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Science of the Dammed: Expertise and Knowledge Claims in Contested Dam Removals

Chris S. Sneddon
Dartmouth College, Hanover, NH, USA; cssneddon@dartmouth.edu

Francis J. Magilligan
Dartmouth College, Hanover, NH, USA; fjm@dartmouth.edu

Coleen A. Fox
Dartmouth College, Hanover, NH, USA; coleen.fox@dartmouth.edu

ABSTRACT: Historically, science and its associated expert voices often serve multiple roles in the context of complex environmental conflicts: investigators of undesirable environmental conditions; guarantors of "value-free" and de-politicised expertise and information regarding those conditions; authors of rationales that support one management decision over another; and sources of authority used to persuade sceptics or the public that a certain environmental action is logical and desirable. However, recent thinking in science and technology studies (STS) and political ecology emphasises how scientific knowledge and expertise are co-produced with the political, economic, and cultural arrangements characteristic of a given society and a given locale. In many environmental conflicts, expert knowledge is challenged on the grounds that it is out of touch and politically compromised. This paper examines the diverse scientific discourses and environmental narratives surrounding dam-removal processes in the region of New England, United States. Dam removals are increasingly seen by environmental advocacy organisations and state agencies as a means to rehabilitate degraded riverine systems, and these actors muster an array of science-based arguments in support of removal. Conversely, opponents highlight their place-based knowledge to counter the claims of removal advocates and question the motivations of expert knowledge. These competing claims feed into conflicts over dam removals in intriguing ways, and understanding how scientific knowledge and expertise are used (and misused) is crucial to understanding conflicts over river restoration and developing more participatory strategies of water governance. The question is not so much whose claims are truthful, but how such claims are inserted into, and negotiated within, controversial ecological interventions.

KEYWORDS: Dam removal, expert knowledge, public understanding of science, political ecology, New England

INTRODUCTION

It is now nearly a truism that scientific expertise and applied scientific knowledge are shaped by political, economic and cultural forces. Recent applications of scientific knowledge to river restoration through dam removal in the United States and globally illustrate this science-politics nexus. Among environmental managers in the United States and elsewhere, dam removal has recently emerged as perhaps the foremost means of rehabilitating river systems impaired by years of physical alteration and industrial pollution (Bednarek, 2001; Stanley and Doyle, 2003; O'Connor et al., 2015; Magilligan et al., 2016). The scientific knowledge underpinning dam removal and river restoration in general – while compelling in terms of the likely biophysical benefits – is incomplete and not immune from politicisation. The politicised character of science and problems of 'translation' in environmental

conflicts – prominent themes within the broad literature on public understanding of science (Weingart, 1999; Wynne, 2014), political ecology (Forsyth, 2004), and science and technology studies (Jasanoff, 2014) – figure conspicuously in cases of dam removal. Opponents of dam removal may reject expert claims regarding the physical integrity of dams and challenge the arguments of river scientists regarding the ecological benefits of removal (Fox et al., 2016; Magilligan et al., 2017). The question of 'whose knowledge counts', and when it counts, constitutes a key element in explicating conflicts over dam removal and working towards more desirable socioecological outcomes in the context of ecological restoration initiatives.

In this paper, we analyse the circulation of scientific knowledge claims and how these are presented, wrestled over, and challenged by a variety of actors in the process of removing a dam. Dam removal, as one of the most effective means of promoting river restoration over large scales, presents unique challenges for explaining the role of expert knowledge in ecological interventions. We highlight two prominent themes that characterise dam removal processes and illuminate broader conceptualisations of the role of science in environmental conflicts. First, scientific knowledge regarding the potential impacts of dam removal (or 'science of the dammed') enters debates over river restoration through multiple paths and at different moments in what is frequently a contested and drawn-out process. Because decisions to remove dams must overcome several important regulatory and policy hurdles, debates about their status are frequently aired in forums that provide spaces and moments to present and contest scientific knowledge claims. Second, scientific knowledge claims concerning removal are most often contested by the residents of communities confronting removal who prefer the dammed landscape for historic, economic, and aesthetic reasons despite the claims of experts that removal offers multiple social and biophysical benefits. Dam removals thus provide a revealing lens into how scientific discourses are mobilised and struggled over within the environmental politics of ecological restoration. The use (and misuse) of scientific knowledge claims and expertise in conflicts over dam removal exposes both the authority and limitations of science in environmental politics.

Dam removal and river restoration specifically, as well as ecological rehabilitation initiatives more broadly, would benefit from closer examination of how expert and lay knowledges are mobilised according to different rationalities. Our goal is to use debates about dam removal to reveal the structure and ambiguities of scientific knowledge claims and the iterative process of reconciling scientific 'facts' with public perceptions in environmental conflicts. Unlike adaptive management strategies and mainstream restoration interventions, where the environmental goals are often clear while the means of achieving those goals are recursive and informative, conflicts over dam removal are more frequently about the *outcome* (to remove or not) and the associated biophysical responses as opposed to the tools or approaches used to get there. This contested space over outcomes gives opponents and proponents of dam removal alike seemingly legitimate claims to the 'science of the dammed'.

SCIENCE OF THE DAMMED: WHOSE KNOWLEDGE COUNTS?

As a collaboration among a physical scientist and two social scientists, our research emerged from an intriguing question regarding dam removal – how is expert knowledge mobilised and received in different ways during a controversial environmental intervention? At one level, and one most typically thought of when considering ecological restoration efforts, an array of biophysical scientists (e.g. biologists, fluvial geomorphologists, geologists, and other environmental scientists) are engaged in studies to both assess the broad environmental impacts of dams and evaluate (and predict) changes in a river system's hydrology and ecology following removal. A second level consists of a more sundry coalition of knowledges emerging from the opponents of dam removal, who frequently mobilise both their own tacit knowledge of the local landscape in addition to experts focused on legal matters and, importantly, the historical value of a dam and its associated landscape. However, there are important

differences in how expert knowledge is received and judged within specific locales where removal is proposed, making it nearly impossible to predict why and how scientific knowledge is simply acknowledged as legitimate or actively contested.

