Complex systems methods for impact evaluation: lessons from the evaluation of an environmental boundary organisation

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SUMMARY

Successfully managing complex environmental issues in multifunctional habitats requires the integration of knowledge from diverse and often conflicting sources. As a result, there is a growing need for boundary organisations to exchange knowledge, co-produce plans, and facilitate action that could not be led by any single interested/affected party alone. This article evaluates the impact of a boundary organisation that sought over ten years to bring together disparate partners to protect, restore and sustainably manage peatlands in the UK. The evaluation was done using Participatory Systems Mapping to develop a systems-based Theory of Change map, via workshops with the organisation's staff and steering group members supplemented by qualitative analysis of semi-structured interviews with key partners. The findings show the pivotal role of this boundary organisation in advancing new evidence-informed peatland policy and practice. This success was driven by its ability to convene different interested/affected parties and facilitate knowledge exchange between networks that would otherwise have had limited engagement, along with the creation of a financial mechanism to fund the achievement of its aims. This is one of the first evaluations using participatory systems methods that have been able to assess causal drivers of benefits for the natural environment arising from an environmental boundary organisation. As such, the study provides lessons for the design and operation of boundary organisations working on environmental issues, and for impact evaluation more widely. Complex systems methods have the potential to integrate evidence from multiple sources and to trace non-linear causal relationships through complex systems of actions and impacts, and thus to provide robust evidence of impact.

KEY WORDS: IUCN UK Peatland Programme, Participatory Systems Mapping, peatland conservation

INTRODUCTION

Successfully managing complex environmental issues such as climate change, in multifunctional habitats such as peatlands, requires the integration and management of knowledge from diverse and often conflicting sources (Reed *et al.* 2013, 2014; Fazey *et al.* 2013). The wide range of ecosystem services and beneficiaries in complex social-ecological systems means that their management requires multiple forms of natural science evidence, in addition to evidence from the social sciences and the lived experience of those who inhabit and/or depend on those landscapes (Cvitanovic *et al.* 2014, Reed *et al.* 2018a). Whilst the potential for collaboration and synergies is high, so also is the potential for conflict, and where evidence is contested this may lead to policy inertia (Reed *et al.* 2018b). No single organisation, including policy and international bodies, can legitimately claim a dominant interest and make decisions on behalf of others without inflaming conflict, unless they are able to integrate or at least find common ground between the interests of multiple interested/affected parties (note: we use this phrase in preference to "stakeholders" as part of wider attempts to decolonise language in research; Sharfstein 2016).

As a result there is growing recognition for the role that can be played by boundary organisations such as landscape partnerships, and by organisations with convening power such as National Park Authorities and other statutory bodies (Cvitanovic *et al.* 2017, 2018). Boundary orgnisations operate at the intersection between science and policy, as intermediaries to mediate interactions between organisations and governance at various levels (Cash 2001, Niederberger 2005, Hellstrom & Jacob 2003) around often contested issues (Pesch *et al.* 2012) to resolve issues or inform decisions (Lidskog 2014).

Increasingly, research organisations are creating boundary organisations in the form of centres that co-produce applied research with interested/affected

parties (e.g. Cvitanovic *et al.* 2018, Barbrook-Johnson *et al.* 2021) and institutional structures designed to exchange knowledge between researchers and interested/affected parties, for example in policy or industry, whether operating within a single research institution across multiple issues (e.g. University of Stirling's Public Policy Hub) or across multiple institutions on a focal issue (e.g. N8 AgriFood's Food Systems Policy Hub). By occupying the liminal space between different organisations and groups, and their differing interests, boundary organisations have the capacity to exchange and integrate knowledge, co-produce plans and facilitate action that could not be led by any single group alone (Cvitanovic *et al.* 2015a, Jarvis *et al.* 2015, Lacey *et al.* 2015, Bednarek *et al.* 2018).

Working with boundary organisations, knowledge brokers often build relationships and networks with, among and between the producers and users of knowledge, helping to exchange knowledge and build capacity for evidence-informed decision-making (Bornbaun *et al.* 2015). Such individuals may be researchers embedded within decision-making organisations or practitioners embedded within research teams via secondments or team roles in research projects (Bruce & O'Callaghan 2016, AAAS 2017). Both boundary organisations and knowledge brokers need to be perceived by interested/affected parties as relevant, legitimate and credible (Cash *et al.* 2003, Reinecke 2015). As a result, they must be perceived as neutral and trustworthy, and need to have a deep understanding of the evidence and organisations they work with (Michaels 2009, Saarela & Söderman 2015). They must also be able to interpret, frame and communicate the evidence needs and perspectives of non-academic partners and interested/affected parties to the research communities they are connected to (Cvitanovic *et al.* 2017).

However, despite the growing rhetoric around the benefits of boundary organisations for evidence-informed policy and research impact (e.g. Reed & Cairney 2021, Reed 2022), there is a mismatch between the aims of many environmental projects (to generate impact) and their ultimate claims (to have generated or exchanged knowledge; Karcher *et al.* 2021), and the majority of evidence for actual benefits is anecdotal or derives from sectors such as health and education (Cvitanovic *et al.* 2015b). One of the reasons for this is the complex network of causal factors that lead to impact from the work of boundary organisations, often including significant time-lags and confounding factors that make it difficult to assess their contribution towards impacts in policy or practice (Reed *et al.* 2021). In addition to this, there is often limited investment in the evaluation of boundary organisations, with resources typically invested in evaluating specific impacts sought by funders or that are likely to be particularly significant or far-reaching (Reed *et al.* 2021). As a result, impact evaluations tend to be limited in scope and biased towards the assessment of specific, instrumental and positive outcomes, and are of limited formative value to the organisations that seek to facilitate the impacts (Reichard *et al.* 2020). This research therefore sought to:

- use complex systems methods to evaluate the impact of a boundary organisation working over a ten-year period with partners across the peatland research, policy and practitioner communities in the UK;
- explore the extent to which these methods can provide both formative and summative evidence that has the potential to enhance the impact of the case study organisation and similar boundary organisations internationally; and
- discuss the application of complex systems methods to impact evaluation more broadly, as research funders increasingly demand evidence of non-academic impacts arising from their investments.

