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Co-productive agility and four collaborative pathways to sustainability transformations

Abstract

Research and practice are increasingly co-produced to facilitate 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 attempt to address a range of social-ecological sustainability challenges, 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. We suggest that this tendency to 'close down' rather than 'open up' agendas is related the standards of 'success' that researchers and practitioners are held accountable to.

Key words: co-production, transformative processes, social-ecological sustainability, tensions, power relations, impact

1. Introduction

'Co-production'[1] and 'transformation'[2] have gained momentum in sustainability science and practice. While co-production efforts seek to generate interlinked knowledge and action more capable of resolving complex social-ecological problems (Mauser et al. 2013; Wyborn et al. 2019; Knapp et al. 2019), the increasing focus on transformation pushes initiatives to consider what actions are needed to fundamentally address widespread societal challenges (Abson et al. 2017; Bennett et al. 2019; Scoones et al. 2020). 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 (Mitlin 2008; Leach et al. 2012; Page et al. 2016; Klenk et al. 2017; Bennett et al. 2019; 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 & Meadow 2018). However, this may overlook important *differences among aims* and the relative *transformative potential* of different approaches (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 (Olsson et al. 2004; Lang et al. 2012). Scholars increasingly distinguish between types and subprocesses of sustainability transformations (Leach et al. 2012; Westley et al. 2013; Moore et al. 2014; Scoones et al. 2020), and the role of different types of co-production processes ([redacted] et al. under review; Pereira et al. 2019; Schneider et al. 2019). However, normative principles and practical guidance are often framed in generic terms (Moore et al. 2014; Norström et al. 2020). There is scant empirically derived guidance on the tensions faced in *different* types of co-production processes seeking transformation, and how they can be navigated in ways that address conflicts and power struggles.

Much attention has been given to 'scaling up' or 'out' by identifying and replicating transformative frames and approaches in new locations (Westley et al. 2011; Moore et al. 2014; Termeer & Dewulf 2019). Yet, any bottom-up transformation process is likely to encounter active resistance by those with power (Avelino & Rotmans 2009). There is limited understanding of how to work within and across scales to break down

[1] "Processes that iteratively unite ways of knowing and acting – including ideas, norms, practices, and discourses – leading to mutual reinforcement and reciprocal transformation of societal [including environmental] outcomes" (Wyborn et al. 2019 p. 320).

[2] "A fundamental, system-wide reorganization across technological, economic and social factors, including paradigms, goals and values" (IPBES 2019 p. 14).

resistance, such as by 'scaling deep' (i.e. "changing values and mindsets"; Lam et al. 2020 p. 2). Various studies 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 & Meehan 2015). Finally, there are growing concerns over the privileged role that scientific researchers often hold over other actors in co-production processes ([redacted] et al. under review; Moore et al. 2014; Polk 2015; Klenk 2018; Knapp et al. 2019). This has sparked efforts to foster transformative processes that balance the power of different roles 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 have navigated tensions among perspectives in ways that can 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 ([redacted] et al. under review), we demonstrate that the potential of co-production to transform paradigms, practices, *and* institutions depends on fostering 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. 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 practices.

Our paper is structured as follows. First, we develop and operationalize the concept of 'co-productive agility', drawing upon literature from various fields. We then provide a brief overview of our 32 cases and explain our methodological approach. This is followed by our empirical results. In section 4, we present critical tensions that emerged in our cases. The next section demonstrates how avoiding or exacerbating these tensions can in some cases hinder transformation (i.e. 'co-productive rigidity'). Following this, we share 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 different 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 (Stirling 2008). Fostering co-productive agility in these pathways 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 collaborative transformation processes, from setting the project boundaries to iteratively tracking changes. We conclude by exploring how the four identified pathways can connect in synergistic ways, and examine how and why research and practice can hinder rather than enable co-productive agility.

2. Operationalizing 'agility' in collaborative transformations

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 critical leverage for social learning and transformation (Maclean et al. 2015; Cockburn et al. 2018; Skrimizea et al. 2020). Other studies have shown 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, such as through concepts like 'collective agility' (Zheng et al. 2011), 'integrative ambidexterity' (Andriopoulos & Lewis 2008), and 'organizational improvisation' (Hadida et al. 2015). These concepts seek to move beyond a 'defensive' approach 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 & 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 & 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 & 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) tension between the individual and the collective requires collaborative forms of leadership that can take people on collective journeys that reveal what matters to whom, as opposed to activities that presuppose fixed stakes (Klenk & Meehan 2017; Steyaert & 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, unsustainable 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. Dumrongrojwatthana & Trébuil 2011; Haller & Merten 2018), (trans)national learning networks (e.g. Steyaert & 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.