Historically, science and its associated expert voices are often required to serve multiple roles in the context of complex environmental conflicts: discoverer of undesirable environmental conditions; guarantor of value-free and de-politicised expertise and information regarding those conditions; author of rationales that support one political decision over another; and a source of authority used to persuade sceptics or the public that a certain position is logical and desirable when those decisions are contested (Ozawa, 1996; Turnhout et al., 2013). It is hardly surprising, then, that the lay public is at best confused and at worst deeply sceptical of knowledge produced by supposed experts when this knowledge is used to justify controversial policies and actions or, in the case of the current debate on climate change, consensus-driven scientific prognoses are trumped by political ideologies (Oreskes et al., 2004; Cook et al., 2016).

Indeed, scholars working within the tradition of social and technology studies (STS) argue that scientific knowledge and expertise are always *co-produced* with the political, economic, and cultural arrangements characteristic of a given society (Jasanoff, 2004a). Co-production refers to the process through which technologies – including their "material features" and "associated imaginations of risks and benefits" – and forms of scientific knowledge are "defined to harmonise with underlying vision of the state and its rights and obligations vis-à-vis citizens" (Jasanoff, 2012: 8).[1] Put another way, science produces "particular epistemic orders or cultures" that "interconstruct and mutually reinforce with particular social or political orders, in a historically contingent way" (Wynne, 1996: 76). This co-production and intermingling of science and social order comes into sharp focus in social conflicts over the environment, despite the efforts of scientists and other actors to draw boundaries around what is and what is not credible scientific knowledge (Roth et al., 2004).[2] As both the dam and the river it has altered become 'matters of concern' (Latour, 2007) around which knowledge claims are mustered to explain or promote how removal of the dam might rehabilitate a river, expert claims are frequently confronted with surprise, disbelief, and suspicion from local residents who privilege their own understandings of what the dammed river represents.

The expert-lay divide

Despite several decades of research and writing on citizen science and other rubrics for examining the disjunctures among expert knowledge, public policy, and the broader citizenry, the precise nature of the relationship between scientist and citizen, and between expert and lay knowledge, remains an open question (Jasanoff, 2004b).[3] Early work addressing public incredulity about scientific knowledge tended to highlight a deficit model of the relation between expert and lay knowledge – the assumption that such gaps were the result of a lack of scientific or technical knowledge on the part of the general public (see Sturgis and Allum, 2004). This assumption has given way to a more nuanced view of the divergences between expert and other forms of knowledge, one emphasising how scientific knowledge is produced and utilised to conform to specific interests, how the perceived connection between

[1] Perhaps intentionally, Jasanoff in her many writings on the subject does not offer a highly precise definition of co-production. We interpret this as recognition of the myriad ways that scientific and technical knowledges shape and are shaped by political and cultural institutions and processes.

[2] There is a vast literature on 'boundary work'–activities of epistemological gatekeepers who decide what does and does not count as scientific knowledge – within STS (Gieryn, 1999). See Weng (2015) for an enlightening analysis of such boundary maintenance within an ecological restoration initiative. We do not engage that work here in part because boundary keeping is not as relevant in the science of dam removal.

[3] See Collins and Evans (2002) for a magisterial overview and critique of work in this vein.

science and oppressive institutions of state and private power, and how interpretations of expert knowledge are always interpreted through a range of culturally and historically contingent filters (Gauchat, 2011; Lane, 2014; Stilgoe et al., 2014). In the United States, researchers have conclusively shown that a deeper understanding of an issue involving some level of complexity (or enhanced scientific literacy) does not translate into greater trust in expert knowledge on the part of the lay public with a stake in that issue (Douglas, 2015). This is in part explained by the numerous ways that expert knowledge is linked to centres of political and economic power (de Vries, 2007: 800-801). This is not to denigrate the hard-earned knowledge that environmental scientists and other experts have gathered over the years; rather, it is to simply point out that the conditions through which that knowledge is possible (e.g. society's educational priorities and professionalisation, funding agencies' priorities) are always contingent on previously arranged institutions for knowledge creation.

The existence of multiple epistemologies and the role of expertise are especially salient in the case of efforts to restore, rehabilitate or otherwise intervene in ecological systems perceived to be significantly damaged or impaired by human activity. Ecological restoration has emerged in recent years as both a practical and philosophical point of divergence in environmental politics (Suding, 2011). Among the few works that directly consider the role of technical or scientific expertise in adjudicating decisions regarding ecological restoration, researchers are uncovering how expert knowledge intersects with epistemological conflicts, as well as lay attitudes towards science in general. Through a case study of the principles that guide current stream restoration efforts in the USA, Lave (2012) demonstrates that conflicts over scientific knowledge and its application to resources management initiatives *within* communities of expertise are as heated and politicised as conflicts involving expert versus lay knowledge clusters. In a different vein, the 'existing expert-lay hierarchy' of many conservation and restoration projects (i.e. the assumption that expert knowledge is inherently more valid) involving some level of citizen participation can undercut the democratic goals of these same projects (Weng, 2015). In some cases, restoration advocates wield scientific expertise in a heavy-handed fashion, ignoring alternative views offered by long-term residents and generating heated public controversy (Helford, 2000). In certain restoration projects involving invasive species, scientific knowledge itself exhibits anti-exotic biases and fails to appreciate shifting scientific understandings of invasive plants' role in the functioning of riverine ecosystems that are the focus of restoration efforts (Stromberg et al., 2009).

Despite these examples, the now significant literature on ecological restoration too often sidesteps issues of divergent knowledge claims in restoration controversies, preferring instead to focus on how the 'science-practice divide' – the division between restoration goals grounded in scientific research and implementation of those goals in actual practice – might be more productively managed to produce better restoration outcomes (e.g. Turner, 2005; Cabin, 2007; Dickens and Suding, 2013).[4] As we demonstrate below, a focus on dam removal directs attention towards how expert knowledge is legitimised, presented, and contested as it circulates through the often-punctuated process of dam removal. As in dam removal or any environmental conflict, there is a need to always place both expert and lay forms of knowledge within their broader political-economic and cultural contexts: "people do not use, assimilate, or experience science separate from other elements of knowledge, judgement, or advice" (Wynne, 1991: 114). The implication is that the scientific knowledge brought to bear on problems of public interest such as dam removal is never presented in isolation from other types of knowledge that people might use to evaluate a proposed environmental initiative. We do not offer a blueprint for how expert knowledge might be better integrated within the practices of river restoration advocates and thus more readily achieve their socioecological aims; rather, our goal is to elucidate how

[4] Yet there are also examples of how vernacular knowledge of landscapes, if brought into conversation with expert knowledge within carefully designed collaborations, can generate environmental management interventions that acknowledge multiple shareholder values and also achieve improved biophysical conditions (see Simpson et al., 2015).

the gaps between expert and lay knowledge claims come into being in ways specific to dam removal and frustrates well-intentioned restoration interventions.

