



# Ecologies of co-production in the Anthropocene

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## Abstract

The urgency, uncertainty and unevenness of the Anthropocene has foregrounded the spatial and temporal multiplicity of co-production between science and society. In this article, we draw together work in geography, science and technology studies and cognate disciplines concerned with ‘co-producing’ knowledge for environmental governance, and with the ‘co-production’ of science and politics. Yet these existing studies and approaches have tended to focus on discrete moments of co-production within bounded time-spaces. Building on work associated with ecologies of participation and geographies of science, we introduce the notion of ‘ecologies of co-production’ as a way to more faithfully attend to multiple co-existing co-productions and the interrelations between them. We define this as diverse interrelating practices and spaces of co-production which intermingle and are co-produced with(in) wider systems and political cultures in which they are situated. We set out how this opens up new ways of thinking about and attending to the *spaces and interrelations, diversities and exclusions, histories and constitutions, and responsibilities and affects* of co-productions between science and society in the Anthropocene. We suggest that this approach can make a difference in how we do co-production, how we analyse co-production and how we live, act and figure in an Anthropocene world.

## Keywords

Co-production, Anthropocene, ecologies of co-production, environmental knowledge, relational geography

## 1. Introduction

The heralding of the Anthropocene has stimulated a range of new thinking on the ontological foundations of geographical thought. While scholars may be divided on questions of whether the Anthropocene either re-inscribes or finally dissolves dualisms such as nature/culture and environment/society, a widespread relational ontology prompts new thinking on the interrelations between science/society and science/politics.

The apparent urgency, uncertainty and unevenness of the transformations associated with the Anthropocene have led a number of scholars to rethink how knowledge systems, and their connections to political systems,

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might be redesigned to meet the challenges of this putative new epoch (Beck 2019; Castree 2014; Castree et al. 2014; Lövbrand et al. 2015; Guldi 2021). One prominent proposal for meeting the challenge of environmental knowledge production in the Anthropocene is *co-production* – a heterodox set of proposals to diversify the kinds of actors permitted to engage in socially and politically relevant knowledge production (Lemos et al. 2018; Zurba et al. 2022). There is an intentionality in this form of co-production to bring science and society – which are thought to be distinct arenas – together to co-produce knowledge or other things (e.g., Future Earth). There is an emphasis, as we illustrate throughout the article, to do co-production in particular settings for particular ends, in discrete ways. The focus on ‘doing’ co-production procedurally often prescribes best practice ideals for doing co-production, in what arenas and with what actors focus on (Bremer and Meisch 2017; Djenontin and Meadow 2018; Lemos et al. 2018; Turnhout et al. 2020).

Another dominant form of co-production refers to a bundle of theoretical approaches to understanding the mutual constitution of science, technology and society (e.g., Latour 1991; Jasanoff and Wynne 1998; Jasanoff 2004) that can be productive for understanding the relations between science and society in the Anthropocene (Bonneuil and Fressoz 2016). The intentionality behind this form is to ‘study’ and analyse co-production as it plays out in our past and present, and to better understand how science and society are made in practice. This approach, unlike the former, is normatively agnostic with no *a priori* assumption of what is or can be co-produced, nor about prescribing best practice approaches. There is potential for this form of co-production to attend to the multiplicity of co-productions in the Anthropocene. However, how it has been taken up previously demonstrates how scholars have studied discrete moments associated with the co-production of science and society (see

Miller 2004; Mahony and Hulme 2016; Selcer 2018).

We are now seeing increasing attempts to study ‘doing’ co-production through an analytical co-productionist lens (van der Hel 2016; Miller and Wyborn 2018; Beck 2019; Montana 2019; Brix, Krogstrup and Mortensen 2020). Yet, even these studies attempting to bring the two dominant models of co-production together remain focused on discrete and specific institutions or moments of co-production. For instance, Beck’s (2019) analysis of the co-production of Future Earth focuses on a particular institution with specific intentions, aims and procedures without looking more broadly at the multiple co-productions across diverse spaces, interrelations, or historical constitutions associated with the wider system of transnational environmental organisations and governance (e.g., the Intergovernmental Panel on Climate Change [IPCC], Intergovernmental Panel on Biodiversity and Ecosystem Services [IPBES]).

In this article, we take seriously the notion that everything is co-produced. As such, we argue that most existing work on co-production operates *within* discrete and bounded time-spaces focusing on individual moments of co-production. We argue that the persistent focus on discrete time-spaces of co-production misses, excludes, or underplays the importance of ongoing interrelations *between* spaces of co-production in wider systems and temporalities associated with the multiple challenges and opportunities brought forward by the Anthropocene. Building on work associated with ‘ecologies of participation’ (Chilvers, Pallett and Hargreaves 2018) and ‘epistemic geography’ sensibilities (Mahony and Hulme 2018), we propose an ‘ecologies of co-production’ approach to recognise the diverse interrelating practices and spaces of co-production which intermingle and are co-produced with(in) wider systems and political cultures in which they are situated.<sup>1</sup>

In developing this approach, through reviewing literature in geography, science and technology

studies (STS) and other cognate disciplines, we go on to illustrate that attending to the interrelations of co-production can make a difference in how we intervene and do co-production, how we study and analyse co-production and how we live, act and figure in an Anthropocene world. In doing so, we contend that not only will scholars and practitioners who attempt to do co-productionist interventions get a different sense of how to do co-production ‘better’; we propose that attending to ecologies of co-production involves cultivating new responsibilities for the *effects* both of doing and studying co-productions that are often primarily focused within discrete and bounded time-spaces.

