



## Co-productive agility and four collaborative pathways to sustainability transformations



Josephine M. Chambers <sup>a,b,c,\*</sup>, Carina Wyborn <sup>b,d</sup>, Nicole L. Klenk <sup>e</sup>, Melanie Ryan <sup>b</sup>, Anca Serban <sup>b</sup>, Nathan J. Bennett <sup>f,g</sup>, Ruth Brennan <sup>h</sup>, Lakshmi Charli-Joseph <sup>i</sup>, María E. Fernández-Giménez <sup>j</sup>, Kathleen A. Galvin <sup>k</sup>, Bruce E. Goldstein <sup>l</sup>, Tobias Haller <sup>m</sup>, Rosemary Hill <sup>n</sup>, Claudia Munera <sup>o</sup>, Jeanne L. Nel <sup>p,q</sup>, Henrik Österblom <sup>r</sup>, Robin S. Reid <sup>s</sup>, Maraja Riechers <sup>t</sup>, Marja Spierenburg <sup>u,v</sup>, Maria Tengö <sup>r</sup>, Elena Bennett <sup>w</sup>, Amos Brandeis <sup>x</sup>, Paul Chatterton <sup>y</sup>, Jessica J. Cockburn <sup>z</sup>, Christopher Cvitanovic <sup>aa</sup>, Pongchai Dumrongrojwatthana <sup>ab</sup>, América Paz Durán <sup>ac,ad</sup>, Jean-David Gerber <sup>ae</sup>, Jonathan M. H. Green <sup>af</sup>, Rebecca Gruby <sup>ag</sup>, Angela M. Guerrero <sup>r</sup>, Andra-Ioana Horcea-Milcu <sup>ah</sup>, Jasper Montana <sup>ai</sup>, Patrick Steyaert <sup>aj</sup>, Julie G. Zaehringer <sup>ak</sup>, Angela T. Bednarek <sup>al</sup>, K Curran <sup>al</sup>, Salamatu J. Fada <sup>am,an</sup>, Jon Hutton <sup>ao</sup>, Beria Leimona <sup>ap</sup>, Tomas Pickering <sup>aq</sup>, Renee Rondeau <sup>ar</sup>

<sup>a</sup> Forest and Nature Conservation Policy Group, Wageningen University, Wageningen, The Netherlands

<sup>b</sup> Luc Hoffmann Institute, IUCN Conservation Centre, Gland, Switzerland

<sup>c</sup> Department of Geography, University of Cambridge, Cambridge, UK

<sup>d</sup> Institute for Water Futures, Fenner School of Environment & Society, Australian National University, Canberra, Australia

<sup>e</sup> Department of Physical and Environmental Sciences, University of Toronto, Toronto, Ontario, Canada

<sup>f</sup> Institute for the Oceans and Fisheries, University of British Columbia, Vancouver, British Columbia, Canada

<sup>g</sup> The Peopled Seas Initiative, Vancouver, British Columbia, Canada

<sup>h</sup> Trinity Centre for Environmental Humanities, School of Histories and Humanities, Trinity College Dublin, Dublin, Ireland

<sup>i</sup> Laboratorio Nacional de Ciencias de la Sostenibilidad, Instituto de Ecología, Universidad Nacional Autónoma de México, Mexico City, Mexico

<sup>j</sup> Department of Forest and Rangeland Stewardship, Colorado State University, Fort Collins, CO, USA

<sup>k</sup> Department of Anthropology and Geography, Colorado State University, Fort Collins, CO, USA

<sup>l</sup> Program in Environmental Design, University of Colorado Boulder, CO, USA

<sup>m</sup> Institute of Social Anthropology, University of Bern, Bern, Switzerland

<sup>n</sup> CSIRO Land and Water and James Cook University Division of Tropical Environments and Societies, Cairns, Australia

<sup>o</sup> Fenner School of Environment and Society, Australian National University, Canberra, Australia

<sup>p</sup> Sustainability Research Unit, Nelson Mandela University, George, South Africa

<sup>q</sup> Earth Observation and Environmental Informatics Group, Wageningen University & Research, Wageningen, The Netherlands

<sup>r</sup> Stockholm Resilience Centre, Stockholm University, Stockholm, Sweden

<sup>s</sup> Department of Ecosystem Science and Sustainability, Colorado State University, Fort Collins, CO, USA

<sup>t</sup> Faculty of Sustainability, Leuphana University of Lüneburg, Lüneburg, Germany

<sup>u</sup> Leiden University, Leiden, The Netherlands

<sup>v</sup> Stellenbosch University, Stellenbosch, South Africa

<sup>w</sup> Department of Natural Resource Science and Bieler School of Environment, McGill University, Montreal, Quebec, Canada

<sup>x</sup> Architecture, Urban & Regional Planning, LTD., Hod HaSharon, Israel

<sup>y</sup> School of Geography, University of Leeds, Leeds, UK

\* Corresponding author at: Forest and Nature Conservation Policy Group, Wageningen University, Wageningen, The Netherlands.

E-mail addresses: [jmichambers@gmail.com](mailto:jmichambers@gmail.com) (J.M. Chambers), [carina.wyborn@anu.edu.au](mailto:carina.wyborn@anu.edu.au) (C. Wyborn), [nicole.klenk@utoronto.ca](mailto:nicole.klenk@utoronto.ca) (N.L. Klenk), [melyran@wwfint.org](mailto:melyran@wwfint.org) (M. Ryan), [adamerell@wwfint.org](mailto:adamerell@wwfint.org) (A. Serban), [ruthbrennan@gmail.com](mailto:ruthbrennan@gmail.com) (R. Brennan), [lakshmi.charli@ieecologia.unam.mx](mailto:lakshmi.charli@ieecologia.unam.mx) (L. Charli-Joseph), [maria.fernandez-gimenez@colostate.edu](mailto:maria.fernandez-gimenez@colostate.edu) (M.E. Fernández-Giménez), [kathleen.galvin@colostate.edu](mailto:kathleen.galvin@colostate.edu) (K.A. Galvin), [brugo@colorado.edu](mailto:brugo@colorado.edu) (B.E. Goldstein), [tobias.haller@anthro.unibe.ch](mailto:tobias.haller@anthro.unibe.ch) (T. Haller), [ro.hill@csiro.au](mailto:ro.hill@csiro.au) (R. Hill), [claudia.munera@anu.edu.au](mailto:claudia.munera@anu.edu.au) (C. Munera), [henrik.osterblom@su.se](mailto:henrik.osterblom@su.se) (H. Österblom), [robin.reid@colostate.edu](mailto:robin.reid@colostate.edu) (R.S. Reid), [riechers@leuphana.de](mailto:riechers@leuphana.de) (M. Riechers), [m.j.spierenburg@fsw.leidenuniv.nl](mailto:m.j.spierenburg@fsw.leidenuniv.nl) (M. Spierenburg), [maria.tengo@su.se](mailto:maria.tengo@su.se) (M. Tengö), [elena.bennett@mcgill.ca](mailto:elena.bennett@mcgill.ca) (E. Bennett), [amos-br@inter.net.il](mailto:amos-br@inter.net.il) (A. Brandeis), [p.chatterton@leeds.ac.uk](mailto:p.chatterton@leeds.ac.uk) (P. Chatterton), [j.cockburn@ru.ac.za](mailto:j.cockburn@ru.ac.za) (J.J. Cockburn), [christopher.cvitanovic@anu.edu.au](mailto:christopher.cvitanovic@anu.edu.au) (C. Cvitanovic), [jean-david.gerber@giub.unibe.ch](mailto:jean-david.gerber@giub.unibe.ch) (J.-D. Gerber), [jonathan.green@york.ac.uk](mailto:jonathan.green@york.ac.uk) (J.M.H. Green), [rebecca.gruby@colostate.edu](mailto:rebecca.gruby@colostate.edu) (R. Gruby), [andraioana.horceamilcu@ubclj.ru](mailto:andraioana.horceamilcu@ubclj.ru) (A.-I. Horcea-Milcu), [jasper.montana@ouce.ox.ac.uk](mailto:jasper.montana@ouce.ox.ac.uk) (J. Montana), [psteyaert@grignon.inra.fr](mailto:psteyaert@grignon.inra.fr) (P. Steyaert), [julie.zaehringer@cde.unibe.ch](mailto:julie.zaehringer@cde.unibe.ch) (J.G. Zaehringer), [ABednarek@pewtrusts.org](mailto:ABednarek@pewtrusts.org) (A.T. Bednarek), [kcurran@pewtrusts.org](mailto:kcurran@pewtrusts.org) (K. Curran), [jhutton@wwfint.org](mailto:jhutton@wwfint.org) (J. Hutton), [l.beria@cgiar.org](mailto:l.beria@cgiar.org) (B. Leimona), [tomas.pickering@colostate.edu](mailto:tomas.pickering@colostate.edu) (T. Pickering), [reneerondeau@colostate.edu](mailto:reneerondeau@colostate.edu) (R. Rondeau).

<sup>z</sup> Department of Environmental Science, Rhodes University, Makhanda (Grahamstown), South Africa  
<sup>aa</sup> Australian National Centre for the Public Awareness of Science, Australian National University, Australian Capital Territory, Australia  
<sup>ab</sup> Department of Biology, Chulalongkorn University, Pathumwan, Bangkok, Thailand  
<sup>ac</sup> Instituto de Ciencias Ambientales y Evolutivas, Universidad Austral de Chile, Valdivia, Chile  
<sup>ad</sup> Instituto de Ecología y Biodiversidad, Casilla 653, Santiago, Chile  
<sup>ae</sup> Institute of Geography & Center for Regional Economic Development (CRED), University of Bern, Bern, Switzerland  
<sup>af</sup> Stockholm Environment Institute York, Department of Environment and Geography, University of York, York, UK  
<sup>ag</sup> Department of Human Dimensions of Natural Resources, Colorado State University, Fort Collins, CO, USA  
<sup>ah</sup> Hungarian Department of Biology and Ecology, Babeş-Bolyai University, Cluj-Napoca, Romania  
<sup>ai</sup> School of Geography and the Environment, University of Oxford, Oxford, UK  
<sup>aj</sup> UPEM LISIS INRA, Champs sur Marne, France  
<sup>ak</sup> Centre for Development and Environment, University of Bern, Bern, Switzerland  
<sup>al</sup> The Pew Charitable Trusts, Washington DC, USA  
<sup>am</sup> School of Nature Sciences, Bangor University, Bangor, UK  
<sup>an</sup> University of Jos, Nigeria  
<sup>ao</sup> WWF International, Gland, Switzerland  
<sup>ap</sup> World Agroforestry (ICRAF), Bogor, West Java, Indonesia  
<sup>aq</sup> Graduate Degree Program in Ecology, Colorado State University, Fort Collins, CO, USA  
<sup>ar</sup> Colorado Natural Heritage Program, Fort Collins, CO, USA

## ARTICLE INFO

## ABSTRACT

## Keywords:

Co-production  
 Transformative processes  
 Social-ecological relations  
 Tensions  
 Power relations  
 Impact

Co-production, the collaborative weaving of research and practice by diverse societal actors, is argued to play an important role in sustainability transformations. Yet, there is still poor understanding of how to navigate the tensions that emerge in these processes. Through analyzing 32 initiatives worldwide that co-produced knowledge and action to foster sustainable social-ecological relations, we conceptualize ‘co-productive agility’ as an emergent feature vital for turning tensions into transformations. Co-productive agility refers to the *willingness and ability of diverse actors to iteratively engage in reflexive dialogues to grow shared ideas and actions that would not have been possible from the outset*. It relies on embedding knowledge production within processes of change to constantly recognize, reposition, and navigate tensions and opportunities. Co-productive agility opens up multiple pathways to transformation through: (1) *elevating marginalized agendas* in ways that maintain their integrity and broaden struggles for justice; (2) *questioning dominant agendas* by engaging with power in ways that challenge assumptions, (3) *navigating conflicting agendas* to actively transform interlinked paradigms, practices, and structures; (4) *exploring diverse agendas* to foster learning and mutual respect for a plurality of perspectives. We explore six process considerations that vary by these four pathways and provide a framework to enable agility in sustainability transformations. We argue that research and practice spend too much time closing down debate over different agendas for change – thereby avoiding, suppressing, or polarizing tensions, and call for more efforts to facilitate better interactions among different agendas.

## 1. Introduction

‘Co-production’ and ‘transformation’ have gained momentum in sustainability science and practice (Wyborn et al., 2019; Bennett et al., 2019; Leach et al., 2012). While co-production efforts seek to “iteratively unite ways of knowing and acting” (Wyborn et al., 2019, p. 320) to better address complex social-ecological problems (e.g. Knapp et al., 2019; Mauser et al., 2013), the increasing focus on transformation (e.g. Abson et al., 2017; Bennett et al., 2019; Scoones et al., 2020) pushes initiatives to consider what actions can spark “fundamental, system wide reorganization” (IPBES, 2019, p. 14). A growing body of literature connects the two, showing that collaborative knowledge- and action-making processes are fundamental to achieving just, creative, and durable transformations (Bennett et al., 2019; Klenk et al., 2017; Leach et al., 2012; Mitlin, 2008; Page et al., 2016; Pereira et al., 2019). Yet, co-production discourse and practice is also often critiqued for insufficiently attending to conflicts and power relations and overlooking ‘root’ problems (Turnhout et al., 2020; Jagannathan et al., 2020; Blythe et al., 2018). This paper bridges this gap between insufficient practice and transformative potential by offering an empirically derived conceptual and practical framework for *navigating tensions and power dynamics among diverse actors to create broad ownership and action for transformative social-ecological change*.

Existing co-production frameworks often focus on how particular practices can help achieve *intended aims*, such as influencing decisions towards particular social-ecological outcomes (e.g. Mauser et al., 2013; Beier et al., 2017; Djenontin and Meadow, 2018). However, this may overlook important differences among aims and approaches, such as the

idea that aims should emerge from the process rather than be pre-determined (Abson et al., 2017; Moore et al., 2014; Klenk et al., 2017). In contrast, sustainability transformations literature dissects the stages of transformation processes, from preparatory activities, such as collective problem exploration, to post-intervention activities, like resilience building (Lang et al., 2012; Olsson et al., 2004). Scholars increasingly distinguish between types and subprocesses of sustainability transformations (Leach et al., 2012; Moore et al., 2014; Scoones et al., 2020; Westley et al., 2013), and the role of different types of co-production processes (Chambers et al., 2021; Pereira et al., 2019; Schneider et al., 2019). However, there is limited empirically derived practical guidance on how to navigate conflicts and power struggles in co-production processes that pursue societal transformation. Literature explores ways to foster learning and reflexivity in co-production (Norström et al., 2020; Caniglia et al., 2020; Roux et al., 2017; Pohl et al., 2010). Yet, normative principles and practical guidance are often framed in generic terms, with little tailoring of advice to *different types of co-production processes*.

Much attention has been given to ‘scaling up’ or ‘out’ by identifying and replicating transformative frames and approaches at different scales or in new locations (Moore et al., 2014; Termeer and Dewulf, 2019; Westley et al., 2011). Yet, any bottom-up transformation process is likely to encounter active resistance by those with power (Avelino and Rotmans, 2009). There is limited understanding of how to work within and across scales to break down resistance, such as by ‘scaling deep’ (i.e. “changing values and mindsets”; Lam et al., 2020, p. 2). Scholars have cautioned that co-production and transformation discourse and practice can reinforce existing power relations by shifting the burden onto

vulnerable parties or exacerbating conflicts (Blythe et al., 2018; Avelino, 2017; Goldman, 2007). This has led to calls for improved guidance on understanding and addressing conflicts (Turnhout et al., 2020; Bennett et al., 2019; Klenk and Meehan, 2015). Finally, there are growing concerns over the privileged role that scientific researchers often hold in co-production processes (Chambers et al., 2021; Knapp et al., 2019; Klenk, 2018; Polk, 2015; Moore et al., 2014). This has sparked efforts to establish more equitable co-production partnerships (Vincent et al., 2020; Ott and Kiteme, 2016), and develop processes that balance power among actors and constructively navigate divergent views (Drimie et al., 2018; Pereira et al., 2019; Fuller Transformation Collaborative, 2019).