Environmental narratives and the circulation of knowledge

Conflicts over dam removal encompass several themes that are foundational within political-ecological research: competing understandings over what constitutes 'nature'; ambiguous and contested state interventions in socioecological relations; and, most importantly for the present work, how environmental knowledge is used to justify specific resources management practices. A number of studies within political ecology underscore the powerful ways that environmental narratives – emerging from scientific understandings that ironically have not stood up under the scrutiny of continuing scientific studies – have generated policy and management actions that have misinterpreted biophysical dynamics and hence undermined the livelihoods of communities dependent on those processes (Fairhead and Leach, 1996; Forsyth, 2004; Davis, 2006). In addition, relatively recent studies on the political economy of knowledge production rightfully focus on the deep linkages between environmental science and the political-economic networks that promote and benefit certain types of neoliberal science (Robertson, 2004; Lave et al., 2010). In the rural hinterlands of the western United States, experiential (or 'barstool') knowledge of local landscapes and ecological processes often conflicts with scientific discourses of environmental degradation, influencing the region's environmental politics and resources management planning in surprising ways (Robbins, 2006). In other parts of the world, coalitions of environmental groups have creatively engaged local and indigenous knowledge within disputes over, for example, the impacts of mining on tropical forests and biodiversity in Ecuador, on occasion even situating that knowledge within the register of hegemonic and expert-driven neoliberal discourses regarding the impacts of extractive enterprises (Buchanan, 2013).

Recent work attempting to integrate political ecology and STS – driven more forcefully by practitioners of the former – is especially relevant to explicating the roles of science and expert knowledge in cases of dam removal conflict. The broad aim of this marriage is to shift "more attention to the areas of interface between the sphere of knowledge production and those of application and circulation" (Turner, 2011: 29). The spatial and temporal disjoints between knowledge produced under one set of historical and geographical conditions and then circulated across space and time to very different political-economic and cultural contexts is clearly evident in the case of large dam construction, and examples drawn from India (Phadke, 2011) or more globally (Sneddon, 2015) demonstrate the often negative socioecological and geopolitical consequences associated with 'packaged' sets of knowledges. Moreover, the universal application of science and technical knowledge produced in certain centres of geopolitical and economic power and disseminated – with problematic results – to more peripheral regions have led to calls for different kinds of scientific inquiry. Drawing on the case of ethnic minorities and watershed degradation in northern Thailand, Forsyth (2011: 42-43) argues that situating scientific knowledge about soil erosion processes within "local framings of environmental problems" by farmers actually produces "less simplistic" understandings and more effective interventions.

Dam removal turns some of the standard political ecology treatments of scientific knowledge and environmental narratives on their heads. For removal advocates in government and environmental organisations, scientific knowledge is propagated in the service of what they see as an incontrovertible socioecological 'good' – as proclaimed succinctly by American Rivers, "there is no faster or more effective way to bring a river back to life than removing a dam" (American Rivers, n.d.). The residents of communities resisting dam removal, by rejecting or side-stepping these knowledge claims, exhibit a fairly significant degree of power to reject expert advice they view as underpinning a negative intervention. The case of scientific expertise and knowledge claims in the context of dam removal and river restoration initiatives in the USA thus raises questions at the nexus of knowledge claims and environmental conflict. Whose knowledge should count in weighing removal options, and how is such

knowledge circulated? What happens when the place-based lay knowledge of landscape processes comes into conflict with scientific knowledge and expertise focused on river restoration?

A useful framework for addressing these questions can be found in the work of Lane (2014), who argues for a socio-hydrological perspective to better understand controversies involving hydrological science – which he argues is inherently contested – and to better address those conflicts in ways that draw on both the biophysical and social sciences. Two key ideas from a socio-hydrological perspective are especially relevant to our research. First, Lane stresses that how the results of hydrological studies become inserted into decision-making processes is far from a linear process. Indeed, decision makers looking for certitude in the findings of experts are bound to be disappointed; "science proceeds by discovering its own uncertainties" (Lane, 2014: 932). This is certainly the case in the science of dam removal wherein, as we document below, a paucity of post-removal biophysical studies and the need to meet regulatory requirements imbues any knowledge claims from experts with a fair degree of ambiguity. Second, although scientific knowledge may be necessary for arbitration of conflicts concerning water resources, it is never sufficient and is always subject to influence by the values of different actors in the conflict. As a way of overcoming the stalemates in decision making that can arise from such 'knowledge controversies', Lane (2014) is optimistic about the potential for co-produced socio-hydrological knowledge involving both experts and lay persons who cooperatively define and seek solutions to water-related problems. Yet our research on dam removal controversies challenges this optimism by underlining how efforts at co-producing knowledge through expert-lay collaborations can be stymied by entrenched local interests regardless of how scientific knowledge is presented and received.

SCIENCE, EXPERTISE, AND KNOWLEDGE CLAIMS: DAM REMOVALS IN NEW ENGLAND

This section aims to shed light on how different knowledges are disseminated, how they come into conflict, and how and when settlements are reached. We proceed with a brief discussion of the institutional and political context for the increasing interest in dam removal as a river restoration tool in New England, and highlight the numerous completed and planned removals that have generated social conflicts. We then turn to a discussion of the role that scientific knowledge has hitherto played in shaping the dam removal process and subsequent conflicts over removal. This discussion emphasises, first, the production and circulation of expert knowledge surrounding research on altered/regulated rivers, and, second, the various ways and moments that this knowledge is communicated to and potentially disputed by a broader public (including removal opponents).