Ultimately, we seek to answer the question: what difference does it make, analytically and practically, for scholars and practitioners in geography and STS to view co-production ecologically? We answer this question over the following sections: in Section 2, we further outline the dominant doing and studying variants of co-production. Here we develop our argument that the *philosophical–analytical* variant, while analytically powerful, has remained limited in its approach to particular space-times of co-production. In Section 3, we propose our ‘ecologies of co-production’ approach and set out how it opens up new ways of thinking about and attending to the *spaces and interrelations, diversities and exclusions, histories and constitutions*, and the *responsibilities and affects* of knowledge co-production by drawing on relevant literature in geography, STS, critical social science and cognate disciplines. In the concluding section, we expand on the implications of such an approach for theorists and practitioners of co-production in the environmental sphere and beyond, with a particular emphasis on going beyond bounded spaces to look at the relations between co-production in the multiplicity brought forward in the Anthropocene. To do this reinforces matters of care, intentionality and responsibility for interventions made under the banners both of theory and of practice.

## 2. Two versions of ‘co-production’

In this section, we explore how analysts and practitioners of co-production have worked to do and study co-production. While distinct in many ways, others have shown they share some common ontological and normative underpinnings (e.g., Bremer and Meisch 2017; Lemos et al. 2018; Wyborn et al. 2019) and perhaps differ most markedly in questions of intentionality.

### 2.1. Normative–procedural co-production: making things together

Co-production is increasingly talked about in relation to practices of knowledge production. *Normative–procedural* co-productions are often an explicit attempt to intervene in or produce knowledge with and between various stakeholders in various forms of deliberative or participatory circumstances, often when societal challenges are thought to be particularly complex and open to a diverse range of solutions (Lemos et al. 2018; Beck 2019; Turnhout et al. 2020). The language and practice of knowledge co-production can be found in the methods of transdisciplinary and citizen science (Pettibone et al. 2018), in the priorities of research councils (e.g., the UK’s ESRC), at academic conferences (including RGS-IBG 2014), in conversations around open government and policy (Howlett, Kekez and Poocharoen 2017; Sorrentino, Sicilia and Howlett 2018), in the arts (Honeybun-Arnolda and Obermeister 2019) and humanities (Pente et al. 2015), and in the making and design of global knowledge institutions (van der Hel 2016). Environmental fields – like sustainability science, conservation biology and climate services – feature particularly loud calls for greater knowledge – or *normative–procedural* – co-production (Djenontin and Meadow 2018; Norström et al. 2020). This is a result of the continued process of problematisation in

policy and academic arenas that underscored cohesive and inclusive synthesis of perspectives as the most suitable method of knowledge- and policymaking for environmental challenges (Barry and Born 2013), reflecting a lingering commitment to the idea that challenges like climate change represent solvable ‘problems’, amenable to relatively simple solutions made possible through the application of more or ‘better’ knowledge (Hulme 2009; Levin et al. 2012).

*Normative-procedural* co-productions are commonly framed such that wider input or participation in knowledge-making is assumed to lead to more socially robust and policy-relevant knowledge (Bremer and Meisch 2017; Djenontin and Meadow 2018; Honeybun-Arnolda et al. 2023). They are defined by a particular kind of intentionality: knowledge is co-produced for particular purposes and in specific settings with a view that the knowledge produced will be more legitimate, more robust and more usable, as a result from the wider sets of inputs. Co-production of this kind is also highly specific, seeking to deliberately implement particular (often pre-established) models of science and society interaction in discrete moments and tightly bounded time-spaces e.g., enhancing legitimacy of place-based decision-making (Clement 2022; Collins, Shaw and Wills 2022) or to cultivate more just environmental management (Tubridy, Lennon and Scott 2022).

In many ways calls to do co-production in the environmental field rehearse older arguments for ‘post-normal’ (Funtowicz and Ravetz 1993) or ‘Mode-2’ science (Gibbons et al. 1994), both of which emerged during the 1990s in response to the apparent uncertainties and urgencies of emerging environmental and societal problems – the objects of concern which were taken to characterise the ‘risk society’ (Beck 1992) or ‘late modernity’ (Lash, Szerszynkis and Wynne 1996). The models of post-normal and Mode-2 science both considered that conventional disciplinary science was unsuited to new societal

challenges, and that new modes of inter- and transdisciplinary collaboration were required to ensure the relevance, credibility and quality of knowledge production processes (Ravetz 1999; Nowotny, Scott and Gibbons 2001). Since then, calling for more knowledge ‘co-production’ between disciplines, stakeholders and publics has become *de rigueur*, particularly in environmental contexts, even if hierarchies of epistemic authority continue to exert a powerful hold (Gay-Antaki 2022).

In the nascent and febrile Anthropocene, such calls have grown louder still. The casting of humans as geological agents interfering with the functioning of planetary systems – and potentially pushing them into unprecedented states – greatly expands the challenge of uncertainty as conceived by earlier theorists of environmental risk (Biermann 2021). The Anthropocene proposition likewise stresses interconnection and complex feedback loops, meaning that established disciplinary forms of knowledge may be insufficient for grappling with likely futures (Berkes 2017; Renn 2020). At the same time, the rise of earth system science as the privileged *episteme* of the Anthropocene (Uhrqvist and Lövbrand 2009; Bonneuil and Fressoz 2016) is indicative of the challenges of scale – earth systems may increasingly be anthropogenic but they are markedly inhuman (Clark 2011) in terms of their dynamism, spatiotemporal scale, and their apparent distance from ‘local’ practices of collective human life and meaning-making (Jasanoff 2010; Biermann et al. 2016; Eckersley 2017). This poses fundamental challenges of democratic accountability for institutions concerned with measuring, monitoring and governing the Anthropocene (Lövbrand et al. 2015; Castree 2016; Dryzek and Pickering 2018; Jasanoff 2021).