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3.2. Data collection and analysis

All 32 cases were extensively implemented and/or researched by at least one of the 42 co-authors of this paper. Following an information-oriented, maximum variation approach to sampling, these cases were selected to assemble a set of cases that maximized diversity in types of co-production practice, scalar engagement, and geographical locations (Flyvbjerg 2006). First, eight diverse cases were selected through two exploratory workshops in the United States and Mexico. They were then supplemented by a search process in Google Scholar which paired 10 variants of the term 'social-ecological 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 to examine the emergence and navigation of tensions, 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, the lead author ([redacted]) interviewed a leading researcher/practitioner in each case and analyzed a mean of six documents/publications per case. While the lead author conducted all initial analyses (for independence), case contributors (also co-authors) iteratively interrogated emerging concepts and validated interpretations.

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 used to gather case data on varying co-production rationales and challenges. Based on an initial analysis of this data, we refined these categories, and then conducted a systematic analysis of how all 32 cases varied for each identified

rationale. Further analysis of the relative expression of different rationales within and across cases revealed that some cases expressed strong tensions between rationales, while others fostered complementarities – which we found to be linked to improved navigation of challenges and the emergence of more transformative aims and outcomes[3]. Our analysis also revealed that particular rationales were linked to distinct pathways to transformation. For each of four pathways, we subsequently 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.

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 the struggle between using co-production to advance desired solutions (justified by rationales such as 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 – *"who decides why/how to pursue transformation?"* – entailed struggles over who holds power to influence co-production decisions, such as whether particular solutions are questioned or pursued, and how different actors are involved. In particular, there existed a tension between initiators maintaining power (justified by rationales such as controlling outcomes and achieving consensus) versus yielding power to participants (based on rationales such as engendering humility, inclusivity, 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 managed to transcend these dual tensions by articulating rationales for their interdependency, such as by showing how prioritizing process could further transformative impacts. Table 3 spotlights how an agile approach to managing these tensions (i.e. neither suppressing nor romanticizing the agendas of different actors involved) enabled the transformation of sustainability paradigms and practices; for example, in fostering co-management possibilities amidst a marine protected area dispute in Scotland (Brennan 2018), cutting across silos to conserve rivers and wetlands of South Africa (Nel et al. 2016), connecting Indigenous and scientific knowledge systems in global biodiversity assessments (Tengö et al. 2017), and restoring a degraded river along the Israel-Palestine border (Brandeis 2005).

[3] In our companion piece ([redacted] et al. under review), we present the methods which empirically show a positive relation between iteratively navigating tensions and more transformative aims and outcomes.

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5. Co-productive rigidity: avoiding or exacerbating tensions

Our analysis revealed four main ways in which avoiding 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" hero vs. host roles[4] (Frieze & Wheatley 2011), and distinct roles of science in society (Pielke 2007; Turnhout et al. 2013).

The "hero" archetype represents how some co-production initiators 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 particular set of values or expertise often struggled to engage actors with alternative views who were not interested in operating within the project's dominant frame. In some cases, this led to increased polarization 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 weak control by co-production initiators could hinder transformation by avoiding tensions. For example, the "genie" archetype represents how some project initiators 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, it also limited the ability to *challenge* and *change* agendas with existing priority, and to productively navigate tensions among groups supporting different priorities. 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, they struggled to connect this

[4] As indicated on the website (https://www.artofhosting.org/), The Art of Hosting is "an approach to leadership that scales up from the personal to the systemic using personal practice, dialogue, facilitation and the co-creation of innovation to address complex challenges". The approach supports people to shift from heroic forms of leadership to facilitative forms of leadership they call "hosts" – i.e. "calling together people from all parts of the system to work together to solve seemingly intractable problems" (Frieze & Wheatley 2011 p. 1).

to tangible changes in practice due to less focus on action and little engagement (and thus avoided tensions) with external actors positioned against desired changes. The "host" role (also outlined in Frieze & 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).

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). A common factor behind co-productive rigidity across all roles was a separation between knowledge- and action-making processes, as this hindered the ability to diversify notions of problems and relevant expertise, and generate reflexive practices and relations. In some cases, actors explicitly sought to develop this agility, yet broader contextual issues presented barriers to taking such an approach.

