**TITLE PAGE**

# Building Local Capacity for Managing Environmental Risk: a Transferable Framework for Participatory, Place-Based, Science-Narrative Knowledge Exchange

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## ABSTRACT

This paper evaluates a unique, transdisciplinary participatory research and knowledge exchange methodology developed in the Drought Risk and You (DRY) project and offers it as a transferable framework for others engaging stakeholders with environmental risk. Drought in the UK is a complex, diffuse and hidden risk, involving multiple stakeholders and systemic connections across diverse sectors. Historically drought risk management has been underpinned by specialist science and technology implemented by statutory stakeholders. This paper critically evaluates the social learning from a longitudinal research process that involved co-working with seven river catchment-based, multi-stakeholder groups. This project was a creative experiment in bringing drought science and stories into the same space, aiming to reveal different knowledges - specialist science, practical sector-level insight, and local knowledge - as a new evidence base to support better decision-making in UK drought risk management.

An evaluative multi-method research methodology was overlaid on this process, using surveys, within meeting reflective evaluations and summative semi-structured narrative interviews. This paper reflects on participant experiences of the ‘open’ scientific modelling development, ‘storying’ approaches, and their iterative interaction. It outlines the enablers, inhibitors and required support for this engagement process, which aimed to facilitate integration of different forms of knowledge as evidence, with social and sustainability learning among diverse stakeholders at its core. The process offered opportunity for valuable experiential learning as researchers of the nuanced impacts of intersecting factors on participatory place-based methods. It showed that similar approaches to science-narrative dialogic processes can play out locally to integrate aspects of social and sustainability learning in different ways. This sustainability learning provided a valuable platform for creative multi-stakeholder scenario-ing of possible drought futures for increased local climate resilience.  It then proposes a transferable research framework that promotes participatory, place-based, science-narrative knowledge exchange for building local capital for managing systemic environmental risk.

**Keywords:** drought modelling, social capital, river catchment, hybrid knowledge, climate resilience, participatory storytelling

## Author contributions

Conceptualisation: [Lindsey McEwen, Liz Roberts, Antonia Liguori; James Blake, Tim Taylor]; Methodology: [Lindsey McEwen, Liz Roberts, Andrew Holmes]; Formal analysis and investigation: [Andrew Holmes; Liz Roberts; Lindsey McEwen]; Writing - original draft preparation: [Lindsey McEwen, Liz Roberts, Andrew Holmes]; Writing - review and editing: [Lindsey McEwen, Liz Roberts, Antonia Liguori, James Blake, Tim Taylor]; Figures: [Lindsey McEwen, Andrew Holmes, James Blake, Liz Roberts, Tim Taylor]; Funding acquisition: [Lindsey McEwen]

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## 1. INTRODUCTION

Drought is a complex, pervasive and hidden risk set to increase during the Anthropocene (van Loon et al., 2016). Historically in more economically developed countries, effective drought risk management (DRM) has been predicated on developing a strong evidence base of specialist science for use by statutory organisations (e.g. water supply companies; environmental regulators) in their decision-making. In the UK, experience, knowledge and capacities in managing relatively rare severe drought tends to be located in these organisations within key individuals. Knowledge of such historic events can sit isolated and unarchived. Within the UK's planning for local risk resilience undertaken within multi-stakeholder Local Resilience Fora, drought tends to be considered as 'medium' risk, and hence rarely prioritised in planning. DRM in the UK can be framed as a 'wicked problem' (cf. Rittel and Webber, 1973). All droughts are different in intensity, duration and spatial extent with hidden impacts, incomplete data and multiple stakeholders.

Building multi-stakeholder capacity out from statutory stakeholders to understand the diverse, complex nature of drought risk in the UK, its systemic impacts, and adaptive potential across sectors at nested scales, is therefore critical for building socio-ecological resilience to live with uncertain and changing conditions. This imperative is acute, given that projections indicate increased drought risk, and population-driven increasing water demands (Office of National Statistics, 2017[1]). However, developing local capital(s) to build resilience to current and future drought in a country perceived by many publics as wet (Weitkamp et al. 2020) is a challenge.

This paper critically evaluates the development of a longitudinal, participatory, place-based, science-narrative, knowledge exchange process – a set of 'creative experiments' - that promotes social learning among individuals and organisations. UK Research Council-funded DRY (Drought Risk and You) project ran local river catchment-based, multi-stakeholder groups over four years[1]. This research process was unusual both in its length, and in how the same participatory process played out near simultaneously in locally tailored ways, within seven river catchments. This paper aims:

- to outline the science-narrative knowledge interactions within this process;
- to evaluate critically its inhibitors, enablers and support strategies in building local capital about (drought) risk management;
- to appraise stakeholder perceptions of the participatory processes and their legacy for individuals and organisations involved; and
- to develop a Framework for Participatory, Place-Based, Science-Narrative Knowledge Exchange, learning from the above evidence.

## 2. BACKGROUND LITERATURE

### 2.1 Different knowledges: specialist, lay and hybrid

Traditionally specialist science has dominated Western risk management decision making for climate resilience (Mazzocchi, 2006; Nakashima, 2016). However, international recognition of the value in local, indigenous knowledge in disaster risk management (e.g. Hiwasaki et al., 2014) grows, and of 'making space for' place-based experiential knowledge in local climate adaptation (e.g. Dujardin et al., 2018) and sustaining resilient landscapes (Johnson et al., 2016). Combining specialist science and lay knowledge can be useful to build collective capital for local decision-making, e.g. in flood risk management, and respond to 'Environmental knowledge controversies' where different forms of knowledge sit in conflict (Callon, 1999, Landström et al., 2011, Whatmore, 2009). Hybrid knowledge is valuable in risk management organisations (Haughton et al., 2015), with professionals bringing specialist and locally attuned knowledges into their decision-making. This reframing of knowledge requires a rethinking of who is considered 'expert' (McEwen and Jones 2012).

The interplay of place attachment, place identity and forms of localised expertise are particularly pertinent in context of drought risk (Moser, 2014). Having common ground geographically enables exchange of expertise, as experiences of drought will be spatially differentiated, given different hydrological conditions and varying adaptive capacity.

The power of stories and their performance is increasingly recognised (e.g. Heras and Tàbara, 2015 in environmental management). Story can have a particular role in overcoming conventional approaches to risk assessment and management. Galafassi et al. (2018) link the mutual roles of socio-ecological knowledge and creative story co-creation to transformations in this context – emphasising the three key processes of "unravelling", "meshing" and "ravelling" in knowledge co-creation. In a drought risk context, stories and storytelling have already proved crucial in forming opinions and preferences around drought adaptation (Fløttum and Gjerstad, 2016), with questions about how this approach might be further developed.

**2.2 Building knowledge networks, capacities and social capital through social and sustainability learning**

In exploring local knowledge-building practices, several literatures are useful – on defining social learning, building social capital, in developing communities of practice. Bandura's (1977) theory of social learning emphasises the significant role of observation, modelling, and imitation in learning from other's behaviours and attitudes. More recently interest has focused on the importance of social learning (exchange of knowledge, skills, values) in building adaptive capacity for socio-ecological resilience to risk and disasters (e.g. O'Brien et al., 2010; Pelling et al., 2015). McCarthy et al. (2015, np) define social learning as

> *"an on-going, adaptive process of knowledge creation that is scaled-up from individuals though social interactions fostered by critical reflection and the synthesis of a variety of knowledge types that result in changes to social structures (e.g., organizational mandates, policies, social norms)."*

Stakeholder engagement in governance can have benefits for social learning for this reason (Benson et al., 2015 for flood risk management; Wehn et al., 2017 for wider water governance).

Social learning is a key means to build capacity and capital within a community, organisation or society. "Capacity" refers to "all the strengths, attributes and resources available ….to manage and reduce disaster risks and strengthen resilience" (UNISDR Terminology, 2017, p12), including "human" knowledge, skills and collective attributes like social relationships. "Social capital" can be variously understood: from people's links and networks, to much more complex relationships between trust, shared values, bonding over commonalities and bridging differences, to norms, cohesion, participation, and agency (Ottesen et al. 2010; Putnam 2000; Poortinga 2012; Townsend et al. 2016) so that people can work together (cf. Keeley, 2007). In contrast to knowledge as science, 'storying,' as a form of social glue, is constitutive of social and knowledge capital, in building people's networks and resources, increasing cohesion, collective goals, participation and agency within groups. Stories can be vehicles for sharing experiential and inter-generational learning, and building local adaptive capacity, as knowledge that prioritises different values for resilience (e.g. Kirmayer et al., 2012).

Wenger (1998, p1) proposed 'Communities of Practice' (CoPs) as a social learning theory where:

> *'engagement in social practice is the fundamental process by which we acquire knowledge and by which we become who we are', with 'the primary unit of analysis […] the informal 'communities of practice' that people form as they pursue shared enterprises over time.'*

CoPs provide an important nexus for knowledge co-generation and sharing within and between organisations, with essential pre-conditions like trust and mutual value (Uroso et al. 2007). This motivated us to think about how we could develop CoPs through our research processes.

Sustainability learning relates to **"**learning to develop the capacity to manage options for the adaptation of human societies to the limits and changing conditions that are imposed by their own social-ecological systems" (Tabara and Pahl-Wostl 2007, p11). Such learning is systemic, complex and holistic as it "draws across diverse disciplines" (Edwards et al., 2020, p253). Burns (2009) identifies four key elements in sustainability pedagogy: content (thematic, multidisciplinary); perspectives (diverse, questioning of dominant paradigms); process (participatory, experiential, relationship building) and context that is place based.

A key question is how sustainability learning can be transformational, and how ecological principles can guide these participatory processes? (Burns, 2011).

The potential for spaces to be created for people to be exposed to practices and experiences that would be transformative and shift people's consciousness was identified by Pisters et al. (2020) as being important in delivering sustainability initiatives and drive deeper learning. The need for such spaces to operate at catchment level to address drought issues, and for such spaces to bring together science and policy actors, lay behind the development of the DRY project.

### 2.3 Different models of participatory research

Different participatory models of co-production in transdisciplinary (TD) research that build capacities and local capital for stakeholders have been developed and tested – in challenges of water risk management and wider sustainable development. Concerns include giving strong attention to processes as well as outcomes (e.g. development of design principles (Tejada et al., 2019); adaptive shaping of the TD processes for societal effectiveness (Lux et al., 2019); and how knowledge is co-created and used (Jacobi et al. 2022), and how CoPs might be developed for sustainability learning (Cundill et al., 2015).