Future Earth is perhaps the most prominent example of a global knowledge institution embracing the language and practice of *normative-procedural* co-production. Emerging in

2012 and operational by 2015, Future Earth superseded a host of global change research initiatives (such as the International Geosphere-Biosphere Program). Bringing multiple environmental research initiatives together was one aspect of a stated goal to develop a ‘new type of science’ fit for the Anthropocene (Lahsen 2016; Kershaw 2018, 108). Another was the explicit adoption of co-production and co-design as means of developing ‘a new “social contract” between science and society’ (ibid). Sandra van der Hel (2016) identifies three ‘logics’ of co-production at work in the institutionalisation of Future Earth. A ‘logic of accountability’ seeks to use practices of co-production to ensure that research governance is accountable to the needs and preferences of society and policy. A ‘logic of impact’ aims to use co-production more instrumentally, to ensure the ultimate uptake of scientific knowledge by bringing potential knowledge users into the process early on. Finally, a ‘logic of humility’ seeks to use *normative-procedural* co-production practices to open up the space of scientific knowledge production and recognise extra-scientific actors as bearers of valid and relevant knowledge. van der Hel (2016) concluded that the former two logics – accountability and impact – were dominant during the setting-up of Future Earth, and that distinct tensions exist between the three logics (see also Lahsen 2016). Nonetheless, the ambiguous relations between the three logics meant that they could be strategically deployed by different actors to shape the work of the organisation.

Similar calls for more deliberate knowledge co-production to address the epistemic and democratic challenges of the Anthropocene can be mapped onto these logics. For instance, Verburg et al.’s (2016) call for more co-production around socioecological systems modelling centres on the potential of stakeholder involvement and co-design to enhance the uptake and use of findings (a logic of impact), as well as the potential of co-production processes to bring in more

diverse forms of data and knowledge that may directly improve models (a logic of humility). Karlin et al. (2016) offer a model of engaged scholarship for the Anthropocene-based, among other principles, on equitable co-production processes which can likewise enhance the impact, accountability and humility of knowledge-making. Nonetheless, van der Hel’s ‘logic of humility’ features less prominently in the literature dealing explicitly with the Anthropocene, and tends to be proffered by critical social scientists arguing for the inclusion of their own knowledges or positioning themselves as representatives or conveyors of a wider set of knowledge (Lövbrand et al. 2015). The logic of humility is much more prominent in the literature concerning more ‘local’ environmental issues, such as adaptation to climate change or ecological stewardship, yet many knowledge co-production initiatives continue to reproduce implicit hierarchies of knowledge and political power (Latulippe and Klenk 2020; Ledingham and Hartley 2021).

These kinds of observations and critiques have been particularly strong from scholars working with the *philosophical-analytical* version of co-production. The next section introduces this approach and its utility for exploring the wider transformative effects of normative forms of co-production beyond discrete interventions in knowledge-making practices and participation.

## 2.2. *Philosophical-analytical co-production: everything is always co-produced*

A *philosophical-analytical* version of co-production is defined by the intention to better understand, describe and analyse how science and society are always co-produced – however, wherever, and whenever this may have happened (Shapin and Schaffer 1985; Latour 1991; Pickering 1995; Jasanoff and Wynne 1998; Jasanoff 2004; Lövbrand 2011; Mahony and Hulme 2016). Here the emphasis is on theorising,

studying and analysing the mutual construction of things in practice rather than *doing* co-production *per se*. *Philosophical–analytical* notions of co-production can be summed up by the proposition that ‘the ways in which we know and represent the world (both nature and society) are inseparable from the ways in which we choose to live it’ (Jasanoff 2004, 2). Knowledge is simultaneously a ‘product of social work and constitutive of forms of social life’, and scientific knowledge ‘both embeds and is embedded in social practices, identities, norms, conventions, discourse, instruments and institutions ... in all building blocks of what we term the social’ (Jasanoff 2004, 3).

The co-productionist idiom was developed as a framework to study the relations between science, technology and society, culminating from many prior years’ work on the sociology of science. Environmental politics always loomed large over this work, and the genealogies of the co-productionist idiom can be traced to an avowedly normative and activist discourse on the relationship between science, politics and expertise, forged amid societal controversies over nuclear power, biotechnology, technological militarism and environmental risk. This tradition, largely North American in origin, can be contrasted to a generally more agnostic vein of work in Europe which cohered in the 1970s and ‘80s into actor–network theory (Latour 1991) and the ‘strong programme’ of the Sociology of Scientific Knowledge (Barnes, Bloor and Henry 1996), which largely peered into the scientific community’s internal controversies, rather than science’s often troubled interactions with society (Jasanoff 2016).

A number have scholars have explicitly used the *philosophical–analytical* co-productionist approach to understand the recent knowledge politics of environmental change, and particularly the workings of the ‘science–policy interface’ (e.g., Miller 2004; Lövbrand 2011). These include explicitly geographical engagements with environmental knowledges, which have explored the co-production of space,

knowledge and power in efforts to govern environmental risk and global change (Donovan and Oppenheimer 2016; Mahony and Hulme 2018; Meehan, Klenk and Mendez 2018; de León Escobedo 2023). For the most part, work with the co-productionist idiom has been focused on the national or global scale. While some have posited scale as itself a relational outcome of *philosophical–analytical* co-production (Beck, Esguerra and Goerg 2017; Beck et al. 2017), certain scales of analysis tend to be given primacy, and sometimes treated in isolation. Nation-state level analyses are particularly prominent, especially with co-productionist concepts like civic epistemology (Jasanoff 2005) and sociotechnical imaginaries (Jasanoff and Kim 2009, 2015).

Work in this tradition has helped reveal how knowledge practices are inevitably and often unintentionally bound up with the making of policy, and how certain policy discourses and practices have powerfully shaped the production of environmental knowledge. Such work dislodges ‘linear’ conceptions of the science–policy relationship, which holds that more and better science will inevitably lead to better policy (Beck, 2011). We can detect such conceptions in many of the aforementioned calls for more deliberate and intentional knowledge co-production: by enhancing and diversifying the knowledge-making part of the process, the argument runs, and improved policy outcomes will result. Yet scholars studying co-production would argue that knowledge co-production processes, like any process of knowledge production, are shaped in consequential ways by power relations, path dependencies, cultural norms, institutional epistemologies and the material realities of scientific practices and visions of change (Longhurst and Chilvers 2019; Borie et al. 2021).