METHODS

The International Union for the Conservation of Nature's (IUCN) UK Peatland Programme

IUCN is a democratic membership union which brings together some of the world's most influential conservation organisations to conserve nature and facilitate sustainable development. The IUCN UK Peatland Project is one of several projects governed by the IUCN National Committee UK (Figure 1). It was established in 2009 to promote peatland restoration in the UK, promoting the multiple benefits of peatlands through partnerships, research, policy and practice. Data were collected in 2019 to assess the impact of the first ten years of the Programme's operation. One of the researchers was Research Lead for the Programme since 2012 and the other was independent from the Programme. A mixed methods approach was used, combining Participatory Systems Mapping to develop a systems-based Theory of Change map (c.f. Bruhn 2021, Wilkinson *et al.* 2021) via workshops with Programme staff and key partners. The map considers links between actions and impacts, noting key vulnerable factors which might threaten impacts in the future. We define actions as the range of activities used by the Programme to generate intended impacts, and we

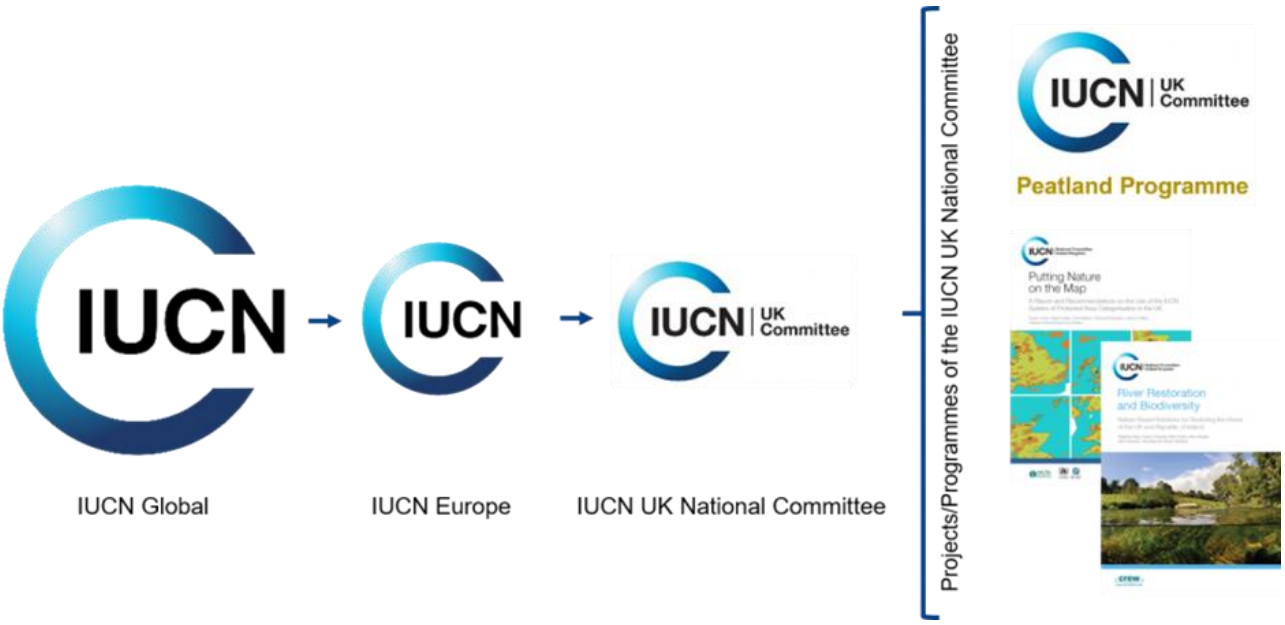

Figure 1. Governance hierarchy showing how the boundary organisation studied fits within the wider structures of its parent organisation.

define impact as demonstrable benefits as perceived by the Programme and its partners (Reed *et al.* 2021). Qualitative analysis of semi-structured interviews with key partners was then used to validate and further enrich the systems-based Theory of Change map, as described in Barbrook-Johnson & Penn (2022) and the rest of this section. Selection of partners for participation in workshop and interviews was purposive, led by Programme staff on the basis of their extent of involvement in the Programme over the preceding ten years.

Participatory Systems Mapping

Two workshops were held with IUCN UK Peatland Programme staff and key partners, to develop a causal system map of the UK peatland management system and the Programme's activities within it. The purpose of this exercise was two-fold: first, to generate detailed discussion on the wider system the Programme was operating in and how this affected its efforts; and second, to develop a shared systems-based Theory of Change for the Programme, which showed its activities within the wider system in a way that was systems-based (Wilkinson *et al.* 2021) and complexity-appropriate (Barbrook-Johnson *et al.* 2021).

The Participatory Systems Mapping (PSM) approach was used, as proposed by Barbrook-Johnson & Penn (2021, 2022) and Penn & Barbrook-Johnson (2019). PSM involves building relatively large system maps which represent causal relationships between factors in a system. Maps are built by groups of interested/affected parties and can include any type of factor as long as it is expressed as a variable. The causal relationships between factors are represented by arrows and may be positive (i.e. as one factor increases or decreases, so does the other), negative (i.e. as one factor increases the other decreases, or vice versa), or complex (i.e. a nonlinear, uncertain, or more complex relationship between the two factors). Maps are often annotated to provide additional context prior to analysis. This approach has much in common with Causal Loop Diagramming (see Barbrook-Johnson & Penn 2022) and Fuzzy Cognitive Mapping (see Penn *et al*. 2013). However, it takes a more inclusive and whole-systems approach to the construction of maps than Causal Loop Diagramming, and uses a combination of network analysis, causal flows and subjective information from interested/affected parties to develop bespoke analysis, as opposed to developing quantitative analysis in Fuzzy Cognitive Mapping.

Analysis of the map involved identifying sub-sections of the map which addressed specific questions, or offered 'ways in' to understanding the fuller map, which would have been overwhelming as a whole. The mapping and project design processes are elaborated in Penn & Barbrook-Johnson (2019) and Penn & Barbrook-Johnson (2022), respectively; here the method is outlined to show how it was applied in the case study:

- The mapping process began by defining the system and its boundaries with the members of the Programme and its partners. For this map, the system was pragmatically defined as the system

the IUCN UK Peatland Programme is acting in, that is the peatland management system in the UK. This includes the bio-physical systems of peatland but is more focused on the social, cultural, political and economic systems through which peatland is managed and impacted.

- The next stage involved defining focal factors to build the map around. These were defined as the key impacts the Programme sought to contribute to, namely: (i) expanding the area of peatland under restoration or sustainable management; (ii) the level of scientific consensus over ecosystem service benefits and avoided costs to society associated with restoration and sustainable management of peatland; and (iii) the scale, relevance and engagement of the wider peatland community. From here, the partners and Programme staff individually brainstormed factors that affected, or were affected by, these key impacts. These were then combined, duplicates removed, and refined, before being connected to the key impacts and each other through an iterative process of building up the map from the focal factors.
- Once a map of the impacts and the general system factors had been created, the next stage was to bring in the interventions and activities of the Programme. These were intentionally added later in the process, when there was already a relatively complex picture of the system, to help avoid linear or simple models of change from intervention to impact emerging. Once a first version of the map was complete, additional information on factors and connections was added (e.g. what is important or vulnerable to change?), and the map was refined iteratively, especially in the second workshop.
- A decision was made in the second workshop to present the map in a left-to-right intervention-to-impact layout, to emphasise and facilitate the use of the map as a Theory of Change of the Programme's work. This version of the map is shown in Figure 2. The activities of the Programme are in blue on the left, and the impacts in green on the right. Factors that were described by participants as vulnerable to change are highlighted in brown in the centre. During map construction, the topics which generated the most discussion included: branding and governance of the Programme and how this impacts and enables activities, and vice versa; the combined causal influence of a number of factors on land managers' decisions and the difficultly this creates in understanding this part of the system; and the nature of evidence and scientific debates on the topic of peatland restoration and management and how scientific activity drives a lot of action in this field.

