy problem without a political solution? *Environ. Plan. C Gov. Policy* 17 (1), 69–90. <https://doi.org/10.1068/c170069>.
- Jordan, A., Jeppesen, T., 2000. EU environmental policy: adapting to the principle of subsidiarity? *Eur. Environ.* 10 (2), 64–74. [https://doi.org/10.1002/\(SICI\)1099-0976\(200003/04\)10:2%3C64::AID-EET19%3E3.0.CO;2-Z](https://doi.org/10.1002/(SICI)1099-0976(200003/04)10:2%3C64::AID-EET19%3E3.0.CO;2-Z).
- Jordan, A., Wurzel, R.K.W., Zito, A., 2005. The rise of 'new' policy instruments in comparative perspective: has governance eclipsed government? *Polit. Stud.* 53 (3), 477–496. <https://doi.org/10.1111/j.1467-9248.2005.00540.x>.
- Kampa, E., von der Weppen, J., Farmer, A., 2012. 2nd stakeholder workshop for the fitness check of EU freshwater policy. Organised by ecologic, IEEP and BioIntelligence on behalf of the European Commission, Ecologic. [https://www.ecologic.eu/sites/files/publication/2014/kampa\\_12\\_fitness\\_check\\_ws\\_paper\\_0.pdf](https://www.ecologic.eu/sites/files/publication/2014/kampa_12_fitness_check_ws_paper_0.pdf) (Accessed 1st August 2018).
- Kati, V., Hovardas, T., Dieterich, M., Ibsch, P.L., Mihok, B., Selva, N., 2015. The challenge of implementing the European network of protected areas Natura 2000. *Conserv. Biol.* 29 (1), 260–270. <https://doi.org/10.1111/cobi.12366>.
- Kelemen, R.D., 2010. Globalizing European union environmental policy. *J. Eur. Publ. Policy* 17 (3), 335–349. <https://doi.org/10.1080/13501761003662065>.
- Kelly, M.G., Birk, S., Willby, N.J., Denys, L., Drakare, S., Kahlert, M., Karjalainen, S.M., Marchetto, A., Pitt, J.-A., Urbanič, G., Poikane, S., 2016. Redundancy in the ecological assessment of lakes: are phytoplankton, macrophytes and phytobenthos all necessary? *Sci. Total Environ.* 568, 594–602. <https://doi.org/10.1016/j.scitotenv.2016.02.024>.
- King, G., 2011. Ensuring the data-rich future of the social sciences. *Science* 331 (6018), 719–721. <http://science.sciencemag.org/content/sci/331/6018/719.full.pdf>.
- Krasny, M.E., Russ, A., Tidball, K.G., Elmqvist, T., 2014. Civic ecology practices: participatory approaches to generating and measuring ecosystem services in cities. *Ecosyst. Serv.* 7, 177–186. <https://doi.org/10.1016/j.ecoser.2013.11.002>.
- Leese, F., Bouchez, A., Abarenkov, K., Altermatt, F., Borja, A., Bruce, K., Ekrem, T., Čiampor, F., Čiamporová-Zat'ovičová, Z., Costa, F.O., Duarte, S., Elbrecht, V., Fontaneto, D., Franc, A., Geiger, M.F., Hering, D., Kahlert, M., Kalamujčić Strojil, B., Kelly, M., Keskin, E., Liska, I., Mergen, P., Meissner, K., Pawlowski, J., Penev, J., Reyjol, Y., Rotter, A., Steinke, D., van der Wal, B., Víteček, S., Zimmermann, J., Weigand, A.M., 2018. Chapter two - why we need sustainable networks bridging countries, disciplines, cultures and generations for aquatic biomonitoring 2.0: a perspective derived from the DNAqua-net COST action. In: Bohan, D.A., Dumbrell, A.J., Woodward, G., Jackson, M. (Eds.), *Advances in Ecological Research*. Academic Press, pp. 63–99.
- Lockwood, M., Davidson, J., Curtis, A., Stratford, E., Griffith, R., 2010. Governance principles for natural resource management. *Soc. Nat. Resour.* 23 (10), 986–1001. <https://doi.org/10.1080/08941920802178214>.
- Macleod, C.J.A., Blackstock, K., Brown, K., Eastwood, A., Gimona, A., Prager, K., Irvine, R.J., 2016. Adaptive management: an overview of the concept and its practical application in the Scottish context, The James Hutton Institute, Aberdeen, Scotland. [https://www.hutton.ac.uk/sites/default/files/files/research/srp2016-21/RESAS\\_srp143\\_aD1\\_ReportOnRelevantAdaptiveManagementApproachesForScotland\\_v0.8Final.pdf](https://www.hutton.ac.uk/sites/default/files/files/research/srp2016-21/RESAS_srp143_aD1_ReportOnRelevantAdaptiveManagementApproachesForScotland_v0.8Final.pdf) (Accessed 8th August 2018).