Models of transdisciplinary research include: Stakeholder Competency Groups in participatory flood modelling (Landström et al. 2011); Learning and Action Alliances for social learning in the integration of flood risk management into urban planning (Van Herk, 2011; Ashley et al., 2012; McDonnell et al., 2018); Community-based Participatory Action Research (Durham Community Research Team 2011); and participatory storytelling as a deliberative method negotiating across different forms of expertise (e.g. Ryfe, 2006; Endres, 2012). These participatory models vary in their transdisciplinary setting, terminology used, nature and mix of participants and their prior capital, focus, types of knowledge generated and valued, processes, resources and outcomes. This poses questions about relationships between participatory processes in sustainability research and practice. For example, de Vente et al. (2016) propose good practice in the design of participatory processes in the management of social-ecological systems that include attention to knowledge, power relations and trust. They explicitly and positively link participatory processes to environmental and social outcomes, “carefully considering the extent to which process design” (e.g. facilitation; flexibility) and “local versus national context influence these outcomes” (p2). Lang et al. (2012) highlight the need for drawing lessons from assessment of transdisciplinary sustainability science projects to aid in better designing of processes. In this paper, we attempt to describe the process of the DRY project and to critically evaluate it, drawing on qualitative interviews of participants and scientists.

The imperative for increased engagement and participation is also evidenced in water management policy and practice. Examples of actively engaging (non-statutory) stakeholders in drought planning include the US National Drought Mitigation Center[2], which aims to build resilience through engagement with specialist science. International initiatives like Cadwago[3] aimed to engage researchers and stakeholders to: “improve water governance by developing a more robust knowledge base and enhancing capacity to adapt to climate change” (Cadwago, 2016). In Europe, participatory stakeholder engagement has been required in actions under the Water Framework Directive (WFD), with varying degrees of success (Jager et al., 2016). The WFD, however, focused/focuses on water quality, although measures were taken to promote action on water scarcity and drought under the Portuguese EU presidency (2007). EU policy (and hence stakeholder participation) on drought tends to crisis-orientation, rather than wider adaptation (Stein, 2016).

### 2.4 ‘Learning for resilience’ and ‘Resilience as practice’

Literature on “resilience” abounds - understood in different disciplinary contexts as resistance, bouncing back, adaptation and transformation (Whittle et al. 2010; Twigger Ross et al., 2014) in the context of both sudden shocks and on-going uncertainty and flux (e.g. Zevenbergen et al., 2020 in flooding). Adaptive capacity refers to ‘individuals’ and organisations’ ability to respond. Creating conditions for building socio-ecological resilience (cf. Adger, 2000) is critical, with strong attention to “learning for resilience” (McEwen et al., 2018). This means different things in different risk contexts, disciplines (cf. Dubois and Krasny, 2016), professions and organisations (see ‘resilience practice’; Walker and Salt 2006; 2012; Krasny et al., 2010). It also acknowledges the well-established gap between individual learning, advances in scientific knowledge and subsequent action in risk management (Baker, 2007), alongside the value-action gap in individual behaviours towards environment and climate change (Moser and Dilling, 2011; Gifford and Nilsson, 2014). Given these critical intersections of knowledges, learning and building capacity for resilience, we now share background to the transdisciplinary project – DRY (Drought Risk and You).

## 3. DRY'S CASE-STUDY CATCHMENTS AND THE PARTICIPATORY PROCESS

The five-year, interdisciplinary DRY project's overarching aim was to bring science and story together to support systemic thinking and more holistic decision-making in UK drought risk management. It used a case-study approach, identifying seven river catchments in Scotland (1), Wales (1), and England (5). Catchments were selected on hydrological, socio-economic and rural-urban gradients across the UK, and with varied geology, topography, land-use, demography, drought experiences and culture (Blake and Ragab 2014). We aimed to undertake meaningful research processes that facilitated longitudinal, multi-directional, transdisciplinary knowledge exchange and meaningful co-production (see National Institute of Health Research, 2021 principles). DRY's academic research team had prior connections with a few stakeholders in several catchments, and associated relationships of trust. However, the majority of connections were new.

Work with stakeholders within DRY's catchment-based Local Advisory Group process (hereafter "DRY-LAG") was envisaged as a 'creative experiment', iteratively sharing and co-developing hydrological drought risk modelling and drought stories. For each catchment, a physically-based distributed hydrological model (incorporating key hydrological processes including rainfall, interception, evaporation, transpiration, surface water run-off, soil moisture fluxes, groundwater flows and river discharge) was developed. Where possible, stakeholder local knowledge was incorporated by the scientists, to help improve model parameterization, calibration, and validation. This iterative process is examined further in Liguori et al. (2021). Having developed a reliable catchment hydrological model, past drought events (1961-2012) in the modelled timeseries were explored in relation to local drought experience. The model was then used to project the drought past into different possible futures using an iterative 'scenario-ing' process. This involved modelling locally resonant potential changes in climate, land use and water management, developed iteratively in collaboration with the stakeholders (see Liguori et al., 2021). Further technical details and results for specific catchments may be found in Afzal and Ragab, 2019, 2020 and on the DRY Utility.

This process aspired to build both local scientific and narrative literacy that incorporated new knowledges for drought resilience. DRY conceived science and story as different types of 'data' strongly linked to a catchment scale; its science-narrative process involved garnering and synthesis of these data collectively - attempting to avoid traditional definitions and preconceptions of 'science' and 'stories'.

Our participatory processes intended to build relationships, trust and a CoP in catchment-focused, drought risk management (DRM) that would remain beyond the project. The groups were initially conceived with an 'advisory' function. However, this quickly transitioned into co-production that became central to our catchment-based processes. DRY-LAG participants represented wide-ranging groups (statutory, non-statutory, business, voluntary sector and civil society) with variance across catchments (Figure 1). DRY aspired to ensure different sectors (environment, built environment, agriculture, business, health and wellbeing and public/communities) were represented. Participants brought diverse types of capital, including both active and retired professionals. DRY-LAGs also varied by catchment in other ways, for example, in prior scientific and narrative literacy, and recency and severity of past drought experiences.

The DRY-LAGs met for six six-monthly, face-to-face meetings alongside on-going virtual engagements through listserv email groups. The latter were used for sharing of local resources (e.g. reports, photographs etc.), discussion of research processes and outputs, and as a test-bed for attuning decision-support resources co-developed within DRY (see DRY Utility 'Resources'[4]). In the latter stages of DRY's processes, DRY-LAG participants were invited to webinars to share DRY's research results within and across catchments. In total, 42 DRY-LAG meetings were facilitated over the project's lifespan. Two hundred and fifty individuals attended one DRY-LAG meeting, with 118 attending >1 meeting, and 28 attending 3-6 meetings. Organisational participation was more sustained albeit with the individuals representing some organisations changing over the project timeline. Meetings were held in diverse venues, mainly within locally-embedded catchment settings (e.g. community halls; spaces used by NGOs; local government offices). Only three meetings were held within an urban university setting.

DRY-LAG members also participated in DRY project in other ways: by creating their own digital stories, developing stories they had shared in DRY-LAG meetings (26 participants; see DRY Story Bank); on river walks to engage local communities around local drought risk (5+ participants); co-organising sectoral workshops with DRY (7+ participants); and participating in DRY's droughted grassland experiment (mesocosm) site visits (12+ participants). In the Bevills Leam DRY-LAG, 15 participants engaged in an arts-based 'conflict resolution' process (The 'Reasons'; Bakewell et al., 2018), integrated into DRY's participatory processes. The disciplinary composition of DRY researcher participation in DRY-LAGs varied in science and narrative capital by catchment. We drew on wider team expertise through creation of video resources (e.g. on different disciplinary takes on scenario-ing[5]), for example, to overcome geographic and team capacity barriers. The same lead academic (LM) chaired 38 out of the 42 DRY-LAG meetings; 3 to 4 of DRY's academic researchers participated in each DRY-LAG, based on proximity, specialism and interest, aiming for consistency across the six meetings.Each DRY-LAG had a main researcher contact for continuity; researchers from different disciplines facilitated the sequence of dialogic activities within an individual meeting (Figure 2).A themed programme of DRY-LAG meetings evolved as participatory stages as the DRY project developed, opening up the process of science-narrative interaction (see “adaptive participatory storytelling approaches”, Roberts et al., submitted; “creative participatory science”, Liguori et al., 2021; Figure 2; SM1). Each stage had a progressive ‘science-narrative’ focus tailored to local needs and interests of DRY-LAG participants, and specifics of the locale and environmental/ demographic changes within each catchment. This allowed iterative testing and development of our science-narrative processes, so that we could be responsive to feedback and our observations of ‘what worked’. We distinguish between narrative approaches, and working with stories and storytelling (accounts of events) as data[6]. Galafassi et al. (2016) distinguish similarly – with stories as “specific and particular accounts of certain events and lived experiences” and narratives as more abstract, systemic and socio-ecological. Selected stories from the catchment were shared at each DRY-LAG meeting, encouraging storied responses to science (mostly hydrological modelling) materials presented. Selected examples of such stories are presented in SM2. The Fowey catchment acted as pilot for each round of DRY-LAG meetings in generally similar sequence. A simple formative evaluation was used after initial DRY-LAG meetings to gain rapid feedback on experiences of participation.

## 4. METHODOLOGY

The methodology for evaluating participant experiences of the emergent science-narrative processes was longitudinal (during process and after) and multi-method. . In concluding each sixth (last) face-to-face meeting in each catchment, a summative evaluative questionnaire survey was administered (27 completions) to DRY-LAG participants, along with reflective group discussions on the DRY-LAG process immediately after the survey had been completed. The survey aimed to evaluate both the research process in general and to assess perception of stakeholders to the different knowledge activities including the relationships between science and story. The survey covered their motivations for participation, expectations from involvement, open questions on what worked well and less than planned, whether being involved in the DRY-LAG had an impact on their work within the catchment, and whether they anticipated any future activity/planning individually or within their organisation based on their participation in the DRY-LAG.

All data gathered were thematically analysed as a precursor to in-depth individual, semi-structured narrative interviews with selected DRY-LAG participants to explore their perceptions of the process. These took place 3-6 months after the formal participatory process ended. The sample consisted of DRY-LAG members who had participated in three or more sessions in each of the seven catchments (see SM3 for topic guide). Twenty telephone interviews (30-40 minutes duration) were conducted by AH, who had not been part of the DRY-LAG process. Themes discussed were: the participant's background, their prior experience of research, their role and experience within the DRY-LAG process, their experience of engaging with the science, their experience of working with stories, their observations on the interactions of science and stories, any impacts of their experiences on their working practices, and any suggested improvements to the DRY-LAG processes. In addition, individual academic researchers from the DRY team provided their critical reflections on DRY-LAG processes, with seven team participants writing or filming their narrative reflections.