The information presented and analysed in this article was gathered during semi-structured interviews, participant observation, and document analysis over the past five years (2011-2016). We coded and categorised data from over 125 cases where dams were removed throughout the New England region and from approximately 50 cases where dam removal has been stalled or eliminated as a river restoration option. While ancillary parts of this research have been presented elsewhere (Fox et al., 2016; Magilligan et al., 2017), the results presented here focus on the role of scientific knowledge in the dam removal process. Our interviews – totalling 36 separate conversations with individuals and groups involved with dam removal in the six New England states (Maine, Vermont, New Hampshire, Connecticut, Massachusetts and Rhode Island) – engaged a variety of actors, including: state officials in resources management and historic preservation agencies; Federal agents responsible for coastal conservation, fisheries management and regulation of restoration initiatives; local government policy-makers; national and state environmental organisations; and community members opposed to removal. For the purposes of this paper, we asked research participants specific questions regarding the role of expert scientific knowledge in dam removal, highlighting its representation to the public (e.g. "How are the likely biophysical impacts of removal presented at public meetings?"), its reception by the public (e.g. "How do you respond when someone questions the scientific data presented to the

public?"), and its relative effectiveness in facilitating or hindering the removal process. We also attended six public meetings and witnessed how scientific claims from both scientists and the public were presented and debated, and interrogated a range of textual material (e.g. local news media reports, organisational websites) wherein experts and non-experts commented on the scientific dimensions of removal. The excerpts presented below are representative of the most common themes and perspectives regarding science and expert knowledge on dam removal among the dozens of New England cases.

Dam removals in New England – which at first glance seem rather straightforward efforts to reinstate a historic, purportedly more natural landscape – represent a constellation of complex biophysical, ideological and institutional processes with numerous actors and stakeholders claiming legitimacy in defining the appropriate 'natural' condition or assuming a predominant role in the decision-making process. The region once hosted significant migratory runs of Atlantic Salmon, which have been extirpated from most New England watersheds. The construction of over 14,000 dams over the past 2 centuries has been implicated as a proximate cause of their decline, prompting many NGOs and state and federal agencies to clamour for their removal (Magilligan et al., 2016). However, the recent spate of dam removals is not limited to environmental advocacy. Concerns over liability and safety also figure prominently in the process, further demanding state and institutional vigilance and oversight. As noted previously, these combined environmental and socioeconomic factors have led to over 125 removed dams since the early 1990s, with more than 50 more dams currently under consideration for removal.

In regions like New England, where – unlike the western US – public lands are scarce and 'stakeholders' (tribes, urban interests, ranchers, etc) are less well-defined in their enmity, and where the scale of the activity is localised and typically occurs on privately held lands, activities like dam removal have become surprisingly complicated and contested. Although these conflicts do not occur on public lands, this does not suggest that state is absent in these conflicts; instead, the bifurcated institutional structure within and between states engenders complex forms of power relations and jurisdictional struggles, frequently allowing for non-state actors – ranging from national environmental groups to *ad hoc* neighbourhood associations – to intervene and play important roles in decision making. Resistance to dam removal ranges from a small number of local residents concerned with how removal will alter the character of their cultural landscape to more organised groups of community members who see a dam as part of a valuable local/regional history. Of the dams removed in New England and the more than 50 that are ongoing, stalled, or completely halted, nearly all have been contested to some degree. As a result of regulatory hurdles, the need for 'buy in' among multiple stakeholders, funding requirements, and in many cases active opposition to removal, the entire process for removing a dam can take anywhere from 3 to 10 years and on occasion even longer (Magilligan et al., 2017).

The evolving science of dam removal

One of the most salient ways that scientific knowledge becomes enrolled in dam removals – in both efficacious removals and ones that generate controversy – is through the claims that scientists and dam removal advocates make regarding the likely impacts of removing a dam. There is now a decades-long record of the multiple social and ecological disruptions brought about by the construction of dams (see McCully, 1996; Rosenberg et al., 2000), and biophysical scientists remain at the forefront of documenting how dams impair river systems by severing hydrologically and ecologically important upstream-downstream relations and, concomitantly, reducing biodiversity (Graf, 2006). Yet the important question remains: what does an undammed, or 'natural', river look like, and how should one characterise it? An obvious corollary, according to the 'best science', is what is dam removal supposed to accomplish?

Amidst budget and staff shortages in recent years, both federal and state resources management agencies are keenly aware of the need for better monitoring of the biophysical effects of dam removal.[5] NOAA provides baseline metrics for assessment (Wildman, 2013), but in most instances, the benchmark may be merely the re-introduction of migratory and resident fish species to historically unattainable watershed locales (Hogg et al., 2013, 2015; Pess et al., 2014) or the generation of more re-connected coupled geomorphic and ecological attributes (Pess et al., 2008; Magilligan et al., 2016). While fluvial geomorphologists have developed several principles and management templates for guiding river restoration through combined ecological, hydraulic, and geomorphic assessments of river conditions (e.g. Brierly et al., 2010; Beechie et al., 2010; Wohl et al., 2015; Tullos et al., 2016; Kasprak et al., 2016), the actual research to undertake such comprehensive studies relies on multiple measures of what constitutes a 'desirable' and 'healthy' river, and requires substantial funding and, potentially, years of data collection. This explains why monitoring is rare, and thus limits accurate prediction of outcomes. In a recent compilation of post-removal monitoring, Bellmore et al. (2016) show that of the more than 1,200 removals in the US, only 130 had monitoring of any kind with only 35 having combined ecological and geomorphic monitoring – and with only five of those combined assessments extending beyond the first two years. These assessments are not only rare but tend to be concentrated in specific geomorphic and ecologic regions in the US (Midwest and Northeast), leaving large portions of the US void of critically important baseline conditions to guide restoration efforts (Foley et al., 2017).

The science of dam removal is also complicated by the need to integrate scientific knowledge within a very specific set of regulatory parameters. In 2001, the National Academy of Sciences' National Research Council (NRC) published a report with recommendations on wetlands restoration and mitigation strategies that resonate with efforts to restore streams via dam removal. For instance,

> Linking designs to ecological performance can be extremely difficult, because [river] science and restoration … efforts are still developing and must be tailored to individual sites. However, much can be accomplished within the limits of the current science. … In short, we can design sites with a high probability of becoming functional [river systems], but whether particular sites will always result in particular functional outcomes is less certain… Permit conditions for legal compliance with the mitigation obligation should recognise this reality (NRC, 2001: 150).

This statement recognises one of the key aspects of dam removal science: in order for removal to proceed, permitting agencies and personnel must recognise the legitimacy of scientific claims regarding the biophysical impacts of dam removal. Although it may seem counterintuitive given that the goal of dam removal is improvement of river functioning, any alteration to a stream or river requires permitting for, and possible mitigation of, potential impacts on associated wetlands, biological communities, and other biophysical entities.[6] The state of science on river restoration via dam removal is arguably even less developed than that for wetland restoration, and the NRC strongly suggests that applicants coordinate with relevant regulatory entities as early as possible during dam removal planning and design process, including *all* relevant agencies, not only the one requiring the mitigation to occur. The implications are clear: the scientific knowledge brought to bear on dam removal, no matter how rigorously produced, is always subject to the administrative process of permitting, which can at a minimum delay the removal process.