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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 identify and develop more transformative actions over time. Our study found 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 relatively greater degree of control by participants in transformation processes than the other two pathways.

We identified six processes that foster co-productive agility, which are navigated differently within each pathway: 1) *setting boundaries* of 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 implications of approaches (Fig. 3). These six processes pull together different aspects of other

frameworks which have emerged to support transformation (e.g. Moore et al. 2014; Hermans et al. 2016; Fuller Transformation Collaborative 2019; Scoones et al. 2020). Below, we share specific considerations, practices, and methods that were 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 them 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.

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6.1. Elevating marginalized agendas for change

Elevating marginalized agendas involves being responsive to 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 & 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 & Dearden 2014). It was therefore critical to question: who decides ***what agendas are unjustly "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 to inform and shape decisions that impact their lives.

These cases ***cultivated spaces of humility to build trust****,* where all actors could both contribute to and question knowledge, with no one group framed as the "expert". For example, a collaboration between Indigenous peoples and climate researchers in central Australia 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 (Hill et al. 2020). Such navigation required facilitators experienced in both Indigenous and scientific cultures to avoid disempowering discourses or actions, such as "building capacity", which assumes the "other" "needs" your knowledge. It was therefore crucial that scientists were held directly accountable to how they might impose their knowledge and interests on societal groups, and that the emphasis was on growing genuine partnerships rooted in mutual trust and humility.

Over time, some cases sought to ***broaden struggles for justice****,* recognizing that the initial goals of partnerships that focus 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 there was a 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 keeping the colonized in a position of subordination, 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*). Similarly, another case broadened environmental agendas within government policies by reframing views that separated water and land ecosystems to a broader frame that recognizes their fundamental interconnections (Nel et al. 2016).

Having initiated processes, ***expanding legitimacy in spaces of power*** helped efforts gain political traction. For example, the collaborative process described in Tengö et al. (2017) 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 the creation of high-level fora with contributions from different kinds of experts (Tengö et al. 2014, 2017). Boundary organizations (such as International Indigenous and Local Knowledge) played a vital role for connecting the legitimacy of Indigenous organizations with science-policy platforms. In East Africa, Reid et al. (2016) created a similar boundary organization (Reto-o-Reto Foundation) to connect pastoral communities to national policy processes. Such boundary organizations strengthened links between research and societal impact, yet also posed unique challenges to the positionality of science, such as instances where community groups and policy-makers sought to wield scientific information as an instrument of power. Fostering relations of trust and multiple communication pathways was crucial for navigating 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), this required asking: what happens to different kinds of knowledge when they come together? Tengö et al. (2017) advocate for considering how knowledge systems are 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. Similarly, in East Africa, Reid et al. (2016) showed how boundary organizations can support continual engagement across knowledge systems over 20+ years, rooted in relations of trust. 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 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 management and use upfront to diffuse future tensions around data integrity and accessibility (*ibid*).

Finally, ***examining what elevated agendas do*** facilitated learning and improvement. Here, project leaders found that it was critical to focus on process and not just outputs, such as focusing on the role of boundary

objects to facilitate new types of collective meaning and actions (cf. Diver 2017). Impacts took on many forms. For example, cases supported community members and scientists from disadvantaged backgrounds to pursue careers in science and policy (Cockburn et al. 2016; Reid et al. 2016; Fernández-Giménez et al. 2019), catalyzed new management actions (Cockburn et al. 2016; Reid et al. 2016; Hill et al. 2020), and also supported community dialogue with government actors to challenge broader narratives and policies (Reid et al. 2016; Fernández-Giménez et al. 2019; Malmer et al. 2019). One initiative 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 discuss and address 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 (Reid et al. 2016; Tengö et al. 2017; Fernández-Giménez et al. 2019).

6.2. Questioning dominant agendas for change

By ***questioning dominant agendas***, projects sought to deeply engage with powerful actors who hold stakes in dominant systems to question and challenge their positions of 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 (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 also produce common goods (Österblom et al. 2017; Christie et al. 2017). For example, Österblom et al. (2015) began such work by identifying "keystone actors" that disproportionately influence global marine ecosystems. 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*** – spaces 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 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). A global dialogue platform for ocean stewardship (Keystone Dialogues) cultivated a legitimate space for companies to understand and engage in 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; Österblom et al. 2017; Christie et al. 2017). Cases with polarized conflict required a strong reason for collaboration, such as a mutual desire to restore a degraded river that impacted

everyone (Brandeis 2005). Failing to develop a shared legitimate purpose of learning could lead to certain actors attempting to co-opt the process over time to serve their vested interests (Brandt et al. 2018).