The above evidence was audio-recorded, transcribed, and analysed for emergent themes coded using QSR Nvivo by three researchers from the team [AH, LR, AL], and validated as part of an iterative process of review with the wider authoring team (Braun and Clarke 2006; 2013; Clarke and Braun, 2017; SM4). The interviewees have been anonymised into 5 or 6-figure codenames: the first letter of which refers to the catchment, the number refers to the order of interview, then the last two/three letters correspond to abbreviations of their roles e.g. NGO (Non-governmental Organisation).

## 5. RESULTS

### 5.1 Motivations and expectations for participation

Participants attended DRY-LAG meetings for varied reasons and reflected a spectrum of investment in the process. Each DRY-LAG had a core participant group that attended the majority of meetings, but retaining a broader group was challenging. We experienced issues with recruitment and participation across some catchments due to local perception of low drought risk. The DRY methodology, working on 'gradients', deliberately selected some catchments that were not the most drought prone in the UK. Participants attended due to a statutory remit; to replace a previous DRY-LAG participant; having related water interests (e.g. member of local community flood group); a sense that water scarcity was a growing policy issue ("*I'd been picking up on the vibes*" - Ebbw DRY-LAG participant) or more speculative interests (e.g. heritage NGOs). For one water company representative, attendance was driven by a desire to be able to control messages about drought that were happening within the catchment.

### 5.2 Participant experience of narrative-science interface

Through (out) the DRY-LAG process, stories and science were shared separately and trialled in various ways to interweave them. This section discusses how DRY-LAG participants reacted to the science, the story and then different creative experiments that brought science and story together.

### 5.2.1 Participant experience of opening up the science

The specialist drought science presented was acknowledged as complex and challenging to communicate. The scientists' preferred medium of communication (graphs in PowerPoint) presented the starting point, with experimentation (e.g. animation) as the project progressed. There were staff changes in the researchers undertaking the science modelling in four catchments over the project timeline that mitigated against some researchers learning longitudinally through the participatory process. Some participants with high prior scientific capital, such as in the catchment G DRY-LAG, commented positively on its translation:

> *"The discussions have been great and good to see climate/hydrology science translated into meaningful language*." (G11ER, Environmental Regulator)

However, G11ER (environmental regulator)also recognised the challenge of opening up specialist drought science to non-scientists, and how the DRY team members had adapted – like many of the LAG members – to the new terrain:

> *"I just enjoyed watching [named researcher] and his team go through their evolution of trying to communicate their science, across to the group."* (G11ER)

B13ER liked the way that the science reaffirmed his own work.

> "*It was interesting, going through all that science-y stuff, to see what was happening and what was going on. So it was good learning but, also, knowing that it matches up with what we're doing."* (B13ER, Environmental Regulator)

However, G11ER also felt that some science presentations did not quite "*hit home*":

> *"Some of the science that I see presented is … just impenetrable. It makes somebody who understands the science have to really work to understand what the graph or what the data set was trying to tell you… I've seen a few examples of that."* (G11ER, Environmental Regulator)

For some LAG members, particularly – but not exclusively - those from a non-science background, also felt the drought science needed more simplification.

> *"The presentations were pitched far too high, for me. I didn't understand what was being said which tended to make you feel detached from it and not involved. "* (G2CSG, Civil Society)

> "*Some of the presentations that [named researcher] gave were pretty hard work for some of us… And that's not to say [named researcher] isn't a great communicator. He's really good but it's just the nature of the beast, really."* (A8ET, NGO/Charity)

DRY-LAG participants were largely sympathetic to the difficulties faced in the science communication – the balance between simplification and losing the content.

Inevitably, there was variable extent and depth of discussion about the science depending on the collective science literacy among the DRY-LAG participants. Frustration could also pervade if participants felt they had personal scientific capital but could not understand the science.

The effect of our evolving experimentation with science communication was that participants often described variations in engagement success.

"*I found some of the live mapping, which they did, visually, easily accessible. Some of the graphs, I got a little bit lost in, [but] when it was overlaid on a map, and how that changed over time. I found that much easier to follow."* (E11LT, NGO/Charity)

C17LG similarly responded well to data movement against time, with catchment-based animations introduced as front ends to modelling:

> *"I realised how much more often low flows happen after looking at the data [in the animation], because…a dry-ish spring or summer can have a significant flow impact even if you've got individual days that are sort of quite wet. The cumulative effects were interesting."* (C17LG, Local Government)

Such creative interfacing of science gained positive feedback from participants across a wide range of prior scientific capital. Drought knowledge in this context was becoming more co-produced and hybrid in form, bringing new capital strongly linked to place into local decision-making. A DRY scientist reflected positively on his new experience of co-production:

> *"The DRY-LAG process was one of true iterative co-development which first drew upon local knowledge, data and understanding to improve the drought risk hydrological modelling…"* (JB)

**5.2.2 Participant experience of the storying**

DRY found a recurrent problem in stakeholder engagement with UK drought: shared memories are ambiguous (positive, negative, associated with sun or heat), or hidden and not shared in families or communities.  Sharing stories horizontally and vertically can mitigate this. Through the DRY-LAG process, participants variously came to understand a story's value for communicating, public engagement and decision-making. For those who had good buy-in to the story work, it had multiple benefits for their organisations.

Participants found that stories are good for making complex things relatable and closer to lived experience ('*gets people thinking about abstract things in down to earth ways*' - A8ET). They articulated that stories can make you think differently, that they convey experiences that cannot be conveyed through numbers, improve attitudes, act as a way of capturing themes and thoughts, and demonstrate best practice. They are useful, 'fascinating' even, through enabling vivid accounts, to deliver key messages, as an easy way to deliver information, and are important for explaining and changing behaviour.

Specifically, for those working with drought within their organisations, there were some genuine moments of shifting practice. An environmental regulator employee commented that stories added '*flesh to the bones of a drought plan/response*' (E3ER). A local government employee described a moment when '*the penny dropped*' and she realised that she could use one aspect of the story work with her colleagues to develop their drought resilience internally. A public health representative described how stories can illustrate unfamiliar risks as is the case with hidden and infrequent drought impacts, and for scene setting. A participant from a national heritage NGO theorised that stories were an effective way – by distilling key points - to make an impact on policy makers, who are often non-experts and have limited time.  Another environmental regulator participant valued the stories that shared historical drought impacts and responses through memories as keeping drought resilience in peoples' minds.

Limitations to use of storytelling for knowledge sharing within organisations to help deal with drought were also identified. Certain statutory organisations felt that their remit was limited in terms of whether and how they could adopt similar approaches. One participant (G6WSC; water company) felt that the drought stories presented by DRY were too parochial to help build resilience, and questioned whether they could truly lead to behaviour change. The same participant voiced uncertainty about how he could use stories for better management, while another participant was concerned that stories might be '*taken for facts*' (G2CSG). Some stories criticise other stakeholders, which a public health representative noted would not be share-able as a public organisation.

A section of DRY-LAG participants found that the storytelling aspects of the process were a barrier to their engagement.

> "*I'm too old fashioned. I took the farmer [stance]. It's not in my line to create stories or things like that. I was kind of a sleeping participant*." (D2B, Business)

> "*It just doesn't sit particularly easily with me. We had to draw a story, draw pictures to illustrate something and it doesn't come easily to me. It's not the sort of thing I enjoy doing.*" (G2CSG, Civil Society)

Part of the resistance was due to being asked to participate in storytelling activities where individuals could be taken outside their comfort zone. While some participants remained sceptical about the usefulness of stories - as "*too subjective*" – some came to appreciate their value to different degrees.

> "*Not to the scientific side because our minds were already fully open to that. But the social sciences approach and all these different tools for using narrative to inform*

> *the conversation about water management that was quite new, in a way, to us*."
> (A8ET, NGO/Charity)

An environmental regulator participant reflected on leaving her "*comfort zone*":

> *"My very first memory was I felt out of my comfort zone…We were shown videos and asked how we felt and to write down how we felt and that, as a scientist, is quite unusual…just opening, embracing it and opening my mind, actually, and I did actually enjoy those stories. Listening to other people's experiences and thinking, this is actually really all quite relevant."* (C12ER, Environmental Regulator)

Similarly, an environmental regulator from a science background, felt that "*a lot of the things around storytelling and narrative, it's not my kind of area*…" but had seen positive outcomes later in building 'evidence for decision-making'.

> *"I wasn't sure what the outcome was going to be from that. Now, obviously, I see things on the website that have come from it."* (D13ER, Environmental Regulator)

Participant experience was therefore variable, with some more entrenched in individual and perceived organisational resistance to conceiving story as data, and some shifting perceptions.

### 5.2.3 Observing science and story interactions

DRY sought to bring science and stories together in different ways with varying degrees of integration through its activities and development of resources (e.g. guidance on communicating UK drought risk). Early in the DRY-LAG process, and at its simplest level, we worked to bring science and story (not necessarily cross-referring) into the same space so they ‘bumped’ against each other. The uniqueness of DRY-LAGs was that we deliberately tried to bring new and unexpected voices into DRM discussions. So early on in one catchment, a local historian and photographer ended up passing round his photo archive of the local river at low and high flows, and the group matched these against the past hydrological modelling. This spontaneous sharing was observed to totally shift the tone and nature of the discussion to one that was more inclusive. As the DRY-LAG meetings evolved and the scientists experimented with different ways of communicating, story began to function as paratext to science (see Figure 3 with different visualisations drought risk science for Fowey as exemplar). ‘Paratext’ is a term originating in literary theory where interpretive and contextualising material supplement and mediate the main text to generate meaning. Some researchers began to narrate their development of science resources, and used storied impacts and methodological anecdotes to elucidate difficult concepts.

> *“My own approach is to ‘tell’ a scientific story and so arguably mine is a scientific storytelling approach.”* (IG)

We explored different ways of storying graphs and other visualisations[7] like animations, created by the scientists, to ease comprehension. One DRY-LAG participant spoke about one moment during the DRY-LAGs when they felt science had been storied particularly well, with the animation of their catchment during the extreme 1976 drought compared with the ‘normal’ year of 2008[8]. Towards the end of the DRY-LAG process, we asked participants to work with us to use our modelled future drought risk scenarios (based on land use, climate and water management) to inspire stories of what future impacts on the catchment might look like. The storyboards and resulting digital stories (see Liguori et al.,

2021) used the science as stimulus to imagine possible future impacts and adaptation strategies.

The DRY-LAG participants variously understood the value of story and science together in relation to one or more of these approaches (see Figure 4 for interactions and outcomes). This influenced whether they thought that they could be used together for decision-making, or whether the relationship involved stories in the service of science or vice versa.  In exploring narrative-science territory, many DRY-LAG participants felt more comfortable with story as a communication and engagement tool for science: for framing, as a bridge, for scene-setting and simplification. For some, this seemed natural and self-evident, for others it was vital to respond to drought risk moving forwards. However, some remained sceptical of the types of context where the approach would be valid.