This paper examines how existing co-production initiatives navigated tensions among different perspectives in ways that either hinder or enable transformations. We analyzed 32 case studies that employ a range of approaches to co-produce knowledge, action, and diverse social-ecological outcomes at local, regional, and international scales. In a companion piece (Chambers et al., 2021), we demonstrate that the potential of co-production to transform paradigms, practices, and institutions depends on iteratively balancing critically reflexive and solutions-oriented spaces to facilitate the willingness and ability of diverse “actors to navigate different agendas for change to grow ideas and actions which were unforeseen from the outset” (p. 10). In this paper, we define this collective, emergent feature as ‘co-productive agility’ and draw upon case studies to explore the *actual processes and roles* entailed to constructively navigate tensions and broaden collective pathways to more just and sustainable futures.

Our paper is structured as follows. First, we articulate the concept of ‘co-productive agility’ in section 2, drawing upon literature from various fields. Section 3 then briefly introduces our 32 cases and explains our methodological approach. In Section 4, we present critical tensions that empirically emerged in our cases. Section 5 demonstrates how approaches to these tensions in some cases hindered transformation (i.e. ‘co-productive rigidity’). Section 6 details diverse empirical examples to illustrate how particular approaches navigated emerging tensions in ways that broadened ownership and action for sustainability transformations (i.e. ‘co-productive agility’). By outlining four pathways in which co-productive agility can turn tensions into transformations, our analysis shows that co-productive agility can ‘open up’ and facilitate multiple pathways to sustainability (after Stirling, 2008). Fostering co-productive agility requires facilitative leadership that embeds research in practice to explicitly navigate tensions and grow transformative action. We present an empirically derived framework that provides guidance for navigating different phases of co-production processes for transformation, from setting project boundaries to iteratively tracking changes. We conclude by briefly exploring how the four identified pathways may connect in synergistic ways, and reflecting on how and why research and practice might hinder rather than enable co-productive agility. Both of these topics are highlighted as critical avenues for future research.

## 2. Operationalizing ‘agility’ in co-production processes for transformation

This paper foregrounds the potential of ‘agility’ to strengthen the growing link between the co-production of knowledge, action, and change by diverse actors, and just and durable sustainability transformations. The constructive exploration of tensions and conflict is increasingly recognized as a catalyst for social learning and transformation (Bulter et al., 2021; Skrimizea et al., 2020; Cockburn et al., 2018; Maclean et al., 2015). Other studies show how overlooked tensions among contradictory ‘logics’ or ‘rationalities’ can challenge the viability of collaborative governance (Bäckstrand et al., 2010; van der Hel, 2016; Montana, 2020; Dekker et al., 2020). Organizational change literature explores the productive role that tensions can play to spur transformation, through concepts like ‘collective agility’ (Zheng et al., 2011), ‘integrative ambidexterity’ (Andriopoulos and Lewis, 2008), and

‘organizational improvisation’ (Hadida et al., 2015). These concepts move beyond ‘defensive’ approaches to managing tensions (i.e. valuing one side and devaluing the other), to a willingness to understand such elements as “complex interdependencies rather than competing interests” (Jarzabkowski et al., 2013, p. 249).

An emphasis on ‘agility’ can therefore support actors to engage with seemingly contradictory agendas. Here, we focus on ‘agendas’ to acknowledge the ways that knowledge, values, and goals are intertwined in claim-making regarding what kind of change is needed and how it can be achieved. ‘Agility’ among agendas in co-production spaces is cognitive, relational, and organizational. It is *cognitive* in terms of the competency to understand different viewpoints and opportunities, and craft skillful tactics and solution pathways that draw support from team members (Body and Kendall, 2020; Haider et al., 2018; Reed et al., 2020). It is *relational* in the sensitivity and responsiveness it demands of participants to adjust goals and practices to new knowledge and changing social relations among team members (Vardy, 2020; Gren and Lenberg, 2020). Finally, it is *organizational* in requiring forms of leadership, project management, and resource allocation that are flexible, robust, and collaborative (Walter, 2020; Howlett et al., 2018).

Co-productive agility is an inherently political concept. It enables the constructive exploration of tensions to support transformation in roles, paradigms, practices, relationships, and structures. In framing tensions as a productive force for transformation, we build on the concept of “agonistic public spaces” (Mouffe, 2013), where the primary purpose of politics is not to seek consensus and resolve tensions, but rather to learn to “stay with the trouble” of difference and the discomfort it brings (Haraway, 2016). From this struggle emerges new possibilities for collective action across diverse social groups. In contrast to previous terms that emphasize resources and capacities that *underpin* possible interactions (e.g. “coproductive capacities” – van Kerkhoff and Lebel, 2015), we directly examine these interactions. Agility means moderating responsiveness to different pulls and pushes within and outside co-production processes in ways that do not compromise the individual positionality of the diverse actors involved, nor the creation of collective concerns. Working with(in) tensions between the individual and the collective requires facilitative leadership that can take people on collective journeys that reveal what matters to whom, as opposed to activities that presuppose fixed stakes (Klenk and Meehan, 2017; Steyaert and Jiggins, 2007).

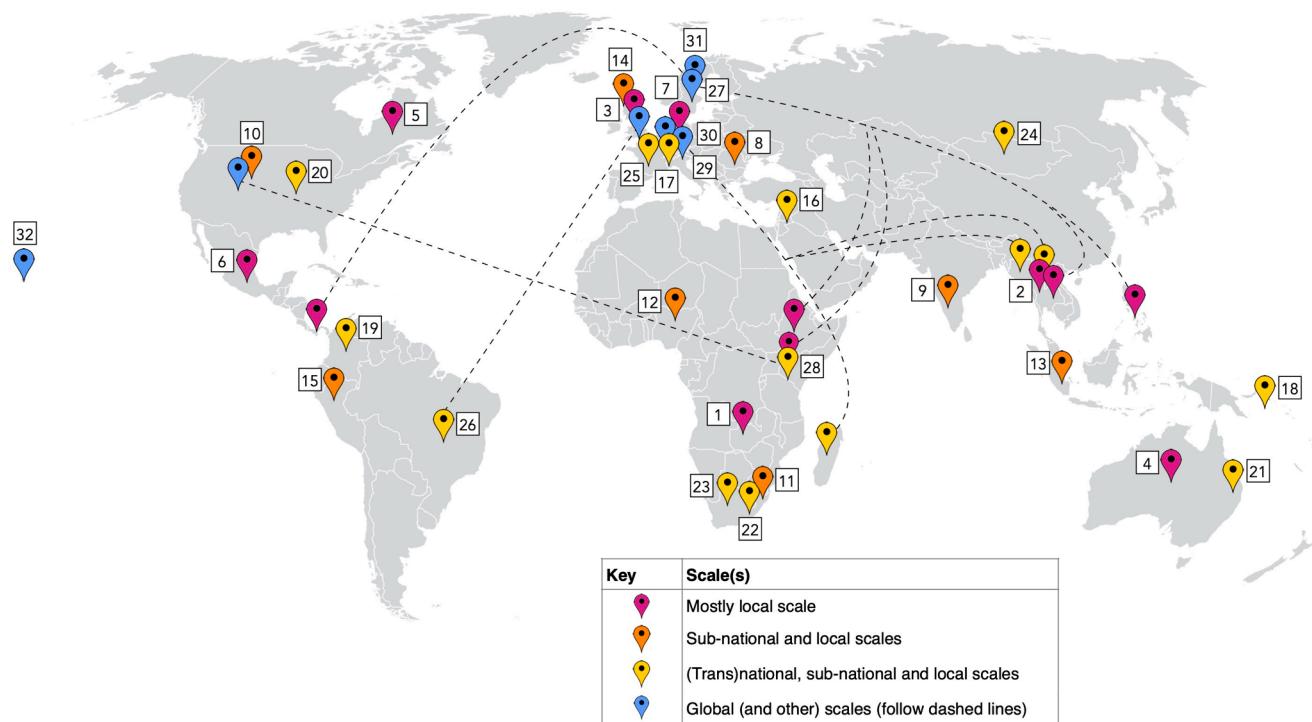
## 3. Methods

### 3.1. Overview of co-production initiatives

Our analysis examines 32 initiatives that sought to co-produce knowledge and action to address diverse sustainability issues at local to global scales related to, for example, ecosystem degradation, climate change, wildfires, supply chains, and cities (Fig. 1). These initiatives (Table 1) employed diverse approaches; for example, participatory ecosystem modelling (e.g. Mitchell et al., 2015; Rondeau et al., 2017), research-informed co-management processes (e.g. Dumrongjowatthana and Trébuil, 2011; Haller and Merten, 2018), (trans)national learning networks (e.g. Steyaert and Jiggins, 2007; Goldstein et al., 2018) and global dialogue platforms (e.g. Österblom et al., 2017; Christie et al., 2017). Some cases involved actors with relatively aligned values and goals (e.g. Charli-Joseph et al., 2018; Fischer et al., 2019), while others navigated polarized disputes (e.g. Brandt et al., 2018; Brennan, 2018). We note that not all cases adopted the precise language of ‘sustainability transformations’; however, all cases sought to transform nature-society relations to varying degrees and using different approaches.

### 3.2. Data collection and analysis

The 32 cases were selected to maximize diversity in types of co-production practice, scalar engagement, and geographical locations,



**Fig. 1.** Case study locations. The map (and legend) shows the locations (and scales) where the co-production initiatives took place. Case details are available in Table 1, with the same case IDs. See section 3 for details on the case selection process.

following an information-oriented, maximum variation approach to sampling (Flyvbjerg, 2006). First, eight diverse cases were selected through two exploratory workshops in the US and Mexico. They were then supplemented by a Google Scholar search which paired 10 ecosystem-focused variants of the term 'sustainability' such as 'social-ecological' and 'nature conservation' with 22 variants of 'co-production' such as 'co-design', 'social learning', and 'transdisciplinary' to identify cases that further diversified the sample (Appendix A). As a result, our cases provide a rich and diverse set of co-production experiences, with the majority of cases spanning at least three sectors and four academic disciplines. To develop a robust interpretation and comparative analysis of all cases, a representative of each case was invited to contribute to the analysis and co-author this paper. In 29 cases, the case contributor held a leadership position in the case as a practitioner and/or researcher (often both), while in 3 cases they had extensively researched it.

We conducted iterative qualitative analyses to identify and examine the rationales expressed in each case for why co-productive efforts were designed and implemented in particular ways. A common enquiry framework drawn from the exploratory workshops and key literature debates was initially used to gather case data on varying co-production features, rationales, and challenges (Appendix B). To complete this framework for each case, the case contributor provided a mixture of scholarly (e.g. publications, PhD theses) and gray literature (e.g. strategic documents, donor reports, websites) that encompassed different perspectives on the case. The lead author (J.M.C.) analyzed these materials and then interviewed each contributor for approximately one hour (audio recorded and transcribed) to clarify and deepen the case understanding documented in the common enquiry framework. A mean of 6 documents were analyzed per case (186 total); this ranged from a PhD thesis in two cases (containing analysis of further case materials), to 10–13 documents in five cases. While the lead author conducted all initial analyses (for independence), case contributors iteratively interrogated emerging concepts and validated interpretations, both through pairwise discussions and two participatory workshops in the US and UK. Each case contributor coordinated with the societal actors involved in their case to gather additional information, as needed. As a result,

through the mixture of document analysis, interviews, and collaborative analysis, we accessed detailed tacit knowledge of both researchers and practitioners involved in these cases.

After initial inductive coding, a circumplex of 14 rationales behind co-production processes were identified (Appendix C) and interrogated by half of the author team in a two-day workshop. As a result, the list was refined to four overarching categories of rationales (shown in Table 2: impact, process, control, inclusion). The lead author then conducted a systematic analysis of how all 32 cases varied for each identified category by coding all case materials and interviews that related to each of the four rationale categories, and related tensions. Each case contributor reviewed and commented on these findings. Further analysis of the relative expression of different rationales within and across cases revealed that some cases expressed strong tensions between certain rationales, while others fostered complementarities. We characterized this latter dynamic as 'agility' and documented aspects of cases that qualitatively showed how (in)agility shaped the (in)ability to navigate challenges and attain certain types of outcomes. Our analysis revealed that particular rationales were linked to distinct pathways to transformation. For each of the four pathways, we selected 5–6 cases that had addressed emerging tensions in agile ways, and analyzed the strategies they used to address challenges and enable transformation towards sustainability. This analysis led to the identification of six crucial processes across all four pathways. Cases were then analyzed according to each process to identify shared wisdom and salient examples in publications and interviews. In order to concisely portray results of numerous cases, illustrative interview quotes are confined to Tables, while mainly case publications are cited in the empirical sections to direct readers to further details.

#### 4. Critical tensions in co-production processes

The analysis of competing rationales revealed two major tensions (Table 2). The first tension – “*why/how does the initiative contribute to transformation?*” – embodied struggles between using co-production to advance desired solutions and *impacts* (justified by rationales such as

**Table 1**

Overview of the 32 case studies. Case ID numbers and colors are associated with the map and scales listed in Fig. 1.