[5] This sentiment was conveyed in multiple interviews with river management experts in a variety of governmental agencies.

[6] Federal agencies often play a prominent role during the permitting and broader regulatory phases of removal. The US Army Corps of Engineers is "almost always involved in dam removal through its regulatory authorities", particularly permitting under Section 404 of the Clean Water Act. This statute "requires that a public interest review be carried out" and a "determination of the effects of the dam removal on wetlands, fish and wildlife, water quality, water supply, energy conservation, navigation, economics, and historic, cultural, scenic, conservation, and recreational values" (Conyngham et al., 2006:7).

Aside from regulatory hurdles, the lack of a singular metric of restoration success for dam removals has led removal advocates in New England to highlight socioeconomic rationales (e.g. safety, liability, aesthetics, etc) that often lack clearly articulated biophysical goals. Even when environmental rationales are stated, dam removals rarely identify clearly stated ecological standards, and 'successful' outcomes can be more anecdotal rather than scientific (Jähnig et al., 2011). In some instances, the implicit assumption by many observers is that a river with a removed dam is in a more 'natural' state and therefore the restoration goal is self-evident. As one regulatory specialist states, "if the dam is removed for safety reasons, its removal already signals a successful activity – why do you need to monitor it? The dam is clearly gone, and the goal was achieved".[7] Such perspectives bolster our claim that removal is not about stream restoration *per se*. Rather it is probably the most important vehicle to rehabilitate human-altered riverine systems. And while there remains a good deal of uncertainty about the precise effects of dam removal, river science experts nearly universally agree that an undammed river is an improvement over a dammed one.

Some baseline technical expertise is also pertinent in determining if a dam removal might actually cause ecological harm, as in the case of contaminated sediments temporarily sequestered in reservoirs from decades of pollution (Stanley and Doyle, 2003), a problem particularly relevant to the New England context where rivers have been linked to industrial production since the 19th century (Steinberg, 1991). A NOAA fisheries specialist involved in dozens of dam removals throughout the region describes the import of sediment management and other issues and how this has changed as dam removal initiatives have evolved.

> In terms of the NOAA perspective, we've got this down pretty well. We've done this over so many times we *know* what technical issues need to be addressed. Sediment migration, are there contaminants [in the sediment], the hydrology that might have an effect on wetlands [in the area]. I've been doing this for 16 plus years… You start planning it out along with your project partners, whoever the lead entity is, you have strategising meetings, how are we going to do this? I go out and take the sediment samples… If it's contaminated that's when you will find it. In the old days, people weren't as technically competent, they didn't have the right equipment or they were trying to avoid finding the right sample.[8]

Knowledge of whether or not the sediment behind a dam is one of the numerous 'technical details' that the managers of dam removal projects must attend to, in part because, as alluded to above, this information is required before the appropriate permits can be issued.

Some important observations regarding the evolving science of dam removal are warranted here. First, despite the recent advances in understanding the biophysical impacts of dam removal – and the decades of research demonstrating conclusively the myriad ways that dams impair river systems across a range of hydrologic, geomorphic and ecological variables – the scientific knowledge associated with removals is being outpaced by the policy and management imperatives of river restoration (see Weng, 2015 for a parallel example). State officials and environmental advocacy organisations are caught in something of an epistemological bind; when a removal opportunity presents itself – most commonly due to an owner facing liability expenses for a dam in need of repair – management agencies and environmental groups predisposed to river restoration seize this moment to push forward removal plans, regardless of the paucity of data on the biophysical impacts of removal. Second, resource managers contemplating removal must be keenly aware of the regulatory requirements necessary to move forward with a given project. Even at the most fundamental level of producing robust environmental knowledge regarding removal impacts, the science of the dammed is co-produced with the political and institutional factors that structure its creation.

[7] Interview, US Army Corps of Engineers, 12 June 2014.

[8] Interview, NOAA fisheries scientist, Narragansett, RI, 14 August 2015.

Third, it is clear from our conversations that the vast majority of dam removal experts – whether associated with state or management agencies or with non-governmental organisations – have a keen understanding of the scientific knowledge on which they base their evaluations of different removal parameters and place great trust in the process of producing that knowledge. Yet it is also clear that they understand the need to integrate their scientific knowledge of streams and rivers with communication strategies during public meetings and other forums where communities may be sceptical of expert knowledge claims.

The 'stinky mudflat': Accepting and disputing expert knowledge

The 'general public' in any given dam removal controversy is a potentially diverse group, encompassing homeowners concerned about the impacts of dam removal on their property values, elderly residents worried about the 'natural' beauty of a cherished landscape created by a dam, local conservation commissions that perceive environmental value in the existing altered landscape, or outdoor enthusiasts eager to pursue fishing and other recreational activities on a free-flowing river. As in many controversial environmental governance decisions involving the presentation of scientific knowledge of the issue, "people do not experience scientific expertise in a pure context" (Yearley, 2000: 106). Time and again during our interviews and attendance at public meetings regarding dam removal in locales throughout New England, residents would express the concern that the river or stream would become a 'stinky mudflat' without the dam's presence. This not only flies in the face of scientific knowledge of dams' impacts on river systems, but also captures the frequently meaningful divide between expert and lay knowledge, expressed here as a belief that a dam is what sustains a river.

The assorted actors thus contemplating dam removal interpret the knowledge offered by experts in divergent and often unexpected ways. Residents confronting removal projects often unite behind 'common sense' understandings of environmental conditions that are far removed from expert scientific knowledge when that knowledge contradicts their established positions. As expert knowledge is brought forward and circulated by state and non-state environmental organisations in a dam-removal process that can take several years (often over a decade), there is a constant need to defend and reformulate this knowledge, particularly in cases where removal is contested. The rest of this section draws on specific examples of dam removal in New England to highlight the different ways that knowledge about dammed rivers moves through a range of specific political and cultural milieus. We pay particular attention to those cases of removal where expert knowledge claims are called into question, and how different actors are compelled to re-formulate that knowledge or engage in entirely new issues requiring expertise.