As a science communication aid, interviewees felt that stories convey scientific information in a short concise format that grabs attention. Several participants identified how it is necessary to 'tell a story with your data or graph' to engage:

> *"...if you do the same thing with drought, you could...simplify the science down to absolute basics...so that the public can understand that visually, in a sense it's a kind of story, you...you weave into the story."* (G10CSG, Civil Society)

The introduction of animation (see above) seemed a breakthrough moment in many catchments as being a powerful way of illustrating the hydrological models results and resonating with participants' local knowledge.

> *"...things like those videos... of [catchment G] drying and wetting, as they run their model simulation through time, so you see all the colours moving from blue to red and then from red to blue again, that's really effective. ...You need to wrap that*

> *with a bit of narrative to explain what's going on but that's the kind of thing that is gripping."* (G11ER, Environmental Regulator)

Participants could relate to 'their patch' spatially within the catchment, but also discussed things like how quickly catchments returned to average conditions after extreme dry or wet events, commenting on how changes in land use might be altering that. Participants also liked to see stories pinned geographically to catchment maps.

Many DRY-LAG participants articulated stories as bridging, connecting abstract science to human experience, to make complex science more tangible and significant.

> *"...you connect through values and other things … I suppose the stories are a bit of a bridge between quite complex stuff and stuff that's very relatable to people, and potentially that's got application, whether you're dealing with colleagues or politicians or the public."* (F8LG, Local Government)

For those occupying this position, combining story and science was less for decision-making and more for engaging or describing:

> *"...it's good for illustrating an unfamiliar risk and for people who might, subsequently, have to make a decision or a risk assessment. It adds value to what the hazard is or the risk. So I think that it's better for scene setting, rather than being fundamental to a decision.*" (C10GHO, Health professional).

Storying as a bridge for science was felt to be particularly useful given the infrequency of extreme UK drought with its more hidden impacts. The value of this was heightened for DRY-LAG groups, especially in clarifying how they could work with drought risk in non-statutory roles. Combining story and science was seen as useful when talking to policy makers for conveying large amounts of information quickly, and to resonate 'importance' at an everyday, vernacular or even emotional level. An agricultural development professional (B14FP) felt that this approach could be far more powerful over a petition or letter as a lobbying tool because it engendered empathy.

Several DRY-LAG participants strongly agreed that science and stories worked together in supporting decision-making, and that the DRY-LAG process had affirmed this as "absolutely vital" (G11ER).

> *"Well, prior to being on the project, I wouldn't have thought that stories had any involvement, any place, in scientific decision making. [Now] I can see that bringing them together is the key part….stories and science actually do come together, nicely, now that I know it can be done."* (D3WT, NGO/Charity).

One participant felt that the processes of mixing stories and science, over the project's course, had "*opened our minds to new approaches*" (A8ET; NGO/Charity). Other participants questioned whether this approach was the right way to communicate with particular groups, such as farmers, or suggested that story was more appropriate in some cases and science in others rather than together. Another found a mismatch between the simplicity of story and the technicality of science.

In some catchments, statutory organisations are used to working with anecdotal alongside other forms of evidence. For example, local authorities have identified different extreme weather incidents through a search of newspaper and online coverage. As such, they are familiar with some narrative forms. For others, there was novelty and risk. Through DRY, less heard forms of water knowledge and 'everyday' stories have been brought into the UK drought discourse, sometimes in a disruptive way.

## 5.3 Benefits and challenges of DRY-LAG participation

For many participants, the meetings became important networking opportunities – formal and informal over 'good sandwiches'. For new companies or restructured organisations, the DRY-LAGs were an additional forum to promote their own work and communicate with other water-related stakeholders. This was particularly useful when dealing with large statutory organisations who could be fairly impenetrable, and where individual contacts were important but could be easily lost through staff turnover. Participants reported having the confidence to reach out to other participants to work collaboratively on drought work and other issues beyond the timeframe of DRY, as a result of relationships and networks established through the DRY-LAGs.

> *"A lot of the university contacts were completely new. The National Trust, the people from their kind of national water team... I met people that I probably should have been in contact with and hadn't previously been in contact with. So it was a really positive thing.* (G3RT, Consultancy)

DRY also acted in some cases as a catalyst for future work or strengthened relationships between stakeholders making future collaboration more likely, with several participants identifying future partnering. DRY-LAGs provided a neutral space to interact with a water company or local communities they would not normally reach, for example, the farming or business communities and associated professional bodies and NGOs.

Most significantly, the DRY-LAGs functioned as forums for genuine, multi-directional knowledge exchange. One participant commented that the best part of each meeting was the 'what is new around the table' section (Figure 2) that allowed each participant to give organisational and/or personal updates on local drought risk management activity. This section, and the meetings as a whole, gave participants an insight into operational aspects of the participating organisations, which increased local knowledge of drought risk and adaptation strategies, and enabled greater collaboration through increased understanding. Knowledge exchange happened formally through agenda items, and more informally through the research team and participants signposting each other to information and resources.

> “*The real strength of the group was the immense pool of experience and information which the participants of the group brought and were willing to share.”* (Catchment D DRY-LAG)

This reciprocity enabled participants to take learning, resources and practices back into their own work setting but also build collective capital. The refreshment breaks also resulted in participants ‘*serendipitously hearing useful things*’ (catchment B DRY-LAG participant). Participants gained knowledge about their own catchment, and some commented on the usefulness of learning about other catchments for transferable knowledge.

This knowledge fed back into organisations’ own work, especially those who had a remit to report on drought and climate risk. Participants described different types of knowledge they gained from the DRY-LAGs and how that supplemented their organisational knowledge around drought. For example, a local government representative felt better prepared to communicate drought risks to colleagues within her organisation, while a farming agency representative told us that it would enable him to better participate in national organisational conversations and set the region apart from others.

The challenges of participating in the DRY-LAGs related to the structure and content of the DRY-LAGs themselves, to organisational constraints and the variable prior capital of the participants. Some interviewees commented on (scientific) information overload, that the day felt too busy or too rushed, and several felt that there was not enough focus on clear outcomes.

> *The thing that I felt was that we were always too busy, at our meetings. There was too much information to share and always a bit of a rush to fit things in.* (D3WT), NGO/Charity

> *Sometimes I wasn't quite clear on what the outcomes that were wanted from the project were, as we were going through. […] A lot of the things around storytelling and narrative, it's not my kind of area anyway so it almost felt like I wasn't sure what the outcome was going to be from that.* (D13ER, Environmental Regulator)

One person referred to this as ‘airy fairy’ while another described it as ‘woolly’. Lack of consistency of the groups in terms of numbers and individuals was also seen as disappointing by some, and some wanted a more varied group at the meetings. For some, the actual content seemed ‘too academic’ and ‘box-ticking’, and use of terminology (across the board, not just scientific) was a frustration. More practical information and usable resources were desired from earlier on in the process, rather than sharing of large documents. Related to the ‘wooliness’, some felt the focus of the agendas were tangential to their core work (e.g. on flood resilience) so difficult to justify time to it, and one participant found the catchment scale limiting when needed for national reporting. Some of this response may, in part, be attributed to a clear switch from outcome driven work within organisations to a more co-productive process with its focus on knowledge exchange in the DRY-LAG, which whilst challenging resulted in many learnings and longer-term impacts for participants.

**5.4 DRY's legacy: main learnings and impacts on participants**

Participants shared memorable 'moments of sustainability learning' within the process in terms of their personal engagement. For some, there were transformative moments, such as realisation that floods and droughts needed to be conceived systemically and require integrated adaptive solutions. This formed part of an integrated catchment approach that individuals found useful. For several participants from statutory organisations, a new appreciation of how story and experiences can be useful as scientific evidence resulted from the process, recognising the need to connect more with those affected 'on the ground' during drought. Some participants learnt how to communicate better with different groups affected by drought, bringing in 'story data', and realisation that science and communications teams needed to be better connected within statutory organisations. Importantly participants indicated that the DRY-LAG process had confirmed for them the importance of including multiple stakeholders in drought planning at a catchment scale (cf. traditional organisational practices).

DRY project resources shared at DRY-LAGs are seeing wider application, with participants promoting and applying them in their own drought risk management and catchment activities. Early in the DRY-LAG process, a popular hand-out in the Frome catchment was a thematic mapping of the stories collected, which represented 'real world,' cross-sectoral and place-specific evidence that could ground and diversify organisational drought-scenario-ing exercises. The DRY project website resource[9] is being promoted across organisations (D3WT, B14FP), the crowdsourced 'map my drought' tool[10] was requested to ‘stay live’, the DRY primary school picture book[11] is being used in educational outreach (Jones et al., 2021), hydrological modelling is feeding into drought plans while stories are feeding it into messaging to the public[12]. The storytelling process took on an agential or generative role within some catchments, building story/local capital across distinct sectors, organisations and groups through our DRY-LAGs.

Participation in science-narrative processes in DRY-LAGs had influence on how some participants continued their work in their organisations. Participants told us that they were now incorporating videos and personal accounts into their projects and reports:

> *“It’s one of the tools I will take away from this and I’ve got it in mind for particular aspects of a particular project we’re doing...one of the factors in that it helps articulate the views of a certain group.”* (A8ET, NGO/Charity)

Stories were identified as part of a strategy to use different media, especially in educational contexts. A local government participant saw an opportunity to use scenario-ing with colleagues and others; another could imagine how to use this approach in her organisation's future projects. For others, drought had become a more prominent factor in wider management planning:

> “*It certainly made me think in terms of management planning and how the need to think about drought regimes, with regard to my work around tree management but also soil health*.” (E11LT, NGO/Charity)

> *“One of the key components of the internal drought plan is how we engage and I remember adapting that based on some of the outputs from the community aspect of DRY*.” (E3ER, Environmental Regulator)

One NGO participant, working with farmers, identified that they would be able to incorporate their new knowledge into making future recommendations.

A final legacy of participation was the new or strengthened relationships - a community of practice - that would in turn result in more multi-stakeholder work within the catchments. In the Bevills Leam catchment, dialogue between the National Farmers Union and the Great Fen Project facilitated during our DRY-LAG meetings led to the suggestion (so far not implemented) to attach an ‘exhibition farm’ to the Great Fen Visitor Centre. In the Fowey, the Catchment Partnership is seeking to broaden participants’ thinking about flood management into something more holistic due to its inclusion in DRY-LAGs and DRY’s scenario-ing workshops that demonstrated how management decisions around drought could impact in different ways on flooding and vice versa. In the Ebbw DRY-LAG, a professional stakeholder, working with large quantitative datasets, had questioned how he could use stories as evidence within the same space. However, after attending the DRY-LAGs, he went on to develop further story-based work through an additional project with researchers from the DRY team. New knowledge sharing, increased recognition of the value of different forms of knowledge, as well as new connections and relationships were built through this process working towards building catchment level drought resilience.