- Margoluis, R., Stem, C., Salafsky, N., Brown, M., 2009. Using conceptual models as a planning and evaluation tool in conservation. *Eval. Program Plann.* 32 (2), 138–147. <https://doi.org/10.1016/j.evalprogplan.2008.09.007>.
- Mark, M.L., Greene, J.C., Shaw, I., 2006. The evaluation of policies, programs and practices. In: Shaw, I., Greene, J.C., Mark, M.L. (Eds.), *The SAGE Handbook of Evaluation*. SAGE, London, pp. 1–30.
- Mason, M., 2010. Information disclosure and environmental rights: the Aarhus convention. *Glob. Environ. Polit.* 10 (3), 10–31. [https://doi.org/10.1162/GLEP\\_a.00012](https://doi.org/10.1162/GLEP_a.00012).
- McLain, R.J., Lee, R.G., 1996. Adaptive management: promises and pitfalls. *Environ. Manag.* 20 (4), 437–448. <https://doi.org/10.1007/BF01474647>.
- Michener, W.K., 2015. Ecological data sharing. *Eco. Inform.* 29, 33–44. <http://www.sciencedirect.com/science/article/pii/S1574954115001004>.
- Mickwitz, P., 2003. A framework for evaluating environmental policy instruments: context and key concepts. *Evaluation* 9 (4), 415–436. <https://doi.org/10.1177/1356389003094004>.
- Mickwitz, P., Aix, F., Beck, S., Carss, D., Ferrand, N., Görg, C., Jensen, A., Kivimaa, P., Kuhllicke, C., Kuindersma, W., Máñez, M., Melanen, M., Monni, S., Pedersen, A.B., Reinert, H., van Bommel, S., 2009. *Climate Policy Integration, Coherence and Governance. PEER - Partnership for European Environmental Research*, Helsinki.
- Morandi, B., Piégay, H., Lamouroux, N., Vaudor, L., 2014. How is success or failure in river restoration projects evaluated? Feedback from French restoration projects. *J. Environ. Manag.* 137, 178–188. <https://doi.org/10.1016/j.jenvman.2014.02.010>.
- Murray-Darling Basin Authority, 2017. Basin plan adaptive management framework, Murray-Darling Basin Authority, Canberra. <https://www.mdba.gov.au/sites/default/files/pubs/basin-plan-adaptive-management-framework-2017.pdf> (Accessed 29th November 2018).
- Nilsson, M., Griggs, D., Visbeck, M., 2016. Map the interactions between sustainable development goals. *Nature* 534 (7607), 320–322. <https://doi.org/10.1038/534320a>.
- OECD, 2015. OECD principles of water governance, OECD, Directorate for Public Governance and Territorial Development. Paris. <http://www.oecd.org/governance/oecd-principles-on-water-governance.htm> (Accessed 3rd August 2018).
- Olsson, P., Folke, C., Berkes, F., 2004. Adaptive comanagement for building resilience in social-ecological systems. *Environ. Manag.* 34 (1), 75–90. <https://doi.org/10.1007/s00267-003-0101-7>.
- Ortega-Argueta, A., González-Zamora, A., Contreras-Hernández, A., 2016. A framework and indicators for evaluating policies for conservation and development: the case of wildlife management units in Mexico. *Environ. Sci. Pol.* 63, 91–100. <https://doi.org/10.1016/j.envsci.2016.05.003>.
- O'Sullivan, R.G., 2004. *Practicing Evaluation: A Collaborative Approach*. Sage, London.
- Pahl-Wostl, C., 2007. Transitions towards adaptive management of water facing climate and global change. *Water Resour. Manag.* 21 (1), 49–62. <https://doi.org/10.1007/s11269-006-9040-4>.
- Pahl-Wostl, C., Tàbara, D., Bouwen, R., Craps, M., Dewulf, A., Mostert, E., Ridder, D., Taillieu, T., 2008. The importance of social learning and culture for sustainable water management. *Ecol. Econ.* 64 (3), 484–495. <https://doi.org/10.1016/j.ecolecon.2007.08.007>.
- Patton, M.Q., 2010. *Developmental Evaluation: Applying Complexity Concepts to Enhance Innovation and Use*. Guilford Press, London.