ID	Case title	Dates	Main aim	Case contributor(s)* & links
1	Crafting local ownership of institution-building processes (i.e. Constitutionality): The case of the Kafue Flats fisheries in Zambia	2005–2010	To craft local by-laws for the fisheries in the Kafue Flats Floodplain in Zambia to manage conflicts which have arisen from the overuse of fisheries due to the erosion of governance institutions	<b>Tobias Haller</b> <sup>1*</sup> Haller and Merten (2017; 2008); Haller et al. (2016)
2	Gaming and simulation for co-learning and collective action in Northern Thailand	2007–2010	To use a Companion Modeling approach to mitigate a conflict over the access to ambiguous forest-farmland between local herders and forest conservation agencies	<b>Pongchai Dumrongjroatthana</b> <sup>1*</sup> Dumrongjroatthana et al. (2017); Dumrongjroatthana et al. (2011); Dumrongjroatthana & Trébuil (2011)
3	Recasting Urban Governance through Leeds City Lab	2015–2017	To explore radically different institutional personae that can respond to deficits in contemporary urban governance	<b>Paul Chatterton</b> <sup>1*</sup> Chatterton et al. (2018); Campbell et al. (2016)
4	Managing Indigenous lands under a changing climate	2013–2019	To produce a book for Indigenous communities and others to learn and talk more about climate change and what will help their communities deal with these changes in the weather	<b>Rosemary Hill</b> <sup>1*</sup> Hill et al. (2020); Hill et al. (2015); Mooney et al. (2014)
5	Montérégie Connection: linking landscapes, biodiversity, and ecosystem services to improve decision making	2011–2014	To develop an ecosystem services, biodiversity and connectivity modeling framework to support communities to manage land	<b>Elena Bennett</b> <sup>1*</sup> Mitchell, Bennett, et al. (2015); Ziter, Bennett, et al. (2013); Mitchell, Bennett, et al. (2014); Mitchell, Bennett, et al. (2015); Lamy et al. (2016); Renard et al. (2015) <b>Lakshmi Charli-Joseph</b> <sup>1*</sup> Charli-Joseph et al. (2018); Eakin et al. (2019); Ruizpalacios, Charli-Joseph et al. (2019) <b>Maraja Riechers</b> <sup>1*</sup> Riechers et al. (2019)
6	Promoting Agency For Social-Ecological Transformation: A Transformation-Lab In The Xochimilco Social-Ecological System	2016–2019	To promote collective agency through the use of “Transformation Labs” (T-Labs) in Xochimilco, Mexico City	<b>Andra Ioana Horcea-Milcu</b> <sup>1*</sup> Fisher, Horcea-Milcu et al. (2019); Lam, Horcea-Milcu et al. (2019)
7	Stories of favourite places in public spaces: Emotional responses to landscape change	2017–2018	To explore issues of landscape change and people's emotional responses towards it through engaging with social landart (land art)	<b>Anca Serban</b> <sup>1*</sup> Serban (2018)
8	Amplifying sustainability initiatives in Southern Transylvania	2016–2019	To support and enable sustainability-transformation processes in the region by identifying and analyzing leverage points and amplifying beyond the local scale	<b>Renee Rondeau</b> <sup>12*</sup> <b>Carina Wyborn</b> <sup>1*</sup> Rondeau et al. (2017)
9	Assessing the socioeconomic and environmental implications of land sharing and land sparing strategies	2013–2018	To explore the real-world implications of land sparing and land sharing strategies in local communities	<b>Jessica Cockburn</b> <sup>1*</sup> <b>Preshnee Singh</b> <sup>1*</sup> Cockburn et al. (2016); Taylor, Cockburn et al. (2016)
10	Building Social-Ecological Climate Resilience in Southwestern Colorado	2013–2017	To facilitate climate change adaptation that contributes to social-ecological resilience, ecosystem and species conservation, and sustainable human communities	<b>Salamatu Fada</b> <sup>12*</sup> Management report available upon request
11	Durban Research Action Partnership for local land-use planning and management	2011 - ongoing	To build science-action partnerships to improve local land-use planning and management	<b>Beria Leimona</b> <sup>12*</sup> Leimona et al. (2015)
12	Establishing inclusive participatory protected areas management: GyaraYankari	2016–2018	To update the highly outdated and expired protected area management plan through a process that is participatory and inclusive, particularly of surrounding communities	<b>Ruth Brennan</b> <sup>1*</sup> Brennan (2018a; 2018b)
13	Knowledge co-production for negotiating payment for watershed services (PWS) in Indonesia	2012–2015	To investigate how knowledge sharing towards collaborative products helps to clarify the performance-based indicators for effective PWS negotiation	<b>Josephine Chambers</b> <sup>1*</sup> Chambers et al. (2019); Chambers (2018)
14	Probing the cultural depths of a nature conservation conflict in the Outer Hebrides, Scotland	2009–2015	To create a space for articulation and recognition of different value systems shaping conservation and natural resource management decisions by making visible the socio-cultural relations attached to landscape and seascapes	<b>Amos Brandeis</b> <sup>2*</sup> Brandeis (2005)
15	Transforming 'win-win' conservation and development theory and practice in northeast Peru	2014–2019	To explore dominant approaches to joint conservation and development, examine their implications, and shape discourse and practice	<b>Jean-David Gerber</b> <sup>1</sup> Gerber (2018)
16	Alexander River Restoration Project	1995 - ongoing	To restore a heavily polluted cross border river and foster cooperation and peace between Israeli and Palestinian neighbors amidst the conflict	<b>Chris Cvitanovic</b> <sup>1*</sup> Cvitanovic et al. (2016)
17	Between top-down and bottom-up institution building for landscape management: Chasseral Regional Nature Park	1997 - ongoing	To reconcile regional economic development and landscape conservation through a new institutional structure bringing together actors with various interests at different levels of government	<b>Claudia Múnera</b> <sup>1*</sup> <b>Carina Wyborn</b> <sup>1*</sup> Múnera & van Kerkhoff (2019); van Kerkhoff, Múnera et al. (2019)
18	Building adaptive capacity to climate change in the South Pacific	2013–2014	To develop new climate models and projections to support fishers/farmers in the South Pacific region and improve the uptake of these models by Pacific communities and NGOs	<b>Bruce Goldstein</b> <sup>1</sup> The Nature Conservancy (2016)
19	Future-Proofing Conservation: Enabling adaptive governance in protected areas	2015–2018	To strengthen protected area adaptive governance through tools for strategic thinking and collective learning to anticipate and respond to long-term social and ecological change amidst uncertain information	<i>(continued on next page)</i>
20	The Fire Adapted Community Learning Network (FAC-NET)	2013 - ongoing	To enhance fire-adaptation capacity at multiple scales through a learning network	
21		2005–2012		

**Table 1 (continued)**

ID	Case title	Dates	Main aim	Case contributor(s)* & links
1	eWater Cooperative Research Centre in Australia (Source Catchments)		To develop Australia's first national eco-hydrological modelling and decision support platform to help inform decision-making at a range of scales for improved water, environment and societal outcomes	Melanie Ryan <sup>2*</sup> Waltham et al. (2014); Welsh et al. (2013)
22	Farm dwellers, the forgotten people? Consequences of conversions to private wildlife production	2007–2014	To address the socio-ecological impacts of the conversion to game farming amidst post-Apartheid conflicts and power imbalances	Marja Spierenburg <sup>1*</sup> Spierenburg (2019); Brandt et al. (2018)
23	Knowledge co-production and boundary work to promote implementation of conservation plans	2008–2011	To apply co-production concepts to regional conservation planning stages within a national planning project aimed at identifying areas for conserving rivers and wetlands and developing an institutional environment to promote their conservation	Jeanne Nel <sup>1*</sup> Roux, Nel et al. (2017); Nel et al. (2015); Roux, Nel et al. (2015)
24	Mongolian Rangelands and Resilience (MOR2) Project	2008–2015	To integrate across knowledge boundaries to understand how climate, socio-economic and political changes and pastoral social-ecological systems in rural Mongolia mutually influence each other, and the implications of community-based resource management regimes	María Fernández-Giménez <sup>1*</sup> Fernández-Giménez et al. (2019); Jamsranjav et al. (2019); Ulambayar & Fernández-Giménez (2019); Jamsranjav, Fernández-Giménez et al. (2019); Khishigbayar, Fernández-Giménez et al. (2015)
25	Social learning for integrated water management (SLIM)	2001–2004	To understand the application of social learning as a conceptual framework, an operational principle, a policy instrument or governance mechanism, and a process of systemic change in the fields of natural resource management and water catchments	Patrick Steyaert <sup>1*</sup> Steyaert & Jiggins (2007); Ison et al. (2007); Collins et al. (2007); Ison, Steyaert et al. (2004)
26	Contacted: Managing Biodiversity Risks in Global Supply Chains	2014–2018	To develop a science-policy-practice framework to reduce environmental risks from production and trade of soy in Cerrado, Brazil	Paz Durán <sup>1*</sup> Jonathan Green <sup>1*</sup> Angela Guerrero <sup>1*</sup> Virah-Sawmy, Durán, Green, Guerrero (2018); Virah-Sawmy et al. (2019); Guerrero et al. (2021); Durán et al. (2020); Green et al. (2019)
27	Connecting diverse knowledge systems at multiple scales in IPBES assessments and related science-policy contexts	2011 - ongoing	To collaboratively develop tools and theory to equitably include local and indigenous knowledge into global biodiversity assessments for the benefit of ecosystems governance	Maria Tengö <sup>1*</sup> Tengö et al. (2017); Tengö et al. (2014); Malmer et al. (2020); Malmer & Tengö (2020)
28	Balancing wildlife conservation and pastoral development in East Africa	1999 - ongoing	To use science to support both local community-level and national-level action on wildlife conservation and pastoral development issues, driven by the needs of local pastoral communities	Robin Reid <sup>1*</sup> Kathleen Galvin <sup>1*</sup> Reid et al. (2016); Galvin, Reid et al. (2016); Galvin et al. (2018)
29	Managing telecoupled landscapes for the sustainable provision of ecosystem services and poverty alleviation	2015–2020	To devise and test innovative strategies and institutional arrangements for securing ecosystem service flows and human well-being in and between telecoupled landscapes	Julie Zaehringer <sup>1*</sup> Zaehringer et al. (2019)
30	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)	2012 - ongoing	To strengthen the science-policy interface for biodiversity and ecosystem services for the conservation and sustainable use of biodiversity, long-term human well-being and sustainable development	Jasper Montana <sup>1</sup> Pascual et al. (2017); Díaz et al. (2015); Montana (2017)
31	SeaBOS (Seafood Business for Ocean Stewardship) - resulting from the Keystone Dialogues	2012 - ongoing	To lead a global transformation towards sustainable seafood production and a healthy ocean where businesses are stewards of the world's ocean and aquaculture environments	Henrik Österblom <sup>1*</sup> Österblom et al. (2017); Österblom et al. (2020)
32	Think tank on the human dimensions of Large Scale Marine Protected Areas (LSMPAs)	2014–2017	To be proactive in understanding the issues and developing best management practices and a research agenda that address the human dimensions of Large Scale Marine Protected Areas (LSMPAs)	Nathan Bennett <sup>1*</sup> Christie, Bennett et al. (2017); Bennett et al. (2017); Gray, Bennett et al. (2017)

Case contributor attributes: 1 Researcher 2 Practitioner \*Senior leadership role in the case

showing relevance, impact, and efficiency) versus facilitating a co-production process to redefine how “problems” are understood (justified by rationales such as fostering engagement, learning, and trust). The related tension – “*how is decision-making power distributed among actors?*” – entailed struggles over who holds power to influence co-production decisions, such as whether particular solutions are questioned or pursued, and how actors are involved. In particular, there existed a tension between processes that prioritized control (justified by rationales such as controlling outcomes and achieving consensus) versus processes that prioritized inclusion (based on rationales such as engendering humility and plurality).

These tensions were sometimes treated as incompatible binaries by favoring one side and either suppressing or opposing the potential value of the other. For example, some cases expressed that opening up decisions to debate could hinder efficiency and results, while other cases

expressed that defining solutions early on could undermine process quality and learning opportunities (Table 2). In contrast, other cases transcended these dual tensions by articulating rationales for their interdependency, such as by showing how prioritizing process could further transformative impacts. Table 3 spotlights how agile approaches to managing these tensions (i.e. neither suppressing nor romanticizing the agendas of different actors involved) enabled transformation of sustainability paradigms and practices; for example, in fostering co-management possibilities amidst a marine protected area dispute in Scotland (Table 1; Case 14), cutting across silos to conserve rivers and wetlands in South Africa (Case 23), connecting Indigenous and scientific knowledge systems in global biodiversity assessments (Case 27), and restoring a degraded river along the Israel-Palestine border (Case 16).

**Table 2**

The dual tensions of collaborative transformation. The quotes illustrate the rationales that underpinned relatively more binary (grid lines) versus agile (wavy lines) approaches to each tension. The quote numbers correspond to the case IDs in Table 1.

**Tension 1: Why/how does the initiative contribute to transformation? Impact vs. Process**

Description	Impact hinders process	Process leads to impacts	Impacts helped by process	Process hinders impact
Rationales	Choices were justified by a desire to prioritize the process, such as by fostering engagement, learning, and/or trust, with impact motives viewed as potentially harmful	Choices were mostly justified by a desire to prioritize the process, such as by fostering engagement, learning and/or trust, to support co-developing action and impact over time	Choices were mostly justified by a desire to demonstrate relevance and/or impact, with process aspects seen as critical to enhancing those impact goals	Choices were justified by a desire to demonstrate relevance, impact and/or efficiency, with spending time on process aspects seen as detracting from impact goals
Example	Releases pressures/expectations; Reduces risk of reinforcing biases; Supports more open reflection; Offers exciting/unknown journeys; Surfaces more transformative ideas	Builds trust and understanding; Opens space to share values; Connects across conflicts; Reframes towards collective aims; Supports emergence of actions	Fosters actors' engagement; Enhances salience and relevance; Shifts participants' perspectives; Improves effective implementation; Increases visibility of impacts	Maximizes value for money; Completes work more efficiently; Targets most relevant actors; Ensures outputs are completed; Justifies donor contributions
	<i>"Early on participants agreed that success would be defined through process issues rather than tangible outcomes... this reduced different pressures and expectations." (3)</i>	<i>"It was about initiating and managing arenas better adapted to problem formulation to search for the emergence of change rather than prescribing it." (25)</i>	<i>"Interventions that reconcile stakeholders' goals are less vulnerable to failure and carry less risks of being rejected or deterred post implementation." (9)</i>	<i>"The fieldwork we more or less did ourselves. In part this is for efficiency, but also because this is not what is interesting to our stakeholders." (5)</i>

**Tension 2: How is decision-making power distributed among actors? Control vs. Inclusion**

Description	Control risks agenda	Inclusion is facilitated	Control is strategic	Inclusion risks agenda
Rationales	Choices were justified by a desire to empower participants' positions via humility, inclusivity and/or plurality, with initiators' expertise/power seen as hindering that empowerment	Choices were mostly justified by a desire to empower participants' positions via humility, inclusivity and/or plurality, with initiators' expertise/power seen as supporting that empowerment	Choices were mostly justified by a desire to empower initiators' positions, but alongside strategically ceding power to other actors to enhance their engagement	Choices were justified by a desire to empower initiators' own positions via control and/or consensus, with ceding power to other actors seen as risking their own power/position
Example	Participants define problems; Amplifies existing efforts; Transforms extractive models; Reduces scientists' "expert" role; Addresses local concerns	Enables sharing and trust building; Supports genuine empowerment; Establishes ethical representation; Balances power among actors; Facilitates new norms/institutions	Facilitates focused agenda; Fosters broader engagement; Guards space safe for dialogue; Ensures not co-opted by powerful; Increases relevance and impacts	Ensures focused agenda; Guarantees good quality science; Produces useful outputs; Amplifies scientific knowledge; Requires technical expertise
	<i>"The framing of transformation as a matter of amplifying and complementing existing efforts keeps the agenda of change in the hands of local people." (8)</i>	<i>"This approach traces the conditions in which people with different levels of bargaining power collectively enable themselves to regain control over resources they used to manage." (1)</i>	<i>"To include them in a meaningful way, researchers need to build up quite some insights in the issues at stake and the power relations before co-creation can start." (22)</i>	<i>"All of the negotiation decision tools were built by him... and we are the ones who are implementing the concept through the project and through actions on the ground." (13)</i>

## 5. Co-productive rigidity: suppressing or exacerbating tensions

Our analysis revealed four main ways in which suppressing or exacerbating these dual tensions could hinder sustainability transformations. We present this in terms of four archetypal roles in co-production processes (Fig. 2; boxes in the rigid space: hero; host; woodpecker; genie), building on previous distinctions such as the "Art of Hosting" approach that encourages people to shift from 'heroic' forms of leadership to facilitative forms of leadership they call 'hosts' (Frieze and Wheatley, 2011), and distinct roles of scientists in society (Pielke, 2007; Turnhout et al., 2013; Bulten et al., 2021).

The "hero" archetype represents how in some co-production efforts, relatively few people maintained substantial control over processes to pursue *their* desired sustainability outcomes (e.g. ambitious conservation plans, innovative scientific papers), based on *their* perception of the problem. In contrast, the "woodpecker" archetype indicates how other co-production efforts sought to critique and reframe widespread solution agendas, for example, by co-producing knowledge that revealed unsustainable or unjust impacts of dominant practices. This distinction is reminiscent of the "pure scientist" vs. "issue advocate" framing in Pielke (2007); yet, our broadened archetypes acknowledge how scientists and societal actors may equally control co-production processes to either reinforce or challenge existing power relations. In both hero and woodpecker roles, fears were expressed that opening up initial agendas to debate and yielding power to participants might dilute the transformative nature of their efforts, or worse, give power to actors (local or

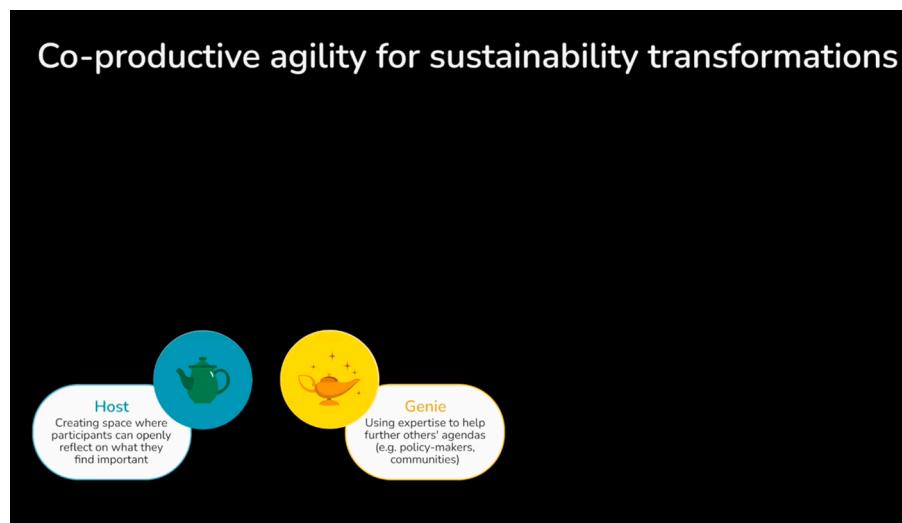
international) who could co-opt the process. Although legitimate fears, projects dominated by one set of values or expertise often struggled to engage actors with alternative views who did not conform to the project's dominant frame. In some cases, this exacerbated tensions if actors chose to actively oppose the efforts. The resistance of these two archetypes to genuinely open up debate over transformative agendas (on paper) therefore risked hindering transformative potential (in practice).