## 6. DISCUSSION

Returning to our four aims, we reflect on the importance of bringing together different knowledges in longitudinal, place-based, inter-professional knowledge exchange and the distinctiveness of our participatory processes. We then distil our learning into a

Framework for Place-based, Science-Narrative Knowledge Exchange in transdisciplinary research and catchment-based practice.

### 6.1 Science-narrative knowledge interactions within our processes

Drought stories in the UK are not like flood stories - both give windows into perceptions and value systems, but the former are more oblique, nebulous and less connected. The core creative experiment was in how different types of place-based knowledge as data could be brought together meaningfully into the same participatory space. We found a need to work in multiple oblique and emergent ways (rather than going in directly ‘about drought’) with creative interactions that allowed local tailoring to the multiple interests and values within any DRY-LAG meeting (cf. ‘participatory daylighting’, McEwen et al., 2020). In our creative work, we identified ways of bringing science and narrative together in different ways: from bumping of boundaries, over-layering, to fuller integration. It is worth exploring the diverse language used by participants in articulating that two-way relationship (e.g. “bridging”, “translating”, “stimulating”; Figure 4). Their perceptions were influenced by the diverse capital and prior conceptions participants brought to the collective discussions, but also whether and how these perceptions did or did not change or moderate over the timeline of the longitudinal participatory research process.

### 6.2 Enablers and inhibitors

Our evaluation detailed explorations of enablers, inhibitors and support strategies – with levels of control variable (Table 2). DRY-LAGs worked best when there was inclusive space for specialist science and diverse local knowledge capitals around the same table, and when both were iteratively shared by the research team and stakeholder participants across sectors.  This finding was similar to those of Vente et al. (2016) who found that the most important factors determining project success was not context (location) but rather who participates and ‘how the process of communication among participants is organised’ (p8). An aspect of the uniqueness of DRY-LAGs was that we deliberately tried to bring new and unexpected voices as enablers into drought discussions.  This gave licence for others to share anecdotes and vignettes of experiences with more confidence that their local knowledges would be valued.  The DRY-LAG contributed this evidence alongside the open hydrological modelling of past droughts, transforming the tone and nature of the discussion to one that was more inclusive. This particular valuing of hybrid knowledge built up from the level of the individual (e.g. knowledge and values of retired professionals involved in DRY-LAG processes). The local catchment-based nature of the groups is important in the drought context, given that prior experiences may be spatially explicit, and that place attachment may play an important role in the uptake of knowledge across the group (Moser, 2014). Inhibitors included any change of participants in a process that builds social capital related to trust and creates a community of practice based on negotiated common ground from meeting to meeting.

### 6.3 Experience and legacy of these distinctive participatory processes

In contrast to some other participatory research models, DRY-LAG group participants were encouraged to adopt different roles as the process developed, moving out from their previous roles and experiences. While our initial aspiration was to secure representation across diverse sectors, other characteristics of our participants became important – their dispositions, willingness to engage with the ‘new’, move out from comfort zones, see connections and seize opportunities in relation to what was already happening in their workplaces.  We built up to asking participants to do more ‘risky’ things (e.g. storyboarding came towards the end of the DRY-LAG process).

Scale and depth of participation varied without ‘one size fitting all’ in terms of engagement and hence experience. The most active group participants adopted different roles as the process played out as organisational participants: as gatekeepers, as storytellers, as sounding boards, as ambassadors for DRY.  Participation inevitably varied with motivations, organisational roles, prior drought experience and wider propensity for risk/resilience thinking. There were issues of continuity of organisational representation; in many DRY-LAGs, we had a series of different representatives from the same organisation as individuals changed roles or retired over the four years.  This necessitated re-building relationships each time, or instead left a noticeable gap in knowledge when no replacement could be established. These both played against the progressive build of social capital in a collective group, with the DRY-LAG process suffering from loss of institutional memory simultaneously experienced by the organisations participating. However, new participants also allowed the serendipitous injection of fresh expertise and the response that gained from participants.

Some participants appreciated the wide stakeholder participation and more diffuse experimental territory explored; others were more goal orientated and harder to engage if they did not see (immediate) outcomes for themselves and their particular sector. For example, we were unable to find a ‘hook’ for some individuals and their stakeholders, who were focused solely on flood resilience related goals, and could not see the relevance of drought in context of wider a flood-drought continuum. Lux et al. (2019) refer to these as ‘first-order effects – those changes that occur within the duration of the project - and second-order effects, for changes that occur within the immediate temporal or spatial context of the project' (p184). In the DRY-LAGs we found examples of participants enjoying a creative boost from simple participation: one that was not necessarily connected to outcomes.

Despite this, we struggled to keep continuity of involvement of the voluntary sector and NGOs. In hindsight, this was an issue of timing; for example, the heritage sector contributed to early parts of the process but were not always there when their knowledge and skills might have woven more easily and beneficially in the later storying and scenario-ing work.

In determining the sustainability and legacy of our processes in terms of capital, impacts on individual participants were diverse from 'no shift' to more transformative changes in perspective about the value of different knowledge systems. For example, this included the role of narrative within different work imperatives like organisational 'communication' and stakeholder messaging. Other experimental activities did gain professional traction, e.g. the cascade of storyboard scenario-ing approaches within the workplace in local government (also see Liguori et al., 2021). A key element of social capital generated was the new networks created of 'experts', 'interests' and 'needs' that would not have engaged about drought risk and its management in any other setting.

### 6.4 Developing a Framework for Participatory Place-based Science-narrative Knowledge Exchange

In Figure 5, we share a new framework as a tool for thinking about internal and external factors in the weave of these Participatory, Place-Based, Science-Narrative Knowledge

Exchange processes that promote sustainability learning.  This draws on insights gained in playing out a sustained participatory multi-stakeholder process that aimed to bring different knowledges together at a catchment scale in exploring a complex, wicked problem involving a hidden risk (here UK drought). In our ‘space metaphor’, we have a core of iterative deliberative dialogue around creative experimental science-narrative activities. These involve different strategies and processes – a rethinking of evidence that embodies creative systemic thinking. Connecting to the core space are semi-fluid sets of researcher-facilitators, participants, settings and co-created tools and resources. The iterative processes can be considered inputs and flows, with the system cycling in three dimensions through the extended engagement timeline.  This framework has implications for the conception and operationalisation of successful transdisciplinary participatory working that has both elements of structure (scaffolding) and creative emergence. While experience can be impacted by varied factors that intersect at the level of the individual, at its best, this science-narrative process can provide collective opportunities for transformative sustainability learning with strong eco-systemic principles and legacy for socio-ecological place-based resilience.

Sustainability science faces a number of critical issues in responding to the challenge of climate change - as discussed by Kates (2011).  The development of our participatory science-narrative knowledge exchange processes permitted a creative place-based exploration of elements of UK drought risk and its management in relation to these big questions.  We offer this Framework as a possible way to help navigate this critical territory in other uncertain and complex risk/resilience contexts with multi-stakeholder interests. This will have utility where risks are less visual or pervasive and more challenging to connect with in building local climate resilience.

## 7. CONCLUSIONS

In this paper, we shared insights gained from a rare research opportunity to undertake a series of seven creative experiments in how to approach science-narrative interactions in place-based adaptive explorations of a hidden, overlooked and increasing risk. The participatory DRY-LAG process enabled progressive connections of diverse past knowledges and experiences tied to place as a platform for creative scenario-ing of possible drought futures. The process was unusual in several ways in its experimental weave of science and story including: its scale over space and time; its complexity of local variables influencing its outcomes; its unique national geography with similar participatory processes playing out synchronously in seven river catchment settings – distinct but on gradients; its varied stakeholders that combined statutory, non-statutory and non-government organisations with citizen volunteers in different combinations in each setting; the interaction of diverse capitals brought to the table within each researcher and stakeholder group; and its disparate goals, outcomes and understandings of what 'success' meant. This process included explicit considerations of formality and informality of setting, of knowledge, of role etc., and what knowledges were shared, connected, promoted and valued by participants as its iterative science-narrative processes played out. While we initially set out to ensure diverse sectors were represented, it became more important to ensure the right mix of knowledges (specialist, lay/ experiential, organisational) and multi-stakeholder buy-in to fuel future-facing dialogue about how to support local drought risk management in creative ways.

In reflecting on its uniqueness, the process offered opportunity for experiential learning as researchers of the often nuanced impact of intersecting factors - that similar approaches (on paper) to science-narrative dialogic processes can play out locally to integrate aspects of social and sustainability learning in different ways. Importantly, our original objectives and expectations for the DRY-LAGs became quickly reframed as relationships and trust built in a process that gave permission for stronger elements of emergence and risk-taking, and the seizing of new participatory opportunities tailored to individuals (i.e. willingness to further embed within the research process). Its iterative processes facilitated sustainability learning that was not homogenous in its socio-ecological connections but rather diverse depending not only on prior knowledge and skills but importantly dispositions - preparedness to work outside personal and organisational ‘norms’ of engagement and to invest in understanding a research process by living it.

The proposed Framework for Place-based, Science-Narrative Knowledge Exchange provides a new way of thinking about this sort of transdisciplinary participatory working drawing across different knowledge domains, and the variables that interweave in increasing the likelihood of its effectiveness in terms of building capacities impact and legacy. As such, it creatively integrates opportunities for both social and sustainability learning in an emerging community of practice.  This has implications for organisational decision-making that gives rigid precedence to a particular hierarchy of knowledge in dealing with a hidden pervasive and changing risk like UK drought.  Learning from these creative experiments in exchange of different knowledges has important implications for strategies to transform multi-stakeholder construction of evidence to support better local socio-ecological resilience building.