- Rauschmayer, F., Berghöfer, A., Omann, I., Zikos, D., 2009. Examining processes or/and outcomes? Evaluation concepts in European governance of natural resources. *Environ. Policy Gov.* 19 (3), 159–173. <https://doi.org/10.1002/eet.506>.
- Regulation (EU) No 1306/2013 of the European Parliament and of the Council of 17 December 2013 on the Financing, Management and Monitoring of the Common Agricultural Policy and Repealing Council Regulations (EEC) No 352/78, (EC) No 165/94, (EC) No 2799/98, (EC) No 814/2000, (EC) No 1290/2005 and (EC) No 485/2008 (OJ L 347 of 20.12.2013) p. 579.
- Rist, L., Felton, A., Samuelsson, L., Sandström, C., Rosvall, O., 2013. A new paradigm for adaptive management. *Ecol. Soc.* 18 (4). <https://doi.org/10.5751/ES-06183-180463>.
- Schmedtje, U., Kremer, F., 2011. Links between the Water Framework Directive and Nature Directives: Frequently Asked Questions, European Commission, DG Environment. <http://ec.europa.eu/environment/nature/natura2000/management/docs/FAQ-WFD%20final.pdf> (Accessed 13th June 2018).
- Schoenefeld, J., Jordan, A., 2017. Governing policy evaluation? Towards a new typology. *Evaluation* 23 (3), 274–293. <https://doi.org/10.1177/1356389017715366>.
- Science for Environment Policy, 2017. Agri-environmental Schemes: How to Enhance the Agriculture-environment Relationship, Thematic Issue 57, Issue Produced for the European Commission DG Environment by the Science Communication Unit UWE, Bristol. <https://doi.org/10.2779/633983>.
- Scott, C.A., Kurian, M., Wescoat, J.L., 2015. The water-energy-food nexus: enhancing adaptive capacity to complex global challenges. In: Kurian, M., Ardakanian, R. (Eds.), *Governing the Nexus: Water, Soil and Waste Resources Considering Global Change*. Springer International Publishing, Cham, pp. 15–38.
- Selomane, O., Reyers, B., Biggs, R., Tallis, H., Polasky, S., 2015. Towards integrated social-ecological sustainability indicators: exploring the contribution and gaps in existing global data. *Ecol. Econ.* 118, 140–146. <https://doi.org/10.1016/j.ecolecon.2015.07.024>.
- Sievänen, T., Arnberger, A., Dehez, J., Grant, N., Jensen, F.S., Skov-Petersen, H. (Eds.), 2008. *Forest Recreation Monitoring – A European Perspective*. Finnish Forest Research Institute, Helsinki.
- Silverman, D. (Ed.), 2004. *Qualitative Research. Theory, Method and Practice*. Sage Publications, London, UK.
- Stem, C., Margoluis, R., Salafsky, N., Brown, M., 2005. Monitoring and evaluation in conservation: a review of trends and approaches. *Conserv. Biol.* 19 (2), 295–309. <https://doi.org/10.1111/j.1523-1739.2005.00594.x>.
- Strobl, R.O., Robillard, P.D., 2008. Network design for water quality monitoring of surface freshwaters: A review. *J. Environ. Manage.* 87, 639–648. <https://doi.org/10.1016/j.jenvman.2007.03.001>.
- Sutherland, W.J., Fleishman, E., Mascia, M.B., Pretty, J., Rudd, M.A., 2011. Methods for collaboratively identifying research priorities and emerging issues in science and policy. *Methods Ecol. Evol.* 2 (3), 238–247. <https://doi.org/10.1111/j.2041-210X.2010.00083.x>.
- The Council of the European Union, 2010. Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. *Off. J. Eur. Union L* 206, 7–50.
- The European Evaluation Helpdesk for Rural Development, 2015. Establishing and implementing the evaluation plan of 2014–2020 RDPs, the European evaluation helpdesk for rural development, Brussels. [https://enrd.ec.europa.eu/evaluation/publications/guidelines-establishing-and-implementing-evaluation-plan-2014-2020-rdps\\_en](https://enrd.ec.europa.eu/evaluation/publications/guidelines-establishing-and-implementing-evaluation-plan-2014-2020-rdps_en) (Accessed 13th June 2018).
- The European Parliament and Council of the European Union, 2000. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for community action in the field of water policy. *Off. J. Eur. Union L* 327, 1–72.
- The European Parliament and Council of the European Union, 2013. Regulation (EU) No 1305/2013 of the European Parliament and of the Council of 17 December 2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) and repealing Council Regulation (EC) No 1698/2005. *Off. J. Eur. Union L* 347, 487–548.