In contrast, two other archetypes demonstrate the flip side – how loosening control over co-production decisions can hinder transformation by suppressing tensions. For example, the "genie" archetype represents how some initiators of projects explicitly chose to release control, such as by looking to policy-makers or communities to set research agendas (reminiscent of Pielke's "science arbitrator" role). While this approach helped *further existing* motivations and goals, the suppression of tensions could also idealize the power of existing local or global solutions and thereby hinder their transformation. Finally, the "host" archetype entailed opening up spaces for reflection and learning, often among relatively like-minded actors. While these processes generated learning and shifts in perspectives, the released control in some cases made it difficult to identify tensions in the room. They also struggled to connect this to tangible changes in practice due to less focus on action and little engagement (and thus suppressed exploration of tensions) with external actors positioned against desired changes. The "host" role (also outlined in Frieze and Wheatley, 2011), somewhat relates to Pielke's (2007) "honest broker" role, but further emphasizes bridging and facilitating repertoires that blur the boundaries between

scientific and societal knowledge production and use roles (see Turnhout et al., 2013; Bulten et al., 2021).

Co-production initiatives were therefore constantly challenged to find a middle space between these archetypal roles – by creating space for all views (host), yet also bringing a critical angle (woodpecker); by not unjustly imposing agendas (hero), but also not romanticizing others’

agendas (genie). We found that fostering such agility among these roles depended on creating processes that weave together and balance power among both critical and solution-oriented perspectives. In some cases, actors explicitly sought to develop this agility, yet broader contextual issues presented barriers to such an approach (Video S1).



**Video S1.** This musical abstract expresses each archetype as a distinct musical instrument and tells the story of how the four archetypal roles might journey from co-productive rigidity to co-productive agility.

**Table 3**

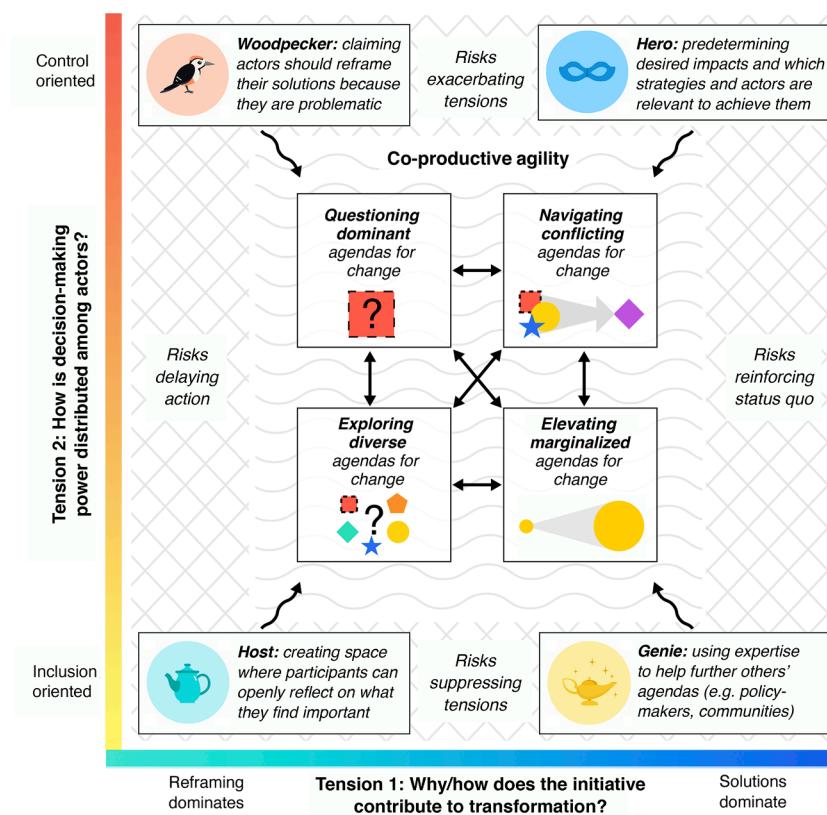
Illustrative examples of how cases establish interdependencies among tensions. For each tension, we highlight two cases that illustrate how agility can be achieved by prioritizing each side of the tension. However, several cases did not neatly fit into these categories and established interdependencies through a combination of approaches over time.

#### Tension 1: Why/how does the initiative contribute to transformation? Impact vs. Process

Process leads to impacts	Impacts helped by process
<p>The initiative “Probing the cultural depths of a nature conservation conflict in the Outer Hebrides, Scotland”, contributed by Ruth Brennan, is an art science collaboration which helped inspire a different approach to a marine protected area dispute between a local community and the Scottish government (Brennan 2018). As Ruth explained: “My aim was NEVER to ‘resolve’ a conflict. The reason I chose to explore different understandings of conservation was because my initial fieldwork revealed that the islanders I interviewed perceived the government as understanding conservation as ‘hands-off, keep out, draw a line around’ whereas the islanders understood conservation as ‘hands-on, use and develop wisely’. This led me to framing the problem as clashes between different values systems and worldviews.” Art science collaborations therefore created “a space for islanders to articulate and value aspects of their bio-physical/cultural heritage to open up possibilities for new narratives to emerge within community-government marine protected area conflict”, which sparked a co-management process, which is evolving and faces ongoing challenges.</p>	<p>The initiative “Knowledge co-production and boundary work to promote implementation of conservation plans”, contributed by Jeanne Nel, had a strong impact mandate from the start - to map out proposed sites for freshwater protection across South Africa, and to build relationships between the separated water and environmental sectors to collectively manage and conserve these (Nel et al. 2016). Up until this point, freshwater ecosystem protection was largely invisible to both sectors. The project carefully designed a process engage end users and departments in the provincial and national spheres of government. Given the broad buy in, the initiative was able to flexibly adapt the process as needed. For example, when they realized some national-scale knowledge was sometimes misused at the local level, they ran a follow up training program for local users. The widespread involvement of institutions ensured legitimate and well disseminated products, and the engagement with local residents has since supported their appeals to oppose mining licenses by providing information on water ecosystem impacts.</p>

#### Tension 2: How is decision-making power distributed among actors? Control vs. Inclusion

Inclusion is facilitated	Control is strategic
<p>The initiative “Connecting diverse knowledge systems at multiple scales in IPBES assessments and related science-policy contexts”, contributed by Maria Tengö, sought to move “from studies ‘into’ or ‘about’ indigenous and local knowledge systems, to engagement with and among these knowledge systems to support mutual investigations into our shared environmental challenges” (Tengö et al. 2017). In particular, the work sought to connect critical local knowledge systems with global science-policy processes on biodiversity. The iterative dialogue process was collaboratively designed to support diverse local and global knowledge systems to interact whilst maintaining their integrity and placing them on more equal ground. A key activity was walking workshops in indigenous communities, where “the local hosts were experts on their own landscape, and the strength of their knowledge systems is undeniable - which leverages the power asymmetries between them and scientists”. As a result, they achieved shifts in mind-sets especially among natural scientists in how they view indigenous and local knowledge and knowledge holders.</p>	<p>The initiative “Alexander River Restoration Project”, contributed by Amos Brandeis, brought Israeli and Palestine restorationists, engineers and officials together to engage the public to restore the heavily polluted cross- border Alexander River (Brandeis 2005). Amos explained how the brokering role by German colleagues was critical to put both sides on equal ground: “Israelis supplied the tent; Palestinians supplied the chairs. Palestinians brought the food; Israelis brought the drinks. Each invited exactly 75 guests”. A very high level of control was necessary to manage the deep tensions and orient discussions towards collective purpose; for example, Amos described how “one of the most tense secret meetings held in a hospital during one of the worst times of the armed conflict began with a clear statement from both mayors: ‘We talk sewage, only sewage. Whoever will say anything related to political issues will have to leave the room immediately.’” In this case, the common language fostered by addressing a common environmental concern helped forge relations that could indirectly help heal deeper conflicts.</p>



**Fig. 2.** Four complementary pathways towards sustainability transformations. Co-productive agility supports initiatives to move beyond the limitations associated with more binary approaches to managing these tensions (four archetypal roles/processes in the corner boxes: Woodpecker; Hero; Host; Genie) and towards collaborating in more agile ways to enable transformative changes (four center boxes). Facilitative leadership of each of the four pathways entails a slightly stronger focus on two sides of the tensions, related to their purpose; e.g. questioning dominant agendas benefits from a design that especially prioritizes reframing and is more control oriented. These four pathways do not neatly follow the four categories outlined in Table 2, and rather use multiple approaches to balancing power and connecting process and impact.

Co-production initiatives were therefore constantly challenged to find a middle space between these archetypal roles – by creating space for all views (host), yet also bringing a critical angle (woodpecker); by not unjustly imposing agendas (hero), but also not romanticizing others' agendas (genie). We found that fostering such agility among these roles depended on creating processes that weave together and balance power among both critical and solution-oriented perspectives. In some cases, actors explicitly sought to develop this agility, yet broader contextual issues presented barriers to such an approach.

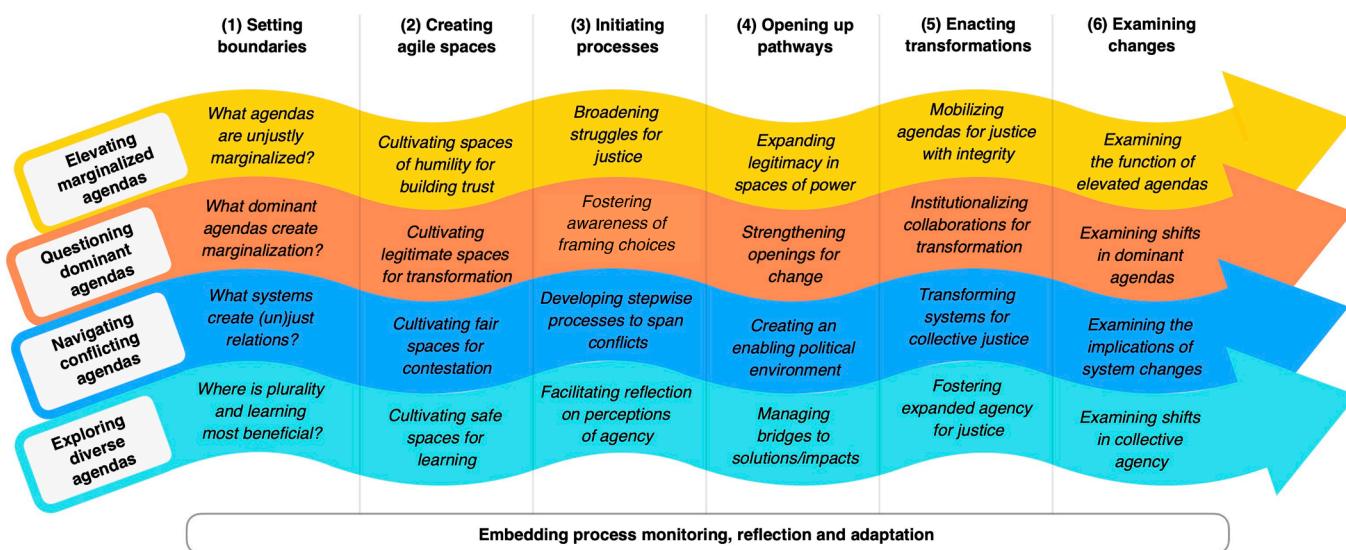
## 6. Co-productive agility: four collaborative pathways from tensions to transformations

An important question that follows is: *how to foster co-productive agility (instead of rigidity) in practice?* Essentially this asks how processes can bring actors with disparate agendas together and nurture a willingness to reshape their perspectives and foster more transformative actions over time. Our study identified four distinct pathways for co-productive agility: (1) *elevating marginalized agendas* supports marginalized actors to elevate their own perspectives and claims in ways that maintain their integrity while broadening struggles for justice; (2) *questioning dominant agendas* deeply engages actors who hold stakes in dominant systems by reflecting on their agendas and exploring more inclusive actions; (3) *navigating conflicting agendas* embraces the political aspect of bringing actors together to decide upon and undertake transformations to interlinked paradigms, relations, practices, policies, and institutions; (4) *exploring diverse agendas* connects actors through exploratory processes that do not aim to empower any particular agenda, but rather foster mutual understanding and respect for a plurality of perspectives. Each pathway slightly favors different sides of the dual tensions, related to their purpose (Fig. 2; boxes in the agile space). For example, efforts to elevate marginalized agendas and explore diverse agendas require a more inclusion-oriented approach to transformation than the other pathways.

We identified six overarching processes that foster co-productive agility, which vary by each pathway: 1) *setting boundaries* around what actors and approaches are relevant; 2) *creating agile spaces* for co-production to occur; 3) *initiating processes* of transformation; 4) *opening up pathways* by engaging upwards; 5) *enacting transformations* to mobilize sustained change; and 6) *examining changes* to iteratively understand their impacts (Fig. 3). These six processes pull together different aspects of other frameworks which have emerged to support transformation (Fuller Transformation Collaborative, 2019; Hermans et al., 2016; Moore et al., 2014; Scoones et al., 2020). Below, we share specific considerations, practices, and methods found to foster co-productive agility within each of the four pathways. The six processes do not outline a linear journey; indeed, many initiatives undertook these processes iteratively and simultaneously, supported by embedded process monitoring, reflection, and adaptation. However, they are explained in the order most likely to be pursued by a single project. In describing each pathway below, we dedicate a paragraph to explaining each of the six processes outlined in Fig. 3, noting relevant case IDs in Table 1.

### 6.1. Elevating marginalized agendas for change

**Elevating marginalized agendas** involves cultivating the potential contributions of perpetually suppressed agendas or novel/creative seeds of change. Broadly, initiatives sought to elevate either social-ecological agendas with local and Indigenous communities (e.g. Reid et al., 2016; Tengö et al., 2017; Hill et al., 2020), or environmental agendas marginalized by decision-makers (e.g. Nel et al., 2016; Cockburn et al., 2016; Fernández-Giménez et al., 2019). In the former, marginalized groups held the agency for change (cf. Latulippe and Klenk, 2020). The latter risked promoting agendas that further marginalize people who have historically suffered the burden of environmental (and other) agendas; for example, conservation agendas that prioritize biodiversity over local livelihoods (cf. Bennett and Dearden, 2014). It was therefore critical to question: who decides **what agendas are unjustly**



**Fig. 3.** Critical processes to foster co-productive agility in each of the four pathways to sustainability transformations.

“marginalized”? If particular agendas are elevated, how will they influence the status quo and affect other marginalized agendas? And how can actors (who may be marginalized) redefine such agendas? Here, we especially focus on the initiatives of marginalized groups who have historically had less power and resources. These case studies were part of long-term partnerships where the positions of different actors were identified and documented over time.

These cases **cultivated spaces of humility to build trust**, where all actors could contribute to and question knowledge – fostering relational accountability, with no one group framed as the “expert” (cf. [Latulippe, 2015](#)). For example, a collaboration between Indigenous peoples and climate researchers in central Australia (#4) sought to move beyond common narratives that frame communities as either the *solution to* or *victims of* climate change by co-creating a process that carefully navigated Indigenous and climate expertise ([Mooney et al., 2014](#); [Hill et al., 2020](#)). This required facilitators experienced in both Indigenous and scientific cultures to avoid disempowering discourses or actions, such as “building capacity”, which assumes the “other” “needs” external knowledge. It was therefore crucial that scientists were held directly accountable to how they might impose their knowledge and interests, through co-production processes that emphasized genuine partnerships rooted in mutual trust and humility.