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Figure 5: A Framework for Place-based, Science-Narrative Knowledge Exchange

**Supplementary data**

SM1: Table outlining the DRY-LAG process in each catchment

SM2: Links to exemplar digital stories

SM3: Topic guide for participant interviews

SM4: DRY-LAG interview matrix

Table 1: The process of opening up the science: explanation of examples in Figure 3

| *Figure header* | *Explanation* |
|---|---|
| A. LAG 1: Exploring local drought context through a visualisation of a precipitation index from 1961 – 2017 (red = drier than usual, blue = wetter). | The science was used as a prompt for discussion of local knowledge and stories about past drought events. |
| B. LAG 3/4: Static plots (of the Fowey catchment area) from a paired animation showing how changing rainfall (left) affects modelled soil moisture (right) over different parts of the catchment during the drought period April – September 1976. | The variations in modelled soil moisture reflect differences in soil type and land use across the catchment, helping to link the results to local knowledge and understanding of past drought events. The animation also illustrates how minor rainfall events during drought have no significant impact on soil moisture over the plant root zone. The scientist delivered a narrative explaining the processes as the animation unfolded to help communication of complex ideas. |
| C. LAG 4/5: Plot showing simplified climate change projections (change in temperature and precipitation compared to a 1961-1990 baseline period) for the Fowey catchment for different time periods, seasons and emissions scenarios. | This was an attempt to present the science at multiple levels of understanding in the same plot, from the detailed numerical values to broader comprehension based on colour scheme (e.g. drier (red) or wetter (blue) for precipitation). The plot was delivered in parallel with a narrative from the scientist highlighting possible implications and further details of the projected changes, for example, increased evaporation, increased summer rainfall intensity, need for increased storage of winter rainfall, farming and gardening irrigation, growing season, plant/crop selection, garden pests and health implications such as heatwaves. The narrative approach allowed the scientist to communicate possible impacts as hypotheses, with iterative feedback from the LAG members as to which areas should be investigated further as possible local drought impact indices. |
| D. LAG 4/5: A plot and example photos comparing average annual temperature for SW England over 'baseline' (1961-1990) and recent past (1987-2016) periods, along with future climate change projections, plus 'baseline' temperatures for selected hotter European countries for comparison. | This was an experiment in communicating climate change data and linking it to personal experience – in this case, the changes in time (i.e. the future climate scenarios) have been juxtaposed with changes in space (images of fields in Summer from other countries with temperatures similar to the projections). To link science to lay knowledge, it was beneficial to draw initial attention to the increased temperatures over the recent past compared to the baseline period, starting |

| | |
|---|---|
| | conversations about changing climate and local experience, before moving into possible future projections. This was not only a prompt for narrative discussion for the science, but reflected a response to feedback and iteration from prior LAG meetings seeking a less numerical presentation of future climate change scenarios (cf. Figure 3.c). |
| E. LAG 6: An experiment in presenting the numerical climate change scenario modelling results using just text. | Although detailed numerical results were also provided, this experiment attempted to respond to the LAG member's requests for results in a more accessible format. As always, there is a scientific narrative presented alongside the PowerPoint slide to explain some of the details and differences apparent in the results. |
| F. LAG 6: An experiment in distilling the results of the climate change, land use change and catchment management scenario modelling into key messages. | Science here is very much responding to narrative as a prompt, given that narrative shaped the scenarios that were modelled and focussed the results on areas of particular interest to Fowey catchment LAG members. |

Table 2: Inhibitors, enablers and support strategies within the DRY-LAG process.

| *Realm/ aspiration* | *Inhibitors* | *Enablers* | *Support strategies* |
|---|---|---|---|
| DRY concept | (In)ability to engage some professions about a hidden risk, categorised as medium on risk registers | Those around table who had actual drought experience | Sharing about past drought events and experiences early in process |
| Engage diverse stakeholders | Challenge to engage all interests over the project lifespan<br>Emergency response needs to flood risk limits potential engagement.<br>Difficult to sustain contacts and communications after the project. | Role of combined expertise, positive disposition and willingness to invest for longer-term return. | Strong attention to maintaining momentum and engagement<br>Scenario-ing 'What Ifs;' with those affected locally |
| Thinking about data differently | Entrenchment of views on 'evidence' and goals | Stakeholder diversity | Cross-organisational sharing and learning |
| Opening up science, DRM and its ways of thinking | Complexity of hydrological modelling<br>Focus on traditional graph based scientific results<br>Conception of specialist science as a fixed, unchanging process with embedded norms.<br>Researcher concern about sharing science before formal publication | Conception of science as 'negotiated'<br>Willingness to take risks and do things differently<br>Ability to learn rapidly from experience<br>Ability to think creatively about alternative accessible visualisations (e.g. catchment-scale animation)<br>Attention to processes as well of outcomes<br>Ability to actively listen to and incorporate lay knowledge<br>Genuine open drought risk modelling | 'Training' in sci-com can only go so far<br>Promote heightened listening skills in scientists<br>Need for multi-level communication of science outputs for different levels of science capital<br>Potential for outdoor learning – e.g. grassland mesocosms |

| | | | |
|---|---|---|---|
| Opening up storying approaches; thinking about stories as data | Variable uptake in learning to deal with science and narrative as evidence | Conception of stories as 'negotiated' | Tagging of stories as a way of both coding and active listening |
| Science and narrative as data | Rigid preconceptions of the value of different form of knowledge and what could constitute 'data'. | Diversity of experimentation<br>Willingness to take risks<br>Identification of bridging concepts or activities (e.g. visualising drought, thresholds, scenario-ing, thematic tagging of drought stories) | Social learning to build of new capital in science and narrative and how to bring these together as evidence |
| Capital of stakeholder participants | Turnover of sectoral capital over project lifespan | Injection of new insights/ perspectives<br>Dispositions matter | Longitudinal working and ongoing dialogue for relationship building |
| Capital of academic research team | Turnover of scientific (hydrological) researchers over project lifespan | Injection of new insights/ perspectives<br>Dispositions matter | Longitudinal working and ongoing dialogue for relationship building |

Figure 1: Location of DRY's seven case-study catchments, with a summarised character of the local stakeholder participation in each setting

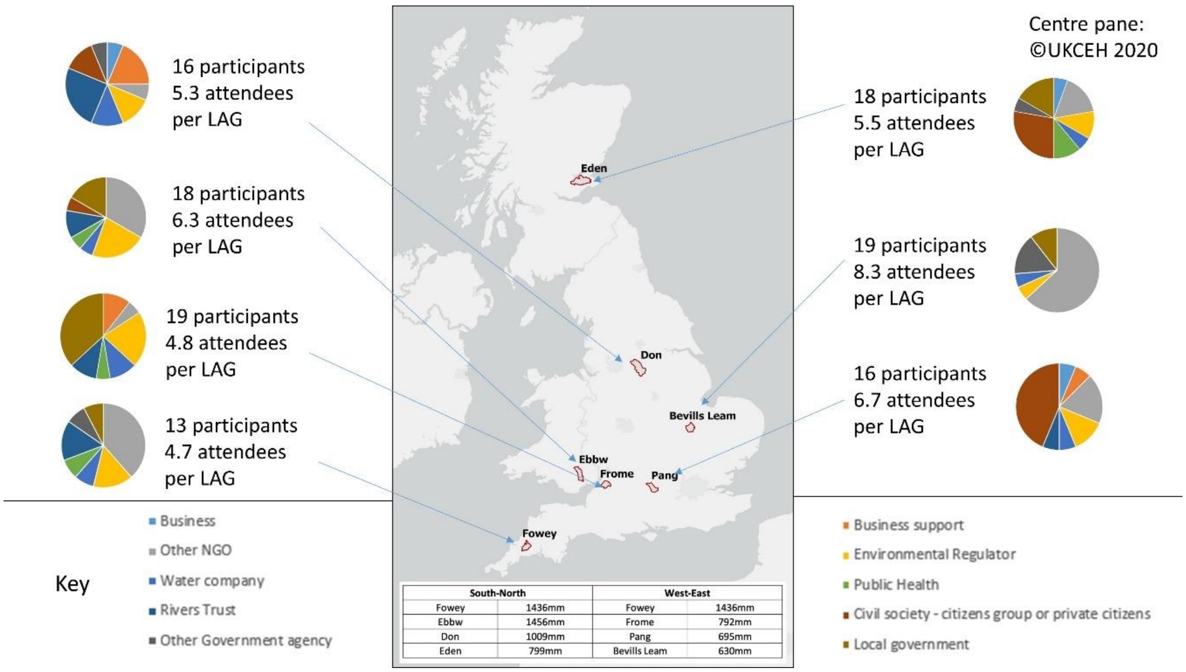


Figure 2: Development of science-story interaction within the DRY-LAG process

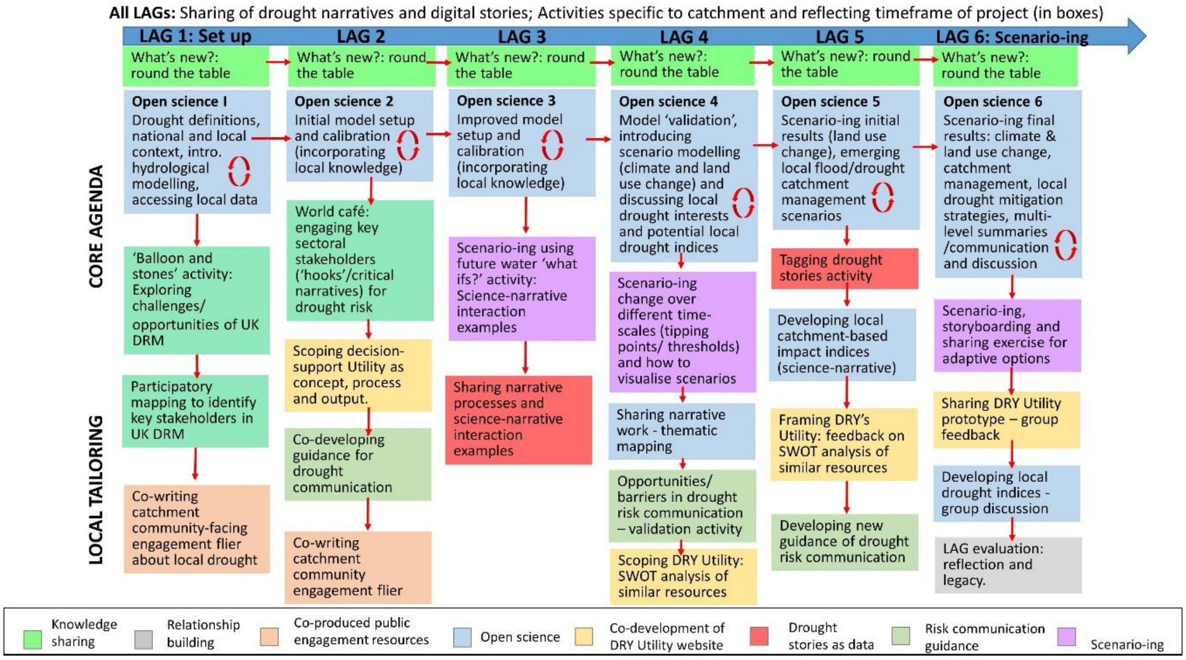


Figure 3: Drought risk science for the River Fowey catchment as an example (Parts 1-3; see Table 1 for explanation)

Part 1: A. LAG 1: Exploring local drought context through a visualisation of a precipitation index from 1961 – 2017 (red = drier than usual, blue = wetter). B. LAG 3/4: Static plots (of the Fowey catchment area) from a paired animation showing how changing rainfall (left) affects modelled soil moisture (right) over different parts of the catchment during the drought period April – September 1976.