- The European Parliament and the Council of the European Union, 2010. Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds. *Off. J. Eur. Union L* 20, 7–25.
- UNECE, 1998. Convention on access to information, public participation in decision-making and access to justice in environmental matters, 2161 UNTS 447; 38 ILM 517 (1999), United Nations Economic Commission for Europe (UNECE), Aarhus. <http://www.uncece.org/env/pp/documents/cep43e.pdf>.
- UNEP, 2009. *Integrated Policymaking for Sustainable Development: A Reference Manual*, Earthprint & United Nations Environment Programme, Division of Technology, Industry and Economics, Geneva, Switzerland.
- Vasseur, L., Horning, D., Thornbush, M., Cohen-Shacham, E., Andrade, A., Barrow, E., Edwards, S.R., Wit, P., Jones, M., 2017. Complex problems and unchallenged solutions: bringing ecosystem governance to the forefront of the UN sustainable development goals. *Ambio* 46 (7), 731–742. <https://doi.org/10.1007/s13280-017-0918-6>.
- Verburg, R., Selnes, T., Verweij, P., 2016. Governing ecosystem services: national and local lessons from policy appraisal and implementation. *Ecosyst. Serv.* 18, 186–197. <https://doi.org/10.1016/j.ecoser.2016.03.006>.
- Vinke-de Kruijf, J., Kuks, S.M.M., Augustijn, D.C.M., 2015. Governance in support of integrated flood risk management? The case of Romania. *Environ. Dev.* 16, 104–118. <https://doi.org/10.1016/j.envdev.2015.04.003>.
- Voß, J., Bornemann, B., 2011. The politics of reflexive governance: challenges for designing adaptive management and transition management. *Ecol. Soc.* 16 (2), 9. <https://www.ecologyandsociety.org/vol16/iss2/art9/>.
- Voulvoulis, N., Arpon, K.D., Giakoumis, T., 2017. The EU Water Framework Directive: from great expectations to problems with implementation. *Sci. Total Environ.* 575, 358–366. <https://doi.org/10.1016/j.scitotenv.2016.09.228>.
- Waterton, C., Wynne, B., 2004. Knowledge and political order in the European Environment Agency. In: *Jananoff, S. (Ed.), States of Knowledge: The Co-production of Science and the Social Order*. Routledge, pp. 87–108.
- Waylen, K.A., Blackstock, K.L., 2017. Monitoring for adaptive management or modernity: lessons from recent initiatives for holistic environmental management. *Environ. Policy Gov.* 27 (4), 311–324. <https://doi.org/10.1002/eet.1758>.
- Weiss, C., 1980. Knowledge creep and decision accretion. *Knowl. Creation Decis. Utilization* 1 (3), 381–404.
- Weiss, C.H., 1993. Where politics and evaluation research meet. *Eval. Pract.* 14 (1), 93–106.
- Whitfield, C., McIntosh, N., 2014. Nitrogen deposition and the nature directives impacts and responses: our shared experiences. Report of the workshop held 2–4 December 2013. JNCC Report No. 521 JNCC, Peterborough, UK. [http://jncc.defra.gov.uk/pdf/Report\\_521\\_web\\_revised.pdf](http://jncc.defra.gov.uk/pdf/Report_521_web_revised.pdf) (Accessed 29th November 2018).
- Williams, B.K., 2011. Passive and active adaptive management: approaches and an example. *J. Environ. Manage.* 92 (5), 1371–1378. <https://doi.org/10.1016/j.jenvman.2010.10.039>.
- Williams, B.K., Brown, E.D., 2014. Adaptive management: from more talk to real action. *Environ. Manage.* 53 (2), 465–479. <https://doi.org/10.1007/s00267-013-0205-7>.
- Yli-Viikari, A., 2011. Numeroiden harhaa vai toteutuksen työkaluja? - indikaattorien käyttö maatalouden ympäristöpolitiisessa suunnittelussa. PhD Thesis presented at the University of Helsinki, MTT, Natural Resources Institute Finland, Helsinki. [www.mtt.fi/mtttiede/pdf/mtttiede16.pdf](http://www.mtt.fi/mtttiede/pdf/mtttiede16.pdf) (Accessed 8th August 2018).
- Young, O.R., 2002. *The Institutional Dimensions of Environmental Change: Fit, Interplay, and Scale*. MIT Press, Cambridge, Mass.
- Zito, A.R., 2005. The European Union as an environmental leader in a global environment. *Globalizations* 2 (3), 363–375. <https://doi.org/10.1080/14747730500377156>.