These cases sought to ***foster frame visibility and reflexivity*** by focusing participants on a higher common purpose. For example, the Keystone Dialogues began with an inspirational speech by Her Royal Highness Crown Princess Victoria of Sweden that legitimized a set of 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, participatory games enabled actors to directly experience and discuss the many ways strategies were failing, prompting discussion about how to address contradictions between assumptions and practices.

Critically, various initiatives ***strengthened broader 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, 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 to push for policy outcomes that could undermine the process. Some projects developed outputs which proved useful for gaining policy influence at a later date when the institutional context became more supportive, such as an internationally co-produced "Code of Conduct for Marine Conservation" (Bennett et al. 2017).

Many initiatives fell short in ***developing pathways 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 case 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 (Österblom et al. 2017; Christie et al. 2017; Brandt et al. 2018; 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 played an important role 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 can 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, Haller & Merten (2010) examined the dynamics that eroded local fishery management systems to the detriment of river health and community livelihoods in the Kafue Flats, Zambia. 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. Virah-Sawmy et al. 2019; Guerrero et al. 2021), 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 between actors, 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 walk a line in between different agendas to find ways of opening up space for different narratives to emerge (Haller & Merten 2018; Brennan 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 recognition of different groups upfront, as well as the role of 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, Haller et al. (2016) developed a "constitutionality" approach by examining how institution-building processes can foster local ownership. 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 & Merten 2018). Several cases used creative methods to surface the voices of more marginalized groups; for example, by mapping stories, songs and art that expressed local cultural values for the sea (Brennan 2018), or using companion modeling to foster co-learning over actors' understandings of systems and management scenarios (Dumrongrojwatthana & Trébuil 2011). It was critical to wait until relatively marginalized stakeholders 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 & Jiggins 2007). In cases where powerful economic interests and private property rights reinforced existing stakes, such as Chasseral Regional Nature Park (RNP), 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 & 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 & Trébuil 2011), changes in park leadership resulted in a fortress approach that blocked co-management possibilities. In the Chasseral RNP case, 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 evolving co-management process in Scotland convinced policy actors to support a genuinely bottom-up approach where ongoing dialogue enabled government officials to genuinely understand the expertise, drive 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 & 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 used reflective meetings and external project reviews to inform ongoing project directions (Steyaert & Jiggins 2007). These cases fundamentally transformed how stakeholders interacted, including their perceptions of each other, the nature of conflicts, and the opportunities to constructively move forward to co-create more just relations that are embedded in new institutional forms and policies designed to sustain them. All cases recognized, however, that these processes never reach a final state of resolution and require ongoing hard work to ensure usefulness and foster ownership for all actors involved.

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 & 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) brought together change agents to foster collective agency within the Xochimilco Social-Ecological System (Mexico), while the Fire Adapted Communities Learning Network (FAC Net) joined U.S. wildfire practitioners to share lessons and improve practice (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 a top-down approach to network building. 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, 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 (Charli-Joseph et al. 2018) engaged those who both depended on the wetland and had a real 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. The 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 (Steyaert & Jiggins 2007) deliberatively avoided matching case comparisons or statistical analysis, as this would have limited their potential to build a reflexive and emergent process.

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 (Steyaert & Jiggins 2007; Goldstein et al. 2018). Reflexivity was essential to ensure that academics did not become too dominant, 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, 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 meet and discuss joint strategies, while at the same time building an understanding that they might actually share 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 different 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 & 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 social-ecological sustainability.* 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, 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.

While there is transformative potential in co-productive agility, there are also critical barriers to fostering it. Challenges emerged, for example, when people used co-production to empower their own agendas, rather than creating space to discuss 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. Thus, research and practice may spend too much time empowering and debating *which* agenda for change is best, and too little time considering *how to facilitate better interactions among different agendas*. A 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 to, and pressure to show immediate tangible outcomes (Edmunds & Wollenberg 2001; Klenk & Meehan 2017; Cockburn et al. 2019). 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 (e.g. Haller & Merten 2018; Österblom et al. 2017).