Qualitative interviews

Semi-structured interviews were subsequently conducted with the IUCN UK Peatland Programme and its partners, using a purposive sample identified via the participatory systems mapping as playing a key role in generating impacts from the Programme's work. The purpose of this was to validate and where possible provide additional information about key impacts identified in the workshops. Full informed consent was gained from each participant under ethics permission granted by Newcastle University Ethics Committee. In total seven interviews were conducted. This included one interviewee from the Programme itself, three from UK government departments/agencies, one from a water utility company engaged in peatland restoration and two from UN organisations. Interviews were loosely structured around the significance and reach of potential impacts arising from the Programme, their attribution to the work of the Programme and learning points that could enable the Programme to engage more effectively in future. Interviews were recorded and transcribed, and analysed inductively using thematic analysis, which involved first reading the transcripts to acquire an overview of the interview data and then coding each interview to identify impact-related themes emerging from the data.

RESULTS

The participatory systems mapping exercise identified three key activities that the Programme had engaged with over the last ten years (Figure 2):

1. bringing the community together through events, platforms and projects etc.;
2. the creation and ongoing operation of the UK Peatland Code, generating private investment in peatland restoration for climate change mitigation; and
3. informing and engaging the wider peatland community through communications, education, training, advocacy work, provision of expertise, support to develop peatland strategies, commissioned research and a Commission of Inquiry on peatlands.

There was a wide range of factors that mediated the extent to which these activities led to beneficial impacts which, taken together, provide the systems-based Theory of Change, explaining how participants perceived that the Programme generated impacts.

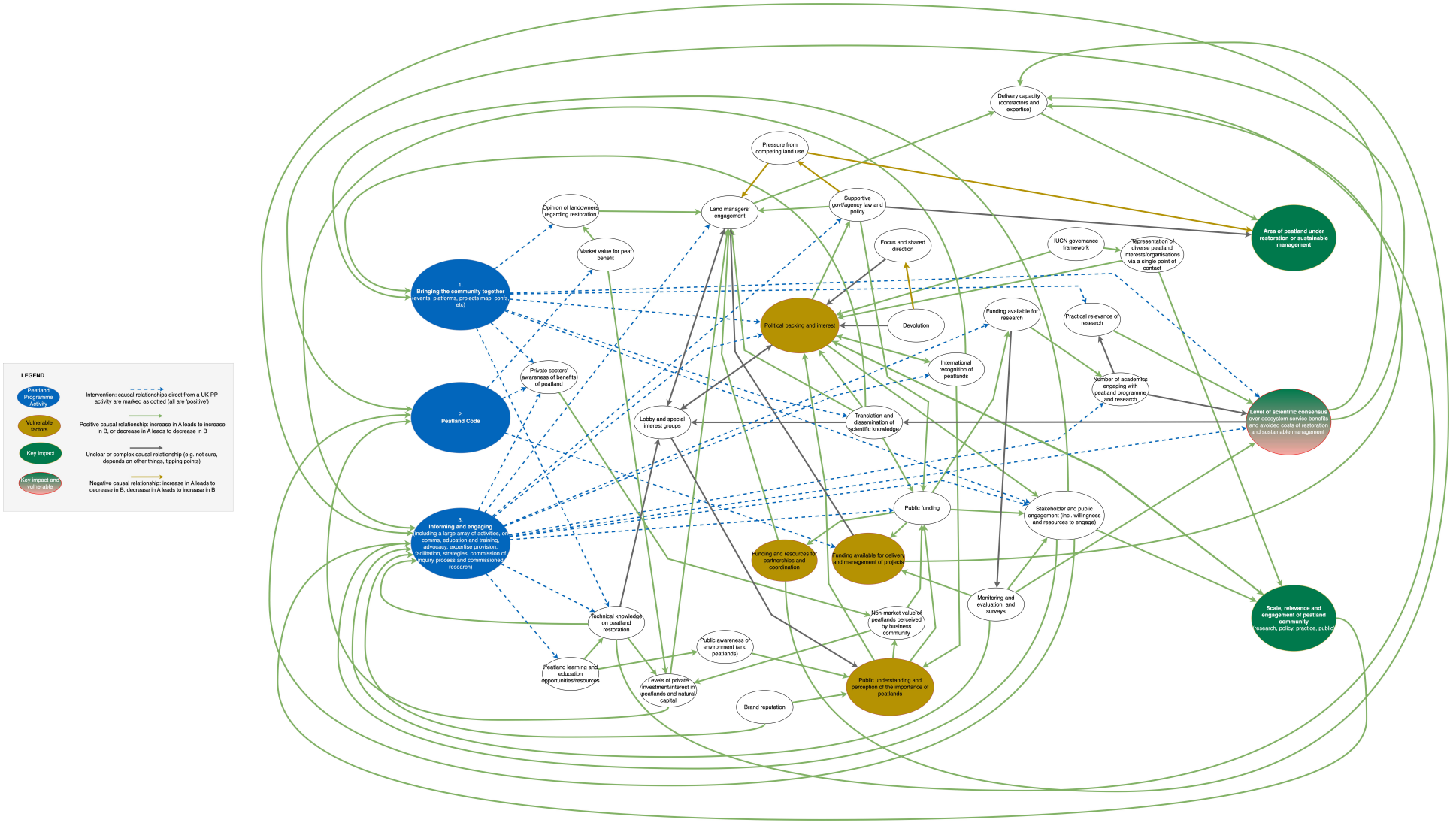

Figure 2. The full Participatory System Map of the UK peatland management system.

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International Mire Conservation Group and International Peatland Society, DOI: 10.19189/MaP.2022.OMB.569

Figure 2 shows the range of causal chains through which impact was mediated, but here we describe two contrasting examples.

The Peatland Code and funding

The first example consists predominantly of positive causal relationships (e.g. where an increase in one variable leads to an increase in a subsequent variable, or a decrease in one variable leads to a decrease in another), leading to a relatively uncontested impact. The following narrative traces relationships in Figure 2 and is shown in a submap in Figure 3, starting with the second activity (blue oval, "Peatland Code", on the left of the diagram, and then supplements this narrative by integrating evidence from interviews. Tracing these causal relationships through the participatory systems map, it can be seen how participants perceived that the operation of the Peatland Code led to an increase in funding available for peatland restoration projects, both from private investors (via the Code) and public sources of funding (which were blended with private investment via the Code, which only requires a minimum of 15 % carbon finance). This funding was, in part, a result of growing political backing and interest in peatland restoration, which was facilitated by effectively communicated and robust evidence about the climate and other benefits of peatland restoration, as well as growing international recognition of peatlands and political engagement from across the peatland community, of which the Programme was part. The increase in funding available increased delivery capacity among restoration contractors, which ultimately delivered an increasing area of peatland under restoration management across the UK; a key aim of the Programme. However, political backing and funding for restoration were both identified as vulnerable factors, due to the potential influence of lobby groups opposed to the objectives of the Programme, a lack of shared direction across the UK due to devolution, and uncertainties around carbon markets and policy decisions that could affect future funding.

At the time of the evaluation, four privately funded projects to restore peatlands had been validated or were in the process of validation under the Peatland Code (confirming CO_2-eq emission reductions of 101,944 t over their lifetime), with a further 20 projects initiated, covering 4,232 hectares of damaged peatlands across England, Scotland and Wales. The Programme estimated that, together, these projects would avoid CO_2-eq losses of at least 570,000 t from peat stocks to the atmosphere, equivalent to taking 230,000 flights from London to Sydney. The interviewee from the Programme explained how interest from the corporate sector in peatland carbon had grown rapidly since the inception of the Code, with demand from investors seeking to mitigate climate change now far outstripping the supply of projects.