Science meets the public

In the most straightforward instances (from the perspective of removal advocates), the scientific case for removal is readily accepted by key actors, or removal itself generates little interest from the public. This occurred with the Kendrick Dam removal in Pittsfield, VT. The Town Manager put it this way:

> …I think generally the board says, well, you're the scientist or you're the engineer, you know more about it than we do. You tell us, Les [state agency representative], that the fish will be happier, you tell us, Brian, that the sediment will come out, and it won't create a mess downstream. Then yes, we rely upon you, yeah.[9]

State officials and environmental advocates are quite sensitive to how the science of dam removal is presented in order to more effectively communicate to their intended audience. And this can shift

[9] Interview with Town Manager, Pittsfield, VT, 29 September 2014.

according to who that audience is. For example, scientific knowledge and the voice of experts on the biophysical impacts of dam removal seem to achieve greater validity once the process becomes part of the regulatory process or is ensconced in legal proceedings. This was the case with removal of the Edwards Dam – a fairly large hydroelectric structure – on Maine's Kennebunk River, which was initially contested by the city of Augusta where the dam was located (Crane, 2009). Removal advocates successfully traversed the regulatory hurdles by bringing attention to the dozens of scientific studies, many emanating from state agencies such as the Department of Environmental Protection (DEP) and the Department of Inland Fisheries and Wildlife (IFW), showing strong evidence that dam removal would improve habitat for important biota. When the conflict over removal was heard by courts, or during regulatory hearings, or by national agencies such as the Federal Energy Resource Commission (FERC), decision-makers tended to trust the scientific evidence presented by pro-removal scientists. According to those familiar with dam removal in Maine, these forums "give an enormous amount of credence to what ME DEP says", and the work of "state biologists will count" a great deal.[10]

In other instances, removal advocates endeavour to simplify the scientific knowledge about the impacts of a dam on river systems, converting it into language that the lay public can more readily digest. As one aquatic ecologist on the staff of a watershed association put it, "I try to take a step outside the ecology" in public forums.[11] This is very helpful at meetings where a Selectboard or other decision-making body is considering removal as an option. Accordingly,

> I would say that we've worked really hard to try to simplify the message and really hit on key points and try to cut out extraneous information… And when we talk about the environmental benefit…we try to resolve it down to terms that folks understand, like, you know, a fish swims upstream, bumps its nose against the dam, so it can't go upstream.[12]

In Massachusetts, representatives of Mass Riverways, the state's primary agency for river restoration, find that the public at open meetings respond to scientific information in a variety of ways.

> You don't use the term organic matter. It's.. there's wood and there are leaves and when the leaves go downstream that helps the food web and the insects eat the leaves and the fish eat the [insects].. you know just reducing things to those terms has, I've found in my public interactions, been very effective. And you see the light turn on… I've had like an old lady pull me back and say, 'we've gotta get the dam out of here to let the leaves go downstream for those insects', you know. It's like, that's great! What a great connection![13]

The question of community linkages often proves to be a significant factor in how communities accept the expert knowledge mustered in favour of removal. Removal advocates perceived as 'insiders' often carry more weight with reticent town residents who are mistrustful of the government or others perceived as non-local. In the aforementioned case of the Kendrick Dam in VT, the removal was abetted by the active involvement of an individual regarded both as a 'local' and as a resource management expert. In the face of community members who held a "natural resentment" towards "people from *away* who make those arguments [in favour of removal]", this person met with local residents to answer questions about the project and its impacts and, in his capacity as an affiliate with the state ANR, served as a key liaison between the community and state officials. His knowledge of the surrounding landscape and the cultural history of the Sugar Hollow Brook region allowed him to

[10] Interview with representatives of the Penobscot River Preservation Trust (PRPT), Office of Natural Resources Council of Maine, August, ME, 20 August 2012.

[11] Interview with representative of Ipswich River Watershed Association, Ipswich, MA, 21 July 2017.

[12] Interview with staff of Massachusetts Riverways (now folded in to the Division of Ecological Restoration, State of Massachusetts), Boston, MA, 14 August 2013.

[13] Ibid.

integrate scientific knowledge regarding the ecological benefits of the removal with a keen assessment of how local residents would best respond to the initiative. The result was a relatively smooth process towards removal. Of the over 100 removal cases we have examined, the Kendrick Dam case had the lowest level of conflict, in part due to the community interlocutor mentioned above, and also because the process was guided by a trusted Town Manager who had confidence in the scientific knowledge presented to him and who negotiated the process with aplomb.[14]

On some occasions, expert knowledge can assuage community anxieties about how dam removal might affect, for example, local fish populations. In the case of the Amethyst Brook Dam removal in north-central MA, late in the project process a citizen

> raised concerns about reintroducing sea lamprey into the system and.. actually went around and had… forty or fifty neighbours sign a petition to not do it because of concerns about ruining the local trout population. And we ended up having a seventh or eighth public hearing that was well attended by probably forty people. And we just made a presentation on sea lamprey, you know, and after a couple of hours those concerns evaporated because there's no risk whatsoever because sea lamprey, when they come into the freshwater, they're blind and have no teeth. So there's no feeding and there's no risk to you or the fish, because they just come up to die and spawn. And we had like the world expert on sea lamprey.[15]

In this instance, fears of what effects an undesirable and poorly understood native fish species, the sea lamprey, might have on more desired fish (or on people) were effectively dampened through a clear explanation of lamprey behaviour and life history and the presence of an acknowledged specialist. The examples in this sub-section show that expert knowledge, presented as part of participatory process and adapted to how people experience their local landscapes, can greatly facilitate restoration initiatives. Perhaps owing to some of the unique characteristics of dam removal, the nuanced presentation of robust scientific knowledge – while necessary – is not always enough to resolve removal conflicts.

The 'other side's scientists'

However, the presentation of knowledge about the river by experts, especially those perceived as 'outsiders' by the residents of a community confronting dam removal, is often a double-edged sword. Opponents of dam removal in New England are a diverse group, comprising – depending on the specific dam and community – historic preservation advocates, residents of local communities with strong attachments to the cultural landscape of the dammed locale, and Town officials who favour alternatives to removal (see Fox et al., 2016). In the case of the Durham Falls Dam (Durham, NH) on the Oyster River, opponents of the removal cited scientific experts – who were also local residents yet not necessarily knowledgeable about rivers and dams – as evidence that the potential physical impacts of removing the dam might produce negative consequences. According to the minutes of one meeting, a resident read a letter from a "research scientist" who expressed concern that "major storm events" might mobilise the large amounts of "accumulated silt" behind the dam. Similarly, a letter from a forest ecologist argued that the

> impact of dam removal on the spread of non-native plants needed to be considered. He said with lower water levels, the exposed land would be colonised by plants, many of which would be invasive species and would form monocultures, especially glossy buckthorn, because there was already a large local seed source for this plant in the area.[16]

[14] Interview with Manager, Pittsfield, VT, 29 September 2014.