Part 2: C. LAG 4/5: Plot showing simplified climate change projections (change in temperature and precipitation compared to a 1961-1990 baseline period) for the Fowey catchment for different time periods, seasons and emissions scenarios. D. LAG 4/5: A plot and example photos comparing average annual temperature for SW England over 'baseline' (1961-1990) and recent past (1987-2016) periods, along with future climate change projections, plus 'baseline' temperatures for selected hotter European countries for comparison.

Part 3: E. LAG 6: An experiment in presenting the numerical climate change scenario modelling results using just text. F. LAG 6: An experiment in distilling the results of the climate change, land use change and catchment management scenario modelling into key messages.

Figure 3A/B

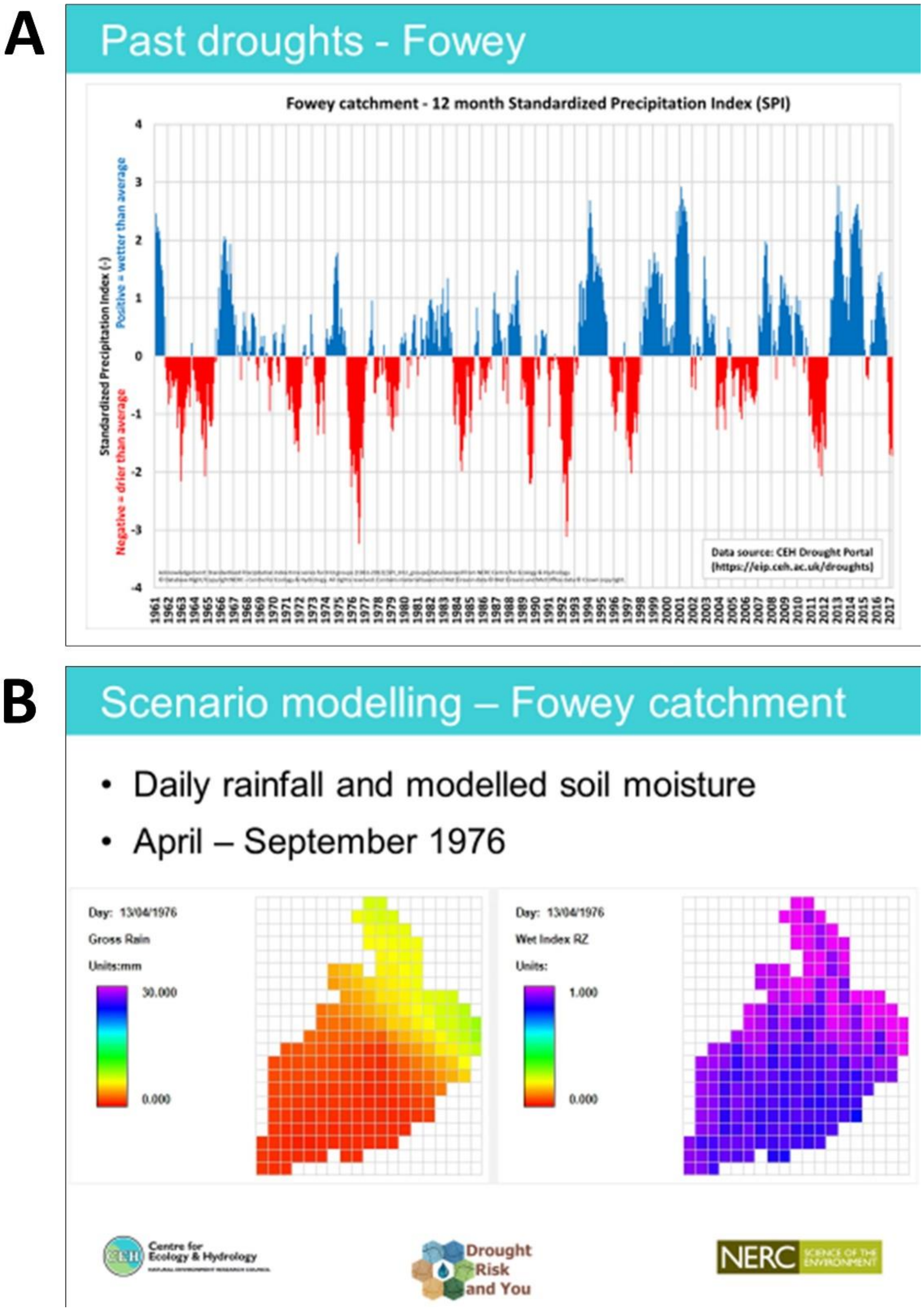
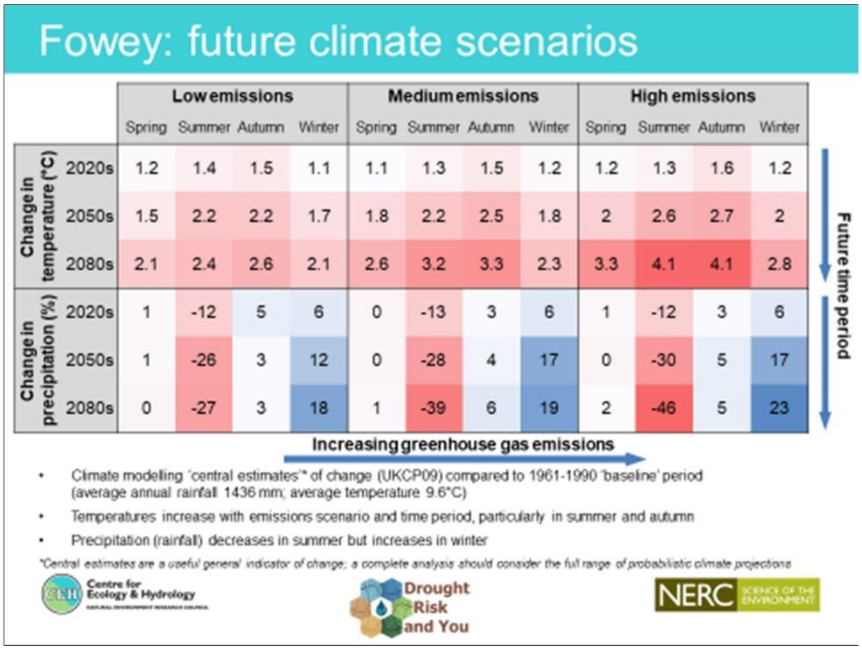

A
Past droughts - Fowey
Fowey catchment - 12 month Standardized Precipitation Index (SPI)
Standardized Precipitation Index (-)
Positive = wetter than average
Negative = drier than average
Data source: CEH Drought Portal
(https://eip.ceh.ac.uk/droughts)
B
Scenario modelling – Fowey catchment
• Daily rainfall and modelled soil moisture
• April – September 1976
Day: 13/04/1976
Gross Rain
Units:mm
30.000
0.000
Day: 13/04/1976
Wet Index RZ
Units:
1.000
0.000
Centre for Ecology & Hydrology
Drought Risk and You
NERC
SCIENCE OF THE ENVIRONMENT

Figure 3C/D

C



Fowey: future climate scenarios

| | | Low emissions | | | | Medium emissions | | | | High emissions | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Spring | Summer | Autumn | Winter | Spring | Summer | Autumn | Winter | Spring | Summer | Autumn | Winter |
| Change in temperature (°C) | 2020s | 1.2 | 1.4 | 1.5 | 1.1 | 1.1 | 1.3 | 1.5 | 1.2 | 1.2 | 1.3 | 1.6 | 1.2 |
| | 2050s | 1.5 | 2.2 | 2.2 | 1.7 | 1.8 | 2.2 | 2.5 | 1.8 | 2 | 2.6 | 2.7 | 2 |
| | 2080s | 2.1 | 2.4 | 2.6 | 2.1 | 2.6 | 3.2 | 3.3 | 2.3 | 3.3 | 4.1 | 4.1 | 2.8 |
| Change in precipitation (%) | 2020s | 1 | -12 | 5 | 6 | 0 | -13 | 3 | 6 | 1 | -12 | 3 | 6 |
| | 2050s | 1 | -26 | 3 | 12 | 0 | -28 | 4 | 17 | 0 | -30 | 5 | 17 |
| | 2080s | 0 | -27 | 3 | 18 | 1 | -39 | 6 | 19 | 2 | -46 | 5 | 23 |



D

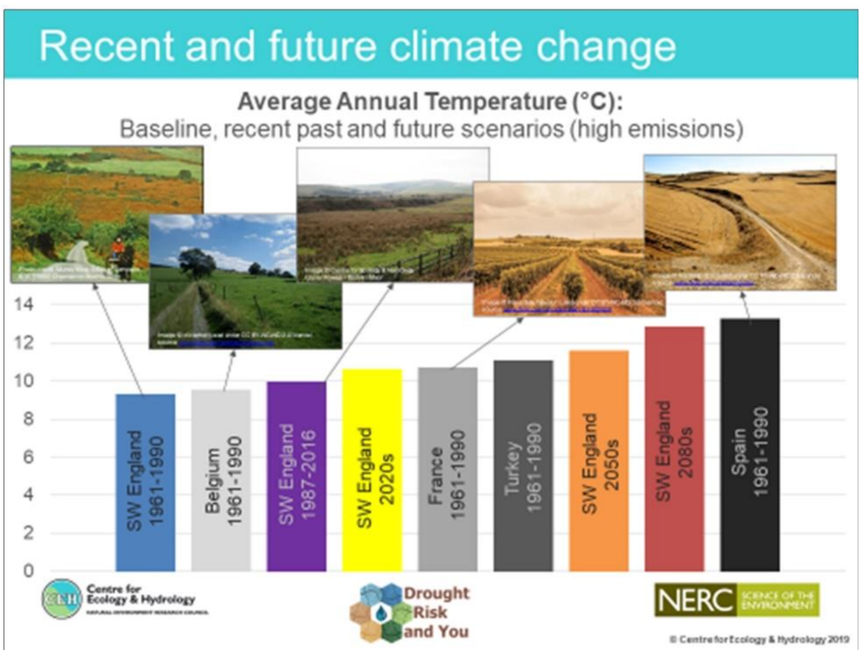
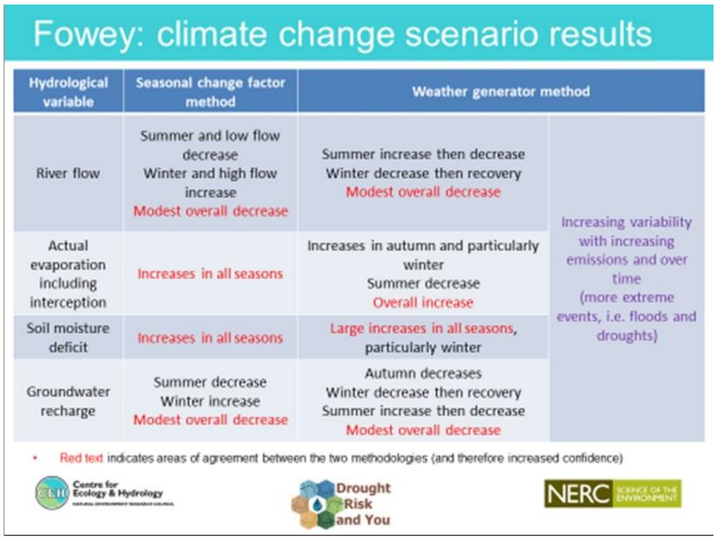