A number of points in the causal chain from the creation of the Peatland Code to the increased area of restored peatland were corroborated with interview data. For example, one interviewee explained how creation of the Peatland Code and the evidence behind it had facilitated new public investment in peatland restoration:

> *"DEFRA was able to secure more than £10M for peatland restoration in the context of an austerity budget (distributed via grants in 2017), as a direct result of evidence from the research underpinning the Peatland Code. Based on the research, we were able to pitch peatland restoration as a carbon benefit in a way that was convincing to Treasury for the first time."*

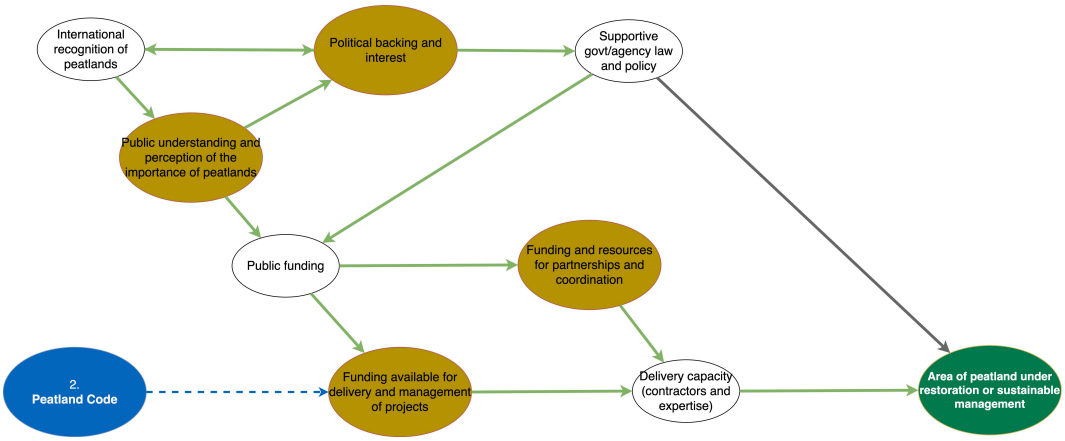

Figure 3. Submap tracing causal flow from 'Peatland Code'. This bespoke submap was created by including nodes on the path between the ''Peatland Code and 'Area of Peatland under restoration or sustainable management' and connected nodes via funding which reflected the material from interviews.

This was further corroborated by an interviewee from another part of the UK, who stated that:

> *"The Peatland Code has been integral to the success of the 1M Welsh Peatlands Sustainable Management Scheme, funded by Welsh Government, giving us the opportunity to leverage additional funding for peatland restoration".*

Another interviewee expanded on the wider role of the Programme in influencing policy, leading to further public investment in restoration:

> "*…significantly informed and shaped peatland policy, enabling civil servants and parliamentarians in each of the four UK countries to prioritise funding for peatland restoration. This included direct input to the structure and content of the UK Peatland Strategy, which has been applauded by governments, UN agencies and NGOs internationally as a world leading approach to peatland conservation. This strategy in turn has driven the creation of peatland policies and strategies in each of the UK countries, leading to investment in peatland across the country, including £250M committed in Scotland over the next 10 years".*

The Peatland Code also helped to justify investment by private companies in peatland restoration:

> "*The Peatland Code is something that we value as a company to be involved with. Most water companies do not get that deeply involved with peatland restoration in the way that we have. It has always seemed to us to be something that was useful and set us apart from other water companies. That's important when you are putting together a business plan for OFWAT who assess your environmental leadership. Although our work with peatlands is just one element of that, they highlighted our environmental leadership when they chose us as one of just three companies who could be fast-tracked without having to significantly revise our plans."*

Engaging with peatland research and the wider community

The second example consists of a mix of positive, negative and unclear or complex causal relationships, leading to a more contested and uncertain impact, as shown in the submap in Figure 4. This narrative starts by tracing relationships from the third activity (blue oval) 'Informing and engaging', on the left of the diagram. The Programme invested in a wide range of events to bring the research, policy and practitioner communities together, and ran a number of activities to engage these communities more deeply, for example the Commission of Inquiry on peatlands and commissioned research and briefings. This was important because when the Programme started there was a lack of consensus around the climate and other benefits of peatland restoration. One of the sources of uncertainty was evidence that there were spikes in methane production (a potent greenhouse gas) after restoration, due to the pooling of water, which promoted methanogenesis. However, subsequent research showed that this was a relatively short-lived

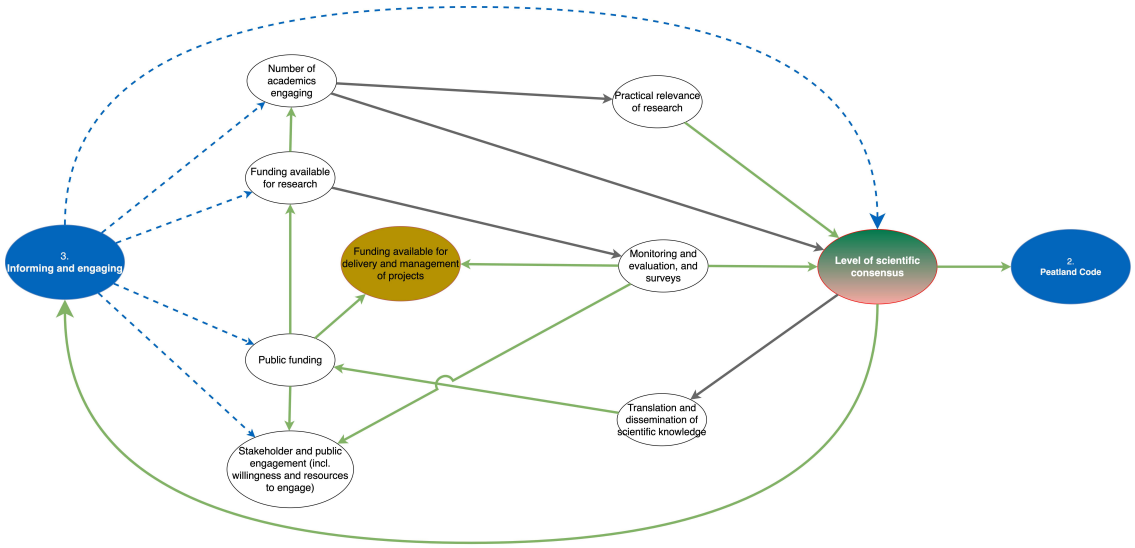

Figure 4. Submap tracing causal flow from 'Informing and engaging'. This bespoke submap was created to show the path between 'Informing and engaging' and 'Level of scientific consensus' and the related nodes reflecting material from the interviews.

phenomenon, and that over sufficient timeframes there was a net climate benefit due to the prevention of oxidation and fluvial losses, which produce carbon dioxide on a continuous basis (until bedrock is reached) in the absence of restoration. Partly due to the availability of new peer-reviewed evidence, and partly as a result of the events at which these research teams were invited to speak and discuss their findings with the wider research, policy and practitioner community, it was possible to reach scientific consensus on the climate benefits of peatland restoration. This consensus was then captured in the IUCN UK Peatland Programme's Commission of Inquiry on Peatlands (Bain *et al.* 2011), which highlighted the GHG emissions from degraded peatlands and the multiple benefits of restoring these habitats. Crucially, this work helped to explain some of the contradictory research findings that had been amplifying uncertainty, given that many of the studies had been conducted over different time horizons or on different peat types of varying condition. The Programme has since worked with UNEP's Global Peatlands Initiative and other partners to resolve issues preventing effective evidence synthesis from peatland research by developing "core domain sets" of key variables that should be measured and reported alongside contextual information for all peatland research and monitoring (Reed *et al.* 2022).