Over time, some cases sought to **broaden struggles for justice**, recognizing that initial partnership goals focusing only on the “marginalized agenda” can hinder broader transformations. Yet, it is ultimately the choice of marginalized groups to decide whether and how to broaden their own struggles, given recognition of broader systems that perpetuate unjust marginalization. For example, the collaboration between Indigenous peoples and climate researchers in Australia experienced a shift in frame over time; they realized the need to go beyond Indigenous adaptation strategies, which were blocked by the state, and towards addressing higher level “articulation complexes” that produce vulnerability and constrain community generated pathways ([Hill et al., 2020](#)). This project critiqued the state’s role in perpetuating ongoing colonial struggle, all the while emphasizing the existing agency of traditional owners with sovereign rights, and that the upliftment of Indigenous peoples’ socio-economic disadvantage is a key shared goal of all Australians and worldwide (*ibid*).

Having initiated processes, **expanding legitimacy in spaces of power** helped efforts gain political traction. For example, the collaborative processes described in [Tengö et al. \(2017\)](#) and [Malmer et al. \(2019\)](#) (#27) enhanced the legitimacy of Indigenous knowledge holders as experts within global biodiversity assessment processes, and

strategically influenced procedures that constrained how Indigenous knowledge could be included. This entailed co-producing an approach for viewing Indigenous and local knowledge as equally valid and creating high-level fora that engaged diverse knowledge holders ([Tengö et al., 2017, 2014](#)). Boundary organizations (such as the IIFB – International Indigenous Forum on Biodiversity) played a vital role for connecting the legitimacy of Indigenous organizations with science-policy platforms. In East Africa, pastoral communities and scientists created a similar boundary organization (Reto-o-Reto Foundation) to connect pastoral communities to national policy processes (#28; [Reid et al., 2016](#)). Such boundary organizations strengthened links between research and societal impact, yet also posed unique challenges to the positionality of science, such as instances where policy-makers sought to ‘cherry pick’ scientific information to justify implementing policy to disempower pastoral communities. Fostering relations of trust and accountability while opening multiple communication pathways helped navigate these challenges.

Having built legitimacy at higher levels, cases set about **mobilizing agendas for justice with integrity**. In the case of weaving multiple knowledge systems ([Tengö et al., 2017](#); [Malmer et al., 2019](#)), this required asking: what happens to different kinds of knowledge when they come together? Their experience demonstrates the importance of considering how knowledge systems can be woven together in ways that maintain the integrity of marginalized knowledge to interact on equal ground – more akin to braiding multiple strands, rather than knowledge blending into an ocean ([Kimmerer, 2013](#); [Tengö et al., 2017](#)). Similarly, the case in East Africa, showed how boundary organizations can support continual engagement across knowledge systems over 20+ years, rooted in relations of trust ([Reid et al., 2016](#)). In mobilizing agendas, cases struggled to remain true to complexities while developing powerful consensus narratives to challenge dominant narratives. For example, diverse university, NGO, government, community actors co-produced research in rural Mongolia (#24) which showed that degradation estimates of pastoral social-ecological systems had been overstated, yet the NGO collaborators felt this framing undermined the urgency of their cause ([Fernández-Giménez et al., 2019](#)). This illustrates the importance of discussing data use and expectations upfront to diffuse future tensions around data accessibility and integrity (*ibid*).

Finally, **examining the function of elevated agendas** facilitated learning and improvement. Here, project leaders found that a focus on process and not just outputs was critical, such as examining the role of boundary objects to facilitate new types of collective meaning and actions (cf. [Diver, 2017](#)). Impacts took many forms, such as community

members and scientists from disadvantaged backgrounds supported to pursue careers in science and policy (Cockburn et al., 2016; Fernández-Giménez et al., 2019; Reid et al., 2016), new management actions (Cockburn et al., 2016; Hill et al., 2020; Reid et al., 2016), and community-government dialogue to challenge broader narratives and policies (Fernández-Giménez et al., 2019; Malmer et al., 2019; Reid et al., 2016). One initiative (#23) identified 37 different policy use contexts for their co-produced maps (Nel et al., 2016). Finally, several cases demonstrated the power of iterative and reflective methods, such as interviews, surveys, reflective essays and team retreats, to navigate issues that are often left ‘unsaid’ (Cockburn et al., 2016; Fernández-Giménez et al., 2019). This helped projects stitch together multiple types of outcomes that mattered to different actors involved (Fernández-Giménez et al., 2019; Reid et al., 2016; Tengö et al., 2017).

## 6.2. Questioning dominant agendas for change

By **questioning dominant agendas**, projects sought to deeply engage powerful actors who hold stakes in dominant systems to question and challenge their power, or how they use their power. Project boundaries were set by asking **what dominant agendas create marginalization** of sustainable and just futures? For example, some cases identified particular narratives and policies that reinforced elite power at the expense of local communities, such as protectionist or ‘win-win’ conservation paradigms, and sought to directly question that power (e.g. Brandt et al., 2018; Chambers et al., 2019). Other cases engaged powerful actors to support them to understand how dependent they are on functioning ecosystems and community trust, with an aim to direct their power to produce common goods (e.g. Christie et al., 2017; Österblom et al., 2017). For example, SeaBOS (#31) – a unique collaboration between leading seafood companies and scientists – emerged from initial work to identify “keystone actors” that disproportionately influence global marine ecosystems (Österblom et al., 2015). Cases noted the importance of examining power relations within systems prior to initiating collaboration to ensure that research questions and designs are not co-opted by powerful actors, thereby further marginalizing groups whose lives are often most affected.

These initiatives depended on **cultivating legitimate spaces for transformation** – where actors saw the primary purpose as learning and questioning existing approaches, rather than fulfilling pre-defined goals. An important starting point was to acknowledge the values of actors involved, but then to frame learning and transformation as an essential enabler of broader collective values (instead of individual positions). For example, a project “future-proofing” conservation in Colombia (#19) used the metaphor of an “evolutionary learning lifeboat” to foster values for shared learning in an open and undefined process (van Kerkhoff et al., 2019). In the case of SeaBOS, Keystone Dialogues cultivated a legitimate global dialogue space for companies to examine the concept of ocean stewardship, which necessitated initiating discussions between only CEOs and scientists to enable open exploration (Österblom et al., 2017). These processes were best facilitated by well-respected individuals who were seen as relatively “neutral” brokers (Brandeis, 2005; Christie et al., 2017; Österblom et al., 2017). Cases with polarized conflict required a strong reason for collaboration, such as a mutual desire to restore a degraded river (Brandeis, 2005). Failing to develop a shared legitimate purpose of learning could lead to certain actors attempting to co-opt the process to serve their vested interests (Brandt et al., 2018).

These cases sought to **foster awareness of framing choices** by focusing participants on a higher common purpose. For example, the Keystone Dialogues began with a speech by Her Royal Highness Crown Princess Victoria of Sweden that legitimized collective concerns for ocean stewardship (Österblom et al., 2017). Two other cases fostered reflection among conservation proponents over strategies which fell short of promises for people and nature in Peru and Colombia (Chambers et al., 2019; van Kerkhoff et al., 2019). Collective reflection explored

problematic assumptions underpinning dominant strategies; for example, notions that the “problem” causing deforestation or weak climate adaptation could be reduced to lack of knowledge or resources. In Peru, dialogues enabled actors to directly experience and discuss the many ways strategies were failing, prompting discussion about contradictions between assumptions and practices (#15; Chambers and Schleicher, 2017).

Critically, various initiatives **strengthened openings for change**. For example, protected area managers in Colombia were eager to explore options for changing current governance models, facilitating the implementation of project activities (van Kerkhoff et al., 2019). For an initiative in South Africa (#22), making a “dent” in dominant “win-win” narratives took time, requiring long-term presence to engage with higher level actors when they were ready (Brandt et al., 2018). For this initiative, gaining trust among stakeholder networks, regular team meetings and engaging with local legal advice was critical to mitigate attempts to co-opt data for political pursuits. This project also constructively addressed donor pressures for policy outcomes that could undermine the process. Some projects developed outputs which later proved useful for gaining policy influence when the institutional context became more supportive, such as an internationally co-produced “Code of Conduct for Marine Conservation” (#32; Bennett et al., 2017).

Many initiatives fell short in **institutionalizing collaborations for transformation**, due to overemphasis on knowledge production and confined learning events. Initiatives that communicated the value of long-term communities of practice and institutional structures showed the greatest potential to link learning to transformation. For example, a successful demonstration project in the Israel-Palestine river restoration (#16) mobilized public and political interest to create an institution to continue the work (Brandeis, 2005). Similarly, the Keystone Dialogues created task forces, where scientists and business representatives collaboratively developed actionable activities, in collaboration with NGOs, governments, and other actors (Österblom et al., 2017). Yet, for other cases, donors focused on measurable outputs and tangible impacts struggled to see the value of supporting ongoing collaborations or networks (Christie et al., 2017; van Kerkhoff et al., 2019). As a result, some initiatives were unable to pursue their identified transformative agendas and activities.

Efforts to **examine shifts in dominant agendas** were vital for sustaining motivations of participants while fostering accountability for claimed social-ecological transformations. Studies examining these processes provide novel conceptual and practical contributions on how science can contribute to transforming the agency of powerful actors (Brandt et al., 2018; Christie et al., 2017; Österblom et al., 2017; van Kerkhoff et al., 2019). These transformations included shifts in beliefs, changes to dominant narratives and policies, and new networks and institutions positioned to support future transformations. Embedded monitoring of how frames, interests, and expectations shifted throughout the process were important in identifying minority views to elevate through dialogues and ideological positions that were likely to hinder learning.

## 6.3. Navigating conflicting agendas for change

The pathways described above may strengthen the foundation for **navigating conflicting agendas**, which embraces the politics of bringing actors together across power differentials to transform interlinked paradigms, relations, practices, policies and institutions. By connecting the boundary setting questions of the previous pathways, this approach asks **what systems create (un)just relations?** For example, a co-management process in the Kafue Flats, Zambia (#1), was sparked by research that examined the dynamics that eroded local fishery management systems to the detriment of river health and community livelihoods (Haller and Merten, 2010). Formulating shared perceptions of political problems is therefore a critical first step towards navigating conflicting agendas. Some projects mapped differences in agendas and perceptions of

problems across different parts of the world (e.g. Guerrero et al., 2021; Virah-Sawmy et al., 2019), but no cases connected this to explicitly political processes to reshape relations. This was often seen as outside the control of typically locally or regionally bounded work.

**Cultivating fair spaces for contestation** was critical to navigate conflicting agendas. This necessitated sufficient time and energy to establish trust, requiring process facilitators to refrain from advocating for a position amidst pressure from interest groups to do so, or forcing an impact agenda too early, such as explicitly trying to “resolve” a conflict. These actors had to carefully balance different agendas to open up space for different narratives to emerge (Brennan, 2018; Haller and Merten, 2018). For several initiatives, researchers saw themselves as *part of the system* where critical self-reflection is essential and *everyone* is challenged to change. Explicit, upfront recognition of different groups and existing institutions was important for nurturing fair spaces.

Once spaces for engagement were perceived as fair, initiatives **developed stepwise processes to span conflicts**. For example, the “constitutionality” approach examines and develops institution-building processes to foster local ownership (Haller et al., 2016). In Zambia, this approach created platforms for different interest groups to openly discuss locally relevant issues in the absence of power asymmetries. Over time, these groups were brought together by recognizing the knowledge of different local groups and rebuilding respected customary institutions to preempt individualistic concerns from co-opting the process (Haller and Merten, 2018). Several cases used creative methods to elevate more marginalized voices; for example, by mapping stories, songs and art that expressed local cultural values for the sea (#14; Brennan, 2018), or using companion modeling to foster co-learning over actors’ understandings of systems and management scenarios (#2; Dumrongrojwatthana and Trébuil, 2011). It was critical to wait until relatively marginalized groups felt confident enough to invite decision-makers from higher levels in the social hierarchy to join the process. Emphasizing process over impact during initial stages allowed actors to move beyond any particular “stake”, to see their roles and values as evolving towards collective purpose (i.e. “stake-holding”) (Steyaert and Jiggins, 2007). That said, with marginalized groups, it was crucial to protect their rights prior to pursuing collective purposes. In cases where powerful economic interests and private property rights reinforced existing stakes, such as Chasseral Regional Nature Park (#17), actions were limited to either smaller scale conservation projects, or larger scale development projects (Gerber, 2018).

Efforts to strengthen emerging institution-building processes depended on **creating an enabling political environment**. Several cases noted the risks of failing to do so. For example, in the Zambian fishery example, implementation was hindered by failure to obtain state support to ratify the co-management by-laws (Haller and Merten, 2018). Thus, the researchers have since given greater attention to studying legal and institutional dimensions of administrations (Haller, 2019). In the Thai companion modeling case (Dumrongrojwatthana and Trébuil, 2011), changes in park leadership resulted in a strict protectionist approach that blocked co-management possibilities. In the Chasseral Regional Nature Park, the bottom-up park management approach was supported by changes to Swiss Federal legislation that incentivized landscape actors to align their interests. However, they faced challenges on the ground that limited possible coordination between public and private actors (Gerber, 2018). In contrast, the co-management process in Scotland convinced policy actors to support a genuinely bottom-up approach where ongoing dialogue enabled government officials to understand the expertise and commitment of local people to manage their resources (Brennan, 2018).

An emphasis on process created mutual understandings, relations, and institutional forms to mobilize the **transformation of systems for collective justice**. These transformations were supported by strategically bringing in actors with needed expertise and agency to implement identified solutions. For example, the Zambian case involved the local Department of Fisheries because of their experience and authority in

crafting by-laws (Haller and Merten, 2018). For many cases, bringing in more powerful actors to formulate implementation plans became less problematic once they had access to views from diverse interest groups. As researchers were often integral in establishing these new institutional spaces, it was critical to transition power to prevent processes from becoming dependent on their facilitating role and to guard against future co-option by vested interests.

Embedded reflexivity was essential; thus, **examining the implications of system changes** required careful attention to intangible outcomes, such as shifts in perceptions of ownership and the meaningfulness of participation. For example, The SLIM project (#25) used reflective meetings and external reviews to inform project evolution (Steyaert and Jiggins, 2007). These cases fundamentally transformed how stakeholders interacted, including their perceptions of each other, the nature of conflicts, and the opportunities to constructively co-create more just relations embedded in new institutional forms and policies designed to sustain them. All cases recognized, however, that these processes are rarely resolved and often require ongoing work to ensure usefulness and foster broad-based ownership.

#### 6.4. Exploring diverse agendas for change

Finally, **exploring diverse agendas**, brings actors together through processes that foster mutual understanding and respect for a plurality of perspectives. This opens up space for learning which is not possible when the aim is to shift power or promote a particular agenda. Here, setting the scope starts by asking – **where is plurality and learning most beneficial?** All cases enhanced learning among change agents who were already motivated to foster transformation, but could benefit from expanding their perceptions, connections and agency (e.g. Steyaert and Jiggins, 2007; Charli-Joseph et al., 2018; Goldstein et al., 2018; Chatterton et al., 2018; Fischer et al., 2019; Riechers et al., 2019). For example, Charli-Joseph et al. (2018) fostered the collective agency of change agents within the Xochimilco Social-Ecological System (Mexico) (#6), while the Fire Adapted Communities Learning Network (FAC Net) connected U.S. wildfire practitioners to share lessons and improve practice (#20; Goldstein et al., 2018). This raises the question: what combination of actors can most benefit collective agendas by engaging in collective learning?

These initiatives sought to **cultivate safe spaces for learning** by striking a careful balance: maximizing the diversity of ideas present, while creating a socially cohesive identity. For example, the FAC Net purposefully excluded environmental advocates and fire scientists in order to avoid building a top-down network. They instead built a “fire doing” network of people actively engaged in managing wildfire. The focus meant that participants have tended to be relatively socio-economically homogeneous; thus, they have tried to actively involve Indigenous and Hispanic groups. Another case, the Leeds City Lab (#3), involved diverse sectors across Leeds (Chatterton et al., 2018). This initiative faced some tensions between the more task-oriented and faster-paced practices of the private sector with the slower and methodologically-preoccupied approach of the university sector, and the risk-averse, and potentially more cautious third and public sectors. This generated fear that others might profit from sharing ideas and reinforce third-sector precarity. The project managed these tensions by emphasizing the emotional aspects of co-production and the need to embrace vulnerability and ‘not knowing’ rather than seeking to resolve differences (Chatterton et al., 2018).