Figure 3E/F

E



Fowey: climate change scenario results

| Hydrological variable | Seasonal change factor method | Weather generator method | |
|---|---|---|---|
| River flow | Summer and low flow decrease<br>Winter and high flow increase<br>Modest overall decrease | Summer increase then decrease<br>Winter decrease then recovery<br>Modest overall decrease | Increasing variability with increasing emissions and over time<br>(more extreme events, i.e. floods and droughts) |
| Actual evaporation including interception | Increases in all seasons | Increases in autumn and particularly winter<br>Summer decrease<br>Overall increase | |
| Soil moisture deficit | Increases in all seasons | Large increases in all seasons, particularly winter | |
| Groundwater recharge | Summer decrease<br>Winter increase<br>Modest overall decrease | Autumn decreases<br>Winter decrease then recovery<br>Summer increase then decrease<br>Modest overall decrease | |

- Red text indicates areas of agreement between the two methodologies (and therefore increased confidence)



F

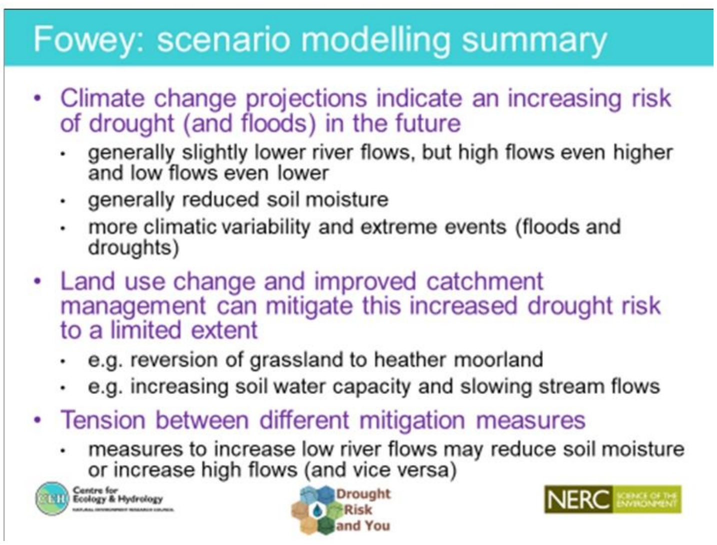


Figure 4: Themes from the science-narrative interface

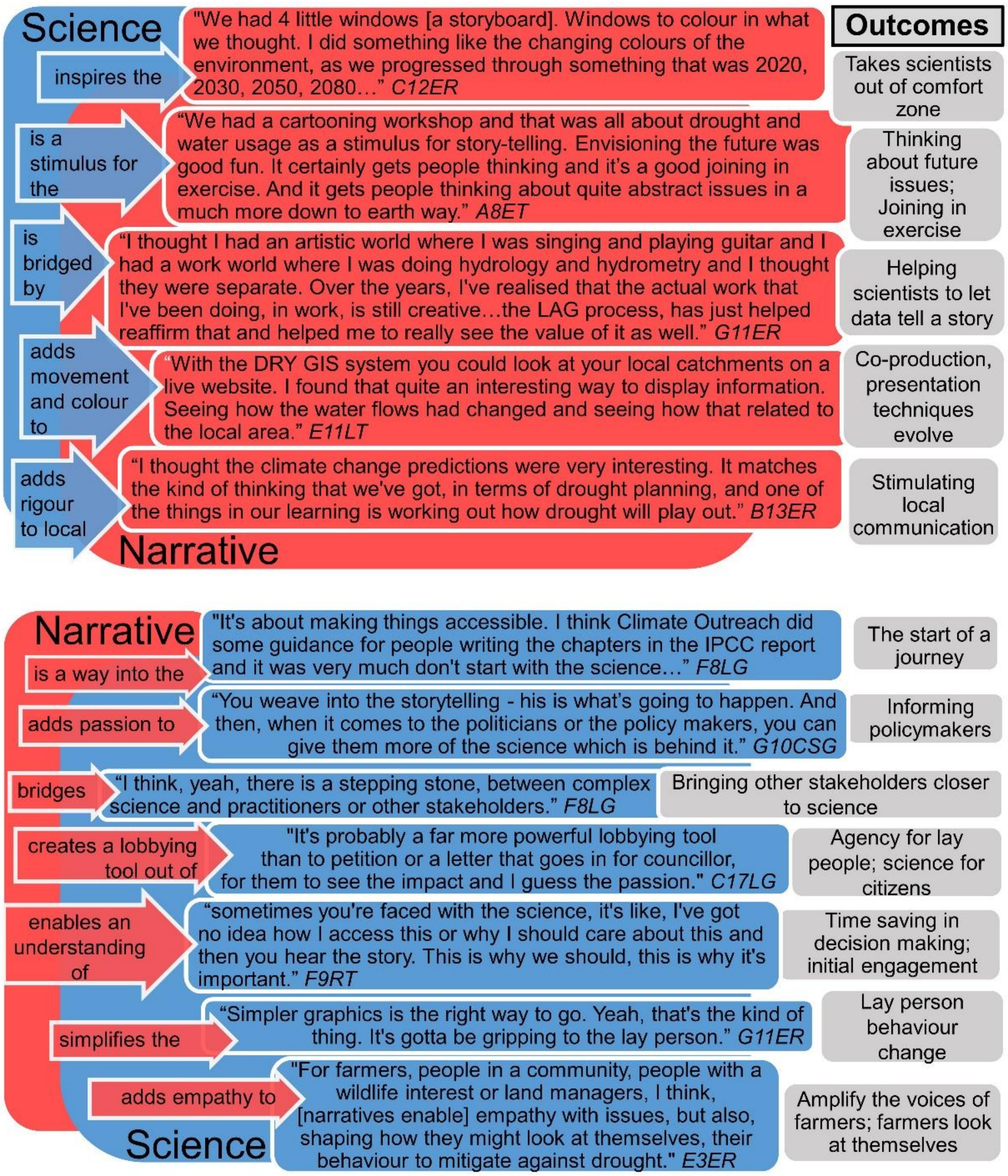
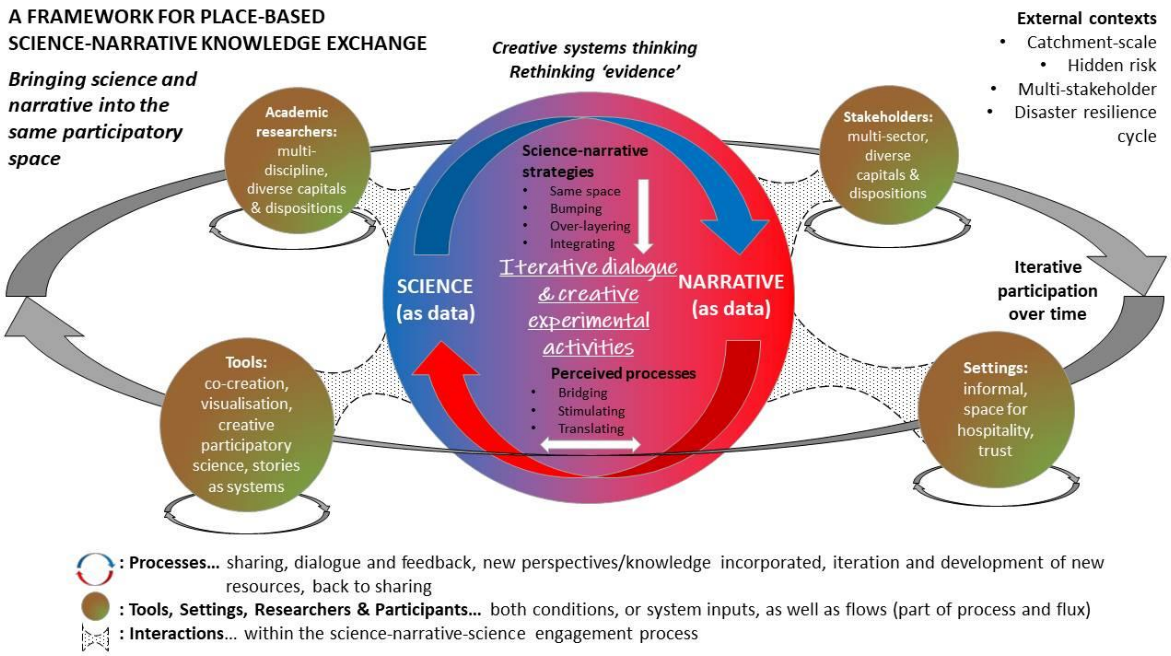


Figure 5: A Framework for Place-based, Science-Narrative Knowledge Exchange




[1] In England, population is projected to grow by 5.9% over the next 10 years, and to almost 64 million by 2050, an increase of nearly 15% from 2017.

[2] The NDMC 'helps people, organizations and institutions build resilience to drought through monitoring and planning'; see https://drought.unl.edu/

[3] Cadwago.net – funded as part of the "Europe and Global Challenges programme"

[4] https://dryutility.info/resources/

[5] Disciplinary reflections on meanings: scenario - https://www.youtube.com/watch?v=AGPPIHyEcpw

[6] One challenge here has been that story and narrative are used interchangeably within non-specialist and conversational discourse and are even used differently across disciplines. Sometimes, narrative is used to define a specific instance of a story, so that one story can exist as multiple narratives. However, especially for those interested in the performative aspects of storytelling, a story is the 'text' that is brought into being by the story*telling* (performance), whereas the narrative is the overarching arrangement in narrative form of a set of events or experiences (in other words, the exact opposite). 'Storying', on the other hand, refers to the dissemination and reception of a set of events through a narrative lens – turning an event into a story.

[7] Dryutility.info. See drought science panels.

[8] See catchment-based drought science sections in DRY Utility (dryutility.info)

[9] Dryutility.info

[10] http://dryproject.co.uk/citizen-science/map-your-drought/

[11] Dryutility.info/learning/

[12] Dryutility.info/story-bank