Studies that analyse moments of co-production have tended to ignore or exclude the cross-scalar, spatially heterogeneous and transformative effects of ongoing, emergent and diverse co-productions

– focusing instead on discrete and bounded case studies (e.g., the IPCC and globalisation of climate science (Miller 2004) and or specific visions of desirable futures associated with social movements (Buzogány and Scherhauser 2022). Works that do or study co-production tend towards particular space-times of co-production – for example, the workshop room and national institutions, respectively. Yet, instances of knowledge-making cannot be understood in isolation from wider, co-produced and co-producing webs or relations. Borie et al.’s (2021) work on the interrelations between global environmental assessment bodies is one case in point. Another is Chilvers et al.’s (2018) work that shows how participatory co-productions don’t occur in isolation but interrelate in wider systems and constitutions. In the next section, we offer ‘ecologies of co-production’ as a way of conceptualising knowledge-making practices and outcomes across science and society in a way which captures their relational geographies. Additionally, the locus of *philosophical–analytical* co-production has become fixated on dominant relations between science, technology and society. In the Anthropocene, we can and should enquire from different starting positions both in terms of content (e.g., the co-production of democracy and STS (Pallett and Chilvers 2022), and co-productions emerging on the margins or peripheries of dominant global North perspectives (Miguel, Mahony and Monteiro 2019).

### 3. Ecologies of co-production

So far in this article, we have seen how scholars and practitioners have drawn distinctions between two dominant ways of thinking and doing co-production. This difference is somewhat artificial as it goes against the very idea of everything being co-produced, and to view these two main versions as somehow separate and not in themselves co-produced. Given this, we suggest that the main difference between them is one of intentionality – or in other words,

what is co-production is for? The Anthropocene poses deeper challenges for co-productionist approaches, which in turn – we suggest – have much more to offer.

The spatial and temporal complexities, diversities and extent of the Anthropocene call into question the partial imaginations of co-production evident in many existing studies. Against this backdrop, *normative–procedural* intentions at doing knowledge co-production and attempts to bring STS *philosophical–analytical* perspectives to bear on them, appear highly specific and particular in terms of what co-production is or should be and the time-spaces in which it occurs. Co-production is seen as something novel, bringing science and society together in the present in new and unique ways to co-produce knowledge in spaces and places traditionally associated with western science and governance, like Future Earth (van der Hel 2016), the IPBES (Montana 2019), government agencies (Brix, Krogstrup and Mortensen 2020), and local authorities (Durose et al. 2013).

By adopting specific pre-given understandings of what co-production is and should be such work excludes and underplays the sheer diversities of past, present and future co-productions between science and society in the Anthropocene. This includes co-productions between environment, science and society that are happening in more distributed ways beyond formal institutions (Van Kerkhoff and Pilbeam 2017) and western epistemologies (Gay-Antaki 2022), in everyday life (Shackley 2001; Michael 2016; Barry 2021), and in the past (Vitale 2017; Baker 2021). We suggest that the diversities of co-production in the Anthropocene come more into view if an STS *philosophical–analytical* perspective is taken as a starting point. As outlined above, under this frame co-production is not seen as particular or specific according to pre-given normativities – everything is co-produced. This more open and diverse meaning of co-production is rarely taken as a starting point in existing work on co-production in the Anthropocene. It offers an imaginary which

opens-up to the multiplicity, diversity and interrelations of co-productions across space and time.

Emerging scholarship taking an STS *philosophical–analytical* perspective on participation and democracy has much to offer in this regard (Marres 2012; Chilvers and Kearnes 2016; Laurent 2017; Lezaun, Marres and Tironi 2017; Voss and Amelung 2017). Most prior work on participation and new forms of democracy has prescribed specific pre-given meanings about what participation is, who participates and what it means to participate well – whether defined in terms of deliberation, citizen science, social movements, social innovation, and so on. Under this dominant perspective, there is an interest in clearly demarcating what does and does not constitute ‘participation’, according to pre-given normativities, which occurs in discrete isolated cases or events. Analysing co-production, on the other hand, views participation, publics and public issues not as pre-given but as co-produced and emergent through the performance of participation in practice (Chilvers and Kearnes 2016). Such perspectives open up to the sheer diversity of ways in which publics are participating in collective public issues like those associated with the Anthropocene, way beyond what is imagined by formal institutions of science and governance and what is traditionally conceived to be ‘public’ (Marres 2007).

Such work has been built on to develop new systemic and relational approaches to participation which show that all forms of participation do not occur in isolation but continually interrelate in wider ‘ecologies of participation’ – i.e., ‘the relational dynamics of diverse interrelating collective practices and spaces of participation which intermingle and are co-produced with(in) wider systems and political cultures’ (Chilvers, Pallett and Hargreaves 2018, 202; also Chilvers and Kearnes 2016; Chilvers and Longhurst 2016). An ecological conception of participation suggests that it ‘is not possible to properly understand any one collective of participation without understanding its relational interdependence with

other collective participatory practices, technologies of participation, spaces of negotiation and the cultural–political settings in which they become established’ (Chilvers and Kearnes 2016, 52). New instrumental forms of knowledge co-production as ‘making things together’ between science and society are a particular form of participation, so a similar move can be made in extending thinking on ecologies of participation to what we call ‘ecologies of co-production’ (cf. Longhurst and Chilvers 2019). Making this link for the first time in this article, then, offers a new way of theorising co-productions in wider ecologies where seemingly discrete collectives of co-production interrelate and intermingle in wider relational and networked spaces of differing qualities, temporalities, and extent.

The move from studying discrete and bounded moments of co-production to studying the ecologies of co-production parallels a disjoint running through the geographies of science literature. The distinction in the latter case is between studies which offer relatively naturalistic descriptions of discrete spaces of knowledge-making e.g., the lab, the field, the coffeehouse (Livingstone 2003), and those that interrogate science’s enmeshing in broader networks or constitutions within which forms of spatial order – such as scale – are co-produced (Greenhough 2006; Mahony 2021). Co-production, like science, has its geographies that impress upon and are shaped by practice – particularly within the diversity of collectives at work internationally under the Anthropocene rubric. Thus, the notion of ecologies of co-production emphasises the intersecting spatialities of co-production – like that of science – that are grounded in cultural–political contexts (Livingstone 2003; Naylor 2005, 2010), that are part of networks of varying spatial reach and stability (Lehman 2020), and which may either reproduce or challenge pre-existing geographies of power, inequality and exclusion (Barra 2021).