These challenges raise the question: *how can co-productively 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. Other fields, such as that of design and systems theory, have already begun to explore what this kind of societal transformation design leadership 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". An important aspect is to consider how existing knowledge (and other) governance models might facilitate or hinder embedding researchers into practice (van Kerkhoff & Pilbeam 2017; Múnera & van Kerkhoff 2019). 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 (Cockburn et al. 2018; Arnott et al. 2020).

We have created a space and structure to further study and understand 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, 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 pathways may support more productive efforts to navigate conflicting frames, even amidst polarized disputes (e.g. Brennan 2018). Learning networks and processes may also play a central role in supporting all pathways towards transformation (e.g. Steyaert & 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 (Mitchell et al. 2015).

The co-production efforts we examined disproportionately sought to elevate marginalized agendas to pursue change, yet what is 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 better understand marginalized actors' experiences of these tensions – 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.

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Figure 1

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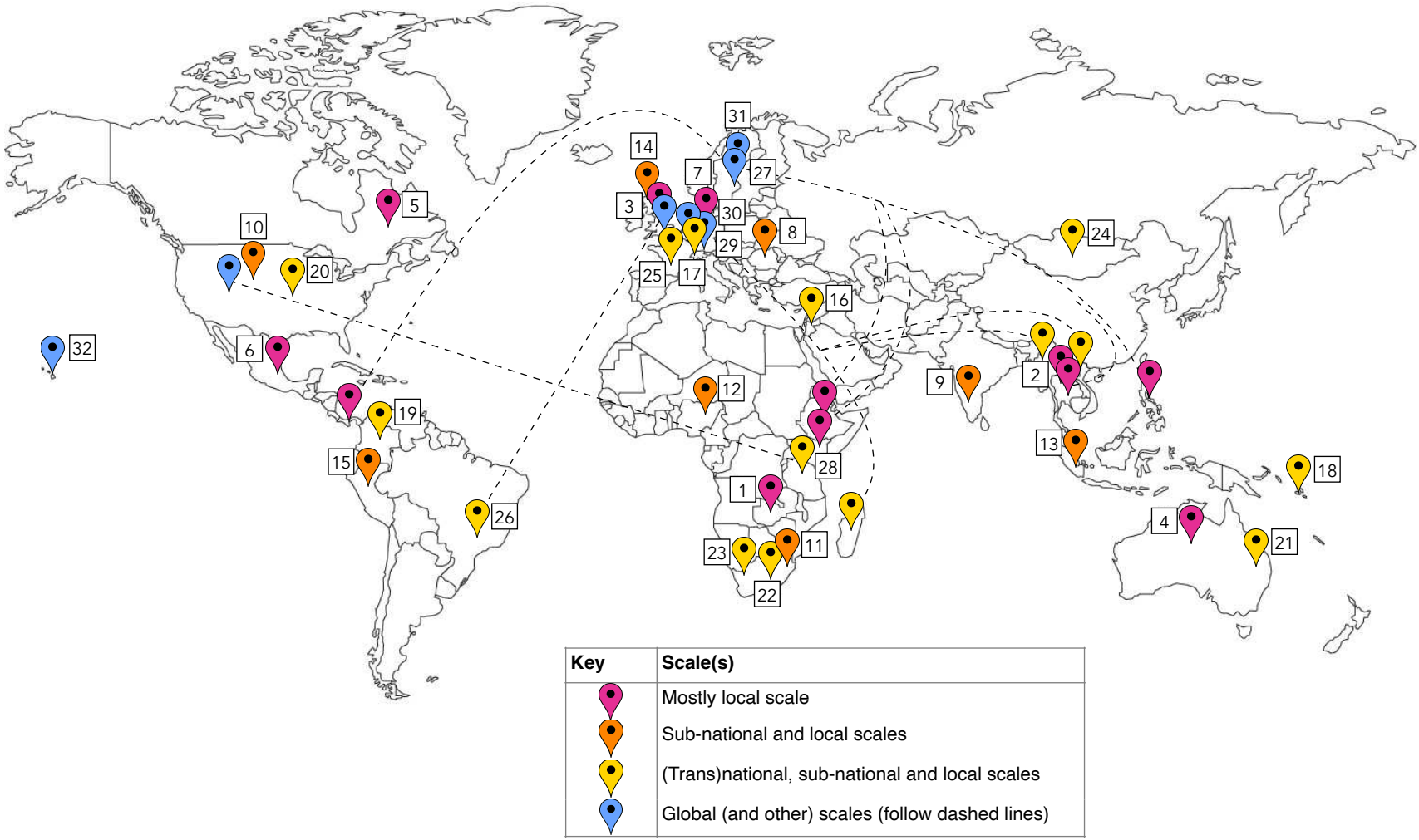

Figure 1. Case study locations. The map shows the locations where the co-production work took place, and the key indicates at what scale(s). Case details are available in Table 1, with the same case IDs. See section 3 for details on the case selection process.