Given the already well-established biodiversity benefits of restoration and growing evidence for water quality benefits, this new consensus helped enable DEFRA to develop a peatland strategy, which included support for the drafting and eventual launch of the Peatland Code (the impacts of which were described in the first example). This was described by one interviewee as follows:

> *"The convening power and evidence provided by the IUCN UK Peatland Programme has had a tangible effect in terms of driving forwards policy on peatlands. The evidence collated by the Programme was necessary to get to a place where DEFRA could commit to a peatland strategy. Before this, peat policy was narrowly focused on biodiversity, but the Programme was instrumental in broadening that focus out to the wider benefits of fully functioning peatlands."*

However, the consensus was vulnerable to the publication of new research that challenged this view, particularly around the issue of burning cessation as part of the restoration process. Although the Programme reviewed the relevant evidence in a position paper on burning, in an attempt to resolve these conflicts, the debate continued in the academic literature. Most of the policy community agreed with the position paper, and this helped retain consensus around the need to avoid burning during restoration management, as well as shaping subsequent policies restricting burning practices on deep peat. However, opposing publications and commentary in the peer-reviewed literature continue to be used by interest groups to oppose the objectives of the Programme, which may pose challenges for engagement with private landowners and managers who routinely use burning as a management tool.

A further threat to the impact of research being used by the Programme was the limited number of researchers engaging with Programme events (although the Programme engages with all the key institutions that lead peatland research in the country), limited funding for ongoing peatland research, and the limited practical value of much ongoing research for application in peatland policy or restoration practice. To achieve its goals, whether via the UK Peatland Strategy, individual country strategies, the Peatland Code or other policy mechanisms, research was still needed, for example to provide emission factors that could extend the application of the Peatland Code to new peatland habitats. The costs of this research were beyond the budgets of government departments and agencies, but not considered sufficiently "cutting edge" to meet the research excellence criteria of Research Councils. As a result, a small pool of researchers who were already engaged with the Programme integrated research needs into larger funded projects, and while these researchers engaged with Programme events, there was not a sufficient critical mass of researchers or research being showcased at these events to attract a wider research audience. Nevertheless, despite the vulnerability of the scientific consensus and associated negative feedbacks within the participatory systems map, it is possible to see how the Programme's engagement activities have facilitated sufficient ongoing consensus to retain progress towards its other two key impacts around widening engagement and the area of peatland under restoration management.

Exploring the need for coordination of peatland activities

One of the more unique aspects of the approach to systems mapping that we use is exploring submaps driven by questions from participants. The Programme undertakes a large number of activities, many of which are aimed at similar things either directly or via mediating factors. Coordination of these activities is a serious concern in the Programme although, during the workshop, participants were

confident that all of the influences from Programme activities were positive (i.e. they influence factors in the same direction). To further explore the need for these activities to be coordinated, we pulled out a submap showing only those nodes directly influenced by the three core activity types and removed all other nodes and connections. The resulting submap is shown in Figure 5. This submap immediately makes clear the factors which are being influenced by multiple Programme activities, and are thus the factors where careful coordination is most likely to be needed. These are overviewed in Table 1.

DISCUSSION

The approach to impact evaluation taken in this article builds on and combines existing system mapping methods (e.g. fuzzy cognitive mapping, theory of change) but with a particularly strong emphasis on participatory design, reframing a complex map as a Theory of Change, and a bespoke approach to analysis using network analysis in combination with the subjective views of interested/affected parties in their system. The resulting maps and Theories of Change should be built by as diverse a range of interested/affected parties as possible, and designed to capture complexity rather than simplify it away.

Building these maps with the interested/affected parties in your 'research impact system', around a mutually interesting topic, can be incredibly useful by itself; the exercise builds understanding and consensus, creating valuable buy-in. The maps also serve as useful planning and evaluation tools. Particularly for evaluation, we can use them to consider where there are gaps in data or evidence gathering, identify key causal mechanisms we may want to monitor, or use them to inform and refine more focused theory of change maps or impact planning and tracking tools; they can serve as key (and updateable) resources we return to again and again during and after a research or evaluation project.

However, it is important to note that these types of approaches typically only provide formative evidence when used in an evaluative process. They can frame and guide the evaluation, but they will not provide the summative evidence around impact or process-type evaluation questions. Thus, they should always be complemented by other methods when used in an evaluation (cf. Barbrook-Johnson & Carrick 2022). We used qualitative interviews, which should be seen as a foundation upon which additional summative evidence can be built, triangulating and further enhancing the rigour of the evaluation. Where possible, quantitative or administrative data should also be used, to provide additional summative evidence. Where this is not available, or only covers some evaluation questions, methods such as Process Tracing (Befani & Stedman-Bryce 2017) and Qualitative Comparative Analysis (Blackman *et al.*