An ecologies of co-production approach offers an expanded sense of knowledge



co-production and sense-making by drawing together existing work in geography, STS, history of science, and emerging co-productionist approaches to participation and democracy. Building on Chilvers and Kearnes (2016) and Chilvers, Pallett and Hargreaves (2018), we define ecologies of co-production as: diverse interrelating practices and spaces of co-production which intermingle and are co-produced with(in) wider systems and political cultures in which they are situated. The notion does not assume demarcated or clear divisions between normative or analytical co-production but instead, co-production is better reconceptualised as collectives in an interrelated network that are embedded in the broader cultural-political contexts that they both shape and are shaped by.

We now return to the core question of this article: what difference does it make, analytically and practically, view co-production ecologically? In the sub-sections that follow we set out what difference an ecologies of co-production perspective can make to research and practice in four main ways, through attending to *diversities and exclusions, spaces and interrelations, histories and constitutions*, and the *responsibilities and affects* of co-production. In doing this we illustrate how ecologies of co-production can offer a constructive way of responding to the deeper, systemic challenges for geographers working with co-production in the Anthropocene. The four categories below are not intended to be prescriptive lenses to be rigidly followed but have emerged from our readings of the literature and our analytical extension of Chilvers and Kearnes (2016) and are included here to offer a tentative structure on how to think about co-production ecologically and what difference this can make to our theoretical commitments and practices.

### 3.1. Spaces and interrelations

An ecologies of co-production perspective foregrounds the interrelations, intermingling and

entanglement of spaces of co-production over time, drawing heavily from geography of science and ideas concerning relational space (Massey 2005; Finnegan 2008). Space has agency in shaping both the conduct and content of science, while scientific practice likewise transforms spatial relations between the producers, users, objects and subjects of knowledge (De Bont 2009; Powell 2017). The spatialities of deliberate and discrete modes of normative-procedural co-production can also be understood to have real effects on their framings, conduct, and outcomes. We suggest, however, that it is possible to go further in spatialising co-production.

Holt et al. (2019), in an introduction of a special issue of *Area*, directly call for greater attention to the voices, participation and co-production practices at the margins of existing work to think more critically and responsibly about the spatiality of normative-procedural co-production practice. For example, by interrogating the sites of co-production in health and social care, Leyshon, Leyshon and Jeffries (2019) revealed the institutional and professional boundaries that either prevented or supported attempts at diverse actors working together. They identified that volunteers, who are intrinsic to a social care programme located in Cornwall, U.K., were actively excluded from perceived sites of legitimate co-production (e.g., formal meetings) due to their lack of professional affiliation but were called upon in more informal settings (e.g., coffee mornings) where the volunteers were allowed to informally contribute. Additionally, in the same issue, Clayton and Vickers (2019) question existing participation methods in co-productionist approaches by exploring the structural and practical dimensions of involving 'desired' actors in migrant research in North East England. They found that processes of normative-procedural co-production are contingent on the organisations, investments, scales and places in which they come to be organised. A more careful and

demonstrative appreciation of this, they argue, would facilitate more productive and fruitful understandings of the emergent and heterogenous nature of co-productions and their place in broader (re)arrangements of knowledge, expertise and social order. To impose that some spaces are more legitimate than others and some actors are more desirable than others ignores the possibility and potentials of co-productionist analyses, in favour of those who are organising and setting the terms of co-production. As discussed above, this ignores the uninvited and unintentional yet equally productive moments of co-production that manifest in excluded spaces or on the periphery. Subsequently, this leads to partial perspectives and intentions claiming to be representative and more legitimate than is the case.

Building on this, a relational-ecologies perspective can also emphasise how particular spaces of co-production are deeply interrelated and entangled – leading to reordering and re-making of the social and political order. Institutional expert bodies that were formed to address problems of the Anthropocene – climate change (IPCC), biodiversity conservation (IPBES) and earth-systems research and governance (Future Earth) – were set up as discrete institutions exhibiting discrete practices of both forms of co-production, through particular forms of expertise and epistemic authority, and have been, for the most part, studied as such in isolated and situated analytical co-productionist accounts. This is problematic from an ecologies of co-production standpoint. The IPCC and IPBES often share or have shared the same actors or practices and are part of a wider institutionalisation of environmental science and global environmental assessments (Obermeister 2017; Borie et al. 2021). In tracing relations between these spaces of institutionalisation, we can detect commonalities in how particular forms of knowledge are validated and used, the actors in which these knowledges emerge and travel, how futures are imagined and presented and by whom, how knowledge is

scaled up or down between local and global scales, and how certain normative aims, spoken or unspoken, circulate between institutional settings (Beck et al. 2014; Obermeister 2017; Oppenheimer et al. 2019; Borie et al. 2021).

There are risks attached to how these expert institutions frame the ‘problem’ of environmental change and in consequence shape the solution-space by deeming what is or is not achievable in these framings (Hulme 2010; Beck and Oomen 2021; Borie et al. 2021). In this context, an ecologies of co-production perspective can help to reveal knowledge regimes – including regimes of institutionalised practices of co-production – and the various forms of resistance they may meet, for example as they bump into conflicting ‘civic epistemologies’ (Jasanoff 2005, 2011) or geopolitical tensions (Meehan, Klenk and Mendez 2018). In so doing, such a perspective can help open-up possibilities for alternative ways of designing and practicing science–society relations in more distributed, plural and polycentric ways (Castree, Bellamy and Osaka 2021). Alternative models are already emerging which seek to transcend institutionalised forms of knowledge co-production to place greater emphasis on the *empowerment* of diverse actors and knowledges (Holt et al. 2019; Maas et al. 2021; Honeybun-Arnolda et al. 2023).