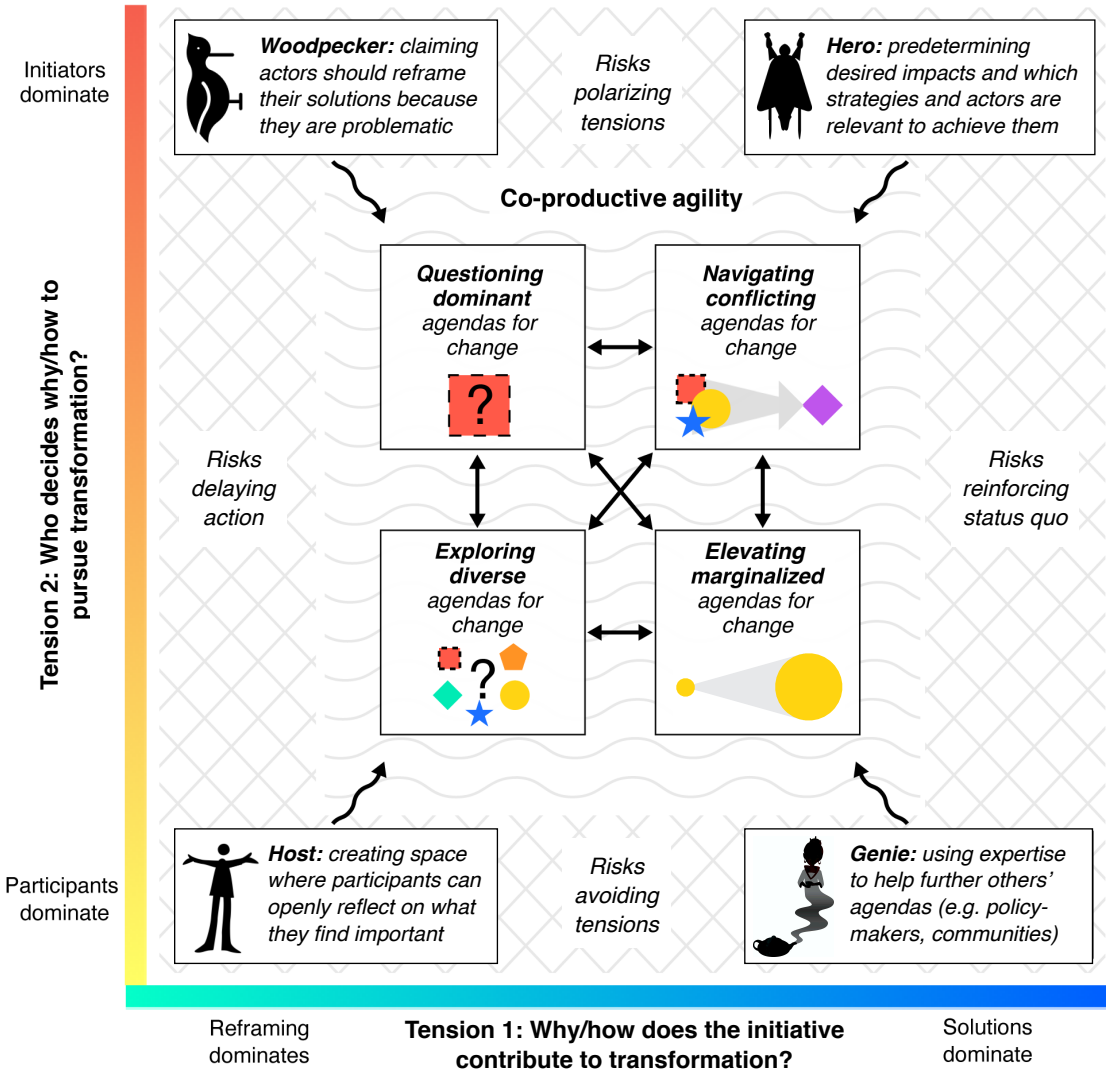

Figure 2. Four complementary pathways towards sustainability transformations
Co-productive agility supports initiatives to move beyond the limitations associated with more binary approaches to managing these tensions (four archetypal roles/processes in the corner boxes: Woodpecker; Hero; Host; Genie) 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 gives initiators of reframing slightly greater control. These four pathways do not neatly follow the four categories outlined in Tables 2 and 3, and rather use multiple approaches to balancing power and connecting process and impact.