Safe learning spaces enabled the uncomfortable but potentially empowering task of **facilitating reflection on perceptions of agency**. For example, the Mexican Transformation-Lab engaged those who depended on the wetland and had a direct impact on its evolution to explore their individual agency, and how to develop a collective sense of agency that could be mobilized in novel ways (Charli-Joseph et al., 2018). Researchers positioned themselves as facilitators and conveners, primarily concerned with how the process could facilitate agency, instead of

producing a specific action or pathway of change. Other cases used diverse methods such as facilitated discussions around stories or past failures, “walkshops”, serious games, and creating art to surface different emotions and views. Similarly, the researcher learning network in SLIM deliberatively avoided matching case comparisons or statistical analysis, as this would have limited their potential to build a reflexive and emergent process (Steyaert and Jiggins, 2007).

**Managing bridges to solutions/impacts** was a substantial challenge faced by these learning processes. It was uncomfortable and potentially disempowering for actors to think that the process might not lead to any solution. This was exacerbated by broader institutional requirements to produce papers (researchers), or show impact (NGOs). This created a fundamental tension whereby researchers who did not want to push an impact agenda, eventually felt responsible to support emerging solutions, which then depended on additional funding. The major risk was that institutions (alongside promises of funding) could exploit these processes for their own interests, and thus crowd out learning. Navigating these tensions therefore required long term independent income and facilitation, alongside equitable governance that included those positioned to re-embed learning in institutional contexts and programs. For example, both the FAC Net and SLIM network were established to generate learning from and embed it back into practice (Goldstein et al., 2018; Steyaert and Jiggins, 2007). Reflexivity was essential to ensure that academics did not dominate, and research outputs were not biased by the political agendas of non-academic partners.

Through productive engagement with emerging impact rationales, several initiatives showed how learning processes can **foster expanded agency for justice**. For example, in the case of the Transylvania Leverage Points project (#8), fragmented NGOs developed a sense of “we are all in this together” by creating a common vision “Balance Brings Beauty” and sharing strategies (Fischer et al., 2019). The project saw collective agency emerge in previously conflictual settings; for example, when farmers requested that they play a “serious game” with a mayor who they were in conflict with. The neutral space provided by the game context enabled real-life adversaries to discuss joint strategies, while at the same time building understanding of potential common interests. Other initiatives facilitated spaces where people could reflect on their emotions to recognize their own disempowering narratives and co-create more empowering ones (Charli-Joseph et al., 2018; Riechers et al., 2019). Fostering expanded agency required pushing the boundaries of traditional spaces for interaction, such as by developing more diverse spaces where actors can meet rather than creating a single co-productive space (Chatterton et al., 2018).

To **examine shifts in collective agency**, cases emphasized emergent shared notions of “success” to reduce pressures and expectations. Several cases noted the difficulty of tracking learning impacts that permeate throughout networks in unexpected ways. Yet, for these initiatives, embedded monitoring and reflection was inherent to facilitating learning and change. For example, the Mexican Transformation-Lab used cognitive mapping and social network analysis to understand people’s perceptions of agency and track how they changed over time (Charli-Joseph et al., 2018). Like many initiatives, this case showed how people reinterpreted their own narratives, developed empathy for new actors and forged new alliances; for example, from seeing “two conflicting worlds” and focusing on technological solutions, to seeing “many worlds” and emphasizing social solidarity. The FAC Net used social network analysis to examine how it functions as a network, and Ripple Effects Mapping to gather stories of how the network influenced practices and results (Medley-Daniel and Troisi, 2019). Some cases broadly shared their methods and lessons, such as through blogs and methodological guides (e.g. Ruizpalacios et al., 2019). Participant ownership over their own data was critical to protect confidentiality while maximizing exchange.

## 7. Fostering co-productive agility for sustainability transformations

This paper makes conceptual and practical contributions to understanding *how to navigate tensions and power dynamics among diverse actors to collaboratively define and implement transformative change for sustainable social-ecological relations* – what we call ‘co-productive agility’. These actors may not have been willing to set shared goals from the outset, but become willing to do so over time as they foster trust and accountability, reframe their views, and build collective purpose and action. We empirically explore what constitutes co-productive agility in four identified pathways to transformation: 1) elevating marginalized agendas; 2) questioning dominant agendas; 3) navigating conflicting agendas; and 4) exploring diverse agendas. These pathways entail distinct considerations; for example, each pathway cultivated agile spaces by prioritizing different values – humility, legitimacy, fairness, and safety (see Fig. 3). Cultivating these spaces required different forms of facilitative leadership – from taking a more leading role in spaces of power, to stepping back in spaces of marginalization.

Our analysis demonstrates the potential of co-productive agility to fundamentally change the willingness and ability of diverse people to work together and foster new paradigms, relations, and institutions in support of sustainability. However, we also identified critical barriers to fostering it. Challenges emerged, for example, when people directed co-production processes to empower their own agendas, rather than creating space for a plurality of agendas. Even if agendas were potentially transformative on paper, if they failed to actually navigate the tensions and politics inherent to the transformation they proposed *within* co-production processes, those politics nevertheless emerged – often to the detriment of intended transformations. In contrast, when tensions between process vs. impact and exclusion vs. inclusion (Table 2) were navigated in an agile way, important transformations in support of sustainability were documented (shown in Table 3 and Section 6). Thus, research and practice may spend too much time debating *which* agenda for change is best, and too little time considering *how to facilitate better interactions among different agendas*. The tendency to close down debate over co-production agendas, and cover up disagreements for sake of convenient consensus is linked to the standards of “success” by which scientists and practitioners are held accountable, alongside pressure to show immediate tangible outcomes (Cockburn et al., 2019; Edmunds and Wollenberg, 2001; Klens and Meehan, 2017). Such time pressure can incentivize the rapid creation of large ‘inclusive’ multi-stakeholder platforms; yet, co-productively agile initiatives consistently *limited* participation in important ways to effectively balance power relations and cultivate safe spaces (Haller and Merten, 2018; Österblom et al., 2017).

These challenges raise the question: *how can co-productive agility be recognized, nurtured, and evaluated in research and practice?* Facilitative leadership that enables the emergence of co-productive agility is not actively supported by most institutional structures in which researchers and practitioners are embedded (Balvanera et al., 2017; Clark et al., 2016). Such a facilitative role, if properly cultivated, would be freed from predetermined measures of progress, instead embracing more emergent process-based criteria and evaluation approaches that support continuous reflection and adaptive course correction. Other fields, such as design and systems theory, are already exploring what such societal transformation design and evaluation looks like (Banerjee, 2008; Fuller Transformation Collaborative, 2019). Indeed, we found that embedding research into practice moved initiatives into spaces of co-productive agility, as otherwise the initial problem frame was too fixed as either “lack of knowledge” or “lack of the kinds of solutions we are already invested in”. It is important to consider how existing knowledge (and other) governance models might facilitate or hinder embedding researchers into practice (Múnera and van Kerkhoff, 2019; van Kerkhoff and Pilbeam, 2017). Enabling cognitive, relational, and organizational aspects of co-productive agility may therefore necessitate shifts in

institutional environments and funding criteria, to recognize the value of processes that carefully and iteratively navigate tensions (Arnott et al., 2020; Cockburn et al., 2018).

We have created a space and framework to further examine what co-productive agility is and how it can matter for sustainability transformations. A key aspect appears to be “staying with the trouble” of difference to proactively transform power relations (Haraway, 2016), instead of avoiding, suppressing, or polarizing difference. Further research and practice could explore novel approaches to these four pathways, as well as how they are relational with each other and can enable broader transformations across scales. For example, some cases suggest that elevating marginalized agendas may help question dominant agendas, and vice versa (e.g. Hill et al., 2020; Brandt et al., 2018; Christie et al., 2017), and generally also entails exploring diverse agendas in a safe way (e.g. Tengö et al., 2017). These three pathways may enable more productive efforts to navigate conflicting agendas, even amidst polarized disputes (e.g. Brennan, 2018). Efforts to explore diverse agendas, such as through learning networks and processes, may also play a central albeit less easily traceable role in supporting all pathways towards transformation (e.g. Steyaert and Jiggins, 2007; Goldstein et al., 2018). Finally, particular practices such as future visioning may draw upon multiple pathways by jointly elevating, questioning, exploring and navigating conflicting agendas (e.g. Mitchell et al., 2015). Our analysis suggests that these four pathways can be powerful both individually and in combination. However, further research is needed to understand how they may be synergistic or produce trade-offs – both temporally within initiatives, and across different initiatives.

The co-production efforts we examined disproportionately sought to elevate marginalized agendas to pursue change, yet what was seen as “marginalized” was subjective. In some cases, “marginalized” agendas could be seen as “dominant” agendas by others (e.g. Guerrero et al., 2021). We therefore suggest reflecting on how to elevate agendas in ways that help broaden (rather than hinder) struggles for justice. This also includes broadening research to hear marginalized actors’ experiences of these tensions firsthand – an aspect which is notably absent from our study, which foregrounds researcher/practitioner experiences. We also highlight the need for greater attention to questioning dominant agendas, navigating conflicting agendas, and exploring diverse agendas. In particular, it is critical to examine how all pathways can extend beyond local initiatives to enable broader transformations across scales and geographies, but at the same time ensure that global and national co-production efforts do not undermine local and/or marginalized actors. We hope that by sharing our collective experiences in navigating the tensions and politics of transformation, we can enable more agile and powerful pathways to just and sustainable futures.

## Author contributions

J.M.C., C.W. and M.E.R. conceived the project and co-led the design of methods, with contributions from R.S.R., M.E.R., A.S., N.J.B., C.C., M. E.F.G., K.A.G., B.E.G., N.L.K., M.T., A.T.B., K.C., R.G., T.P. Authors J.M. C., M.E.R., C.W., R.S.R., and A.T.B organised and designed all workshops. J.M.C. coordinated the study, gathered all data, and led the data analysis in collaboration with all authors. J.M.C., C.W., and N.L.K. drafted the manuscript and all authors contributed and commented on drafts and the final version.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Acknowledgments

This project and paper were supported by the Luc Hoffmann Institute and MAVA Foundation. We acknowledge the Center for Collaborative Conservation, the Programme on Ecosystem Change and Society (PECS), the Cambridge Conservation Initiative (CCI), and The Pew Charitable Trusts for hosting our workshops. J.M.C. received additional support from the Economic and Social Research Council (grant RG97777). J.J.C. was funded by a Rhodes University Postdoctoral Fellowship, and acknowledges the contributions of Preshnee Singh and Smiso Behngu to analysing the Durban Research Action Partnership case. H.Ö. was funded by the Walton Family Foundation (grant 2018-1371), The David and Lucile Packard Foundation (grant 2019-68336), and The Gordon and Betty Moore Foundation (grant GBMF5668.02). J.G. was supported by the UK Research and Innovation’s Global Challenges Research Fund (UKRI GCRF) through the Trade, Development and the Environment Hub project (project ES/S008160/1). A.I.H.M. was supported from a Volkswagen Stiftung and the Niedersächsisches Ministerium für Wissenschaft und Kultur grant (A112269) followed by a Marie Skłodowska-Curie grant (840207). A.I.H.M also acknowledges support from the Leverage Points project practice partners and all project team members. J.M. was supported by the Leverhulme Trust. J.G.Z. was funded by the r4d programme of the Swiss Programme for Research on Global Issues for Development (grant 400440 152167). Elements of this work were undertaken whilst J.G.Z. was a visiting scholar at the Department of Geography, University of Cambridge (May 2018–April 2019), supported through Scientific Exchange funding from the Swiss National Science Foundation (grant IZSEZ0\_180391).

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.gloenvcha.2021.102422>.

## References

- Abson, D.J., Fischer, J., Leventon, J., Newig, J., Schomerus, T., Vilsmaier, U., von Wehrden, H., Abernethy, P., Ives, C.D., Jager, N.W., Lang, D.J., 2017. Leverage points for sustainability transformation. *Ambio* 46, 30–39. <https://doi.org/10.1007/s13280-016-0800-y>.
- Andriopoulos, C., Lewis, M.W., 2008. Exploitation-exploration tensions and organizational ambidexterity: managing paradoxes of innovation. *Organ. Sci.* 20, 696–717. <https://doi.org/10.1287/orsc.1080.0406>.
- Arnott, J.C., Neuenfeldt, R.J., Lemos, M.C., 2020. Co-producing science for sustainability: Can funding change knowledge use? *Glob. Environ. Change* 60, 101979. <https://doi.org/10.1016/j.gloenvcha.2019.101979>.
- Avelino, F., 2017. Power in sustainability transitions: analysing power and (dis)empowerment in transformative change towards sustainability. *Environ. Policy Gov.* 27, 505–520. <https://doi.org/10.1002/eet.1777>.
- Avelino, F., Rotmans, J., 2009. Power in transition: an interdisciplinary framework to study power in relation to structural change. *Eur. J. Soc. Theory*. <https://doi.org/10.1177/1368431009349830>.
- Bäckstrand, K., Khan, J., Kronsell, A., Lovbrand, E., 2010. Environmental politics and deliberative democracy: Examining the promise of new modes of governance, in: *Environmental Politics and Deliberative Democracy*. Edward Elgar Publishing, p. 13822. 10.4337/9781849806411.00009.
- Balvanera, P., Calderón-Contreras, R., Castro, A.J., Felipe-Lucía, M.R., Geijzendorffer, I.R., Jacobs, S., Martín-López, B., Arbieu, U., Speranza, C.I., Locatelli, B., Harguindeguy, N.P., Mercado, I.R., Spierenburg, M.J., Vallet, A., Lynes, L., Gilson, L., 2017. Interconnected place-based social–ecological research can inform global sustainability. *Curr. Opin. Environ. Sustain.* 29, 1–7. <https://doi.org/10.1016/j.cosust.2017.09.005>.
- Banerjee, B., 2008. *Designer as Agent of Change*. Stanford University.
- Beier, P., Hansen, L.J., Helbrecht, L., Behar, D., 2017. A how-to guide for coproduction of actionable science. *Conserv. Lett.* 10, 288–296. <https://doi.org/10.1111/conl.12300>.
- Bennett, N.J., Blythe, J., Cisneros-Montemayor, A.M., Singh, G.G., Sumaila, U.R., 2019. Just transformations to sustainability. *Sustainability* 11, 3881. <https://doi.org/10.3390/su11143881>.
- Bennett, N.J., Dearden, P., 2014. Why local people do not support conservation: community perceptions of marine protected area livelihood impacts, governance and management in Thailand. *Mar. Policy* 44, 107–116. <https://doi.org/10.1016/j.marpol.2013.08.017>.
- Bennett, N.J., Teh, L., Ota, Y., Christie, P., Ayers, A., Day, J.C., Franks, P., Gill, D., Gruby, R.L., Kittinger, J.N., Koehn, J.Z., Lewis, N., Parks, J., Vierros, M., Whitty, T.

S., Wilhelm, A., Wright, K., Aburto, J.A., Finkbeiner, E.M., Gaymer, C.F., Govan, H., Gray, N., Jarvis, R.M., Kaplan-Hallam, M., Satterfield, T., 2017. An appeal for a code of conduct for marine conservation. *Mar. Policy* 81, 411–418. <https://doi.org/10.1016/j.marpol.2017.03.035>.

Blythe, J., Silver, J., Evans, L., Armitage, D., Bennett, N.J., Moore, M.-L., Morrison, T.H., Brown, K., 2018. The dark side of transformation: latent risks in contemporary sustainability discourse. *Antipode*. <https://doi.org/10.1111/anti.12405>.

Body, A., Kendall, J., 2020. Expansive opportunity makers but selective opportunity takers? Positional agility and tactical social skill in English third sector social service. *J. Civ. Soc.* 16, 15–34. <https://doi.org/10.1080/17448689.2020.1719626>.

Brandeis, A., 2005. Restoration and Management of Degraded River Basins - The Alexander River Case Study, in: *River Basin Restoration and Management*, Water and Environmental Management Series. IWA Publishing.

Brandt, F., Josefsson, J., Spierenburg, M.J., 2018. Power and politics in stakeholder engagement: Farm dweller (in)visibility and conversions to game farming in South Africa. 1708-3087.