[15] Interview, Massachusetts Riverways, 24 July 2013.

[16] Durham Town Council Meeting Minutes, 4 May 2009, Oyster River High School, Durham, NH.

Removal opponents also argue that a dammed landscape is in essence 'natural' because of the length of time that local ecological conditions have adapted to regulated flows. Advocates of restoration acknowledge this challenge, with one of our informants commenting that engineering firms undertaking restoration have to "decide what a natural channel is".[17] This is certainly the case in the Swift River campaign, where local residents produced a 70-page report documenting the numerous animal species – particularly mammals, reptiles, and fish (and to some extent plants and insects) – that characterised the wetlands environment of the Swift River impounded behind the Upper Bondsville Dam in central MA (SRPA, 2012). While this local ecological knowledge was not based on 'hard science', it offered compelling evidence to community residents and their allies in the broader region that removing the dam would destroy the 'natural' wetland created by the dam.[18]

This was also the tactic of opponents in the Oyster River example. As recorded in the minutes of a Town Council meeting in 2009, an anti-removal resident pointed out that:

> the dam had been there [in Durham] for at least 350 years, and noted that the area was many centuries past being a wilderness area. He said Mill Pond was a feature of the natural landscape now, and said Durham residents were a part of the ecosystem.[19]

At this same meeting, state and regional scientists based their conclusions on research conducted over several years demonstrating that local fish populations were threatened, and that removing the dam would be unequivocally beneficial to local ecosystems. A representative of NH Fish and Game referenced his work on the State's Wildlife Action Plan, wherein he documented the "fish species in the area that were in trouble". In addition, his agency "had surveyed most of the area above the dam, and said the species there [fish and invertebrates] would prefer to have a free-flowing system, where the flows fluctuated". He also noted that "it was important to remember that abundant runs of herring were a part of the history of this area, and said bringing them back would be a huge benefit to the public". A representative of the Piscataqua Region Estuaries Partnership, a group that for years "had worked cooperatively with towns and conservation groups within the Oyster River watershed to protect and improve the ecological integrity of the system", asserted that

> removal of the Oyster River Dam would improve the ecology of the river and would restore functions and habitats that were lost long ago. She said these long-term ecological benefits represented important community benefits, as well as benefits for the larger Great Bay estuary system. She spoke in detail on these ecological benefits, which included improved water quality, expanded estuarine habitat, and improved access to critical fisheries habitat.[20]

Ultimately, anti-removal forces prevailed and the Oyster River Dam, after a town-wide vote on a referendum, will remain in place for the foreseeable future. What might account for the seemingly flippant dismissal of expert knowledge so common among community members opposed to dam removal in New England? Sociologists of science recognised long ago that the general public is evaluating the perceived goals of the conveyors of expert knowledge as much as the knowledge itself. As Yearley (2000: 107) points out, "people evaluate the information in the light of their regard for the organisation disseminating it and of any ulterior purpose they believe they can spot". Dam removal opponents are thus technically capable of evaluating the likely impacts of dam removal based on expert opinion, they simply see this as part of a broader package of removal advocacy they vehemently disagree with. As the Swift and Oyster River cases show, proponents of preserving dams muster their

[17] Interview with civil engineer, Plymouth, MA, 19 July 2017.

[18] Interview with SRPA representatives, 21 August 2013, Belchertown, MA.

[19] Durham Town Council Meeting Minutes, 4 May 2009, Oyster River High School, Durham, NH.

[20] Ibid.

own knowledge claims regarding the impacts of dam removal and conflate eliminating the dam with destruction of 'their' river.

The role of competing claims to scientific knowledge and outcomes is perhaps best illustrated by arguments of removal opponents that a given dam can be retro-fitted for hydropower. As a staff member of The Nature Conservancy (TNC) expresses, despite detailed explanations at public forums that retro-fitting a dam is not viable due to the extant hydrologic and geomorphic site conditions and the lack of connection to the regional power grid, citizens will often insist that it *could* be possible to retro-fit the dam. In several instances, TNC has had to hire outside consultants to verify their initial claims about the inappropriateness of hydropower retro-fitting. After several months of analysis, the consulting firm reports back to the town and echoes TNC's earlier arguments regarding the lack of the necessary conditions for economically viable energy production, hence eroding the main argument of removal opponents. In numerous cases, one of the first questions from the audience is, "what does the other side's scientist think?"[21]

The long path to removal

In the midst of conflicts over dam removal, the claims and counterclaims regarding the impacts that undamming the river will have can become quite complicated, and at some point, the lines between scientific and political rationality become blurred. Consider the exchanges between proponents and opponents of the Swanton Dam removal in VT. During a public meeting about potentially removing the dam in 2008, a local reporter noted that former Fish & Wildlife Commissioner Wayne LaRoche, a long-time supporter of taking the dam out, "faced a lot of resistance to his assertion, but the tone of the meeting was calm. He argued with science. Dam proponents argued mostly from emotion" (Thompson, 2008). Yet the Swanton case – where the dam remains in place – clearly demonstrates that sound scientific knowledge and associated claims about removal impact can be effectively trumped by savvy local actors able to manoeuvre local political dynamics in a way that favours keeping a dam in place (see Magilligan et al., 2017). In the drawn-out process of removal, science often seems to be on constantly shifting ground, and new issues arise that require different forms of expertise.

Representatives of an NGO, Lake Champlain International (LCI), describe the dynamic when powerful 'common sense' perspectives run up against knowledge of how rivers function hydrologically and ecologically at meetings concerning the future of the Swanton Dam during the period 2008-2012. Townsfolk against removal would claim, "the river's gonna run dry, the town's gonna flood", and "we won't have any water for our fire trucks" if the dam is removed. The removal opponents' arguments, and their ideological undertones, continued.