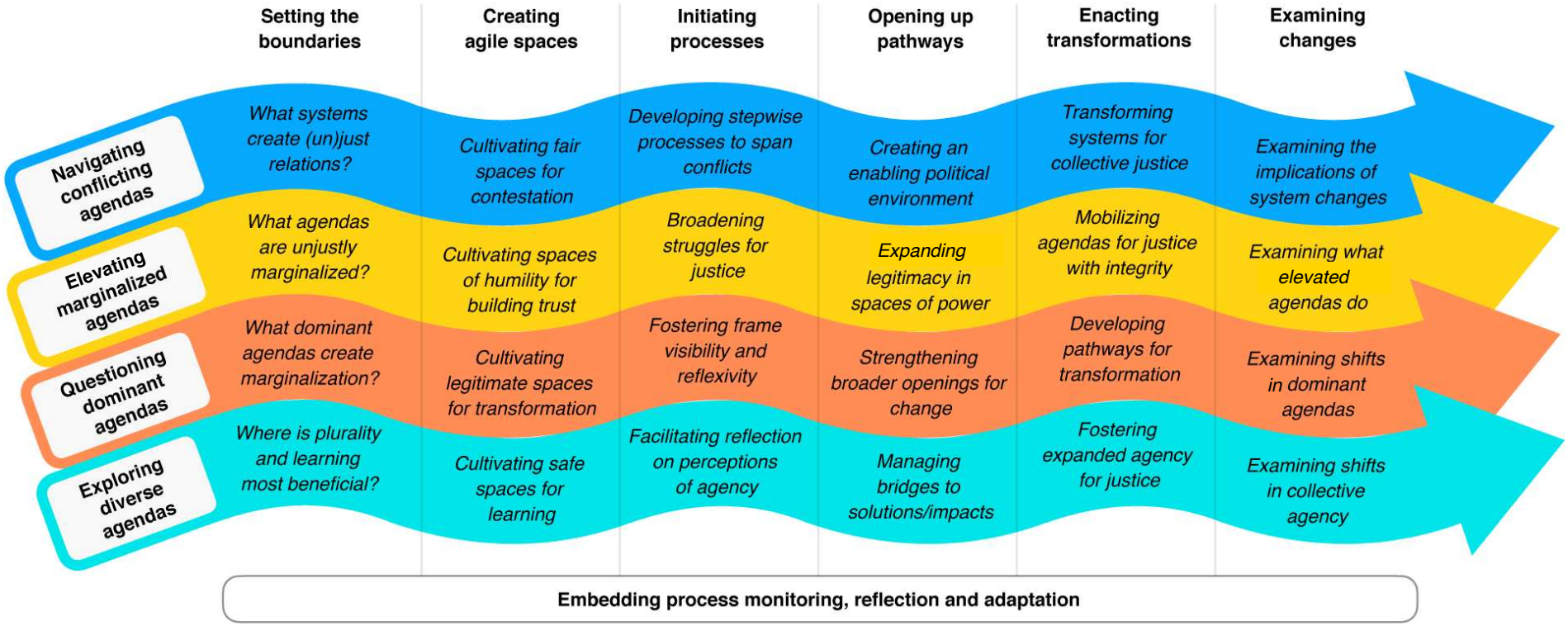

Figure 3. Critical processes to foster co-productive agility in each of the four pathways to sustainability transformations. The lower positioned pathways may especially help enable higher positioned pathways, yet can be more difficult to justify funding due to less emphasis on direct impact.