Brennan, R.E., 2018. Re-storying marine conservation: integrating art and science to explore and articulate ideas, visions and expressions of marine space. *Ocean Coast. Manag.* 162, 110–126. <https://doi.org/10.1016/j.ocecoaman.2018.01.036>.

Bulter, E., Hessel, L.K., Hordijk, M., Segrave, A.J., 2021. Conflicting roles of researchers in sustainability transitions: balancing action and reflection. *Sustain. Sci.* <https://doi.org/10.1007/s11625-021-00938-7>.

Caniglia, G., Luederitz, C., von Wirth, T., Fazey, I., Martín-López, B., Hondrila, K., König, A., von Wehrden, H., Schäpke, N.A., Laubichler, M.D., Lang, D.J., 2020. A pluralistic and integrated approach to action-oriented knowledge for sustainability. *Nat. Sustain.* 1–8 <https://doi.org/10.1038/s41893-020-00616-z>.

Chambers, J., Aguila Mejía, M.D., Ramírez Reátegui, R., Sandbrook, C., 2019. Why joint conservation and development projects often fail: an in-depth examination in the Peruvian Amazon. *Environ. Plan. E Nat. Space* 3, 365–398. <https://doi.org/10.1177/2514848619873910>.

Chambers, J., Schleicher, J., 2017. Building bridges for the conservation of forests and well-being of communities in San Martín, Peru (English translation). *Amazónicos por la Amazonía (AMPA) and Centro de Conservación, Investigación y Manejo de Áreas Naturales – Cordillera Azul (CIMA)*, San Martín Region, Peru.

Chambers, J.M., Wyborn, C., Ryan, M.E., Reid, R.S., Riechers, M., Serban, A., Bennett, N.J., Cvitanovic, C., Fernández-Giménez, M.E., Galvin, K.A., Goldstein, B.E., Klenk, N.L., Tengö, M., Brennan, R., Cockburn, J.J., Hill, R., Munera, C., Nel, J.L., Österblom, H., Bednarek, A.T., Bennett, E.M., Brandeis, A., Charli-Joseph, L., Chatterton, P., Curran, K., Dumrongrojwattana, P., Durán, A.P., Fada, S.J., Gerber, J.-D., Green, J.M.H., Guerrero, A.M., Haller, T., Horcea-Milcu, A.-I., Leimona, B., Montana, J., Rondeau, R., Spierenburg, M., Steyaert, P., Zaehringer, J.G., Gruby, R., Hutton, J., Pickering, T., 2021. Six modes of co-production for sustainability. *Nat. Sustain.* 1–14. <https://doi.org/10.1038/s41893-021-00755-x>.

Charli-Joseph, L., Siqueiros, J.M., Eakin, H., Manuel-Navarrete, D., Shelton, R., 2018. Promoting agency for social-ecological transformation: a transformation-lab in the Xochimilco social-ecological system. *Ecol. Soc.* 23, 46. <https://doi.org/10.5751/ES-10214-230246>.

Chatterton, P., Owen, A., Cutter, J., Dymski, G., Unsworth, R., 2018. Recasting urban governance through Leeds city lab: developing alternatives to neoliberal urban austerity in co-production laboratories. *Int. J. Urban Reg. Res.* 42, 226–243. <https://doi.org/10.1111/1468-2427.12607>.

Christie, P., Bennett, N.J., Gray, N.J., 'Aulani Wilhelm, T., Lewis, N., Parks, J., Ban, N.C., Gruby, R.L., Gordon, L., Day, J., Taei, S., Friedlander, A.M., 2017. Why people matter in ocean governance: Incorporating human dimensions into large-scale marine protected areas. *Mar. Policy* 84, 273–284. <https://doi.org/10.1016/j.marpol.2017.08.002>.

Clark, W.C., van Kerkhoff, L., Lebel, L., Gallopin, G.C., 2016. Crafting usable knowledge for sustainable development. *Proc. Natl. Acad. Sci.* 113, 4570–4578. <https://doi.org/10.1073/pnas.1601266113>.

Cockburn, J., Cundill, G., Shackleton, S., Rouget, M., Zwinkels, M., Cornelius, S. (Ancia), Metcalfe, L., van den Broeck, D., 2019. Collaborative stewardship in multifunctional landscapes: toward relational, pluralistic approaches. *Ecol. Soc.* 24, 10.5751/ES-11085-240432.

Cockburn, J., Palmer, C. (Tally) G., Biggs, H., Rosenberg, E., 2018. Navigating multiple tensions for engaged praxis in a complex social-ecological system. *Land*, 7, 129. <https://doi.org/10.3390/land7040129>.

Cockburn, J., Rouget, M., Slotow, R., Roberts, D., Boon, R., Douwes, E., O'Donoghue, S., Downs, C., Mukherjee, S., Musakwa, W., Mutanga, O., Mwabvu, T., Odindi, J., Odindo, A., Proches, S., Ramdhani, S., Ray-Mukherjee, J., Sershen, Schoeman, M.C., Smit, A., Wale, E., Willows-Munro, S., 2016. How to build science-action partnerships for local land-use planning and management: lessons from Durban, South Africa. *Ecol. Soc.* 21.

Dekker, L.A.G., Arts, K., Turnhout, E., 2020. From rationalities to practices: understanding unintended consequences of CBNRM. *Conserv. Soc.* 18 (2).

Diver, S., 2017. Negotiating Indigenous knowledge at the science-policy interface: Insights from the Xáli'p Community Forest. *Environ. Sci. Policy* 73, 1–11. <https://doi.org/10.1016/j.envsci.2017.03.001>.

Djenontin, I.N.S., Meadow, A.M., 2018. The art of co-production of knowledge in environmental sciences and management: lessons from international practice. *Environ. Manage.* 61, 885–903. <https://doi.org/10.1007/s00267-018-1028-3>.

Drimie, S., Hamann, R., Manderson, A.P., Mlondoboz, N., 2018. Creating transformative spaces for dialogue and action: reflecting on the experience of the Southern Africa Food Lab. *Ecol. Soc.* 23 (3).

Dumrongrojwattana, P., Trébui, G., 2011. Northern Thailand case: gaming and simulation for co-learning and collective action; companion modelling for collaborative landscape management between herders and foresters. In: *Knowledge in Action*, Mansholt Publication Series. Wageningen Academic Publishers, Wageningen, pp. 191–219. [https://doi.org/10.3920/978-90-8686-724-0\\_9](https://doi.org/10.3920/978-90-8686-724-0_9).

Edmunds, D., Wollenberg, E., 2001. A strategic approach to multistakeholder negotiations. *Dev. Change* 32, 231–253. <https://doi.org/10.1111/1467-7660.00204>.

Fernández-Giménez, M.E., Allegretti, A., Angerer, J., Baival, B., Batjav, B., Fassnacht, S., Jamsranjav, C., Jamiyansharav, K., Laituri, M., Reid, R.S., Thompson, J., Ulambayar, T., Venable, N., 2019. Sustaining interdisciplinary collaboration across continents and cultures: lessons from the mongolian rangelands and resilience project. In: Perz, S.G. (Ed.), *Collaboration Across Boundaries for Social-Ecological Systems Science: Experiences Around the World*. Springer International Publishing, Cham, pp. 185–225. [https://doi.org/10.1007/978-3-030-13827-1\\_6](https://doi.org/10.1007/978-3-030-13827-1_6).

Fischer, J., Horcea-Milcu, A.-I., Lang, D., Thale-Bombien, L., Abson, D., Apetrei, C., Clarke, E., Derwort, P., Dorninger, C., Duse, I., Freeth, R., Jager, N., Kłaniecki, K., Lam, D., Leventon, J., Newig, J., Peukert, D., Riechers, M., Schaal, T., 2019. Balance Bring Beauty: Strategies for a Sustainable Southern Transylvania.

Flyvbjerg, B., 2006. Five Misunderstandings about case-study research. *Qual. Inq.* 12, 219–245. <https://doi.org/10.1177/1077800405284363>.

Frieze, D., Wheatley, M., 2011. From hero to host: a story of citizenship in Columbus, Ohio. In: Wheatley, M., Frieze, D. (Eds.), *Walk out, Walk on: A Learning Journey into Communities Daring to Live the Future Now*. BK Currents, New York, pp. 188–215.

Fuller Transformation Collaborative, 2019. *The art of systems change: Eight guiding principles for a green and fair future*. World Wildlife Fund, Washington, DC.

Gerber, J.-D., 2018. Regional Nature Parks in Switzerland. Between top-down and bottom-up institution building for landscape management. *Hum. Ecol.* 46, 65–77. <https://doi.org/10.1007/s10745-017-9913-6>.

Goldman, M., 2007. How "Water for All!" policy became hegemonic: The power of the World Bank and its transnational policy networks. *Geoforum, Pro-Poor Water? Privatisation Global Poverty Debate* 38, 786–800. <https://doi.org/10.1016/j.geoforum.2005.10.008>.

Goldstein, B.E., Chase, C., Frankel-Goldwater, L., Osbourne-Gowey, J., Risien, J., Schweizer, S., 2018. Transformative Learning Networks. *Proc. 60th Annu. Meet. ISSS - 2016 Boulder CO USA* 1.

Gren, L., Lenberg, P., 2020. Agility is responsiveness to change: An essential definition, in: *Proceedings of the Evaluation and Assessment in Software Engineering, EASE '20*. Association for Computing Machinery, New York, NY, USA, pp. 348–353. [10.1145/3383219.3383265](https://doi.org/10.1145/3383219.3383265).

Guerrero, A.M., Jones, N.A., Ross, H., Virah-Sawmy, M., Biggs, D., 2021. What influences and inhibits reduction of deforestation in the soy supply chain? A mental model perspective. *Environ. Sci. Policy* 115, 125–132. <https://doi.org/10.1016/j.envsci.2020.10.016>.

Hadida, A.L., Tarvainen, W., Rose, J., 2015. Organizational improvisation: a consolidating review and framework. *Int. J. Manag. Rev.* 17, 437–459. <https://doi.org/10.1111/ijmr.12047>.

Haider, L.J., Henati-Sundberg, J., Giusti, M., Goodness, J., Hamann, M., Masterson, V.A., Meacham, M., Merrie, A., Ospina, D., Schill, C., Sinare, H., 2018. The undisciplinary journey: early-career perspectives in sustainability science. *Sustain. Sci.* 13, 191–204. <https://doi.org/10.1007/s11625-017-0445-1>.

Haller, T., 2019. Towards a new institutional political ecology: How to marry external effects, institutional change and the role of power and ideology in commons studies, in: *The Commons in a Glocal World*. 10.4324/9781351050982-7.

Haller, T., Acciaioli, G., Rist, S., 2016. Constitutionality: conditions for crafting local ownership of institution-building processes. *Soc. Nat. Resour.* 29, 68–87. <https://doi.org/10.1080/08941920.2015.1041661>.

Haller, T., Merten, S., 2018. Crafting our own rules: constitutionality as a bottom-up approach for the development of by-laws in Zambia. *Hum. Ecol.* 46, 3–13. <https://doi.org/10.1007/s10745-017-9917-2>.

Haller, T., Merten, S., 2010. "We Had Cattle And Did Not Fish And Hunt Anyhow!" Institutional change and contested commons in The Kafue Flats Floodplain (Zambia). *Disput. Floodplains* 301–360. <https://doi.org/10.1163/097890041853261-454.86>.

Haraway, D.J., 2016. *Staying with the Trouble: Making Kin in the Cthulucene*. Duke University Press.

Hermans, F., Roep, D., Klerkx, L., 2016. Scale dynamics of grassroots innovations through parallel pathways of transformative change. *Ecol. Econ.* 130, 285–295. <https://doi.org/10.1016/j.ecolecon.2016.07.011>.

Hill, R., Walsh, F.J., Davies, J., Sparrow, A., Mooney, M., Wise, R.M., Tengö, M., 2020. Knowledge co-production for Indigenous adaptation pathways: Transform post-colonial articulation complexes to empower local decision-making. *Glob. Environ. Change* 65, 102161. <https://doi.org/10.1016/j.gloenvcha.2020.102161>.

Howlett, M., Capano, G., Ramesh, M., 2018. Designing for robustness: surprise, agility and improvisation in policy design. *Policy Soc.* 37, 405–421. <https://doi.org/10.1080/14494035.2018.1504488>.

IPBES, 2019. Summary for policymakers of the global assessment report on biodiversity and ecosystem services. IPBES secretariat, Bonn, Germany. 10.5281/zenodo.3553579.

Jagannathan, K., Arnott, J.C., Wyborn, C., Klenk, N., Mach, K.J., Moss, R.H., Sjostrom, K.D., 2020. Great expectations? Reconciling the aspiration, outcome, and possibility of co-production. *Curr. Opin. Environ. Sustain.* 42, 22–29. <https://doi.org/10.1016/j.cosust.2019.11.010>.

Jarzabkowski, P., Lê, J.K., Van de Ven, A.H., 2013. Responding to competing strategic demands: How organizing, belonging, and performing paradoxes coevolve. *Strateg. Organ.* 11, 245–280. <https://doi.org/10.1177/1476127013481016>.

Kimmerer, R.W., 2013. *Braiding Sweetgrass: Indigenous Wisdom, Scientific Knowledge and the Teachings of Plants*. Milkweed Editions, Minneapolis.

Klenk, N., 2018. From network to meshwork: becoming attuned to difference in transdisciplinary environmental research encounters. *Environ. Sci. Policy* 89, 315–321. <https://doi.org/10.1016/j.envsci.2018.08.007>.

Klenk, N., Fiume, A., Meehan, K., Gibbes, C., 2017. Local knowledge in climate adaptation research: moving knowledge frameworks from extraction to co-production. *Wiley Interdiscip. Rev. Clim. Change* 8, e475. <https://doi.org/10.1002/wcc.475>.

Klenk, N., Meehan, K., 2015. Climate change and transdisciplinary science: problematizing the integration imperative. *Environ. Sci. Policy* 54, 160–167. <https://doi.org/10.1016/j.envsci.2015.05.017>.

Klenk, N.L., Meehan, K., 2017. Transdisciplinary sustainability research beyond engagement models: toward adventures in relevance. *Environ. Sci. Policy* 78, 27–35. <https://doi.org/10.1016/j.envsci.2017.09.006>.

Knapp, C.N., Reid, R.S., Fernández-Giménez, M.E., Klein, J.A., Galvin, K.A., 2019. Placing transdisciplinarity in context: a review of approaches to connect scholars, society and action. *Sustainability* 11, 4899. <https://doi.org/10.3390/su11184899>.

Lam, D.P.M., Martín-López, B., Wiek, A., Bennett, E.M., Frantzeskaki, N., Horcea-Milcu, A.I., Lang, D.J., 2020. Scaling the impact of sustainability initiatives: a typology of amplification processes. *Urban Transform.* 2, 3. <https://doi.org/10.1186/s42854-020-00007-9>.

Lang, D.J., Wiek, A., Bergmann, M., Stauffacher, M., Martens, P., Moll, P., Swilling, M., Thomas, C.J., 2012. Transdisciplinary research in sustainability science: practice, principles, and challenges. *Sustain. Sci.* 7, 25–43. <https://doi.org/10.1007/s11625-011-0149-x>.

Latulippe, N., 2015. Bridging parallel rows: epistemic difference and relational accountability in cross-cultural research. *Int. Indig. Policy J.* 6. 10.18584/ijip.2015.6.2.7.

Latulippe, N., Klenk, N., 2020. Making room and moving over: knowledge co-production, Indigenous knowledge sovereignty and the politics of global environmental change decision-making. *Curr. Opin. Environ. Sustain.* 42, 7–14. <https://doi.org/10.1016/j.cosust.2019.10.010>.

Leach, M., Rockström, J., Raskin, P., Scoones, I., Stirling, A.C., Smith, A., Thompson, J., Millstone, E., Ely, A., Arond, E., Folke, C., Olson, P., 2012. Transforming innovation for sustainability. *Ecol. Soc.* 17 (2), 11.