### 3.2. Diversities and exclusions

As we have stated, all co-productions are partial, bounded by their assumptions, geographies and normativities, which leads us to consider – what co-productions are excluded in our analyses, practices and histories? Rather than only strive to be inclusive of relevant actors and knowledges in normative forms of co-production, in which ‘scholars and stakeholders interact to define important questions’ (Kates et al. 2000, 2) or seek to include ‘diverse types of expertise, knowledge and actors to produce context-specific knowledge and pathways towards a

sustainable future' (Norström et al. 2020), an ecologies of co-production perspective seeks to reveal co-productions on the periphery, those that would usually be excluded (Holt et al. 2019) or neglected from conventional methods and approaches. For example, this could include ensuring diverse co-productions involving humanities scholars, those with local knowledge, or non-humans, are properly recognised and included in global environmental assessments.

Rather than only providing accounts of the most 'central', powerful or significant moments of analytical co-production and relevant actors – as is often the case in existing studies – a relational and systemic ecologies perspective simultaneously seeks out 'decentred' co-productions on the margins or peripheries (Holt et al. 2019; Medina 2013) or those associated with the mundane and every day (Michael 2016). This may involve moving away from co-production associated with a central institutional site like the IPCC (Miller 2004) or the spaces of specialised UN agencies (Selcer 2018), and instead attending to more local or particular collectives, both historical and contemporary, to examine their role in defining, understanding and governing things like climate: from nineteenth-century life assurance firms (Kneale and Randalls 2020) to colonised peoples (Whyte 2018); from 'amateur' scientists (Endfield and Morris 2012) to local government planners (Knox 2020) and smallholder farmers (Pauline and Grab 2018).

Individually, these collectives reveal rich yet seemingly disparate representations of climate but together contribute to a broader, interconnected ecology of climate knowledge – that is made 'together', continues to (re)make the social order and shape distributed understanding and knowledge. By explicitly attending to diversities and exclusions the emphasis shifts from discrete, bounded studies of co-production and intertwines them with a wider landscape of co-productions in the Anthropocene. To intentionally recognise diversity, exclusions and

acknowledge that all perspectives are partial can lead to more robust and faithful accounts of co-productionist analyses. If everything is co-produced then we cannot legitimately expect to offer complete, overarching and authoritative accounts. Instead, we can expand our purview of the multiplicity associated with the Anthropocene by unpacking the diversity, embracing our intentions and vantage points and lay bare the rich tapestry of the epistemic and ontological relations that (re)shape how we intervene, study and act in the world. Methodologically, mapping approaches emerging in geography and STS – such as controversy mapping, issue mapping and mapping participation (e.g., Latour 2005; Whatmore 2009; Marres 2015; Chilvers, Pallett and Hargreaves 2018; Pallett et al. 2019) – offer promising ways of attending to these diversities, exclusions, spaces and interrelations in wider ecologies of co-production and support radical transformations in the way in which understand co-production in the Anthropocene.

### 3.3. Histories and constitutions

The two preceding sections alert us to the differing temporal and spatial scales of co-production. This necessarily reminds us that deliberate and interventionist forms of co-production between science and society are not a contemporary phenomenon. The high profile of international institutions like Future Earth, which have 'co-produced' knowledge as their default *modus operandi*, can obscure historical attempts at co-production in early environmental work. While not referred to as co-production per se, we see such formations of collaborative knowledge-making through an extension of expertise emerging as applicable solutions to the challenges of environmental change in the mid-twentieth century (Turchetti 2010, 2018; Honeybun-Arnolda 2023a).

A historicisation of co-production (e.g., Coen 2021) can help us to recognise and make sense

of the most durable formations or ‘constitutional moments’ (Jasanoff 2012) of co-production in the making of the Anthropocene. For instance, how states of environmental knowledge came to emerge and be settled through inter-/transdisciplinary research programs did not happen through chance. Rather, diverse collectives of knowledge emerged in different spaces, with different normativities and intentionalities, and with different outcomes. For instance, new ‘environmental’ knowledge emerged through numerous conferences and processes of aggregating expertise (Warde, Robin and Sörlin 2018), through Cold War militarism and research funding (Doel 2003), and shifting domestic policy priorities in western states (Agar 2019; Honeybun-Arnolda 2023b). The concerted effort to organise and collectively make knowledge around a new object of enquiry – the environment – is one that has characterised late twentieth-century practices of science (Agar 2008). A relational-ecologies perspective can help characterise this happening as a transformative constitutional reordering of governance, science and society that helped to conceptualise the ‘environment’ as an object of enquiry to be collectively known through practices of scientific inter- and trans-disciplinarity (Honeybun-Arnolda 2022). This was made possible both through innovative practices and uses of science and technology, and through the neglect of other forms of knowledge and knowledge-making practices (Jasanoff 2011; Bonneuil and Fressoz 2016; Shapin 2018; Renn 2020; Gay-Antaki 2022), opening up a conflictual space in which the ontological politics of the Anthropocene has taken shape.

More recently, discourse about the Anthropocene and practices of co-production have been mutually (co)productive. The emergence of the Anthropocene as an epochal term brought with it new framings of research that orientated environmental knowledge-making and policy on planetary scales (Crutzen 2002; Castree et al. 2014) supposedly

transcending local scales and conventional disciplinary perspectives (Renn 2020) and encouraging new ways of thinking about historical concepts (Lorimer 2015) and legacy institutions (Dryzek and Pickering 2018). In turn, the continued discourse around the Anthropocene as a massive, complex and planetary-scale issue has spawned competing visions of expert-led geo-technocracy and governance regimes based on democratically co-produced knowledges. More recently, some scholars have sought to reinsert a critical localism into Anthropocene knowledge practices (Latour and Weibel 2020; Fortun et al. 2021), emphasising the importance of situated and historically informed practices as a counter to the Anthropocene’s own colonial roots and overtones (Simpson 2020; Sultana 2023).