Table 1. Overview of the 32 case studies. Case ID numbers are associated with the map 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	[redacted] Haller & 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	[redacted] Dumrongrojwatthana et al. (2017); Dumrongrojwatthana et al. (2011); Dumrongrojwatthana & 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	[redacted] Case website (accessed 2020); 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	[redacted] Hill et al. (2020); Hill et al. (2015); Co-produced book: 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	[redacted] 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)
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	[redacted] Case overview (2016); Case video (2019); Charli-Joseph et al. (2018); Eakin et al. (2019); Methodological guide: Ruizpalacios, Charli-Joseph 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)	[redacted] Riechers et al. (2019)
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	[redacted] Case website (accessed 2020); Green book: Fisher, Horcea-Milcu et al. (2019); Lam, Horcea-Milcu et al. (2019)
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	[redacted] Serban (2018)
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	[redacted] Case website (accessed 2020)
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	[redacted] Cockburn et al. (2016); Taylor, Cockburn et al. (2016)
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	[redacted] Management report available upon request (contact)

ID	Case title	Dates	Main aim	Case contributor(s)* & links
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	[redacted] Leimona et al. (2015)
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 seascape	[redacted] Brennan (2018a; 2018b); Cultural map (accessed 2020)
15	Transforming 'win-win' conservation and development theory and practice in northeast Peru	2014 - 2019	To explore dominant approaches to joint conservation and development, explore their implications, and shape discourse and practice	[redacted] Chambers et al. (2019); Chambers (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	[redacted] Case website (accessed 2020); Brandeis (2005); Press release (2005)
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 governement	[redacted] Gerber (2018); Case website (accessed 2020)
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	[redacted] Cvitanovic et al. (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	[redacted] Case overview (accessed 2020); Múnera & van Kerkhoff (2019); van Kerkhoff, Múnera et al. (2019)
20	The Fire Adapted Community Learning Network (FAC-NET)	2013 - pres.	To enhance fire-adaptation capacity at multiple scales through a learning network	[redacted] Case website (accessed 2020); The Nature Conservancy (2016)
21	eWater Cooperative Research Centre in Australia (Source Catchments)	2005 - 2012	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	[redacted] Case website (accessed 2020); 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	[redacted] 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	[redacted] Case overview (accessed 2020); Roux, Nel et al. (2017); Nel et al. (2015); Roux, Nel et al. (2015)

ID	Case title	Dates	Main aim	Case contributor(s)* & links
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	[redacted] 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	[redacted] Steyaert & Jiggens (2007); Ison et al. (2007); Collins et al. (2007); Final report: 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	[redacted] Case overview (accessed 2020); Final report: 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	[redacted] Case website (accessed 2020); 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	[redacted] Reid et al. (2016); Galvin, Reid et al. (2016); Galvin et al. (2018); Case video (2011)
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	[redacted] Case website (accessed 2020); 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	[redacted] Case website (accessed 2020); 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	[redacted] Case website (accessed 2020); Case goals (2020); 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)	[redacted] Christie, Bennett et al. (2017); Bennet et al. (2017); Gray, Bennett et al. (2017)

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

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.

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

	Impact hinders process	Process leads to impacts	Impacts helped by process	Process hinders impact
Description	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
Rationales	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
Example	"*Early on participants agreed that success would be defined through process issues rather than tangible outcomes... this reduced different pressures and expectations.*"	"*It was about initiating and managing arenas better adapted to problem formulation to search for the emergence of change rather than prescribing it.*"	"*Interventions that reconcile stakeholders' goals are less vulnerable to failure and carry less risks of being rejected or deterred post implementation.*"	"*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.*"

Tension 2: Who decides why/how to pursue transformation? Control vs. Release

	Participants drive agenda	Participants are facilitated	Initiators guide process	Initiators drive agenda
Description	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
Rationales	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
Example	"*The framing of transformation as a matter of amplifying and complementing existing efforts keeps the agenda of change in the hands of local people.*"	"*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.*"	"*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.*"	"*It was really led by the scientists saying, this is what you guys really need to know... I think if you can't agree on what the questions are, you've just got to walk away.*"

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
The initiative "Probing the cultural depths of a nature conservation conflict in the Outer Hebrides, Scotland", contributed by [redacted] 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 [redacted] 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.	The initiative "Knowledge co-production and boundary work to promote implementation of conservation plans", contributed by [redacted] 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.

Tension 2: Who decides why/how to pursue transformation? Control vs. Release

Participants are facilitated	Initiators guide process
The initiative "Connecting diverse knowledge systems at multiple scales in IPBES assessments and related science-policy contexts", contributed by [redacted], 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.	The initiative "Alexander River Restoration Project", contributed by [redacted] brought Israeli and Palestine restorationists, engineers and officials together to engage the public to restore the heavily polluted cross- border Alexander River (Brandeis 2005). [redacted] 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, [redacted] 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.