Maclean, K., Robinson, C.J., Natcher, D.C., 2015. Consensus building or constructive conflict? Aboriginal discursive strategies to enhance participation in natural resource management in Australia and Canada. *Soc. Nat. Resour.* 28, 197–211. <https://doi.org/10.1080/08941920.2014.928396>.

Malmer, P., Tengö, M., Fernández-Llamazares, A., Woodward, E., Crawhall, N., Hill, R., Trakansuphakon, P., Athayde, S., Cariño, C., Crimella, D., Farhan Ferrari, M., Pérez, E., Spencer, R., Trakansuphakon, N., Bicksler, A., Cariño, J., Gonzalo, E., Lengoisa, J., Lungharwo, T., Tahi, B., 2019. Dialogue across Indigenous, local and scientific knowledge systems reflecting on the IPBES Assessment on Pollinators, Pollination and Food Production, 21th to 25th January 2019 (Workshop report). *SwedBio at Stockholm Resilience Centre, Stockholm, Sweden., Chiang Mai and Chiang Rai, Thailand.*

Mauser, W., Klepper, G., Rice, M., Schmalzbauer, B.S., Hackmann, H., Leemans, R., Moore, H., 2013. Transdisciplinary global change research: the co-creation of knowledge for sustainability. *Curr. Opin. Environ. Sustain.* Open Issue 5, 420–431. <https://doi.org/10.1016/j.cosust.2013.07.001>.

Medley-Daniel, M., Troisi, E., 2019. FAC Net is Changing Fire Adaptation Work: Highlights from our Evaluation | Fire Adapted Communities Learning Network. *Fire Adapt. Communities Learn. Netw.* URL <https://fireadaptednetwork.org/fac-net-is-changing-fire-adaptation-highlights-from-our-evaluation/>.

Mitchell, M., Bennett, E., Gonzalez, A., Lechowicz, M., Rhemtulla, J., Cardille, J., Vanderheyden, K., Poirier-Ghys, G., Renard, D., Delmotte, S., Albert, C., Rayfield, B., Dumitru, M., Huang, H.-H., Larouche, M., Liss, K., Maguire, D., Martins, K., Terrado, M., Ziter, C., Taliana, L., Dancose, K., 2015. The Montérégie Connection: linking landscapes, biodiversity, and ecosystem services to improve decision making. *Ecol. Soc.* 20 <https://doi.org/10.5751/ES-07927-200415>.

Mitlin, D., 2008. With and beyond the state — co-production as a route to political influence, power and transformation for grassroots organizations. *Environ. Urban.* 20, 339–360. <https://doi.org/10.1177/0956247808096117>.

Montana, J., 2020. Balancing authority and meaning in global environmental assessment: an analysis of organisational logics and modes in IPBES. *Environ. Sci. Policy* 112, 245–253. <https://doi.org/10.1016/j.envsci.2020.06.017>.

Mooney, M., Walsh, F., Hill, R., Davies, J., Sparrow, A., Central Land Council Lytente Apurte Rangers, 2014. Climate Change: Learning About What is Happening with the Weather in Central Australia. *CSIRO with Central Land Council, Alice Springs, Australia.*

Moore, M.-L., Tjornbo, O., Enfors, E., Knapp, C., Hodbod, J., Baggio, J.A., Norström, A., Olsson, P., Biggs, D., 2014. Studying the complexity of change: toward an analytical framework for understanding deliberate social-ecological transformations. *Ecol. Soc.* 19 (4), 54.

Mouffe, C., 2013. *Agonistics: Thinking The World Politically.* Verso, London, New York.

Múnica, C., van Kerkhoff, L., 2019. Diversifying knowledge governance for climate adaptation in protected areas in Colombia. *Environ. Sci. Policy* 94, 39–48. <https://doi.org/10.1016/j.envsci.2019.01.004>.

Nel, J.L., Roux, D.J., Driver, A., Hill, L., Maherry, A.C., Snaddon, K., Petersen, C.R., Smith-Adao, L.B., Van Deventer, H., Reyers, B., 2016. Knowledge co-production and boundary work to promote implementation of conservation plans. *Conserv. Biol.* 30, 176–188. <https://doi.org/10.1111/cobi.12560>.

Norström, A.V., Cvitanovic, C., Löf, M.F., West, S., Wyborn, C., Balvanera, P., Bednarek, A.T., Bennett, E.M., Biggs, R., de Bremond, A., Campbell, B.M., Canadell, J.G., Carpenter, S.R., Folke, C., Fulton, E.A., Gaffney, O., Gelcich, S., Jouffray, J.-B., Leach, M., Le Tissier, M., Martín-López, B., Louder, E., Loutre, M.-F., Meadow, A.M., Nagendra, H., Payne, D., Peterson, G.D., Reyers, B., Scholes, R., Speranza, C.I., Spierenburg, M., Stafford-Smith, M., Tengö, M., van der Hel, S., van Putten, I., Österblom, H., 2020. Principles for knowledge co-production in sustainability research. *Nat. Sustain.* 3, 182–190. <https://doi.org/10.1038/s41893-019-0448-2>.

Olsson, P., Folke, C., Hahn, T., 2004. Social-ecological transformation for ecosystem management: the development of adaptive co-management of a wetland landscape in southern Sweden. *Ecol. Soc.* 9 <https://doi.org/10.5751/ES-00683-090402>.

Österblom, H., Jouffray, J.-B., Folke, C., Crona, B., Troell, M., Merrie, A., Rockström, J., 2015. Transnational corporations as 'keystone actors' in marine ecosystems. *PLoS ONE* 10, e0127533. <https://doi.org/10.1371/journal.pone.0127533>.

Österblom, H., Jouffray, J.-B., Folke, C., Rockström, J., 2017. Emergence of a global science-business initiative for ocean stewardship. *Proc. Natl. Acad. Sci.* 114, 9038–9043. 10.1073/pnas.1704453114.

Ott, C., Kitteme, B., 2016. Concepts and practices for the democratisation of knowledge generation in research partnerships for sustainable development. *Evid. Policy J. Res. Debate Pract.* 12, 405–430. <https://doi.org/10.1332-174426416X14700793045951>.

Page, G.G., Wise, R.M., Lindenfeld, L., Moug, P., Hodgson, A., Wyborn, C., Fazey, I., 2016. Co-designing transformation research: lessons learned from research on deliberate practices for transformation. *Curr. Opin. Environ. Sustain.* 20, 86–92. <https://doi.org/10.1016/j.cosust.2016.09.001>.

Pereira, L., Frantzeskaki, N., Hebinck, A., Charli-Joseph, L., Drimie, S., Dyer, M., Eakin, H., Galafassi, D., Karpouzoglou, T., Marshall, F., Moore, M.-L., Olsson, P., Siqueiros-García, J.M., van Zwanenberg, P., Vervoort, J.M., 2019. Transformative spaces in the making: key lessons from nine cases in the Global South. *Sustain. Sci.* 15, 161–178. <https://doi.org/10.1007/s11625-019-00749-x>.

Pielke, R., 2007. *The Honest Broker: Making Sense of Science in Policy and Politics.* Cambridge University Press.

Pohl, C., Rist, S., Zimmermann, A., Fry, P., Gurung, G.S., Schneider, F., Speranza, C.I., Kitteme, B., Boillat, S., Serrano, E., Hadorn, G.H., Wiesmann, U., 2010. Researchers' roles in knowledge co-production: experience from sustainability research in Kenya, Switzerland, Bolivia and Nepal. *Sci. Public Policy* 37, 267–281. <https://doi.org/10.3152/030234210X496628>.

Polk, M., 2015. Transdisciplinary co-production: designing and testing a transdisciplinary research framework for societal problem solving. *Futures* 65, 110–122. <https://doi.org/10.1016/j.futures.2014.11.001>.

Reed, G., Dagli, W., Odame, H.H., 2020. Co-production of knowledge for sustainability: an application of reflective practice in doctoral studies. *Reflective Pract.* 21, 222–236. <https://doi.org/10.1080/14623943.2020.1733954>.

Reid, R.S., Nkedianye, D., Said, M.Y., Kaelo, D., Neselle, M., Makui, O., Onetu, L., Kiruswa, S., Kamuaro, N.O., Kristjanson, P., Ongutu, J., BurnSilver, S.B., Goldman, M. J., Boone, R.B., Galvin, K.A., Dickson, N.M., Clark, W.C., 2016. Evolution of models to support community and policy action with science: balancing pastoral livelihoods and wildlife conservation in savannas of East Africa. *Proc. Natl. Acad. Sci. U. S. A.* 113, 4579–4584. <https://doi.org/10.1073/pnas.0900313110>.

Riechers, M., Henkel, W., Engbers, M., Fischer, J., 2019. Stories of favourite places in public spaces: emotional responses to landscape change. *Sustainability* 11, 3851. <https://doi.org/10.3390/su11143851>.

Rondeau, R., Bidwell, M., Neely, B., Rangwala, I., Yung, L., Wyborn, C., 2017. *Pinyon-Juniper Landscape: San Juan Basin, Colorado Social-Ecological Climate Resilience Project.* North Central Climate Science Center, Ft. Collins, Colorado.

Roux, D.J., Nel, J.L., Cundill, G., O'Farrell, P., Fabricius, C., 2017. Transdisciplinary research for systemic change: who to learn with, what to learn about and how to learn. *Sustain. Sci.* 12, 711–726. <https://doi.org/10.1007/s11625-017-0446-0>.

Ruizpalacios, B., Charli-Joseph, L., Eakin, H., Siqueiros-García, J.M., Manuel-Navarrete, D., Shelton, R., 2019. The Transformation Laboratory of the Social-Ecological System of Xochimilco, Mexico City: Description of the Process and Methodological Guide. *LANCIS-IE, UNAM, Mexico City, Mexico.*

Schneider, F., Giger, M., Harari, N., Moser, S., Oberlack, C., Providoli, I., Schmid, L., Tribaldos, T., Zimmermann, A., 2019. Transdisciplinary co-production of knowledge and sustainability transformations: three generic mechanisms of impact generation. *Environ. Sci. Policy* 102, 26–35. <https://doi.org/10.1016/j.envsci.2019.08.017>.

Scoones, I., Stirling, A., Abrol, D., Atela, J., Charli-Joseph, L., Eakin, H., Ely, A., Olsson, P., Pereira, L., Priya, R., van Zwanenberg, P., Yang, L., 2020. Transformations to sustainability: combining structural, systemic and enabling approaches. *Curr. Opin. Environ. Sustain.* <https://doi.org/10.1016/j.cosust.2019.12.004>.

Skrimizea, E., Lecuwe, L., Bunnefeld, N., Butler, J.R.A., Fickel, T., Hodgson, I., Holtkamp, C., Marzano, M., Parra, C., Pereira, L., Petit, S., Pound, D., Rodriguez Fernandez, I., Ryan, P., Staffler, J., Vanbergen, A.J., Van den Broeck, P., Wittmer, H., Young, J.C., 2020. Sustainable agriculture: recognizing the potential of conflict as a positive driver for transformative change. *Adv. Ecol. Res.* 255–311 <https://doi.org/10.1016/bs.aecr.2020.08.003>.

Steyaert, P., Jiggins, J., 2007. Governance of complex environmental situations through social learning: a synthesis of SLIM's lessons for research, policy and practice. *Environ. Sci. Policy* 10, 575–586. <https://doi.org/10.1016/j.envsci.2007.01.011>.

Stirling, A., 2008. "Opening Up" and "Closing Down": power, participation, and pluralism in the social appraisal of technology. *Sci. Technol. Hum. Values* 33, 262–294. <https://doi.org/10.1177/0162243907311265>.

Tengö, M., Brondizio, E.S., Elmquist, T., Malmer, P., Spierenburg, M., 2014. Connecting diverse knowledge systems for enhanced ecosystem governance: the multiple evidence base approach. *Ambio* 43, 579–591. <https://doi.org/10.1007/s13280-014-0501-3>.

Tengö, M., Hill, R., Malmer, P., Raymond, C.M., Spierenburg, M., Danielsen, F., Elmquist, T., Folke, C., 2017. Weaving knowledge systems in IPBES, CBD and beyond—lessons learned for sustainability. *Curr. Opin. Environ. Sustain.* 26–27, 17–25. <https://doi.org/10.1016/j.cosust.2016.12.005>.

Termeer, C.J.A.M., Dewulf, A., 2019. A small wins framework to overcome the evaluation paradox of governing wicked problems. *Policy Soc.* 38, 298–314. <https://doi.org/10.1080/14494035.2018.1497933>.

Turnhout, E., Metze, T., Wyborn, C., Klenk, N., Louder, E., 2020. The politics of co-production: participation, power, and transformation. *Curr. Opin. Environ. Sustain.* 42, 15–21. <https://doi.org/10.1016/j.cosust.2019.11.009>.

Turnhout, E., Stuiver, M., Klostermann, J., Harms, B., Leeuwis, C., 2013. New roles of science in society: different repertoires of knowledge brokering. *Sci. Public Policy* 40, 354–365. <https://doi.org/10.1093/scipol/scs114>.

van der Hel, S., 2016. New science for global sustainability? The institutionalisation of knowledge co-production in Future Earth. *Environ. Sci. Policy* 61, 165–175. <https://doi.org/10.1016/j.envsci.2016.03.012>.

van Kerkhoff, L., Munera, C., Dudley, N., Guevara, O., Wyborn, C., Figueroa, C., Dunlop, M., Hoyos, M.A., Castiblanco, J., Becerra, L., 2019. Towards future-oriented conservation: managing protected areas in an era of climate change. *Ambio* 48, 699–713. <https://doi.org/10.1007/s13280-018-1121-0>.

van Kerkhoff, L., Pilbeam, V., 2017. Understanding socio-cultural dimensions of environmental decision-making: a knowledge governance approach. *Environ. Sci. Policy* 73, 29–37. <https://doi.org/10.1016/j.envsci.2017.03.011>.

van Kerkhoff, L.E., Lebel, L., 2015. Coproductive capacities: rethinking science-governance relations in a diverse world. *Ecol. Soc.* 20.

Vardy, M., 2020. Relational agility: visualizing near-real-time Arctic sea ice data as a proxy for climate change. *Soc. Stud. Sci.* 50, 802–820. <https://doi.org/10.1177/0306312720906532>.

Vincent, K., Carter, S., Steynor, A., Visman, E., Wågsæther, K.L., 2020. Addressing power imbalances in co-production. *Nat. Clim. Change* 10, 877–878. <https://doi.org/10.1038/s41558-020-00910-w>.

Virah-Sawmy, M., Durán, A.P., Green, J.M.H., Guerrero, A.M., Biggs, D., West, C.D., 2019. Sustainability gridlock in a global agricultural commodity chain: reframing the soy–meat food system. *Sustain. Prod. Consum.* 18, 210–223. <https://doi.org/10.1016/j.spc.2019.01.003>.

Walter, A.-T., 2020. Organizational agility: ill-defined and somewhat confusing? A systematic literature review and conceptualization. *Manag. Rev. Q.* 10.1007/s11301-020-00186-6.

Westley, F., Olsson, P., Folke, C., Homer-Dixon, T., Vredenburg, H., Loorbach, D., Thompson, J., Nilsson, M., Lambin, E., Sendzimir, J., Banerjee, B., Galaz, V., van der Leeuw, S., 2011. Tipping toward sustainability: emerging pathways of transformation. *AMBIO* 40, 762. <https://doi.org/10.1007/s13280-011-0186-9>.

Westley, F., Tjörnbo, O., Schultz, L., Olsson, P., Folke, C., Crona, B., Bodin, Ö., 2013. A theory of transformative agency in linked social-ecological systems. *Ecol. Soc.* 18, 10.5751/ES-05072-180327.

Wyborn, C., Datta, A., Montana, J., Ryan, M., Leith, P., Chaffin, B., Miller, C., van Kerkhoff, L., 2019. Co-producing sustainability: reordering the governance of science, policy, and practice. *Annu. Rev. Environ. Resour.* 44, 319–346. <https://doi.org/10.1146/annurev-environ-101718-033103>.

Zheng, Y., Venters, W., Cornford, T., 2011. Collective agility, paradox and organizational improvisation: the development of a particle physics grid. *Inf. Syst. J.* 21, 303–333. <https://doi.org/10.1111/j.1365-2575.2010.00360.x>.