Attention to the diverse forms of knowledge-making practices that have constituted the ‘environment’ and the ‘Anthropocene’ in the twentieth century and into the twenty-first century can help demonstrate the differential historical constructions and realities through which new ways of ordering come into being and become durable formations (Trischler 2016). In doing so, critical social scientists and environmental geographers can reflect on the histories and constitutions of knowledge-making (Güttler 2019) to help inform more responsible and reflective frameworks of deliberate co-production (Miller and Wyborn 2018) and recognise the historical role multiple co-productions play in the broader institutionalisation and circulation of ‘new’ knowledge and changing social order – in the Anthropocene or otherwise (Honeybun-Arnolda 2022).

### *3.4. Responsibilities and affects*

Finally, we suggest that an ecologies of co-production perspective makes a difference through prompting more care-full approaches to doing and studying the co-production of

science and society in the Anthropocene (Chilvers and Kearnes 2020; Mahony 2023). A key aspect of this is to bring the critical interpretive sensibilities of *philosophical–analytical* co-production – about power, politics, exclusions, alternative futures, ordering effects – to bear more fully in the theorisation, study, practice and institutionalisation of co-production itself.

This thinking is already being used to insert more humble and reflexive sensibilities into *normative–procedural* attempts to do co-production, paying greater attention to the power, politics, framing effects, and exclusions of these processes (Miller and Wyborn 2018; Wyborn et al. 2019; Turnhout et al. 2020). This often takes the form of principles and frameworks that can guide co-production in practice (e.g., Bremer and Meisch 2017; Miller and Wyborn 2018; Wyborn et al. 2019; Jagannathan et al. 2020; Norström et al. 2020; Turnhout et al. 2020; Zurba et al. 2022). For example, for Miller and Wyborn (2018, 7) this means being ‘inclusive in the diversity of participants, the power ... and the processes and objectives of co-production’, whilst acknowledging that processes of co-production will repeatedly ‘shape the content and relevance of knowledge’.

Wyborn et al. (2019) seek to further this through a nested framework for research and practice that acknowledges how co-production is broadly situated within cultural and institutional contexts, that shape and are shaped by processes of co-production in both the normative and analytical sense. They call for a ‘more coherent theoretical framework to conceptualise power within co-production processes, and ... greater engagement from the STS community ... on how to engage with the inherent politics of co-production interventions’ (Wyborn et al. 2019, 19). Turnhout et al. (2020) take up this call to attend to the political and power dimensions in processes of co-production, suggesting that co-production requires mutuality, reciprocity, and equality. Turnhout et al. (2020)

additionally call for co-production that empowers knowledge contestations – revealing how unequal power relations are overcome and what steps are taken to ensure that existing power dynamics are not reinforced – to ensure that co-production as the ‘best’ solution will yield socially robust, equitable and actionable outcomes.

Beck (2019) uses an analytical co-productionist view for the case of Future Earth and its goals of co-producing science for global change. Beck suggests that the application of co-production as a strategic instrument is a particular method of scientific enquiry which creates ‘both a description of the Anthropocene and a set of tacit prescriptions for how transformations towards sustainability should be managed in response’ (197–8). The instrumental forms of knowledge co-production performed in Future Earth not only produce knowledge and representations of the Anthropocene; they are always bound up with and co-produce imagined social futures and governance arrangements. However, rather than opening up and attending to the multiple possible solutions, pathways or framings, knowledge institutions like Future Earth run the risk of inadvertently closing down responses to single ideals. Hadley Kershaw (2018) has shown how such closing down is further compounded by the predominance of instrumental versions of knowledge co-production in Future Earth, which arguably limits reflexive awareness of the ‘co-production of co-production’ within the organisation and its openness to alternative meanings of the Anthropocene and to diverse sociotechnical futures.

It is one thing to make processes of co-production more effective, but there is still more scope in existing studies to show greater care for and recognition of other excluded co-productions, whether in the past, present or future (cf. Chilvers and Kearnes 2020). An ecologies of co-production perspective goes further still in suggesting that theories and analytical

accounts associated with studying co-production are never external to but are always actively present within systems and ecologies of co-production. To theorise and to study is also to intervene, which projects questions of responsibility and reflexivity back onto the assumptions, normativities, intentionalities, exclusions, and positionality of co-productionist theories and scholars themselves. This can take many forms, including acknowledgement of the ways in which co-productionist studies hold particular assumptions about power and political order, often centring on the powers of nation-states rather than more distributed agencies, in local governance and civil society for example (Jasanoff and Kim 2009, 2015; Jasanoff and Martello 2004). It could also include reflection on the particular geographies and situatedness of theoretical and analytical oriented work on co-production, with its origins in North America and Europe often being co-produced with particular versions of democracy and political culture (cf. Pallett and Chilvers 2022).

As others have noted, publications engaging with co-production in climate change and sustainability science are primarily produced in the West and exclude a number of alternative knowledge systems (Bremer and Meisch 2017; Wyborn et al. 2019). This highlights the need to decolonise co-production in the Anthropocene, to undo extractive forms of knowledge co-production which reproduce coloniality (Klenk et al. 2017), and to embrace more cosmopolitan co-productions in theory and practice (cf. Lövbrand et al. 2015).

Finally, we suggest that an ecologies of co-production perspective brings a new attentiveness to how co-productions in the Anthropocene have future implications and effects on environment and society in wider ecologies. Responsible co-production in the Anthropocene thus also means embodying an anticipatory disposition to reflexivity where the effects and affects, downsides, future implications and social orders produced are reflected on and responded

to before and during, not just after, the event of co-production, whether in theory or practice (cf. Chilvers and Kearnes 2016; Beck and Mahony 2018). This could take the form of anticipatory reflection and foresight over the future implications and affects of particular models of co-production, for example, how integrative and consensual forms of co-production within IPBES or Future Earth are likely to uphold monocentric systems of global governance, capitalism and the commodification of nature, at the expense of more adaptive, diverse and multi-scalar orderings of knowledge–society relations in the Anthropocene (Borie and Hulme 2015).