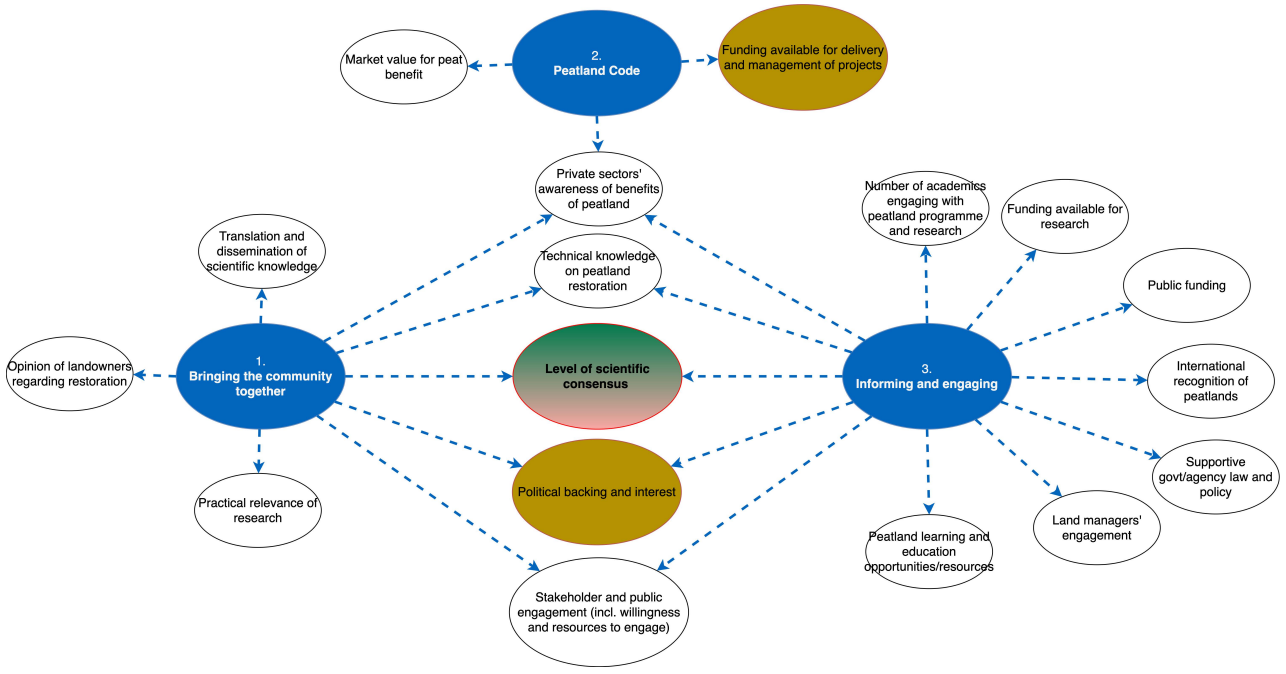

Figure 5. Submap one step downstream of Peatland Programme activities.

2013) are excellent complexity-appropriate methods to bring more formal rigour to an evaluation, if it is desired.

This was not the first study of a peatland boundary organisation. A number of studies have discussed the role of Scotland's Centre of Expertise, ClimateXChange, in facilitating evidence-informed peatland policy (Machen 2018, Reed *et al.* 2018b, Wreford *et al.* 2019). ClimateXChange succeeded by building strong trusting relationships between members of the Scottish research and policy communities, providing a stable point of contact for policy colleagues that could strategically connect those who could learn most from each other, and by pulling research into policy processes as and when it was needed rather than pushing research findings into policy when the research was published. The role of trust was also emphasised by Neumann (2020) who conducted a comparative analysis of the IUCN UK Peatland Programme and a similar organisation (MoorFutures) in Germany. She showed how trust was often linked to the length of people's relationships with each other, historical knowledge of sites and issues, or individual expertise and competencies. The knowledge and experience that each organisation had, working with different interest groups, was particularly valued by those who interacted with them. Similarly, Ferré *et al.* (2022) studied the role of various boundary organisations in facilitating flows of knowledge about peatlands and other environmental issues in science-policy networks. They found that organisations occupying central roles in social networks were more likely to facilitate both knowledge exchange and impact. Although evidence typically came from research, researchers were rarely mentioned by those who received knowledge as their direct source; instead they relied on boundary organisations, often regulatory bodies in this case, to provide them with this knowledge. Many of these lessons resonate with the findings of this study, which also emphasised the central role of the IUCN UK Peatland Programme within diverse research, policy and practitioner communities, the knowledge it mobilised and the trust it engendered among those it interacted with.

CONCLUSION

We have sought to demonstrate how complex systems methods can be used to evaluate a boundary organisation's impacts in a way that is sensitive to the complex actor and causal landscape these types of entities operate in. The approach we have used built on Wilkinson *et al.* (2021), using a participatory systems mapping exercise to develop a systems-based Theory of Change, and then interrogating and refining this with evidence from qualitative interviews

Table 1. Factors affected by two or more Peatland Programme activities.

Factor being influenced by two activities	**Activities influencing them**	**Need for coordination of activities**
Private sector's awareness of benefits of peatland	• Bringing the community together • Peatland Code • Informing and engaging	*High*: all three activities are perceived as influencing the private sector, which is itself a diverse and fractured audience. This makes the potential for overloading this group, or providing confusing messages high.
Technical knowledge of peatland restoration	• Bringing the community together • Informing and engaging	*Low*: a relatively homogenous audience with messages more narrowly focussed on one set of issues.
Level of scientific consensus	• Bringing the community together • Informing and engaging	*High*: as outlined in the example above, the potential for lack of consensus in the scientific community is high.
Political backing and interest	• Bringing the community together • Informing and engaging	*High*: this factor is one of the most influenced in the map, with many factors beyond the Programme itself influencing it. This means this factor is likely to be difficult to influence or may behave in unpredictable ways.
Partner and public engagement	• Bringing the community together • Informing and engaging	*Low*: these large audiences require a lot of activities to influence so the potential for unintended or clashing activities is low.

The resulting evidence was used for summative impact reporting by Newcastle University in the Research Excellence Framework (REF2021) in an impact case study entitled *Restoring Global Peatlands for Climate Benefits*[1]. It was also used in summative mode in confidential reports to funders of the IUCN UK Peatland Programme, and in formative mode to inform the Programme's 5-year strategic plan, providing valuable information that helped justify further investment in the Peatland Code, UK events and networks.

The findings show the pivotal role that the IUCN UK Peatland Programme has played as a boundary organisation bringing together people and organisations with interests in peatland from the policy, practice and research communities over the ten years between its establishment and the evaluation. This is one of the first evaluations using participatory systems methods that have been able to assess causal drivers of benefits for the natural environment and associated interested/affected parties arising from an environmental boundary organisation. As such, the study provides lessons for impact evaluation and for the design and operation of boundary organisations working on environmental issues. In particular, the success of the organisation appears to have been driven by its ability to convene different interested/affected parties and facilitate knowledge exchange between networks that would otherwise have had limited engagement, combined with the creation of a financial mechanism to fund the achievement of its aims. By combining evidence from research networks with experience from policy and practitioner networks, the Programme was able to provide robust advice to governments whilst embedding its financial mechanism within relevant policy processes, lending further legitimacy to the mechanism and enabling the delivery of tangible benefits in policy and practice.

Finally, Participatory Systems Mapping and related methods (e.g. process tracing and Qualitative Comparative Analysis) are examples of complexity-appropriate research methods which can be used in evaluation more broadly (Barbrook-Johnson *et al.* 2021). The application of complex systems methods to impact and process evaluation should be encouraged and developed further. There have been recent pushes in the UK in this direction from groups such as the Centre for the Evaluation of Complexity Across the Nexus and the Centre of Excellence for Development Impact and Learning, but these need to be built on. This extension should take three forms:

- Wider roll out and acceptance of complex systems methods in evaluation, and more broadly theory-based evaluation (Weiss 1997), in appropriate contexts (i.e. in the many contexts in which experimental evaluation designs are not appropriate or feasible). There is still resistance to these types of methods, or an assumption that simple causal evaluation is possible in complex contexts. These views need to be challenged where appropriate, in compelling and useful ways.
- More consensus on what complexity-appropriate evaluation is, and what methods we might include or define as complexity-appropriate. In theory, this sort of definitional question is settled, with official resources such as Bicket *et al*. (2020). However, these methods are yet to permeate through practice and the literature. The inherently open and inclusive approach that complexity-appropriate evaluation engenders will also slow this consolidation.
- Development of bespoke frameworks for specific types or topics of evaluation. For example, a complexity-appropriate research evaluation framework or a complexity-appropriate infrastructure evaluation framework. These are beginning to appear (e.g. Bicket *et al*. 2020) and some are being developed organically as methods are used in evaluations (e.g. the current evaluation of the UKRI Strategic Investment Fund), but we are still in the early stages.