> All the fish are going to get washed away. But the best one is… "this is just like the waste water treatment plant. Before they put in the waste water treatment plant, the fishing was great". So if we let these people … whoever 'they' might be, whoever the enemy is… if we let these people take out the dam, the fishing is going to get even *worse*.

The science-oriented LCI interpreted declines in the fish population differently:

> And that sewage treatment plant happened to go in about the same time that they put a new bridge across. That narrowed the stream by at least, oh, thirty feet, which increased the velocities through there. And at the same time that…did wash everything downstream! And at the same time they tore out all the old mill works … there was a marble mill, so there were all chunks of marble that would have been perfect substrate for spawning sturgeon [with ample] oxygenation.[22]

[21] Interview with TNC representative, 13 June 2016.

[22] Interview, staff of Lake Champlain International, 17 July 2013, Colchester, VT.

And, drawing a conclusion from this complicated episode, LCI believes:

> So, you know, there is an educated opposition that has some irrational beliefs, and then there's an uneducated opposition that's got totally unfounded notions of how the natural world works.[23]

The Swanton conflict also demonstrates the need for flexibility and patience on the part of removal advocates as novel knowledge claims about a dam's functioning are brought forward as part of overt resistance strategies. As early as 2008, office holders in the Swanton town government who were vehemently opposed to removal – and who technically owned the dam – suggested the dam be retrofitted for hydroelectricity production. Removal advocates such as LCI were nonplussed since based on their knowledge of hydropower development in VT and New England generally, re-engineering low-head dams such as the one in Swanton was costly and inefficient. In the words of an LCI staff person,

> And the big sticking point in this is, politics is all about timing, and this issue is political. And the science… my public policy approach is very practical. I will hear both sides, and when we take a position, we'll acknowledge the downsides of our position… I was an electrical officer in the navy, I know a bit about power production, there's nothing mathematical that suggests this is a good place for a hydro facility. If there was, I'd acknowledge it. They… this was in the time of, "oh, climate change, we're gonna get big money from the federal government because this is renewable energy, doesn't matter how much money we're gonna spend, we're gonna build a hydro facility in here".

As noted in the previous section, claims that old dams facing demolition could be re-configured to produce electricity are made in multiple cases of dam removal in New England where the project faces organised opposition. While restoration advocates can readily generate evidence countering such claims – e.g. all efficacious hydropower sites in New England have already been developed, hydropower generation for many old dam sites is economically inefficient, retrofitting requires an arduous and expensive FERC permitting process – dealing with these claims and investigating them draws out an already lengthy process. What is most apparent in these examples of conflicts over scientific knowledge and expertise is that removal opponents are not simply rejecting scientific claims because of ignorance of what is likely to happen following removal. Rather, they are contesting scientific knowledge as a political strategy, as one more rationale in their broad set of arguments that in their minds will delay and obfuscate the removal process.

CONCLUSION

The entry of science and expert knowledge into processes of dam removal can be exceedingly complex. As is the case with many environmental conflicts, there is no single path whereby a pre-packaged set of scientific axioms about dam removal is submitted for public approval and ultimately incorporated as objective truths to guide restoration processes. At every step of the way, scientific knowledge is not only co-produced with institutional, political and cultural forces, it is also circulated, reshaped and re-presented in the extended period (frequently 7-10 years) between conceiving dam removal as a restoration option and the ultimate decision to remove a dam. And this reformulation of the science of the dammed occurs within agency hallways as management and regulatory experts weigh the latest science as well as in public forums where sceptical residents divert expert knowledge claims with their own local knowledge or ask for new kinds of expert knowledge as part of a broader political strategy to prevent removal.

Analysis of the science of dam removal thus offers an important lens into how we think about expert knowledge in cases of ecological restoration by showing how seemingly straightforward scientific

[23] Ibid.

arguments around the benefits of river restoration are often at the mercy of the political dynamics of specific locales. How science is circulated and acknowledged by relevant public actors – typically residents of communities confronting a removal – complicates Lane's (2014) co-production argument where an accommodation is eventually reached between different knowledge systems in the name of pragmatism – resolving an environmental problem. The science of dam removal also challenges political ecology's accounts of environmental knowledge as a frequently oppressive tool of state actors by showing how communities can assert their own powerful political rationalities in the face of robust and widely accepted science. In addition, explication of the contested nature of scientific knowledge in the dam-removal process underscores that there is patently not a knowledge deficit in terms of how opponents of dam removal understand the likely impacts or rejections of science *per se*; resistance to removal is grounded in broader place-based tactics to stymie what many residents of dammed communities regard as unjust and unnecessary interventions into their landscapes.

Part of our project on dam removal is to glean something about knowledge claims inserted into intractable environmental conflicts that might be of use across a range of geographical contexts and ecological interventions. As a transdisciplinary collaboration, we are especially keen to uncover insights about how to re-affirm, on the one hand, the *value* of environmental knowledge in addressing thorny socioecological problems and, on the other, the need to recognise the politicisation of that knowledge from its point of origin through to its insertion into environmental conflicts. Some of this certainly involves academics situating our own knowledge production within broader constellations of powerful institutions, whether those are affiliated with the state, private actors, or non-governmental advocacy groups. This leap may be more difficult for some than others. The idea within the biophysical sciences that the production of 'objective' knowledge is paramount to being effective interlocutors with policy makers is longstanding and difficult to dislodge, although this too is being questioned from within those same sciences (Lane, 2014; Ashmore, 2015). We hope it is clear that our collaboration seeks to contribute to this line of questioning and, in doing so, build a richer, more nuanced understanding of scientific knowledge as certainly influenced by a range of social dynamics yet still a powerful means of gaining insight into nonhuman worlds.

In terms of future research, the foregoing cases of the science of the dammed in New England raise a host of intriguing normative questions that strike at the heart of concerns over alternative water-society relations and are worthy of pursuit. For those advocating dam removal as a crucial means of river restoration, are current understandings of the impacts of dams and the likely biophysical aftermaths of removing them sufficiently robust to confront those who doubt these claims? How is uncertainty over the impacts of removing dams communicated to already sceptical residents of the communities targeted for removal projects? Are 'local' knowledge claims about the impacts of removal incommensurate with those of experts? Perhaps most importantly, do current efforts to integrate scientific knowledge into dam-removal processes result in outcomes that are ecologically desirable and attentive to a participatory ethos? We may never find satisfactory answers to these questions, but we might begin by developing a more incisive view of how scientific knowledge is incorporated into specific kinds of environmental conflict.

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