#### **4. Implications and conclusions: what difference does it make?**

In this article, we have sought to explore what difference it makes – for researchers in environmental geography, STS, and related fields – to think about co-production ecologically. While a number of scholars have begun exploring the critical overlaps between *normative–procedural* and *philosophical–analytical* versions of co-production, we have argued that such work has yet to adequately attend to the multiplicity and relationality of forms of co-production which abound in the Anthropocene. By refreshing both versions of co-production, a more careful and responsible form of both theory and practice can be developed. We offer an ‘ecologies of co-production’ approach as a way of fostering an openness to exploring and tracing the emergent and relational dynamics of various collectives of co-production to break beyond dominant theoretical approaches and encourage more practical and embodied approaches to co-productionist analyses. We have offered four key themes through which an ecology of co-production approach can fruitfully expand our analysis and practice of co-production: *diversities and exclusions, spaces and interrelations, histories and*

*constitutions, and responsibilities and affects.* These should not be seen as exhaustive nor prescriptive, but rather as starting points for more open analyses and practices in the contingent multiplicities of co-production in the Anthropocene.

A core argument we have developed throughout this article is that most existing work on co-production – irrespective of whether the primary intention is on doing or studying co-production – tends to operate *within* discrete and bounded time-spaces. We have argued that internally focusing on discrete time-spaces of co-production in these ways misses, excludes, or underplays the importance of ongoing interrelations *between* spaces of co-production in wider systems and temporalities. Drawing together the four key themes outlined above, we now consider the implications of an ecologies of co-production approach for how we as environmental geography and STS scholars can become more reflexive in our analyses and practices of co-production.

In terms of how the co-production of science and society is theorised and studied, *States of Knowledge* (Jasanoff 2004) remains one of the canonical texts that has shaped work in this field for two decades with much epistemic success. Studies within this canon have often focused on discrete time-spaces of particular institutions (e.g., Miller 2004) or the role of the state in national settings (e.g., Dear 2004). An ecologies of co-production perspective can add to, and extend such analyses. For example, in the case of the role of the IPCC in the mutual construction of global climate science and politics (Miller 2004), an ecologies of co-production approach would be interested in also studying how the IPCC interrelates with the co-productions of other related international institutions (e.g., IPBES, Future Earth), exploring how models of co-production circulate between them (cf. Beck et al. 2014), and understanding how transnational institutional epistemologies and collectively held

know-ways might become established (Borie et al. 2021). It can also help to understand the roles that interrelations between international institutions and more distributed co-productions occurring at different spatial scales, whether nationally or locally, might play (Honeybun-Arnolda and Mahony 2022) in the broader (re)arranging of our social and epistemic lives. Or alternatively, a relational-ecologies perspective would seek to explore how climate science and politics played out in non-Western settings or in longer-term histories that are equally as important for global framings of climate, and cultures of climate governance and democratic participation (Mahony 2014). An ecology of co-production approach not only enhances understanding of interrelations *between* co-productions, then, it also questions the reification of centralised forms of power and authority while also bringing distributed, excluded, or alternative co-productions into view (Honeybun-Arnolda 2022).

When it comes to doing co-production in practice, a relational-ecologies perspective again makes a difference. In any attempt to deliberately establish a process of co-production between science and society – whether that is at an international, national, regional, organisational, or local community level – things will look different according to an ecologies of co-production sensibility. For example, this has been demonstrated in practices and systems of participatory co-productions for low-carbon transitions (see Chilvers et al. 2021, 2022). It is no longer enough to emphasise being inclusive and enrolling ‘all relevant actors’ into a one-off co-production process to ‘make things together’. Ecologies of co-production would also lead oneself to be concerned about and map out other significant co-productions that lie beyond any one organised co-production procedure (Chilvers, Pallett and Hargreaves 2018; Pallett et al. 2019). Such mappings help to spark reflexive questioning of one’s own co-production in relation to other co-productions

– including their alternative definitions of the problem of the Anthropocene, associated visions of the future, alternative knowledges and values, and different courses of action. Under a relational-ecologies perspective, those bringing forward new discrete spaces of co-production would also need to become more attuned to how configurations of past and constitutional co-productions powerfully shape practices of co-production in the present. This in turn reinforces the need for more careful and responsible approaches to co-production that can be open to historical antecedences and power inequalities while anticipating the future ordering effects of co-productions made in the present (Chilvers and Kearnes 2020; Mahony 2023).

It can be easy to think of the co-production of science and society in the Anthropocene existing ‘out there’ either as a theoretical abstraction or a somewhat exceptional formal procedure. Yet, if we are to take seriously the notion that ‘everything is co-produced’ then the implications of the ecologies of co-production perspective that we have developed in this article apply just as much to the more immediate, mundane, and everyday academic practices that make up environmental geography, STS, and our own disciplines. This means that being reflexive and responsible about the diversities, exclusions, interrelations between, and effects of both forms of co-production in the Anthropocene should be distributed qualities that are continually performed and re-made. Such responsibility and reflexive questioning should not only apply to more formal academic writing, theories, methods, empirical studies, and the doing of co-production in practice, but must also extend to our everyday relations with our peers, students, society, non-humans, and the wider world.

We recognise that this is a challenging task and that existing systems, institutions and academic cultures of impact, and auditing within the neoliberal university operates against this. Yet, the calls for dissolving disciplinary boundaries, thinking in radical and transformative

ways and reforming our institutions and structures in the Anthropocene demonstrate the critical importance of careful, reflexive and responsible interventions. If everything is co-produced then we must take this seriously and recognise that the mutual construction of the epistemic and the normative operates in multiple spaces, across and between multiple scales, throughout time. Attending to this can enable geographers, STS scholars, and other practitioners to cultivate more diverse, interrelated, reflexive and responsible co-productions necessary to address the multiple challenges and opportunities brought forward by Anthropocene.

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### Note

1. It is important to note that the ontology of our approach differs from realist meanings of ecology found in the natural sciences (see Chilvers, Pallett, and Hargreaves 2018).

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