For complex environmental issues such as those tackled by the IUCN UK Peatland Programme, it is necessary to integrate evidence from multiple sources and trace non-linear causal relationships through complex systems of actions and impacts, to provide robust evidence of impact. The methods used in this article provide this capability, and could be used in a range of environmental and other complex systems to provide more robust and useful evidence of impact.

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[1] *Restoring Global Peatlands for Climate Benefits* is available from the REF2021 impact case study database at: https://results2021.ref.ac.uk/impact/9318b32e-3b4c-4629-9fea-6b7ede36e4e9

CONFLICTS OF INTEREST

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AUTHOR CONTRIBUTIONS

The authors contributed equally to conceptualisation and writing (original draft, review and editing). MR led on project administration. PBJ led on methodology, software, formal analysis, data curation, visualisation and funding acquisition.

REFERENCES

AAAS (2017) *Connecting Scientists to Policy Around the World: Landscape Analysis of Mechanisms Around the World Engaging Scientists and Engineers in Policy*. Executive Summary, American Association for the Advancement of Science (AAAS), Washington DC, 8 pp. Online at: https://www.aaas.org/sites/default/files/International-Landscape-AnalyisExecSumm-02162017.pdf, accessed 12 Nov 2022.

Bain, C.G., Bonn, A., Stoneman, R., Chapman, S., Coupar, A., Evans, M., Gearey, B., Howat, M., Joosten, H., Keenleyside, C., Labadz, J., Lindsay, R., Littlewood, N., Lunt, P., Miller, C.J., Moxey, A., Orr, H., Reed, M., Smith, P., Swales, V., Thompson, D.B.A., Thompson, P.S., Van de Noort, R., Wilson, J.D., Worrall, F. (2011) *Commission of Inquiry on Peatlands*. IUCN UK Peatland Programme, Edinburgh, 109 pp.

Barbrook-Johnson, P., Carrick, J. (2022) Combining complexity-framed research methods for social research. *International Journal of Social Research Methodology*, 25(6), 835–848.

Barbrook-Johnson, P., Penn, A.S. (2021) Participatory systems mapping for complex energy policy evaluation. *Evaluation*, 27, 57–79.

Barbrook-Johnson, P., Penn, A.S. (2022) *Systems Mapping: How to Build and Use Causal Models of Systems*. Palgrave, London, 203 pp.

Barbrook-Johnson, P., Castellani, B., Hills, D., Penn, A.S., Gilbert, N. (2021) Policy evaluation for a complex world: Practical methods and reflections from the UK Centre for the Evaluation of Complexity across the Nexus. *Evaluation*, 27, 4–17.

Bednarek, A.T., Wyborn, C., Cvitanovic, C., Meyer, R., Colvin, R.M., Addison, P.F., Close, S.L., Curran, K., Farooque, M., Goldman, E., Hart, D. (2018) Boundary spanning at the science–policy interface: the practitioners' perspectives. *Sustainability Science*, 13, 1175–1183.

Befani, B., Stedman-Bryce, G. (2017) Process Tracing and Bayesian Updating for impact evaluation. *Evaluation*, 23, 42–60.

Bicket, M., Christie, I., Gilbert, N., Hills, D., Penn, A., Wilkinson, H. (2020) *Handling Complexity in Policy Evaluation*. Magenta Book 2020 Supplementary Guide, HM Treasury, London, 66 pp. Online at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/879437/Magenta_Book_supplementary_guide._Handling_Complexity_in_policy_evaluation.pdf, accessed 12 Nov 2022.

Bicket, M., Hejnowicz, A.P., Wilkinson, H., Hills, D., Rowe, F., Shaw, B., Penn, A., Gilbert, N. (2020) *Complexity Evaluation Framework: Recognising Complexity & Key Considerations for Complexity-Appropriate Evaluation in the Department for Environment, Food and Rural Affairs (DEFRA)*. Version 2.0 Report by CECAN Ltd. to DEFRA, UK, 53 pp. Online at: https://www.betterevaluation.org/sites/default/files/14675_ComplexityEvaluationFramework.pdf, accessed 12 Nov 2022.

Blackman, T., Wistow, J., Byrne, D. (2013) Using Qualitative Comparative Analysis to understand complex policy problems. *Evaluation*, 19, 126–140.

Bornbaum, C.C., Kornas, K., Peirson, L., Rosella, L.C. (2015) Exploring the function and effectiveness of knowledge brokers as facilitators of knowledge translation in health-related settings: a systematic review and thematic analysis. *Implementation Science*, 10, 1–12.

Bruce, A., O'Callaghan, K. (2016) Inside out: knowledge brokering by short-term policy placements. *Evidence & Policy*, 12, 363–380.

Bruhn, T. (2021) How can transformative sustainability research benefit from integrating insights from psychology? *Frontiers in Psychology*, 12, 676989, 4 pp.

Cash, D.W. (2001) In order to aid in diffusing useful and practical information: agricultural extension and boundary organizations. *Science, Technology & Human Values*, 26, 431–453.

Cash, D.W., Clark, W.C., Alcock, F., Dickson, N.M., Eckley, N., Guston, D.H., Jäger, J., Mitchell, R.B. (2003) Knowledge systems for sustainable development. *Proceedings of the National Academy of Sciences*, 100, 8086–8091.

Cvitanovic, C., Fulton, C.J., Wilson, S.K., van Kerkhoff, L., Cripps, I.L., Muthiga, N. (2014) Utility of primary scientific literature to

environmental managers: An international case study on coral-dominated marine protected areas. *Ocean and Coastal Management*, 102, 72–78.

Cvitanovic, C., Hobday, A.J., van Kerkhoff, L., Marshall, N.A. (2015a) Overcoming barriers to knowledge exchange for adaptive resource management; the perspectives of Australian marine scientists. *Marine Policy*, 52, 38–44.

Cvitanovic, C., Hobday, A.J., van Kerkhoff, L., Wilson, S.K., Dobbs, K., Marshall, N.A. (2015b) Improving knowledge exchange among scientist and decision-makers to facilitate the adaptive governance of marine resources: a review of knowledge and research needs. *Ocean and Coastal Management*, 112, 25–35.

Cvitanovic, C., Cunningham, R., Dowd, A.M., Howden, S.M., van Putten, E.I. (2017) Using social network analysis to monitor and assess the effectiveness of knowledge brokers at connecting scientists and decision-makers: An Australian case study. *Environmental Policy and Governance*, 27, 256–269.

Cvitanovic, C., Löf, M., Norström, A., Reed, M.S. (2018) Building university-based boundary organisations that facilitate impacts on environmental policy and practice. *PloS One*, 13(9), e0203752, 19 pp.

Fazey, I., Evely, A.C., Reed, M.S., Stringer, L.C., Kruijsen, J., White, P.C., Newsham, A., Jin, L., Cortazzi, M., Phillipson, J., Blackstock, K. (2013) Knowledge exchange: a review and research agenda for environmental management. *Environmental Conservation*, 40, 19–36.

Ferré, M., Martin-Ortega, J., Di Gregorio, M., Dallimer, M. (2022) How do information flows affect impact from environmental research? - An analysis of a science-policy network. *Journal of Environmental Management*, 321, 115828, 18 pp.

Hellstrom, T., Jacob, M. (2003) Boundary organisations in science: from discourse to construction. *Science & Public Policy*, 30, 235–238.

Jarvis, R.M., Borrelle, S.B., Bollard Breen, B., Towns, D.R. (2015) Conservation, mismatch and the research–implementation gap. *Pacific Conservation Biology*, 21, 105–107.

Karcher, D.B., Cvitanovic, C., Colvin, R.M., van Putten, I.E., Reed, M.S. (2021) Is this what success looks like? Mismatches between the aims, claims and evidence for impact from knowledge exchange processes in environmental science and policy. *Environmental Science & Policy*, 125, 202–218.

Lacey, J., Howden, S.M., Cvitanovic, C., Dowd, A-M. (2015) Informed adaptation: Ethical considerations for adaptation researchers and decision-makers. *Global Environmental Change*, 32, 200–210.

Lidskog, R. (2014) Representing and regulating nature: boundary organisations, portable representations, and the science–policy interface. *Environmental Politics*, 23, 670–687.

Machen, R. (2018) Towards a critical politics of translation: (Re)Producing hegemonic climate governance. *Environment and Planning E: Nature and Space*, 1, 494–515.

Michaels, S. (2009) Matching knowledge brokering strategies to environmental policy problems and settings. *Environmental Science & Policy*, 12, 994–1011.

Neumann, R.K. (2020) *Uptake of Peatland Ecosystem Service Knowledge for Decision-Making*. Doctoral dissertation, Newcastle University, 212 pp.

Niederberger, A.A. (2005) Science for climate change policy-making: applying theory to practice to enhance effectiveness. *Science & Public Policy*, 32, 2–16.

Penn, A.S., Barbrook-Johnson, P. (2019) *Participatory Systems Mapping: a Practical Guide*. CECAN Toolkit, Centre for the Evaluation of Complexity Across the Nexus (CECAN), University of Surrey, Guildford, UK, 4 pp. Online at: https://www.cecan.ac.uk/wp-content/uploads/2020/09/PSM-Workshop-method.pdf, accessed 12 Nov 2022.

Penn, A.S., Barbrook-Johnson, P. (2022) *How to Design a Participatory Systems Mapping Process*. CECAN toolkit, Centre for the Evaluation of Complexity Across the Nexus (CECAN), University of Surrey, Guildford, UK, 8 pp. Online at: https://www.cecan.ac.uk/wp-content/uploads/2022/03/How-to-design-a-PSM-process-Final.pdf, accessed 12 Nov 2022.

Penn, A.S., Knight, C.J., Lloyd, D.J., Avitabile, D., Kok, K., Schiller, F., Woodward, A., Druckman, A., Basson, L. (2013) Participatory development and analysis of a fuzzy cognitive map of the establishment of a bio-based economy in the Humber region. *PloS One*, 8(11), e78319, 14 pp.

Pesch, U., Huitema, D., Hisschemöller, M. (2012) A boundary organization and its changing environment: the Netherlands Environmental Assessment Agency, the MNP. *Environment & Planning C: Government & Policy*, 30(3), 487–503.

Reed, M.S. (2022) *Impact Culture*. Fast Track Impact, Huntly, UK, 374 pp.

Reed, M.S., Cairney, P. (2021) *Using Evidence to Influence Policy: A Handbook for Researchers.* University of Leeds Press, Leeds, 88 pp.

Reed, M.S., Fazey, I., Stringer, L.C., Raymond, C.M., Akhtar-Schuster, M., Begni, G., Bigas, H., Brehm, S., Briggs, J., Bryce, R., Buckmaster, S., Chanda, R., Davies, J., Diez, E., Essahli, W., Evely, A.C., Geeson, N., Hartmann, I., Holden, J., Hubacek, K., Ioris, I., Kruger, B., Laureano, P., Phillipson, J., Prell, C., Quinn, C.H., Reeves, A.D., Seely, M., Thomas, R., van der Werff Ten Bosch, M.J., Vergunst, P., Wagner, L. (2013) Knowledge management for land degradation monitoring and assessment: an analysis of contemporary thinking. *Land Degradation & Development*, 24, 307–322.

Reed, M.S., Stringer, L.C., Fazey, I., Evely, A.C., Kruijsen, J. (2014) Five principles for the practice of knowledge exchange in environmental management. *Journal of Environmental Management*, 146, 337–345.

Reed, M.S., Vella, S., Challies, E., de Vente, J., Frewer, L., Hohenwallner-Ries, D., Huber, T., Neumann, R.K., Oughton, E.A., Sidoli del Ceno, J., van Delden, H. (2018a) A theory of participation: what makes stakeholder and public engagement in environmental management work? *Restoration Ecology*, 26, S7–S17.

Reed, M.S., Bryce, R., Machen, R. (2018b) Pathways to policy impact: a new approach for planning and evidencing research impact. *Evidence & Policy*, 14, 431–458.

Reed, M.S., Ferre, M., Martin-Ortega, J., Blanche, R., Dallimer, M., Lawford-Rolfe, R., Holden, J. (2021) Evaluating research impact: a methodological framework. *Research Policy*, 50, 104147, 14 pp.

Reed, M.S., Young, D.M., Andersen, R., Bell, N.G.A., Cadillo-Quiroz, H., Grainger, M., Heinemeyer, A., Hergoualc'h, K., Gerrand, A.M., Kieft, J., Krisnawati, H., Lilleskov, E.A., Melling, L., Rudman, H., Sjogersten, S., Taylor, N.G., Walker, J.S., Stewart, G. (2022) Peatland core common outcomes: building consensus on what should be measured in research and monitoring. *Mires and Peat*, 28, 26, 21 pp.

Reichard, B., Reed, M.S., Chubb, J., Hall, G., Jowett, L., Paert, A. (2020) Writing Impact Case Studies: A comparative study of high-scoring and low-scoring case studies from REF2014. *Palgrave Communications*, 6, 31, 17 pp.

Reinecke, S. (2015) Knowledge brokerage designs and practices in four European climate services: A role model for biodiversity policies? *Environmental Science & Policy*, 54, 513–521.

Saarela, S.R., Söderman, T. (2015) The challenge of knowledge exchange in national policy impact assessment–a case of Finnish climate policy. *Environmental Science & Policy*, 54, 340–348.

Sharfstein, J.M. (2016) Banishing "Stakeholders". *The Milbank Quarterly*, 94, 476.

Weiss, C.H. (1997) Theory-Based Evaluation: Past, present, and future. *New Directions for Evaluation*, 1997(76), 41–55.

Wilkinson, H., Hills, D., Penn, AS., Barbrook-Johnson, P. (2021) Building a complexity-appropriate Theory of Change using Participatory Systems Mapping. *Evaluation*, 27, 80–101.

Wreford, A., Peace, S., Reed, M., Bandola-Gill, J., Low, R., Cross, A. (2019) Evidence-informed climate policy: mobilising strategic research and pooling expertise for rapid evidence generation. *Climatic Change*, 156, 171–190.

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